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Proximate and Mineral Elements Composition of Three Forest Fruits Sold in Port Harcourt, Nigeria

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ABSTRACT: This study aimed to assess the nutritional and trace elements composition of selected forest fruits sold for human consumption in Port Harcourt. Fruit contamination by heavy metals is an issue of global concern. Non-degradable elements bioaccumulations in tissues and organs have deleterious effects in man. Three (3) Agroforestry fruits species; (*Spondias cytherea* L. (Anacardiaceae), *Syzygium malaccense* (L.) Merr. & L. M. Perry Myrtaceae and *Cola pachycarpa* K. Schum. Malvaceae) were purposefully selected and sourced from three strategically located markets namely; Oil mill, Choba and D/line fruit markets. The fruit species were procured and washed with distilled water and the edible parts extracted, chopped and sun dried properly. The nutritional composition was analyzed using 18th edition of the Association of Official Analytical Chemist while trace metals were analysed using PIXE Accelerator. *Spondias cytherea* yielded high percentage of crude Protein (8.373±0.1) and Fibre content (11.73±0.03), while *Syzygium malaccense* was rich in Fat (7.17±0.02) and Ash (4.17±0.04). Moisture content was highest in *Cola parchycarpa* (12.63±0.05). PIXE Accelerator analysis revealed that the fruits contain high concentration of trace metals; *S. malaccense* contained Mg (1170±237.0ppm), Si (60.02±68.95ppm), Al (14.89±7.71ppm), Fe (10. 60±4.11ppm), Rb (3.20±0.00ppm) and Ti (1.82±0.00ppm). *C. parchycarpa* had Zn (6.22±11.80ppm), Cr (1.60±0.75 ppm), Mn (0. 71±0.87ppm) and Cu (0.38±0.33ppm). Ni (0.16 ppm) was found only in *S. cytherea* fruit. The forest fruits are rich in nutrients vital for healthy growth but the level of heavy metals (Mg, Al. Cr, Fe and Zn) in each of the fruits were above WHO/FAO permissible limit, therefore excessive consumption on a daily/weekly routine should be avoided.

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Safe and healthy foods are essential for survival, growth and productivity of all living organisms (Omoyajowo *et al*., 2017). Safe and nutritious foods contribute to healthy population of human societies globally. Food contamination by heavy metals and subsequent bioaccumulation of non-degradable element in living organisms especially human beings have deleterious effects. Several ailments in man have been associated with high concentration of heavy metals in the body (Jaishankar *et al*., 2014) and this is an issue of global concern. High level of heavy metals in human body can damage the functioning of the brain, lungs, kidney, liver, blood composition and other important organs. Long-term exposure can lead to Parkinson's and Alzheimer's diseases, muscular dystrophy and cancer amongst others (Jarup, 2003). Fruits are important component of human diet, they are good sources of vitamins and mineral salts (Maha and Ahmed, 2015). Most rural populations in Africa depend on wild fruits and vegetables from the forests for intake of vitamins and micronutrients especially during the off-farm seasons (Dry season). Wide range of edible fruits in the wild includes nuts and seeds used as food supplement (Tehoundjan *et al.*, 2002, Nwiisuator *et al.,* 2012). These forest fruits have played significant roles in rural population food security for centuries till now. Blaney *et al*. (2009) reported dietary nutrient adequacy in children over 2 years to young adults have been associated with wild fruits and animals in Gabon. In southern Nigeria, fruits such as *Dacryodes edulis, Chrysophyllum albidum, Pluckenetia conoflora, Blighia sapida* and *Irvingia gabonensis* provide off season food because they often mature when cultivated staples such as rice, yam, cocoyam are yet to mature (Aju, 2014). Proximate analysis of edible fruits plays a crucial role in assessing their nutritional significance (Pandey *et al.,* 2006). Understanding the nutritional content of a food item is critical in the determination of its relevance to human health and food security while determination of heavy metals provide to a good extent the safety of such food. Heavy metals are generally referred to as

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those metals which possess a specific density of more than 5g/cm^3 and adversely affect the environment and living organisms (Jarup, 2003).

The potential accumulation in different organs of the body thus leads to disastrous side effects (Lenntech, 2004; Ming-Ho, 2005; Aderinola *et al.,* 2009). Technology advancement has instigated the integrity of the environment with emission or discharge of effluents containing these heavy metals (Fulekar *et al.,* 2009; Sabiha-Javied *et al*., 2009). Furthermore, high consumption of heavy metal contaminated food can seriously deplete some essential nutrients in the body thereby causing decrease in immunological defenses, impaired psycho-social behavior and disabilities associated with malnutrition (Ogbuagu *et al*., 2015).

Particularly bio accumulation of Cadmium could result to ovarian Cancer and renal prostrate (WHO, 1992; Satarug *et al*., 2010) while high concentration of lead (Pb) results in cardiovascular diseases, decreases sperm count and spontaneous abortions (WHO, 1992; Hertz-Piccitto, 2000). Polluted environment serve as sources of heavy metals in fruits and vegetables which could hinder their growth and productivity and can also lead to poor vegetation growth and lower plant resistance against pests (Ene *et. al.,* 2009).

In general, heavy metal contaminants in and other sources could threaten fruits quality meant for human population. It is advocated that flooding from heavy downpour may lead to horizontal leaching from dump sites causing metal uptake by roots of crops while the rest may find their way into open water bodies and the entire ecosystem, the entry into food chain of these metals leads to increased susceptibility and exposure to metal poisoning of local population (Zukowska and Biziuk, 2008). Port Harcourt is the heartbeat of oil rich Niger Delta region, but the region experienced flood annually since year 2012.

This is one of the channels by which heavy metals are being transported, accumulated in the soil and subsequently enters human body system via plant foods.

The urgency of the world food problems has thrown challenges to farmers and nutritionists alike to investigate the possibility of utilizing some plants species as additional sources of nutrients (Nwiisuator *et al.,* 2012). Also the safety of fruits consumed by humans and organisms is very essential to life. This research is therefore aimed at analyzing the proximate and mineral elements composition of three fruits of economic importance sold and consumed by people in Port Harcourt, Rivers state, Nigeria.

MATERIALS AND METHODS

Study Area:Port Harcourt city has estimated mean altitude 12m above sea level, located in the eastern part of the Niger Delta and a predominantly low-lying alluvial state in southern Nigeria. It is characterized by heavy and lengthy raining season (February – November) while December and January make up the dry season with a mean maximum and minimum temperature of approximately 31.6ºC and 23.2º C, respectively (NBS, 2011). The months of April through October have the highest temperatures (Okhumode, 2018). The vegetation zones consist of two zones; mangrove swamps and freshwater swamp forests. Rivers state occupies 10,575km^2 with a projected population of 7,303,924 as at 2016 (NBS, 2018).

Description sample materials: The selected fruits include *Spondias cytherea* L. (Anacardiaceae) commonly known as Plum, it is an exotic fruit and originated in the south Pacific (Mohammed *et al*., 2017) and now broadly cultivated in the moist rain forest of coastal area in Nigeria. It is also cultivated as ornamental tree within Port Harcourt metropolis. *Syzygium malaccense* (L.) Merr. & L.M. Perry (Myrtaceae), commonly known as Local apple; is an exotic species that have been cultivated for a long time. Its native range lies in Indo-malaya, south-east Asia and Melanesia (Whistler and Craig, 2006) and *Cola pachycarpa* K. Schum. (Malvaceae) commonly known as Monkey kola and locally called Ochiricha or Achicha in Igbo language. It is a tropical species found in lowland forest of some West African countries including Cameroun, Gabon and Nigeria (Keay *et al*., 1964).

Sample Collection: Matured ripe fruits of *Spondias cytherea* (Plum), *Syzygium malaccense* (Local apple) and *Cola parchycarpa* (Monkey kola) were selected due to their abundance and consumption across all social classes. Three (3) major fruits markets across Port Harcourt metropolis were selected to source the fruits namely; Choba market (Long. 4º 53'18N Lat.6º54' 2E), Oil mill market Long. 4º 51'33N Lat.7º 3' 50'E and D-line fruit market (Long. 4º 47'58N Lat.7º 0' 2E). The selected fruit markets are evenly distributed to cover the entire Port Harcourt metropolis, which would enable evenly distributed and unbiased result.

Sample Processing: The fruits samples were washed thoroughly with distilled water to remove the dust, soil and other forms of impurities. The pericarp of *S. cytherea* was peeled to obtain the edible mesocarp while *S. malaccense* and peeled *C. parchycarpa* were cut into two parts in order to remove the seed. The fruits were opened longitudinally with a sharp knife to extract the edible mesocarp (Plate 1). Samples of each fruit sourced from the three markets were chopped separately with knife into a nearly uniform size in other to facilitate drying and grounding processes. They were thereafter sun dried until they were brittle and crispy.

The dried samples were grounded in agate mortar and mixed with 10% by weight of ultra-pure graphite powder and prepared into thick pellets of 13mm diameter without binder. They were then packaged in transparent polythene bags and properly labeled.

Proximate analysis: Proximate analysis of the fruits was carried out following A.O.A.C., (2005) methods and standards at the Institute of Agriculture Research and Training (IART), Ibadan, Nigeria. All analyses were carried out in triplicates.

Analyses of metal contents: Trace elements were analyzed at the Centre for Energy Research and Development (CERD), Obafemi Awolowo University (OAU), Ile-Ife. PIXE analysis was done using NEC 5SDH 1.7MV Pelletron Accelerator, equipped with a radiofrequency charge exchange ion source, which is equipped to provide proton and helium ions. Using 2.5 MeV proton beam obtained from CERD ion beam analysis (IBA) facility.

The end-station of NEC 5SDH 1.7MV Pelletron Accelerator consists of an Aluminum chamber of about 150cm diameter and 180cm height. This has four ports and a window. Port 1 at 165° is for the RBS detector, Port 2 at 135° is for PIXE detector, port 3 at 30° is for the ERDA detector, the window at 0° is for PIGE. The chamber has a sample ladder that can carry 11(eleven) 13mm diameter sample. Port 2 at 135° which is for PIXE detector was used in analysis of heavy metal composition of the samples.

The end station has a turbo pump and a variable beam collimator to regulate beam size, and an isolation value. Apple leaves were used as the certified standard for the quantitative analyses of the fruits. It was used for the determination of the H-value of the samples. The measurements were carried out with a beam spot of 4mm in diameter and a low beam current of 3-6nA .

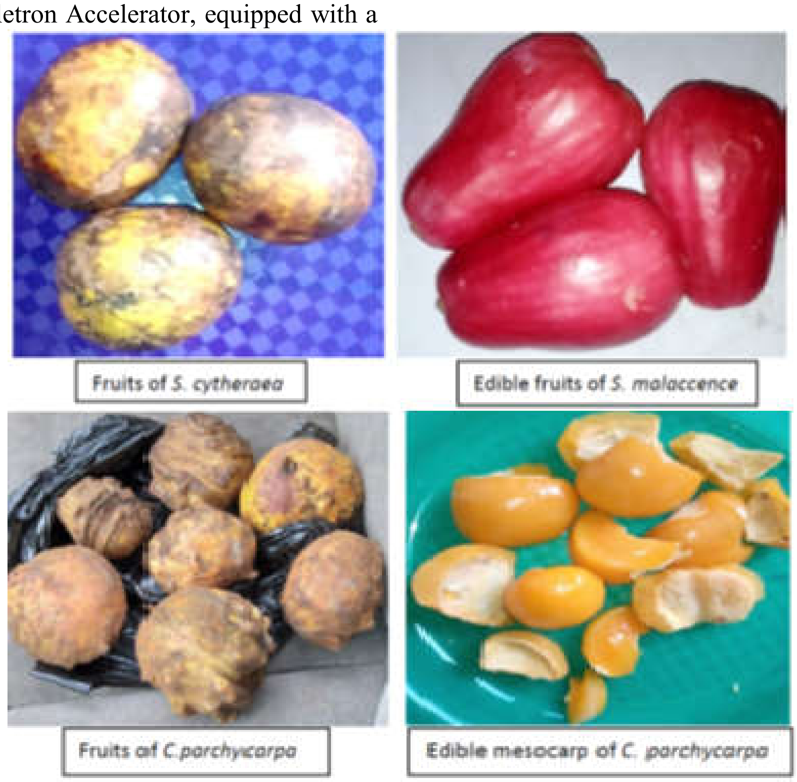

Plate 1: Fruits of *Spondias cytherea* (Plum), *Syzygium malaccense* (Local apple) and *Cola parchycarpa* (Monkey kola) sold in Port Harcourt

The irradiation was for about 10-20 minutes. A Canberra Si(Li) detector Model ESLX 30-150, Berryllium thickness of 25µm, with full width half maximum (FWHM) of 150eV at 5.9keV, with the associated pulse processing electronics and a Canberra Genie 2000 (3.1) MCA card interfaces to a PC were used for the X-rays data acquisition. With respect to the beam director, the sample's normal was located at 0° and the Si (Li) detector at 45°. The PIXE set-up was calibrated using some pure element standards and NIST geological standard, NBS278.

The computer code GUPIXWIN (Maha, and Ahmed, 2015) was uses for the analysis of the PIXE data. This provide a non-linear least square fitting of the spectrum, together with subsequent conversion of the fitted X-ray peak intensifies into elemental concentrations, utilizing fundamental parameter methods for quantitative analysis.

RESULTS AND DISCUSSION

Fruits provides array of nutritional benefits and can significantly influence the quality of food intake by the population. Fruits are a good source of natural vitamins that helps in maintaining healthy body and also play a vital role in immunological defense. Proximate analysis of the forest fruits showed that the three fruits were rich in protein content; *Spondias cytherea* (8.37±0.10g) was highest in crude protein (Table 1) while *Syzygium malaccense* had 5.43±0.06g of protein. There are no significant differences in the protein concentration of the forest fruits. Crude proteins are essential component of diets needed for normal growth and cell building; it is a function of calculated Nitrogen minerals available in a particular food substance. Proteins supply the required amino acids essential for body building and maintenance of proper pH in nutrition (Pugalentnal *et al*., 2004; Hamm *et al*., 2015). Its deficiency could pose serious health challenges especially in developing countries where average family food intake is usually inadequate and mostly of poor quality (Ruel *et al*., 2013). Fruits are major sources of protein in human diet; however, in many circumstances they are not readily available or not affordable in many poor countries. Composition of crude protein in the fruits studied are higher than fruits of several other common fruits in the local markets such as Avocado pear - *Persea americana,* Sweet orange – *Citrus sinensis* and Watermelon - *Citrullus lanatus* grown in Nigeria (Nnaji and Okereke, 2016; Omoyajowo, 2017). The result indicates *S. cytherea, C. pachycarpa* and *S. malaccense* were relatively rich in crude protein compared to some common fruits in the market. However, Christopher and Dosunmu, (2011) reported a slightly higher protein content in African star apple fruits *Chrysophyllum albidium* (5.66±0.01) when compared to that of *S. malaccense* (5.43±0.06). *C. albidum* is a seasonal forest tree species of great potential; juice and wine have been reportedly produced from its fruit sap (Jimoh *et al*., 2014; Kadiri *et al*., 2016), hence several forest fruits not presently considered as staple fruits in our diets are rich in protein content and can contribute to food security in sub Saharan West Africa.

Table 1: Proximate Composition (%) of Three Forest fruits sold in Port Harcourt, Nigeria

Nutrients (%)	Plant Species (Mean±SD) n = 3			LSD
	S. cytherea	***C. parchycarpa***	***S. malaccense***	
Crude protein	8.37±0.10^{a}	7.78±0.09^{b}	5.43±0.06^{c}	0.167
Crude fat	2.28±0.03^{b}	2.08±0.04^{c}	7.17±0.02^{a}	0.063
Crude fibre	11.73±0.03^{a}	3.46±0.02^{b}	1.94±0.02^{c}	0.063
Ash	3.69±0.02^{b}	4.13±0.04^{a}	4.17±0.04^{a}	0.063
Moisture	12.10±0.05^{b}	12.63±0.05^{a}	11.64±0.04^{c}	0.089

Note: Means with different alphabet are significantly different at P is < 0.05

Although fats formed a major source of energy in the body, Mgbemena *et al*., (2019) recommends a maximum daily intake of 30 calories for adult to avoid obesity, diabetes and heart diseases. The values of fats obtained in the three fruits showed that they contain high fat contents of 2.08 - 7.17 percentage range. *S. malaccense* have the highest fat content (7.17%). These fruits if consumed will render energy for proper body functioning especially among children and young adults. *S. malaccense* is commonly known as local apple and it's affordable by the poor people. The three tree species readily grows within the Niger Delta ecosystems and sometimes used as ornamental trees in homesteads. This attributes placed them at advantage over expensive fruits such as Apple and Avocado pear if cultivated on commercial scale. An average size apple fruit (*Malus domestica*) cost 100 – 150₦ (Nigerian Naira) while the local apple (*S. malaccense*) of the same size cost 40 – 50₦. Also the fat contents are higher than those reported for some common fruits such as Mango and Banana values of 0.4 and 0.6g/100g respectively (Guiamba, 2016; Dotto *et al*., 2019).

Crude fibres contribute little to nutritional value of foods but help in proper peristaltic functioning of the alimentary system; it is made of cellulose, hemicellulose, pectic substances, gums, mucilages and a non-carbohydrate component lignin which traps water and supply roughage (Dhingra *et al*., 2012; Mgbemena *et al*., 2019). It impacts healthy living positively by assisting in disease prevention. *S. cytherea* fruit was very rich in crude fibre content (11.73%) while *S. malacense* had the least value for crude fibre (1.94%). Consumption of *S. cytherea* fruits can aid proper functioning of the digestive system. Other common fruits sold in the market such as Banana (5.10%), Pineapple (10.20%), Hog plum (*Spondias mombin* – 4.2%) and *Carica papaya* (11.06%) have lower fibre levels as observed by other workers (Bala and Bashar, 2017). Constipation and colon cancer caused by indigestion can be prevented at a cheap cost with consumption of these forest fruits. High moisture content promotes fruit spoilage by microorganism in storage but it also determines freshness of the fruit. The moisture content values of the fruits fall within the stipulated range (8-14%) for vegetable drugs, which shows that they can be stored for a while without spoilage (Abere and Onwukaeme, 2012). Moisture content values of the three fruits investigated were lower than the findings of Christopher and Dosunmu (2011) on *C. albidium* (66.67±0.02), another common forest fruit in the area. The shelf lives of the fruits are relatively longer than common staple fruits such as Mango and Sweet orange that spoil within 5 -7 days, *C. pachycarpa* can be in storage for about two weeks without spoilage and still remain firm provided the pods are intact (Koyejo and Okonkwo, 2013). Total ash measures the extent of foreign inorganic impurity and contamination with sand, earth, that is, the level of measures employed in drug preparation and which should not exceed 15% (Bigoniya *et al*., 2012). Ash contents of the selected fruits of study were all within the acceptable range *S. cytherea* (3.69±0.02), *C. pachycarpa* (4.13±0.04) and *S. malaccense* (4.17±0.04). Consumption of the fruits does not predispose consumers to accumulation of impurities in the body; hence the proximate results showed that the fruits have the capacity to improve human health. Statistical test on the mean compositions showed significant differences in the composition of crude protein, fat, fibre and moisture content of the three fruits. While the ash composition of *C. parchycarpa* and *S. malaccense* revealed no significant differences in their means.

Trace element content in the Edible parts of selected forest fruits in Port Harcourt: Comparative concentration of trace elements in the three forest fruits procured from Choba, Oil mill and D/line Fruit markets in Port Harcourt showed no significant differences in the mean concentrations of all the mineral elements found in the selected fruits species (Table 2). Eleven elements were detected in the three different fruits samples viz: Mg, Al, Si, Cr, Fe, Zn, Ti, Rb, Mn, Cu and Ni. Lead (Pb) was not detected in any of the three fruits. Some of these elements are vital to physiological and normal metabolic activities required for proper body growth and good health, however, higher concentrations above permissible levels could lead to several human disease conditions. Magnesium (Mg) was observed to be the highest in *S. malaccense* (1170.0±237.00ppm) and least in *S. cytherea* (960.87±126.43ppm). Magnesium is a cofactor in more than 300 enzymes systems performing critical role in energy production and nucleic acid synthesis (Schwalfenberg and Genuis, 2017). Mg is also useful in preventing some heart disorders, high blood pressure and improved lung function if within regulated limits (Olabanji *et al.,* 2014). Its deficiency (hypomagnesaemia) can lead to neuromuscular, cardiac or nervous disorders (Jahnen-Dechent and Ketteler, 2012), while excessive intake of magnesium can result in hypotension and other cardiovascular effects as well as neuromuscular manifestations (Swaminathan, 2003). Magnesium provisional recommended daily allowance (RDA) for adult is 400 – 420mg and 130 – 240mg for children aged 9 – 13years (NAP, 1997). Many authors (Heaton, 2003; King *et al.,* 2005; Griffiths *et al*., 2012) have reported insufficient magnesium intake across populations globally with staple foods such as meat, sugar and white flour contributing less than 20% of RDA. However, the three forest fruits species under study recorded high Magnesium content above RDA limits. The fruits are seasonal in supply, hence their availability in the market is also seasonal therefore they are not consumed as a routine diet; attaining above maximum magnesium intake limit is practically difficult. Usually, the fruits are not consumed in large quantities of up to 1kg daily. Some of these lesser utilized local forest fruits served as snacks and contribute to rural house hold food security and income over time without documented record of hypermagnesaemia within the rural population. They have been complementing magnesium sources in the body but not properly documented for long. *S. malaccense* had highest concentration of Aluminum (244.60±126.39ppm) while *S. cytherea* and *C. parchycarpa* were 166.40±63.57ppm and 166.40±63.57ppm, respectively. Aluminum is a non-essential element and its accumulation can cause series of ailments in humans such as central nervous, skeletal, Alzheimer's diseases and hematopoietic systems of humans (Domingo, 1995) especially in patients with renal dysfunction (Ekanem *et al*., 2009). Compositions of Al in the three fruits were higher than the recommended provisional weekly intake of 60mg/week for adult (FAO/WHO, 2011), hence their consumptions in large amount are not highly recommended as a routine diet. However, Njenga *et al*., (2007) opined that most Aluminium consumed does not accumulate in the body to the point of toxicity since some ligands such as fluoride and citrate are required for Aluminium to be absorbed by the intestine; they are usually excreted from the body. Even though there is the need to exercise precautions in ingesting excess *S. malaccense* particularly, possibility of Aluminium toxicity is very low. In similar findings high levels (321.78 mg) of Al has been reported in fresh vegetable juices and grains consumed daily for therapy in Kenya and China without associated toxicity or safety concerns (Njenga *et al*., 2007; Liang *et al*., 2019).

Table 2: Mean Concentrations (ppm) of Trace elements in edible parts of *S. cytherea, C. parchycarpa* and *S. malaccense* obtained in Port Harcourt

Heavy metals	Plant Species (Mean±SD)						LSD
	S. cytherea		*C. pachycarpa*		*S. malaccense*		
	Trace elements concentration (ppm)	EADC (ppm)	Trace elements concentration (ppm)	EADC (ppm)	Trace elements concentration (ppm)	EADC (ppm)	
Mg	960.87±126.43	124.8	1063.77±352.45	112.85	1170.0±237.00	142.44	NS
Al	166.40±93.93	21.63	166.40±63.57	17.65	244.60±126.39	29.77	NS
Si	354.87±232.46	46.13	426.33±291.03	45.23	986.13±1130.76	120.03	NS
Cr	14.83±31.56	1.93	30.25±14.21	3.21	25.00±10.87	3.04	NS
Fe	114.43±43.34	14.87	118.80±64.46	12.60	174.20±67.44	21.20	NS
Zn	58.77±54.18	7.64	117.30±187.68	12.44	42.90±54.99	5.22	NS
Ti	21.20±2.55	2.76	21.75±6.01	2.31	29.90±0.00	3.64	NS
Rb	43.30±0.00	5.63	45.30±0.00	4.81	52.50±0.00	6.39	NS
Mn	9.20±2.40	1.20	13.45±13.79	1.43	-		-
Cu	3.10±0.85	0.40	7.15±5.30	0.76	-		-
Ni	2.5	0.33	-		-		-
A.W.E.P	65.02±0.01		53.04±0.04		60.86±0.08		

Note: EADC = Estimated Average Daily Consumption based on two (2) fruits/day, A.W.E.P = Average weight of edible part/ fruit (gm)

C. parchycarpa had the highest mean concentration of Chromium (Cr) with 30.25±14.21, *S. malaccense* (25.00±10.87) and *S. cytherea* (14.83±31.56). According to Oladele and Fadare (2015), Chromium (III) is an essential element for healthy growth while Chromium (VI) compounds are toxics and carcinogenic in humans. The problems that are associated with chromium involve skin rashes, stomach ulcer, kidney, liver damages, lungs cancer and ultimate death (Oladele and Fadare, 2015; Muhammad and Sreebas, 2012). The permissible limit set by FAO/WHO (1984) for daily intake in edible plants was 0.02ppm for adult. Therefore, the fruits are not encouraged to be choice fruits on daily basis except taken as occasional snacks. Iron is essential for various body metabolic activities; especially as components of haemoglobin and oxygen transport in the body system. Its' deficiency leads to anaemia which is usually associated with fatigue, heart failure/palpitations, pale skin, and breath seizure. Iron is required for physical development and growth, as well as production of certain hormones (Aggett, 2012). Abbaspou *et al*., (2014) noted that unregulated Iron leads to tissue damage. Concentrations of Iron (Fe) were 174.20±67.44, 118.80±64.46 and 114.43±43.34 in *S. malaccense, C. parchycarpa* and *S. cytherea* respectively. The levels of Fe detected in the forest fruits were far above the recommended daily allowance (RDA) of 11 – 18mg for 14 – 51 years' individuals, while estimated average tolerable upper limits Iron intake is 45mg daily (NIH, 2020; WHO (2008) observed that approximately 1.62 billion people globally are anaemic and half of the figure associated with iron deficiency. Iron deficiency was noted to be a risk factor affecting about 2 billion people globally (Zimmermann, 2007). In Nigeria, Oluwole and Agboola (2018) estimated Iron deficiency anaemia (IDA) among children below age five (<5) at 22.3% and 75.6% among pregnant women in Northern Nigeria alone. It is noteworthy that the cheapest sources of nutritional iron in developing countries such as Nigeria are mainly local fruits and vegetables. Fruits are good sources of Iron, however, regulated quantities of the studied fruits are recommended to prevent tissue damage due to accumulated levels of Iron in the human body. However, the three fruits are really not consumed daily in the study area; they are occasional snacks when the fruits are in their productive seasons, hence they are unlikely to cause health risks. However, human bodies regulate excess iron levels by excreting via urine, stool, skin and during monthly menstrual cycle in women (McDowell, 2003).

Manganese (Mn) is vital for growth and health maintenance; it is related to antioxidant systems, carbohydrate and fat metabolism (Muhammad and Sreebas, 2012; Avila *et al*., 2013). Excessive intake has been noted to cause neurodegenerative disorder while Mn deficiency is rare in man but could result in poor skeletal development and low fertility (Finley *et al*., 2003) if it occurs. *C. parchycarpa* (13.45±13.79) and *S. cytherea* (9.20±2.40) fruits had high levels of Manganese (Mn) while it was not detected in *S. malaccense* fruit samples used in this study.

IOM, (2001) gave the recommended daily allowance (RDA) of Mn as 2.3mg/kg while FAO/WHO (1984) recommended provisional daily tolerable intake of 2.5mg/kg for adult (19-51years). However, concentrations of Mn in the fruits were above the permissible limits. Crude oil polluted soil of <5 pH ignites accumulation of soluble Aluminum and Manganese compounds (Osuji and Ezebuiro, 2006).

Such accumulation creates good condition for Mn uptake by plants which could be traced to high levels of these compounds in the fruits. Local farmers and fruit collectors' source fruits from wild sources of which the soil may have been polluted and in turn sell to unsuspecting consumers.

There are high possibilities that the fruits are sourced from around or within Rivers state which is classified core crude oil exploration area in Nigeria. Zinc (Zn) and Copper (Cu) concentration were also high in the fruits. Zinc is essential for variety of enzymes in man; toxic doses have been implicated for slow growth and delayed sexual organs maturation (Alysson and Fabio, 2014).

Cu acts as metalloproteins and enzymes in the body, deficiency could lead to kidney and liver dysfunction. Provisional maximum tolerable daily intakes (PMTDI) are 0.3-1 and 0.05-0.5 mg/kg body weight for Zn and Cu respectively (FAO/WHO, 2011). Though, high Zinc and Cu content of the three fruits make them unsuitable as routine diet considering the associated health risks, however they are rarely consumed in excess quantity above 1kg daily.

The quantities of heavy metals that an individual could possibly consume daily were calculated; the edible parts of Ten (10) fruits each were extracted and weighed fresh as consumed. Average weight of consumable part per fruit showed *Spondias cytherea* (65.02±0.01g), *Cola parchycarpa* (53.04±0.04g) and *Syzygium malaccense* (60.86±0.08g).

The recommended daily allowances of the elements were given in mg/kg; none of the edible parts in the fruits weighed up to a kg. Hence consuming average of two fruits daily for all the three fruits were below RDAs indicating they are safe to consume (Table 2).

Conclusion: The three fruit species (*S. cytherea, C. parchycarpa* and *S. malaccense*) were found to be rich in trace elements and can be considered safe for consumption provided they are limited to average of two fruits daily. The presence of trace elements in excessive high concentrations in these locally consumed common fruits may not be unconnected to the prevalence of crude oil exploration and exploitation in Rivers state. There is therefore, a need for formulation of enabling policies to secure safe consumption of fruits in this area.

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