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Nutritional composition and heavy metal content of selected fruits in Nigeria

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Abstract: Despite the nutritional benefits obtained from fruit consumption, the presence of heavy metals accompanying it from the environment draws scientific concerns as these affect human health. The aim of this study is to determine nutritional composition and heavy metal content of some commonly consumed fruits (apple, watermelon and sweet orange) in Nigeria. Atomic absorption spectrophotometry was used to determine nickel, cadmium, chromium, lead and copper present in fruits. The results obtained show that the three fruit species contained considerable nutritional value that may meet body needs. Additionally, there was no significant difference in heavy metal content of fruits based on different locations (ANOVA F. test >0.05). This study posits that all fruit species had the heavy metals within world health organisation (WHO) permissible limit except apples. Apples sampled for different locations had nickel and chromium levels above the WHO permissible limits. Based on the observations in this study, there is a need for continuity of heavy metals inspection in agricultural products so as to prevent contamination and secure human safety.

Keywords: *heavy metal, food safety, fruits, nutrition*

Introduction

Food safety is vital for the survival of all living organisms involved in the food chain. In most developing countries like Nigeria, the quest for rapid economic growth through industrialization and modern agriculture have resulted in a concomitant inflow of several contaminants (such as heavy metals) into the environment (Otitoloju, 2016). Advancement in technology has challenged the integrity of the environment with discharge of effluents containing heavy metals (Fulekar *et al.,* 2009; Sabiha-Javied *et al.,* 2009). Although, heavy metals occur as natural constituents of the earth crust, they are mostly considered persistent environmental contaminants since they cannot be degraded or destroyed. Hence, they can enter the body system through food, air, and water. These bio-accumulations could be over a period of time due to their long half-lives, the potential for accumulation in the different organ of body thus lead to unwanted side effects (Lenntech, 2004; Ming-Ho, 2005; Aderinola *et al.*, 2009). Lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), copper (Cu) and many other heavy metals are potentially toxic to humans and are widely dispersed in the environment (Morais *et al,* 2012). In general, heavy metal contaminations threaten agriculture and other food sources for human population. It also leads to poor vegetation growth and lower plant resistance against forests pests (Ene *et al.*, 2009). Decreased sperm count in men, spontaneous abortions in women, cardiovascular and kidney diseases are associated with high lead exposure (Hertz-Picciotto, 2000; WHO, 1992). Cadmium intake above recommended level is associated with renal, prostrate and ovarian cancers (Satarug *et al.*, 2011). High level of nickel may cause nervous system disorder, decreased intellectual capacity, zinc or iron deficiency as well as enzymatic malfunctioning (Jarup, 2003; WHO, 1992). It is well known that copper toxicity induces iron deficiency, lipid peroxidation and destruction of membranes (Zaidi *et al.,* 2005).

On the other hand, a regular consumption of fresh fruits (e.g. apples, water melons and sweet oranges etc) is crucial in supplying nutrients needed for growth and continuity of vigour in humans (Mausi *et al.,* 2014; Feumba *et al.,* 2016). They are widely considered as excellent sources of vitamin C, carotenoids, minerals and dietary fibre which are vital requisites to body optimum immunity functions (Dauchet *et al.*, 2010). Apple (*Malus domestica*) is well known for its beautiful appearance, crispy flesh, pleasant flavour and sweet taste which attract consumers and fetch high price (Abdualrahman, 2015). Similarly, watermelon (*Citrullus lanatus*) is a member of the gourd family, cultivated extensively for its pleasant-tasting fruit and one of the most economically important fruit in the family *Cucurbitaceae* with its origin traced to tropical Africa (WHF, 2011). Dietary intake of water melon may contribute to a proper functioning of the kidney (Ogunbanwo *et al.,* 2013) and protects against cancer (Veazie and Collins, 2004). Citrus fruit is one of the commonest fruit crop in Nigeria. The consumption of citrus fruits also is known to boosts the body immune system and confers some protection against diseases such as cardiovascular disease and cancer (Guimaraes *et al.*, 2010).

Despite the benefits of fruit consumption on human health, heavy metal contents in fruits can be toxic when they exceed the recommended health levels or when they bio-accumulate in the body over a long period (Orisakwe *et al.*, 2012). This study therefore aims at determining the nutritional composition and heavy metal content of some commonly consumed fruits (apple, water melon and sweet orange) in Lagos state, south western part of Nigeria.

Materials and methods

Sample collection and preparation

Three (3) fresh fruit namely apple (*Malus domestica)*, water melon ***(****Citrullus lanatus)* and sweet orange *(Citrus sinensis)* were considered for this study as they are widely consumed. Sampling was done in September 2016 in Lagos. Lagos is situated at 6°45' North latitude, 3°4' East longitude and 35 meters elevation above the sea level. Lagos is mega city in Nigeria, having about 9,000,000 inhabitants. Sampling of these fruits was carried out at various fruit sale points of in three locations per local government area (LGA) in Lagos. 3 apples, 3 water-melons and 3 sweet oranges were sampled per location making a total of 81 fruits. The study covered three LGAs namely Eti-osa, Lagos Mainland and Ifako Ijaiye. While Eti-osa is a riverine area, both Lagos Mainland and Ifako-Ijaiye are industrial bases. Samples were put in polythene bags, properly labelled, and taken to the laboratory for appropriate analysis. Fruit samples were thoroughly shredded and homogenized.

Determination of nutritional composition of fruits by proximate analysis

Moisture content (%) determination

Moisture content of fruit samples was determined according to the method of AOAC (2005). An empty clean crucible was weighed; 5g of the fresh fruit samples was weighed into a crucible and dried in an oven at 105°C to constant weight. The moisture content was then calculated using this equation:

$$\text{Moisture \%} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight of samples}} \times 100$$

Ash content (%) determination

Ash content of fruit samples was determined according to the method of AOAC (2005). An empty clean crucible was weighed; 5g of sample was weighed into the crucible and ashed in a furnace at 550°C to a constant weight. Total ash was calculated as follow:

$$\text{Ash \%} = \frac{\text{Weight of Ash}}{\text{Weight of Sample}} \times 100$$

Crude fat (%) determination

Crude fat was obtained by exhaustively determined method of AOAC (2005); 5g of sample was massed into a polypropylene centrifuge bottle. Sodium acetate, aliquots of methanol, chloroform and water were added into the bottle and shaken for 30 minutes. The content of the bottle were centrifugated at 2500 rpm for 10 min, then it was set in 25°C water bath for 15 minutes. The samples were evaporated to dryness under nitrogen blanket, heated in a drying oven for 30 minutes, and cooled in a desiccator for at least 30 minutes. Fat content was then determined using:

$$\text{Fat \%} = \frac{W_1 - W_2}{(VA \times SW)} \times VC \times 100$$

Where, W_2 was the weight of glass tube and dried extract (g), W_1 was the weight of empty dried glass tube (g), V_C was the total volume of chloroform (ml), V_A was the volume of extract dried (ml), and S_W was the weight of the sample in grams.

Crude protein (%) determination

Crude protein content of fruit was determined according to the method of AOAC (2000). Briefly, 1.0g of sample was weighed into digestion tubes. Two Kjeltabs Cu 3.5 (catalyst salts) were added into each tube; then 20 ml of concentrated sulphuric acid (H_2SO_4) was carefully added into the tube and shaken gently in order to digest samples. Digested samples were cooled for 10 to 20 min. Distillation procedure was then performed using distillation unit and the distillate was titrated with 0.025N sulphuric acid (H_2SO_4) until the end point changes from green to pink. Volume of acid required in the titration was recorded. Blank was prepared with the exclusion of sample.

$$1000 \text{ mL } 1\text{N } H_2SO_4 = 1000 \text{ mL } 1 \text{ N } NH_3 = 17 \text{ g } NH_3 = 14 \text{ g N}$$

$$1 \text{ mL } 1\text{N } H_2SO_4 = 1 \text{ mL } 1 \text{ N } NH_3 = 0.014 \text{ g N}$$

The percentage of protein content was calculated according to Jolaoso *et al.* (2016):

$$\text{\% Nitrogen} = \frac{0.014 \times VD \times 100 \times TV}{\text{Weight of sample} \times AD}$$

$$\text{\% Protein} = \text{\%N} \times F$$

Where, VD is the Volume of digest; N is the normality of acid; TV is the titre value; AD is the aliquot of digest and F is the conversion factor for nitrogen to protein (6.25).

Crude fibre (%) determination

Fibre content was determined according to the method of AOAC (2005). 5g of each fruit sample was weighed into a 1 litre conical flask. Then 200ml of boiling sulphuric acid was added and boiled for 30 minutes over a burner. Swirling is done occasionally to remove solids from adhering to the sides of the flask. The hot solution was decanted through Buchner funnel fitted with Whatman 52 filter paper. All residues were rinsed with boiling water until no colour change in litmus paper to be sure acid has been removed. Then the residue was transferred into a 200 ml of 1.25% Sodium hydroxide (NaOH) solution into a 1 litre flask and brought to boil, maintaining a gentle ebullition for 30 minutes, then it was filtered through rapid hardened filter paper. 1% HCl and distilled water, 15ml of ethyl alcohol and 10ml of diethyl ether were also added. The sample was dried in an oven at 100^{0}C for 1 hour, cooled in a desiccator and weighed (W_1). Sample was put in a crucible in a furnace at 55^{0}C for 3-4 hours; it was cooled in a desiccator and weighed again (W_2). Fibre was calculated thus:

$$\% \text{ Fibre} = \frac{W_1 - W_2}{\text{Weight of the sample}} \times 100$$

Carbohydrate content (%) determination

Carbohydrate content was calculated based on difference calculation (AOAC, 2005):

Carbohydrate = 100% - (% moisture % ash+ % crude protein + % fat)

Procedure for heavy metal determination

The standard procedure described by Association of Official Analytical Chemists (2000) was followed for the samples preparation for the analysis of heavy metals. Samples were digested by measuring exactly (1.0 g) of the milled sample into a digesting glass tube. 12ml of HNO_3 was added to the food samples and mixture was kept for overnight at room temperature. Then 4.0 ml perchloric acid ($HClO_4$) was added to this mixture and was kept in the fumes block for digestion. The temperature was increased gradually, starting from 50^{o}C and increasing up to 250-300^{o}C. The digestion was completed in about 70- 85 min as indicated by the appearance of white fumes. The mixture was left to cool down and the contents of the tubes were transferred to 100 ml volumetric flasks and the volumes of the contents were made to 100 ml with distilled water. The wet digested solution was transferred to plastic bottles labelled accurately. The digest was used for metal determination by Atomic Absorption Spectrophotometer (AAS-700, Perkin-Elmer, USA) using acetylene/air as gas mixture.

Stock standard was prepared by dividing the molar mass of the compound of the element by the molar mass of the element. The standard solution prepared was used to calibrate Atomic Absorption Spectrophotometer (AAS). The prepared sample was aspirated into the AAS; the air, the fuel of the instrument (acetylene) and the sample, formed aerosol inside the AAS. About 10% of the aerosol goes into the flame and 90% passed out as waste. The flame vaporized, dissociated, and atomized the sample from ground state to excited state. The readings were taken from the equipment in mg/g and the results were converted to mg/kg which is the actual concentration of the metal in the sample using the equation (Aderinola *et al.,* 2009):

$$\frac{\text{Concentration of metal calibrated reading x volume of digest}}{\text{Weight of sample}}$$

Statistical analysis

Two ways analysis of variance (ANOVA) was done for nutritional composition and heavy metal content in fruits using Graphpad prism 7. Results were expressed as Mean ± SEM of triplicate determination. Spearman's rho correlation analysis was further used to correlate heavy metal and nutritional composition of fruits using SPSS version 22.

Results and discussion

Nutritional composition

Fruits are widely known to provide humans with nutrients for normal development and thus, they have occupied an important place among food crops (Mausi *et al,* 2014). In this study,

the nutritional composition of fruits was determined and shows comparative variability between apple, water melon and sweet orange. Moisture content for each fruit gotten from different locations was relatively high which is typical of fresh fruits at maturity (Umoh, 1998). Although, no significant difference (P>0.05) in moisture content for each fruits sampled for different locations was observed, there seems to be no location effect for moisture content in each fruit specie. However, there was a significant difference (P<0.0001) in moisture content amongst the fruit species. The mean moisture content ranged from 89.92% being the highest in water melon to 83.47% being the lowest in apple. The moisture content reported by Ugbogu and Ogodo (2015) was higher compared with that of the present study. The increasing magnitude of moisture content is consequently a function of the degree of perishability as a result of microbial contamination with reference to adequate storage facilities (Chilaka *et al*, 2010). However, the relatively high moisture contents of fruit species as observed in this study invariably makes them good sources of hydration for the body as well as possessing the ability to quench thirst (Ogbonna *et al.,* 2013).

Proteins are essential components of diets needed for survival of animals and humans; their basic function in nutrition is to supply adequate amounts of required amino acids in nutrition (Pugalenthal *et al.,* 2004). Protein deficiency causes growth retardation, muscle wasting, edema, abnormal swelling of the belly and collection of fluids in the body (Perkins–Veazie *et al.,* 2005). In this study, no significant difference (P>0.05) in crude protein for each fruit specie sampled for different locations and amongst the fruit species was observed. However, the relatively low percentage crude protein observed in all fruit species.

Agrees with Fila *et al* (2013) that fruits are low in total nitrogenous components as compared to seeds, leaves and some other plant parts and tissues.

Ash content can be translated to be the quantity of minerals present in foods (Coimbra and Jorge, 2011).

Table 1 - Nutritional compositions (%) of fruit species at different locations.

	Apples			Sweet oranges			Water melons		
	A	B	C	A	B	C	A	B	C
Moisture content	83.45 ± 0.455	83.46 ± 1.145	83.50 ± 2.585	85.82 ± 0.130	85.81 ± 1.035	85.89 ± 0.445	89.70 ± 1.30	89.55 ± 2.185	90.52 ± 0.74
Crude protein	0.26 ± 0.000	0.25 ± 0.05	0.25 ± 0.005	0.74 ± 0.09	0.74 ± 0.09	0.74 ± 0.04	0.92 ± 0.015	0.95 ± 0.015	0.88 ± 0.02
Ash content	0.25 ± 0.01	0.26 ± 0.01	0.27 ± 0.000	0.11 ± 0.01	0.09 ± 0.01	0.10 ± 0.01	0.10 ± 0.12	0.09 ± 0.005	0.09 ± 0.000
Crude fat	0.33 ± 0.035	0.34 ± 0.01	0.35 ± 0.000	0.21 ± 0.01	0.20 ± 0.02	0.20± 0.02	0.48 ± 0.02	0.46 ± 0.005	0.45 ± 0.005
Crude fibre	1.80 ± 0.025	1.84 ± 0.02	1.83 ± 0.005	0.24 ± 0.05	0.23 ± 0.01	0.24 ± 0.01	0.12 ± 0.005	0.09 ± 0.005	0.11 ± 0.005
CHO	13.91 ± 0.565	13.85 ± 0.025	13.80 ± 0.000	12.88 ± 0.02	12.93 ± 0.02	12.83 ± 0.02	8.68 ± 0.06	8.86 ± 0.02	7.95 ± 0.035

Values are % mean ± SEM of triplicate determinations; A = Ajah; B = Oyingbo; C = Ifako-Ijaiye

Minerals are important for bone and teeth formation, blood clotting, muscle contraction, transmission of impulses in nerves and maintenance of osmotic balances (Awe *et al,* 2013). No significant difference (P>0.05) in ash content for each fruit specie sampled for different locations and amongst the fruit species was observed. Moreover, the ash content value in this study conformed favourably with most fruits value (Brain and Alan, 1992; Apiamu *et al.,* 2015). Fats are important class of nutrients for normal body metabolism. No significant difference (P>0.05) in crude fat for each fruit specie sampled for different locations and amongst the fruit species was observed. The crude fat content recorded in this study agrees with the findings of Potter and Hotchkiss (1996). The relatively low proportion of crude fat in these fruit species conforms to earlier report by Sheila (1978) that fruits are not very good sources of dietary fats and are usually recommended as part of weight reducing diets.

Dietary fibre is essentially a health promoting nutrient. Adequate intake of fibre has been linked to a reduced risk of diabetes, coronary heart disease and colon cancer (Turner and Lupton, 2011). In this study, no significant difference (P>0.05) in crude fibre for the different locations was observed for each fruit specie. However, a significant difference (P<0.0001) between crude fibre in apple compared to that of sweet orange and water melon was observed. Among these fruit species, apple with mean crude fibre value of 1.82 % had the highest fibre content. Moreover, there was no significant difference (P>0.05) in crude fibre content between sweet orange and water melon sampled for different locations.

Carbohydrate is the most important source of energy for the body metabolism drive. In this study, no significant difference (P>0.05) was observed for carbohydrate content in each fruit specie obtained at different locations. However, a significant difference (P <0.0001) in carbohydrate content was observed for the fruit species. The mean carbohydrate content ranges from 13.85 % being the highest in apple to 8.50 % being the lowest in water melon.

Heavy metal content in different fruits

The human body can be easily contaminated by heavy metals such as Ni, Cd, Cr, Pb, and Cu through dietary exposure or by exposition to heavy metal contaminated environments. Since fruits and vegetables can absorb heavy metal contents from the soil, even the same crops or fruits can differ in mineral and metal contents depending on the soil and the region where the plants are cultivated (Kim *et al.,* 2004). Increased concentration of heavy metals is associated with the etiology of a number of diseases, especially cardiovascular, renal and neurological disorders (Jolaoso *et al.,* 2016).

Table 2 - Heavy metal contents (mg/kg) of fruit species at different locations.

		FRESH FRUITS SPECIES								
		APPLE			SWEET ORANGE			WATER MELON		
E	Safe limit	A	B	C	A	B	C	A	B	C
Ni	0.20	0.475 ± 0.005*	0.420 ± 0.010*	0.400 ± 0.010*	ND	0.005 ± 0.005	0.015 ± 0.005	0.0215 ± 0.001	0.018 ± 0.000	0.020 ± 0.000
Cd	0.20	0.035 ± 0.005	ND	0.02 ± 0.000	ND	0.005 ± 0.005	0.020 ± 0.000	ND	ND	ND
Cr	0.10	0.300 ± 0.010*	0.280 ± 0.000*	0.295 ± 0.005*	0.080 ± 0.010	0.075 ± 0.005	0.070 ± 0.000	0.010 ± 0.001	0.010 ± 0.001	0.01 ± 0.000
Pb	0.30	0.020 ± 0.000	0.010 ± 0.000	0.025 ± 0.005	0.120 ± 0.010	0.095 ± 0.005	0.070± 0.000	0.064 ± 0.001	0.065 ± 0.000	0.063 ± 0.001
Cu	0.20	0.180 ± 0.000	0.208 ± 0.015	0.200 ± 0.002	0.052 ± 0.003	0.044 ± 0.005	0.054 ± 0.005	0.108 ± 0.001	0.110 ± 0.001	0.110 ± 0.001

Values are % mean ± SEM of triplicate determinations; ND = Not Detected; * values greater than FAO/WHO permissible limit (mg/kg), E = Heavy metals; Safe limit (WHO/FAO, 2012).

In this study, no significant difference ($p>0.05$) in Ni level was observed within each fruit specie sampled for different locations. However, a significant difference ($p<0.0001$) in Ni level was observed between fruit species. The mean Ni levels in the fruit species varied between 0.432 and 0.01 mg/kg with the highest observed in apple and the lowest observed in sweet orange. Divrikli *et al.* (2006) have reported Ni level for Indian Basil (0.067 mg/kg) which conforms favourably to the range of values obtained from this study. The mean Ni value for apple was above the WHO/FAO permissible limit of 0.2 mg/kg for the different locations. However, the level of Ni in both water melon and sweet orange were within the WHO/FAO permissible limit. For sweet orange, Ni was detected only two locations (Oyingbo and Ifako-Ijaiye). The prevalence of Ni in apple gotten from Ajah, Oyingbo and Ifako-Ijaiye may be due to contamination from the electronic industries around.

Cadmium (Cd) is a non-essential toxic heavy metal in foods and natural waters and it accumulates principally in the kidneys and liver (Divrikli *et al.,* 2006). No significant difference ($p>0.05$) in Cd levels for each fruit specie within the different locations. Similarly, there was no significant difference ($p>0.05$) in Cd levels between the fruit species sampled at the different locations. Cd was not detected in apples gotten from Oyingbo, sweet oranges gotten from Ajah and in water melons gotten from all the different locations. The levels of Cd analyzed in all fruits sampled occurred within recommended level of 0.2mg/kg (WHO/FAO, 2012). Cd level will therefore pose an insignificant health risk to consumers but an accumulation in the bodies of the consumers over a long period of time is of major concern as it can result to serious health implications. This value conforms favourably with report by Radwan and Salama (2006) and Mausi *et al* (2014). Cadmium level in fruits depends on plant fruit type and its affinity to uptake cadmium from the environment in which fruit plants are grown (Mausi *et al.,* 2014).

Chromium is a toxic naturally occurring element that may be released into the environment through sewage and fertilizers (Ghani, 2011). In this study, there was no significant difference (P>0.05) observed for Cr in each fruit specie within the different locations. However, a significant difference (P<0.0001) in the level of Cr was observed among fruit species. The level of Cr ranged from 0.292 mg/kg, being the highest in apple to 0.010 mg/kg being the lowest in water melon. Most importantly, Cr level observed for sweet oranges and water melons for the different locations was found within the WHO/FAO permissible limit of 0.1 mg/kg which favourably conforms to values recently reported by Akinyele and Shokunbi (2015). This finding was however in contrast to that of Sobukola *et al.* (2010) and Ogunkunle *et al.* (2014) who reported the absence of chromium in some fruits and leafy vegetables from selected markets in Lagos, Nigeria. Only apples sampled for all locations were found above the WHO/FAO permissible limit. Apple is one of the most commonly consumed fruit which is usually imported from neighbouring countries. High chromium levels found in apples sampled at different locations is an indication that they have originated from different growing regions or through transport chain (Krepjcio *et al.,* 2005). Excess intake of chromium may cause skin rashes, stomach upset, kidney and liver damage, lung cancer and ultimately death (Ghani, 2011). Prolonged consumption of unsafe concentrations of chromium through foodstuffs may lead to the chronic accumulation of heavy metals in kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (Satarug *et al.,* 2010).

Lead (Pb) is a highly toxic metal whose widespread use has caused extensive environmental contamination and health problems in many parts of the world (Sharma and Dubey, 2005). For this study, no significant difference (P>0.05) in the level of Pb was observed for different locations. However, apple and sweet orange show a significant difference (P<0.001) while apple and water melon show a significant difference (P<0.1) in Pb level. Pb contents for ranged between 0.064 mg/kg being the highest in water melon to 0.01 being the lowest in apple. Most importantly, these fruits gotten from the different locations had Pb contents within the WHO maximum permissible level of 0.3 mg/kg. The low level of Pb in these fruit species is an indication of food safety to consumers of these fruits since elevated levels of Pb is an indication of the increasing industrialization and uncontrolled development of urban areas.

Table 3 - Spearman's Rho correlation of nutritional composition and heavy metal content in fruits.

Parameters	Fruit type	Moisture	Crude Protein	Ash Content	Crude Fat	Crude Fiber	Carbohydrate
Fruit type	1.000						
Moisture	0.949**	1.000					
Crude Protein	0.969**	0.860**	1.000				
Ash Content	-0.834**	-0.715*	-0.835**	1.000			
Crude Fat	0.476	0.469	0.453	-0.081	1.000		
Crude Fiber	-0.953**	-0.845**	-0.966**	0.910**	-0.408	1.000	
Carbohydrate	-0.949**	-1	-0.860**	0.715*	-0.469	0.845**	1.000
Nickel	-0.474	-0.450	-0.451	0.570	0.410	0.469	0.450
Cadmium	-0.609	-0.578	-0.520	0.351	-0.511	.456	.578
Chromium	-0.953**	-0.937**	-0.898**	0.761*	-0.471	0.849**	0.937**
Lead	0.474	0.417	0.494	-0.545	-0.393	-0.485	-0.417
Copper	-0.474	-0.383	-0.502	0.604	0.435	0.494	0.383

**. Correlation is significant at the 0.01 level (2-tailed).*. Correlation is significant at the 0.05 level (2-tailed).

Since, road side vendors and market places are exposed to emissions from several vehicles (through vehicle exhaust systems) which use leaded fuel, the low Pb level gotten from this study however remains unclear as these fruits were gotten from road side vendors and market place. Moreover, Pb being a serious cumulative body poison enters into the body system through air, water and food and cannot be removed by washing fruits (Divrikli *et al.,* 2003). Pb has been found to be toxic to the red blood cell, kidney, nervous and reproductive systems (Taupeau *et al.,* 2001).

Copper is an essential micronutrient which functions as a biocatalysts, required for body pigmentation in addition to iron, maintain a healthy central nervous system, prevents anaemia and interrelated with the function of Zn and Fe in the body (Akinyele and Osibanjo, 1982). Most plants contain the amount of copper which is inadequate for normal growth and is usually ensured through chemical or organic fertilizers (Itanna, 2002). In this study, a significant difference ($P<0.0001$) was observed for Cu level in apple and water melon. Similarly, there was a significant difference ($P<0.01$) between Cu level in sweet orange and water melon. Cu level between the fruit varieties ranged between 0.05 and 0.20 mg/kg, with orange having the lowest and apple having the highest Cu levels. However, the level of Cu in all fruit varieties sampled was within the WHO permissible limit (0.2 mg/kg) which conforms to similar study as reported by Parveen *et al.* (2003). In contrast, higher Cu levels have been reported in watermelon and orange by Radwan and Salama (2006) and Onianwa *et al.* (2000). The relatively low Cu level in all fruits sampled in this study may be due to less deposition of Cu since soils varies in trace elements (Akinola and Ekiyoyo, 2006).

Relationship between heavy metal contents and nutritional quality in fruits

Results, from Table 3, show that there is an inverse and significant relationship ($r<0.05$) between chromium found in fruit varieties and nutritional quality (moisture content, crude protein, crude fat, crude fibre, ash and carbohydrate content). The study therefore shows that the presence of chromium may significantly affect the nutritive value of fruits. Also, chromium was the only heavy metal that had significant correlational impact on nutritional quality of the fruits.

Conclusion

More recent findings globally have linked excessive bioaccumulation of heavy metals to numerous health abnormalities such as some forms of cancers, decreased intellectual capacity, decreased reproductive health and cardiovascular diseases. It could be concluded from this study that the three fruit species contained considerable nutritional value that may meet body needs. Additionally, there was no significant difference in heavy metal content of the fruits in all the sampled sites (locations) of the study. The study posits that all the fruit species had the heavy metals within world health organisation (WHO) permissible limit except apples. Apples sampled for different locations had nickel and chromium levels above the WHO permissible limits. Excess uptake of chromium and nickel may cause skin rashes, stomach upset, kidney and liver damage, lung cancer and ultimately death (Ghani, 2011). Based on the observations in this study, there is a need for continuity of inspection on other heavy metals in agricultural products in order to prevent their contamination and ensure human safety.

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