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Level of heavy metals in sliced watermelon fruits in selected markets in Akure, Nigeria

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Abstract

Background: Fruits are increasingly becoming important dietaries in Nigeria because of its nutritional importance and one of the most sliced fruits that are highly purchased in Nigeria today is watermelon. Nevertheless, consumption of heavy metal contaminated fruits could pose a risk to human health. Therefore, the aim of this work was to determine heavy metal contamination in sliced watermelon fruits in selected Nigerian markets to ascertain their public health safety before consumption.

Methods: A total of 54 sliced watermelon fruits were randomly sampled from six different vendors (A –F) in each of the selected markets (Isinkan, Shasha, and Oja-Oba). Samples were digested and analyzed for heavy metal concentrations using atomic absorption spectrometry (AAS) and values compared with WHO (World Health Organization) permissible levels.

Results: The nickel (Ni) levels detected in the sliced fruits across the markets ranged from 0.20 ± 0.01 (Isinkan) to 1.42 ± 0.02 mg kg^{-1} (Oja-Oba), while chromium (Cr) levels detected ranged from 0.04 ± 0.01 (Shasha) to 0.12 ± 0.02 mg kg^{-1} (Oja-Oba). Copper (Cu) levels ranged from 0.04 ± 0.00 (Isinkan) to 0.13 ± 0.03 mg kg^{-1} (Oja-Oba). Remarkably, cadmium and lead were not detected in any of the sliced fruits. Additionally, the levels of Cu in this study were generally below the WHO permissible levels. However, the levels of Ni in all the sliced watermelon fruits, aside the one purchased from vendor D in Isinkan market, were found to be above the permissible levels. Similarly, Cr levels in the sliced fruits purchased only from vendors A, E, and F in Shasha and vendor C in Oja-Oba markets were also found to be above the permissible levels.

Conclusion: This research work provides valuable information on heavy metal contents of sliced watermelon fruits in Akure markets when compared with WHO permissible levels. Fruits with higher values of these metals could constitute health hazards when such fruits are consumed. Hence, there is need to monitor the levels of these metals in sliced fruits from exceeding the acceptable levels as established by regulatory agencies.

Keywords: Heavy metal contaminants, Levels, Sliced watermelon fruits, Nigerian markets, Vendors

Background

Over the years, studies have shown that there is a significant increase in the consumption of sliced fruits which are fruits that have been cut into smaller sizes, often eaten directly without necessarily having to cut, peel, or cleanse them again before consumption because they have already been prepared and packaged by the vendors (Roever 2003; Chukwuka et al. 2010; Odebisi-Omokanye et al. 2015). The tremendous increase in the demand of sliced fruits might be because they are easily accessible, convenient, and mostly cheaper than the whole fruits (Roever 2003). Sliced fruits frequently consumed in Nigeria include pawpaw, pineapple, and watermelon (Adesetan et al. 2013; Mbata et al. 2016).

Watermelon (*Citrullus lanatus*) is a significant fruit in the curcurbitaceae family with diverse nutritional and medicinal values (Gwana et al. 2014). For instance, the fruit is enriched with carotenoid, vitamin C, citrulline, carbohydrates, water, sugar, and dietary fiber (Bruton

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et al. 2009), while Ogunbanwo et al. (2013) reported that day-to-day consumption of watermelon can result in proper functioning of the kidney and could also shield against cancer (Veazie and Collins 2004). In Nigeria, the sliced watermelon fruits are either sold by mobile vendors who peddle them around or by stationary vendors who are set up in various strategic places such as stalls, market places, schools, and public bus stations.

In spite of the nutritional importance of consuming these sliced fruits, their consumption has been linked with some health diseases arising from elevated levels of heavy metals. In fact, consumption of heavy metal-contaminated fruit is deleterious to human health, and that is why metal contamination of food is one of the most significant aspects of food quality assurance (Radwan and Salama 2006; Khan et al. 2008). Heavy metal contents in fruits can be toxic when they exceed the maximum permissible limit or when they bioaccumulate in the body over a long period (Orisakwe et al. 2012) thereby resulting to undesirable side effects and serious health risks (Ming-Ho 2005; Aderinola et al. 2009). Thus, it is against this background that this study sought to investigate heavy metal contamination of sliced watermelon fruits in selected markets in Akure Metropolis. The obtained results were compared with that of WHO permissible limits.

Materials and methods

Study area and sample collection

The selected markets in this study were three major markets in Akure (Isinkan, Shasha, and Oja-Oba) as shown in Fig. 1. Three sliced watermelon fruits were purchased separately from six different fruit vendors (A–F) in each of the markets, thus making a total of

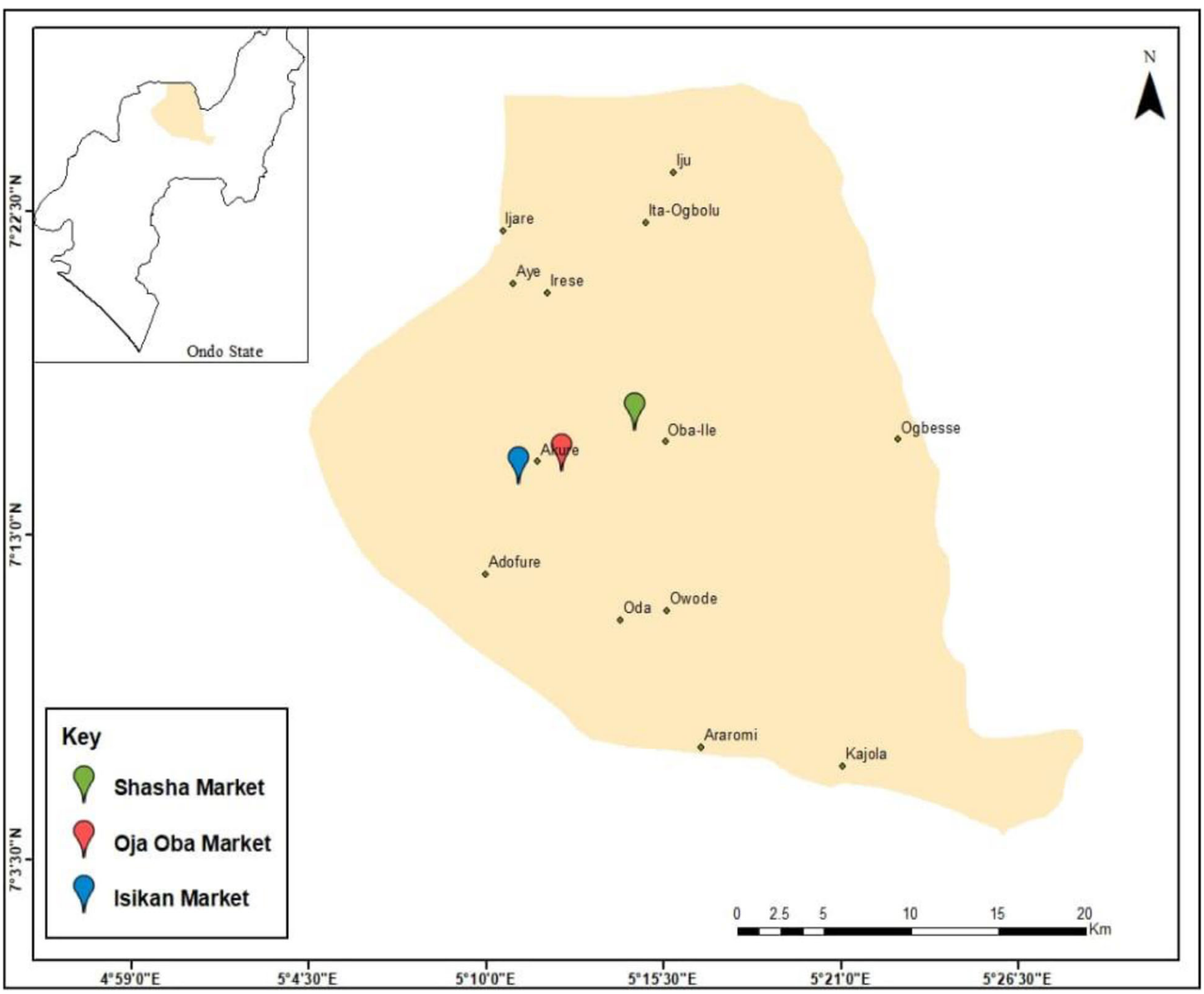

Fig. 1 Location of the selected markets in Akure

fifty-four (54) sliced watermelon fruit samples that were randomly purchased from the 3 markets. However, wholesome fruit served as control. All the fruit samples were collected in sterile universal nylon bags and transported immediately to the research laboratory, Department of Biology, Federal University of Technology, Akure, Ondo State, Nigeria, for heavy metal analysis.

Sample preparation and chemical analysis

Both the sliced watermelon fruits and the control samples were separately homogenized in an electric blender with stainless steel rotor knives and were dispensed in a clean sterile sample bottle. The homogenized samples were extracted using acid digestion method (Cui et al. 2010). Three aliquots of 30 ml each, representing three replicates from each vendor from the selected market were accurately measured and placed in a 200-ml beaker to which 30 ml of 10% concentrated HNO_3 was added and left to settle for 15 min. This was followed by wet acid digestion in 10 ml of 1:3 mixture of concentrated HCl: HNO3 (Merck) using a hotplate, till clear solution was obtained. Digested samples were allowed to cool off at room temperature. Digested samples were then filtered into a 50-ml volumetric flask through Whatman No. 1 filter paper, and the final volume made up to 50 ml with distilled water. The samples were then transferred to clean and dry plastic bottles and the digestate was further analyzed using atomic absorption spectrophotometer (AAS) (model ZA-3300) in order to determine the level of heavy metals present.

Quality control

Appropriate quality assurance procedures and precautions were carried out to ensure reliability of the results. Samples were generally carefully handled to avoid contamination. Glassware was properly cleaned, and the reagents were of analytical grade. Double distilled deionized water was used throughout the study. Reagent blank determinations were used to correct the instrument readings (Wang et al. 2012). Fruit samples were homogenized for analysis using an electric blender with stainless steel rotor knives (Cui et al. 2010). Distilled water was used throughout the sample preparation and analysis.

Statistical analysis

All experiment was conducted in triplicates and the values obtained for metal concentrations were subjected to analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS, IBM, USA) version 21.0. Means were separated by Duncan multiple range test, with the significant difference level of $P = 0.05$.

Results

Level of heavy metals in sliced watermelon fruits purchased from Isinkan market

Concentration (mg kg^{-1}) of heavy metals in sliced watermelon fruits purchased from Isinkan market were presented in Table 1. There was no significant difference ($P > 0.05$) in nickel (Ni) concentrations in the sliced fruits purchased from vendors A (0.25 ± 0.03), B (0.21 ± 0.02), D (0.20 ± 0.01), and the control fruits (0.27 ± 0.01). However, Ni concentrations in the sliced fruits purchased from vendor C (0.35 ± 0.04), vendor E (0.57 ± 0.00), and vendor F (0.57 ± 0.00) were significantly different ($P < 0.05$) from the control fruit. Chromium (Cr) was not detected in the sliced watermelon fruits purchased from vendors B, C, D, and the control fruit. However, Cr concentration in the sliced fruits purchased from vendors A (0.11 ± 0.01), E (0.06 ± 0.02), and F (0.10 ± 0.03) were significantly different ($P < 0.05$) from the control. Meanwhile, copper (Cu) concentrations in the sliced fruits purchased from vendors A (0.14 ± 0.02), B (0.07 ± 0.01), C (0.06 ± 0.04), E (0.04 ± 0.00), and F (0.11 ± 0.01) were not significantly different ($P > 0.05$) from the control fruit (0.08 ± 0.01). However, Cu concentration in the sliced fruits purchased from vendor D (0.17 ± 0.02) was significantly different ($P < 0.05$) from the control. Interestingly, cadmium (Cd) and lead (Pb) were not detected in the control and all the sliced watermelon fruits purchased from all vendors.

Means having the same alphabet within the column are not significantly different from each other using ANOVA and Duncan's test at $\alpha = 0.05$

Table 1 Concentration (mg kg^{-1}) of heavy metals in sliced watermelon fruits purchased from Isinkan market

Vendors	Nickel	Chromium	Copper	Cadmium	Lead
A	0.25 ± 0.03^{a}	0.11 ± 0.01^{c}	0.14 ± 0.02^{bc}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
B	0.21 ± 0.02^{a}	0.00 ± 0.00^{a}	0.07 ± 0.01^{ab}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
C	0.35 ± 0.04^{b}	0.00 ± 0.00^{a}	0.06 ± 0.04^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
D	0.20 ± 0.01^{a}	0.00 ± 0.00^{a}	0.17 ± 0.02^{c}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
E	0.57 ± 0.00^{c}	0.06 ± 0.02^{b}	0.04 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
F	0.57 ± 0.00^{c}	0.10 ± 0.03^{bc}	0.11 ± 0.01^{abc}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Control	0.27 ± 0.01^{a}	0.00 ± 0.00^{a}	0.08 ± 0.01^{ab}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Table 2 Concentration (mg kg^{-1}) of heavy metals in sliced watermelon fruits purchased from Shasha market

Vendors	Nickel	Chromium	Copper	Lead	Cadmium
A	1.21 ± 0.02^{e}	0.11 ± 0.02^{c}	0.07 ± 0.01^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
B	1.29 ± 0.01^{f}	0.04 ± 0.01^{ab}	0.09 ± 0.01^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
C	0.37 ± 0.01^{b}	0.07 ± 0.03^{bc}	0.11 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
D	0.72 ± 0.01^{d}	0.00 ± 0.00^{a}	0.07 ± 0.02^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
E	0.46 ± 0.03^{c}	0.21 ± 0.03^{d}	0.07 ± 0.01^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
F	1.41 ± 0.03^{g}	0.23 ± 0.01^{d}	0.09 ± 0.03^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Control	0.27 ± 0.01^{a}	0.00 ± 0.00^{a}	0.08 ± 0.01^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Means having the same alphabet within the column are not significantly different from each other using ANOVA and Duncan's test at $\alpha = 0.05$

Level of heavy metals in sliced watermelon fruits purchased from Shasha market

Concentration (mg kg^{-1}) of heavy metals in sliced watermelon fruits purchased from Shasha market were presented in Table 2. Nickel (Ni) concentration in the sliced watermelon fruits purchased from vendors A (1.21 ± 0.02), B (1.29 ± 0.01), C (0.37 ± 0.01), D (0.72 ± 0.01), E (0.46 ± 0.03), and F (1.41 ± 0.03) were significantly different ($P < 0.05$) from each other and the control (0.27 ± 0.01). Chromium (Cr) was not detected in the control fruit and sliced fruits purchased only from vendor D but detected in sliced fruits from other vendors, ranging from 0.07 ± 0.03 (vendor C) to 0.23 ± 0.01 (vendor F). Meanwhile, there were no significant differences ($P > 0.05$) in the concentrations of copper (Cu) in both the control fruit and sliced watermelon fruits purchased from all the vendors, and the Cu levels ranged from 0.07 ± 0.01 in vendors A, D, and F to 0.11 ± 0.00 in vendor C. Again, cadmium (Cd) and lead (Pb) were also not detected in the control and all the sliced watermelon fruits purchased from each vendor in the market.

Level of heavy metals in sliced watermelon fruits purchased from Oja-Oba market

Concentration (mg kg^{-1}) of heavy metals in sliced watermelon fruits purchased from Oja-Oba market were presented in Table 3. There was no significant difference ($P > 0.05$) in concentrations of Ni in the sliced fruits purchased from vendors D (0.32 ± 0.03), F (0.23 ± 0.01), and the control (0.27 ± 0.01). However, Ni concentrations in sliced fruits purchased from vendor A (0.75 ± 0.01), vendor B (1.20 ± 0.05), vendor C (1.42 ± 0.02), and vendor E (0.94 ± 0.03) were however significantly different ($P < 0.05$) from the control fruit. Chromium (Cr) was not detected in the sliced watermelon fruits purchased from vendors B, D, E, and the control fruit. Nevertheless, it was detected in the sliced fruits purchased from vendors A (0.08 ± 0.01), C (0.12 ± 0.02), and F (0.10 ± 0.02) that were not significantly different ($P < 0.05$) from each other. Also, there was no significant difference ($P > 0.05$) in concentrations of copper (Cu) in the sliced fruits purchased from vendors A (0.09 ± 0.01), C (0.10 ± 0.01), D (0.07 ± 0.01), E (0.07 ± 0.01), F (0.10 ± 0.02), and the control (0.08 ± 0.01). But Cu concentration in the sliced fruits purchased from vendor B (0.13 ± 0.03) was significantly different ($P < 0.05$) from the control. Likewise, cadmium (Cd) and lead (Pb) were also not detected in the control and all the sliced watermelon fruits purchased from each vendor in the market.

Comparison of heavy metal concentrations in sliced watermelon fruits with WHO permissible limits

Figure 2 shows comparison of Cu concentrations in the sliced watermelon fruit samples across the selected markets with WHO maximum permissible level, and the observed Cu levels were below the WHO permissible limit for Cu (0.2 mg kg^{-1}), while Fig. 3 shows Ni levels in the sliced fruit samples to be above the WHO permissible limit (0.2 mg kg^{-1}) aside sliced fruits purchased from vendor D in Isinkan market. Similarly, Fig. 4 shows Cr levels in the sliced fruits purchased only from vendors A, E, and F in Shasha and vendor C in Oja-Oba markets to also be found above the WHO permissible limit for Cr (0.1 mg kg^{-1}).

Discussion

Results of this study have shown that Ni was detected in all the sliced watermelon fruits purchased from the selected markets and the levels observed, aside the sliced fruits purchased from vendor D only in Isinkan market, were above the WHO maximum permissible level. Nickel has been considered to be an essential trace element for human and animal health (Zaigham et al. 2012). Even, Sobukola et al. (2010) reported that Ni has some functional role in the body such as enzyme functions. Nonetheless, the high concentration of Ni observed in the sliced fruits above the WHO permissible limit is of great concern. According to Divikli et al. (2006), ingestion of unsafe concentration of Ni can result to brain, spleen, kidney, liver, and tissue damage. Salako et al. (2016) also reported that prolonged consumption of food contaminated with unsafe

Table 3 Concentration (mgkg^{-1}) of heavy metals in sliced watermelon fruits purchased from Oja-Oba market

Vendors	Nickel	Chromium	Copper	Lead	Cadmium
A	0.75 ± 0.01^{b}	0.08 ± 0.01^{b}	0.09 ± 0.01^{ab}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
B	1.20 ± 0.05^{c}	0.00 ± 0.00^{a}	0.13 ± 0.03^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
C	1.42 ± 0.02^{d}	0.12 ± 0.02^{c}	0.10 ± 0.01^{ab}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
D	0.32 ± 0.03^{a}	0.00 ± 0.00^{a}	0.07 ± 0.01^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
E	0.94 ± 0.03^{c}	0.00 ± 0.00^{a}	0.07 ± 0.01^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
F	0.23 ± 0.01^{a}	0.10 ± 0.02^{bc}	0.10 ± 0.02^{ab}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Control	0.27 ± 0.01^{a}	0.00 ± 0.00^{a}	0.08 ± 0.01^{ab}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Means having the same alphabet within the column are not significantly different from each other using ANOVA and Duncan's test at $\alpha = 0.05$

concentration of nickel can result to nickel-oriented disease conditions that typically affect the bones and thyroid glands. This toxicity could be linked to contamination of the sliced fruits during processing or from exposure to atmospheric deposition.

Meanwhile, chromium was detected in sliced fruits purchased from vendors A and F (Isinkan market); vendors A, B, C, E, and F (Shasha market); and vendors A, C, and F (Oja-Oba market). This agreed with the earlier reports of Fernando et al. (2012) that chromium is one of the most bioavailable heavy metals in fresh fruits. However, Cr was not detected in the control fruits and sliced fruits purchased from vendors B, C, D, and E (Isinkan market); vendor D (Shasha market); and vendors B, D, and E (Oja-Oba market). This finding was in consonance with the works of Sobukola et al. (2010) and Ogunkunle et al. (2014) who reported absence of chromium in watermelons purchased from selected markets in Lagos, Nigeria. The presence or absence of this metal in these sliced fruits could be traced to their processing environment, waste water, and hygiene status of each vendor. This is because Cr is a naturally occurring element that is released into the environment through sewage and fertilizers (Ghani 2011). However, of great concern again is sliced fruits purchased from vendor A (Isinkan market), vendors A, E, and F (Shasha market), and vendor C (Oja-Oba market) where the Cr levels exceed the WHO maximum permissible limit because consumption of unsafe concentrations of chromium through food can result to chronic accumulation of the metal in the kidney and liver, thereby causing disruption of several biochemical processes which could result to nervous, kidney, and cardiovascular diseases (Satarug et al. 2010).

In the same vein, Cu was detected in all the sliced watermelon fruits in the selected markets and interestingly, the observed levels fall within the WHO permissible limit. This observation could be buttressed with similar study by Parveen et al. (2003). In fact, Sobukola et al. (2010) reported Cu levels below the WHO permissible levels in some fruits and leafy vegetables from selected markets in Lagos, Nigeria. Nevertheless, this observation was in contrast with similar studies by Radwan and Salama (2006) and Elbagermi et al. (2012)

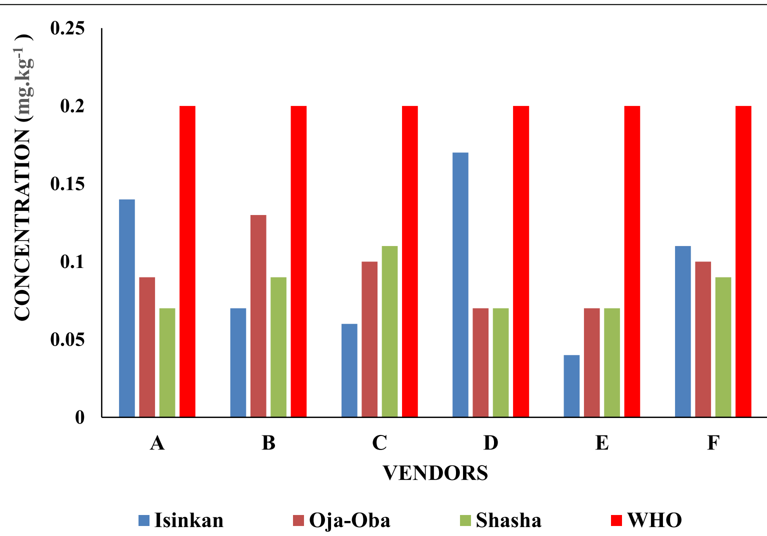

Fig. 2 Comparison of copper concentrations in the sliced watermelon fruits with WHO permissible level

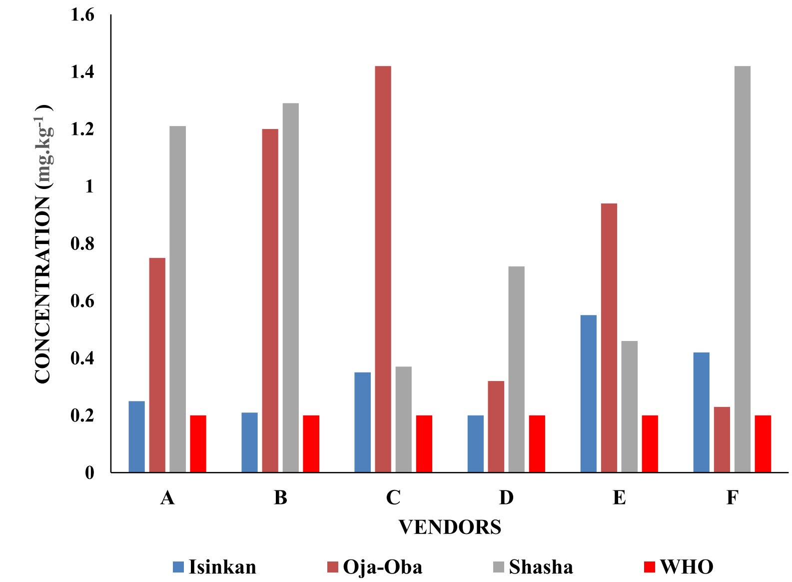

Fig. 3 Comparison of nickel concentrations in the sliced watermelon fruits with WHO permissible level

who reported higher levels of copper in fruits and vegetables. The relatively low copper level in all the sliced watermelon fruits could be attributed to less deposition of copper in the soils (Akinola and Ekiyoyo 2006) and less contamination during processing. Ashish et al. (2013) reported that ingestion of Cu beyond its permissible limit can result to liver and gastrointestinal problems. Flora et al. (2007) also reported that Cu intake beyond its upper limit can result to anemia, anxiety, insomnia, and cardiovascular diseases. Consequently, it is important to monitor Cu levels in food from exceeding the maximum permissible level.

On the contrary, lead (Pb) and cadmium (Cd) were not detected in all the sliced watermelon fruits purchased from different vendors in the selected markets. This was supported by the works of Garba et al. (2015) and Omoyajowo et al. (2017) who reported the absence of Pb and Cd in watermelon fruits sampled from Borno

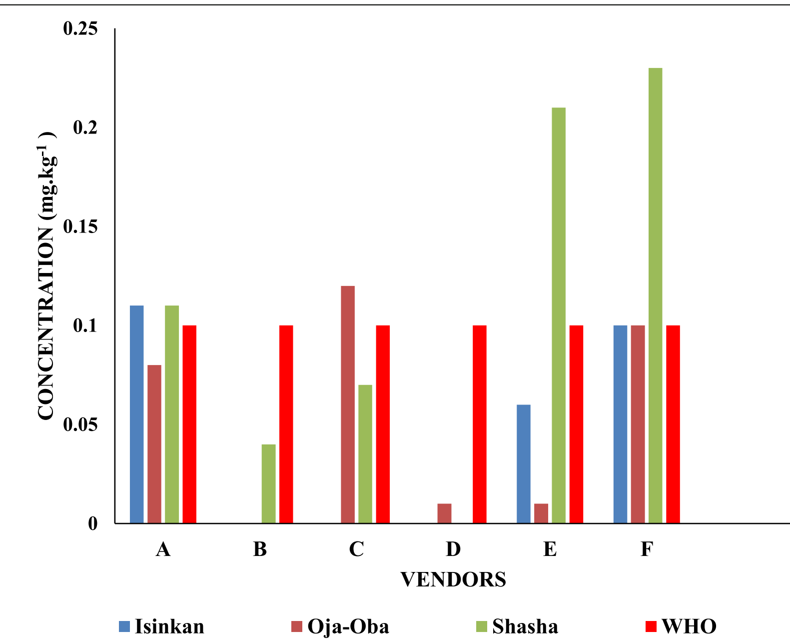

Fig. 4 Comparison of chromium concentrations in the sliced watermelon fruits with WHO permissible level

and Lagos states respectively. However, this observation contradicted the reports of some authors (Radwan and Salama 2006; Sobukola et al. 2010; Elbagermi et al. 2012), who had earlier observed the presence of Pb and Cd in watermelon fruits. Generally, metals such as Pb and Cd should not be found present in fruits especially sliced fruits because Pb is toxic to the red blood cell, kidney, nervous, and reproductive systems (Taupeau et al. 2001), while Bernard (2008) identified Cd as one of the most toxic elements to which humans can be exposed to.

Conclusion

Remarkably, the results of this study have shown that cadmium and lead were not detected in all the sliced watermelon samples. Besides, the levels of copper observed in the all the sliced fruit samples were significantly lower than the WHO maximum permissible values. However, high levels of nickel and chromium above the WHO maximum permissible level in this study is of great concern as nickel is considered a toxic metal capable of causing brain, spleen, kidney, liver, and tissue damage. Hence, use of pesticides, fertilizers, and contaminated soil for growing fruits coupled with the use of wastewater for irrigation in fruit farming, washing, and processing should be discouraged.

Abbreviations

WHO: World Health Organization; AAS: Atomic absorption spectrophotometer; SPSS: Statistical Package for the Social Sciences

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Authors' contributions

All authors contributed to the conception and design of the study, performed the experimental work, interpreted the analyzed data, wrote, revised, and reviewed the draft manuscript. Oluwole O. Oladele corresponded the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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