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Heavy Metal Content and Health Risk Assessment of Jams Consumed in Nigeria

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ABSTRACT: The content and risk of nine heavy metals (Cd, Pb, Ni, Cr, Cu, Co, Mn, Zn and Fe) were quantified and assessed in jams consumed in Nigeria. The heavy metal contents were quantified using atomic absorption spectrometry (AAS) after digesting jam samples with mixture of acids. The quantified content (mg/kg) of the heavy metals in the jams ranged from <0.03 for Cd, < 0.25 for Pb, 0.05-1.55 for Ni, < 0.25-0.50 for Cr, 0.75-7.75 for Cu, <0.25-0.50 for Co, <0.25-13.3 for Mn, <2.00-14.0 for Zn and 13.1-30.8 for Fe. The estimated daily intake (EDI) values of Ni, Co and Mn in 50%, 83% and 67% of jams for children exposure exceeded their tolerable daily intakes (TDI) but the EDI of Cr, Cu, Zn and Fe were below their respectively TDI. The target hazard quotient (THQ) of the respective heavy metals and the total target hazard quotients (∑THQ) were > 1 suggesting health concern for individuals consuming these jams regularly.

Keywords: Heavy metals, Jams, Daily intake, Target hazard quotient

Introduction

Fruits have long been identified as important items of human diet as they have low calories and rich in minerals, dietary fiber and vitamins needed for the proper functioning of the human body (Uusiku *et al*., 2010). The processing of fruits into jams offers a new way of consuming fruits and the popularity of jams is increasing daily as jams are entering the breakfast tables of an ever greater number of people (Mumtaz *et al*., 2019; Khanum *et al*., 2007). Jam is a semi-solid food produced from about 45% of fruit and 55% of sugar (Desrosier, 1978). It is concentrated to 65% or more soluble solids; colouring agents, flavoring agents, pectin and acid may be added to surmount the deficiency that arise in the fruit itself (Mumtaz *et al*., 2019). Jam was initially made in olden days possibly for preservation of some foodstuff and they can be made from both single fruit or mixed fruits (Asema and Parveen, 2018). Fruit products like jams may contain significant amount of heavy metals and irrespective of the health importance of jams, the occurrence of heavy metals in them may pose health concern to the consumers. This is due to the fact that certain heavy metals like cadmium and lead can build up over time in the body and has a variety of chronic effects such as renal problem, reproductive disorders, cancer, endocrine disruption etc (Iwegbue *et al*., 2015b; Bocca *et al*., 2014). However, some heavy metals like copper, zinc and iron are component of enzymes and proteins necessary for metabolism and their scarcity may lead to diseases and metabolic dysfunction even as they can become toxic at higher doses in the body (Iwegbue, 2012; Plum *et al*., 2010). The contamination of jams by heavy metals occur from the heavy metals contents in the fruits used, manufacturing processes, poor packaging, preservation techniques and storage conditions. Hence, it is essential to assess the heavy metal content in jams. Globally, only a few studies (Mumtaz *et al*., 2019; Asema and

Parveen, 2018; Mukantwali *et al*., 2014) have been conducted to determine the content of heavy metals in jams. In Nigeria, there is no information on the content and risks of heavy metals in jams. Thus, the objective of this study was to assess the content and risks of heavy metals in jams consumed in Nigeria.

Materials and methods

Sample collection: Six brands of jams (orange, strawberry, mixed fruit, apricot, pineapple and cherry) were purchased from Supermarkets in Warri, Delta State, Nigeria. Within the same brand, three (3) samples with varied batch number and production dates were obtained to examine the heavy metals variations.

Sample digestion and chemical analysis: Two gram of jam samples was weighed into a 100 mL digestion tube and 25 mL of a mixture of HNO_3, HCl and H_2O_2 in a ratio of 1:3:1 was added. The digestion tube was covered and heated at 100 °C for 1 h with the use of a temperature controlled hot plate until a clear and colourless solution was obtained. The digest was cooled, filtered and made to 50 mL with 0.25 mol/L HNO_3. The content of the heavy metals in the digest were determined with flame atomic absorption spectrometry (Perkin Elmer, Analyst 200).

Quality assurance: The quality assurance procedures employed involved the use of high purity reagents, method blanks and spike recovery technique. The method blanks were undertaken for all heavy metals by going through the steps in the analytical procedure without the sample. The blanks were found to contain no heavy metals. The spike recovery was done by adding known amount of a particular heavy metal into a fresh aliquot of the samples and repeating the steps in the analytical procedure. The percent spike recoveries of the various heavy metals were 90.2%, 95.9%, 101.4%, 92.6%, 99.3%, 90.8%, 94.7%, 93.0% and 97.2% for Cd, Pb, Ni, Cr, Cu, Co, Mn, Zn and Fe respectively.

Evaluation of estimated dietary intake (EDI) and target hazard quotients (THQ): The EDI of heavy metals from the eating of the jams was assessed by using the expression (Iwegbue *et al*., 2015):

$$EDI\ (\mu g/kg\ bw/day)\ = \frac{Ingestion\ Rate \times Concentration\ of\ heavy\ metal\ in\ jam}{Body\ Weight} \quad (1)$$

The ingestion rate of 250 g was used based on the per capita consumption of 91 kg of fruit for sub-sahara Africa (Ibe *et al*., 2019). The body weight used was 60 kg for adults and 15 kg for children.

The target hazard quotient (THQ) was used to assess the extent of concern resulting from intake of the heavy metals via the eating of these jams. The THQ was computed using the expression by the United States Environmental Protection Agency (1989);

$$THQ = \frac{EF \times ED \times EDI}{RFD \times AT} \times 10^{-3} \quad (2)$$

Where EF = exposure frequency (365 days/year), ED = exposure duration (6 and 30 years for children and adults respectively), AT = averaging time for non-carcinogens (ED × 365 days). The AT for children was 2190 days while the AT for adults was 10950 days. RFD = the oral reference dose. The RFDs (in mg/kg/day) used were Ni (2×10^{-2}), Cr (3×10^{-3}), Cu (4.0×10^{-2}), Co (3.0×10^{-4}), Mn (1.4×10^{-1}), Zn (3.0×10^{-1}), Fe (7.0×10^{-1}) (USDOE, 2011). A THQ value < 1 it indicates that there is no health concern and vice versa (Iwegbue *et al*., 2015b). Due to the potential synergistic impacts of heavy metals, the THQ values of the individual heavy metals were added together to obtain the total THQ (∑THQ) which also has the same interpretation as THQ.

Results

The results of the heavy metals content in the jams are displayed in Table 1 while the computed EDI and THQs values of the heavy metals from jam's consumption are presented in Tables 2 and 3 respectively. As shown in Table 1, Cd Pb were below the detection limit of the instrument. The Ni content in the jam samples varied between 0.05 to 1.55 mg/kg with Apricot and Orange jams having the minimum and maximum Ni contents respectively. Chromium was detected in only Apricot and Cherry jams at concentrations of 0.25 mg/kg and 0.50 mg/kg respectively.

Table 1: Heavy metals contents (mg/kg) in jams

Jams	Cd	Pb	Ni	Cr	Cu	Co	Mn	Zn	Fe
Orange	<0.03	<0.25	1.55	<0.25	1.25	0.25	11.5	4.75	22.0
Strawberry	<0.03	<0.25	1.23	<0.25	2.25	<0.25	<0.25	11.3	30.4
Mixed Fruit	<0.03	<0.25	1.45	<0.25	0.75	0.50	<0.25	<2.00	17.7
Apricot	<0.03	<0.25	0.05	0.25	1.25	0.50	13.3	<2.00	13.1
Pineapple	<0.03	<0.25	0.45	<0.25	7.75	0.25	11.8	7.00	14.2
Cherry	<0.03	<0.25	0.33	0.50	2.25	0.25	12.3	14.0	30.8

Results are mean of triplicate analysis

The Cu content in the Jams ranged from 0.75 in mixed fruit Jam to 7.75 mg/kg in pineapple Jam. The Co content in the jams ranged from not detected to 0.50 mg/kg. Cobalt was not detected in Strawberry jam. The Mn content in the jams ranged from not detected to 13.3 mg/kg. The maximum Mn content was found in Apricot jam while Mn was not detected in strawberry and mixed fruit jams. The Zn content in the jams varied from not detected to 14.0 mg/kg. The maximum Zn content was found in Cherry jam while Zn was below the detection limit mixed fruit jam and Apricot jam. Iron was detected in all the Jam samples. The Fe content in the jams ranged between 13.1 mg/kg in Apricot jam to 30.4 mg/kg in Strawberry jam.

Table 2: Estimated daily intakes (EDI) (µg/kg bw/day) of heavy metals in jams

Group	Jams	Ni	Cr	Cu	Co	Mn	Zn	Fe
Children	Orange	25.8	0.00	20.8	4.17	192	79.2	367
	Strawberry	20.5	0.00	37.5	0.00	0.00	188	507
	Mixed Fruit	24.2	0.00	12.5	8.33	0.00	0.00	295
	Apricot	0.83	4.17	20.8	8.33	222	0.00	218
	Pineapple	7.50	0.00	129	4.17	197	117	237
	Cherry	5.50	8.33	37.5	4.17	205	233	513
Adults	Orange	6.46	0.00	5.21	1.04	47.9	19.8	91.7
	Strawberry	5.13	0.00	9.38	0.00	0.00	47.1	127
	Mixed Fruit	6.04	0.00	3.13	2.08	0.00	0.00	73.8
	Apricot	0.21	1.04	5.21	2.08	55.4	0.00	54.6
	Pineapple	1.88	0.00	32.3	1.04	49.2	29.2	59.2
	Cherry	1.38	2.08	9.38	1.04	51.3	58.3	128

As displayed in Table 2, the EDI of Ni varied between 0.83 and 25.8 µg/kg bw/day and 0.21 to 6.46 µg/kg bw/day for the children and adults respectively. The EDI for Cr and Co varied between 0.0 to 8.33 µg/kg bw/day for children and 0.0 to 2.08 µg/kg bw/day for adults. The EDI of Cu via these jams ranged from 12.5 to 129 µg/kg bw/day for children and 3.13 to 32.3 µg/kg bw/day for adults. The EDI of Mn via consumption of the jams ranged between 0.0 to 222 µg/kg bw/day for children and 0.0 to 55.4 µg/kg bw/day for adults. The EDI of Zn via these jams ranged from 0.0 to 233 µg/kg bw/day for children and 0.0 to 58.3 µg/kg bw/day for adults. The EDI of Fe from eating these jams ranged from 218 to 513 µg/kg bw/day for children and 54.6 to 128 µg/kg bw/day for adults.

Table 3: Target hazard quotients (THQs) of heavy metals from jam's consumption

		THQs							
Group	**Jams**	**Ni**	**Cr**	**Cu**	**Co**	**Mn**	**Zn**	**Fe**	**∑THQ**
Children	Orange	1.29	0.00	0.52	13.9	1.37	0.26	0.52	17.9
	Strawberry	1.03	0.00	0.94	0.00	0.00	0.63	0.72	3.31
	Mixed Fruit	1.21	0.00	0.31	27.8	0.00	0.00	0.42	29.7
	Apricot	0.04	1.39	0.52	27.8	1.58	0.00	0.31	31.6
	Pineapple	0.38	0.00	3.23	13.9	1.40	0.39	0.34	19.6
	Cherry	0.28	2.78	0.94	13.9	1.46	0.78	0.73	20.9
Adults	Orange	0.32	0.00	0.13	3.47	0.34	0.07	0.13	4.46
	Strawberry	0.26	0.00	0.23	0.00	0.00	0.16	0.18	0.83
	Mixed Fruit	0.30	0.00	0.08	6.94	0.00	0.00	0.11	7.43
	Apricot	0.01	0.35	0.13	6.94	0.40	0.00	0.08	7.91
	Pineapple	0.09	0.00	0.81	3.47	0.35	0.10	0.08	4.91
	Cherry	0.07	0.69	0.23	3.47	0.37	0.19	0.18	5.2

As shown in Table 3, the THQs values of heavy metals for child exposure in the jams ranged from 0.04 to 1.29 for Ni, 0.0 to 2.78 for Cr, 0.52 to 3.23 for Cu, 0.0 to 13.9 for Co, 0.0 to 1.46 for Mn, 0.0 to 0.78 for Zn and 0.31 to 0.73 for Fe. For adult exposure, the THQs values of heavy metals in the jam samples ranged from 0.01 to 0.39 for Ni, 0.0 to 0.69 for Cr, 0.08 to 0.81 for Cu, 0.0 to 6.94 for Co, 0.0 to 0.40 for Mn, 0.0 to 0.19 for Zn and 0.08 to 0.18 for Fe. The ∑THQ values of the heavy metals in the jams ranged from 3.31 to 31.6 and 0.83 to 7.91 for child and adult exposure respectively.

Discussion

Heavy metals content in jams: The heavy metals content in the Jams varied significantly ($p < 0.05$ and $F_{cal} > F_{crit}$) within the same Jam and among the different Jams. The discrepancies in the heavy metals concentrations in the jams may be due to the heavy metals contents in the fruits used, manufacturing processes, poor packaging, preservation techniques and storage conditions. Although, Cd was not detected in these jam samples, the range of 0.19 to 0.26 mg/kg and 0.01 to 1.46 mg/kg have been reported in jams in Nigeria (Jimoh and Onabanjo, 2012) and Rwanda (Mukantwali *et al*., 2014) respectively. Like Cd, Pb was not also detected in these jams. However, Pb content of 0.46 to 0.55 mg/kg (Jimoh and Onabanjo, 2012), 0.33 to 0.77 mg/kg (Mukantwali *et al*., 2014) and 0.22 to 0.38 mg/kg (Asema and Parveen, 2018) have been documented for jams from Nigeria, Rwanda and India respectively. The range of Cr content obtained in these jams was similar to those (0.56 to 0.67 mg/kg) reported by Jimoh and Onabanjo (2012). The permissible limit of Cu set by World Health Organization (WHO) (2001) is 2.0 mg/kg. The content of Cu in 50 % of the jams was greater than the WHO permissible limit. The range of Cu content obtained in the jams from this study were similar to the range of 1.38 to 3.29 found in jams consumed in Rwanda (Mukantwali *et al*., 2014) but higher than the range of 0.13 to 0.17 mg/kg for Nigeria (Jimoh and Onabanjo, 2012), not detected to 0.76 mg/kg for Bangladesh (Mumtaz *et al*., 2019) and not detected to 0.09 mg/kg for India (Asema and Parveen, 2018). The permissible limit of Mn set by World Health Organization (WHO) (2001) is 5.0 mg/kg. The content of Mn in 67 % of the jams was above the WHO permissible limit. The Mn content obtained in this study was similar to those reported by Jimoh and Onabanjo (2012The permissible limit of Zn set by World Health Organization (WHO) (2001) is 1.5 mg/kg. The content of Zn in 67 % of the jams was above the WHO permissible limit. The Zn content in these jam samples were comparable to others reported in literature (Mumtaz *et al*., 2019; Asema and Parveen, 2018; Mukantwali *et al*., 2014; Jimoh and Onabanjo, 2012). The permissible limit of Fe set by World Health Organization (WHO) (2001) is 1.0 mg/kg. The content of Fe in all the jam samples was above the WHO permissible limit. The Fe content in these jam samples were higher than others reported in literature (Mumtaz *et al*., 2019; Asema and Parveen, 2018; Mukantwali *et al*., 2014; Jimoh and Onabanjo, 2012).

Estimated daily intakes (EDI) of heavy metals in jams: The EDI in 50% of the jams for children exposure was higher than Ni tolerable daily intake (TDI) of 12µg/kg bw/day (WHO, 2008). The recommended daily intake (RDI) of Cr is 200 µg/day (WHO, 2013) while that of Co is 1.7 µg/kg bw/day for a 60kg adult). The EDI of Cr in this study was below the RDI value. However, the EDI of Co in about 83% and 33 % of the jams were above the RDI of Co for the children and adults exposures respectively. The TDI of Cu is 83 µg/kg bw/day for an adult) (Iwegbue *et al*., 2015b). The EDI of Cu in these jams was lower than the TDI of Cu except the EDI of pineapple jam for children exposure. The EDI of Mn in 67% of the jams was higher than the RDI of Mn for children and adults (Iwegbue *et al*., 2015b). The TDI of Zn is 12000µg/day (Iwegbue *et al*., 2015b). The EDI of Zn in these jams was lower than the TDI of Zn. The TDI of Fe is 12500µg/day (Iwegbue *et al*., 2015b). The EDI of Fe in these jams was lower than the TDI of Fe.

Target Hazard Quotients and Total Target Hazard Quotients: The THQ and ∑THQ values are shown in Table 3. The THQ values for the respective heavy metals and ∑THQ were > 1 in the jams for both children and adults exposures except the ∑THQ value for Strawberry in case of adults was < 1. This suggests presence of health risk for individuals eating these jams regularly. Cobalt has higher impact on the ∑THQ values than the other heavy metals. The THQ of the individual heavy metals was in the order of Co > Cu > Mn > Ni > Cr > Fe > Zn while the ∑THQ values for the jams followed the order Apricot > Mixed fruits > Cherry > Pineapple > Orange > Strawberry.

Conclusion

The result of this study showed that the jams were contaminated with heavy metals except Cd and Pb. The Cu, Mn, Zn and Fe contents in > 50 % of the jam samples were above their respective WHO permissible limits. The estimated daily intake (EDI) values of Ni, Co and Mn in 50%, 83% and 67% of jams for children exposure exceeded their tolerable daily intakes (TDI) but the EDI of Cr, Cu, Zn and Fe were below their respectively TDI. The THQ of the individual heavy metals was in the order of Co > Cu > Mn > Ni > Cr > Fe > Zn while the

∑THQ values for the jams followed the order Apricot > Mixed fruits > Cherry > Pineapple > Orange > Strawberry. The target hazard quotient (THQ) of the respective heavy metals and the total target hazard quotients (∑THQ) were > 1 suggesting health risks for individuals that consume these jams regularly.

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