Assessment of Heavy Metals and Human Health Risk in Pastas Consumed in Makurdi, Benue State

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ABSTRACT

This is investigated heavy metals (Pb, Ni, Cd, Zn, and Cr) bio-concentration and bioaccumulation in Spaghetti consumed in Makurdi, Nigeria. The pasta samples were collected randomly from five markets (Modern, Wurukum, High level, Wadata and North Bank) in Makurdi and analyzed for the heavy metals by the atomic Absorption spectrophotometric technique after acid digestion. some human health risk Parameters: daily dietary Intake (DDI), daily intake of metals (DIM), health risk index (I-IRI), and target hazard quotient ((THQ) were also calculated. Heavy metal risk index (HRI), and target hazard quotient (THQ) were also calculated Heavy metal concentrations (mg/kg) in spaghetti across the markets ranged as Pb (1.52), Ni (3.57), Zn (O.39), Cd (0.40), Cr (19.95). The metal concentrations obtained were above the permissible limits recommended by the WHO/FAO, except Pb which was not detected in four (4)markets Comparing the DIM, DDI, HRI and THQ values with reference oral dose (RfDo), suggested that the consumption of spaghetti is nearly free of risks.(THQ) value of the heavy metal were less than one(l) indicating that there is a relative absence of health risk THQ in all metals is less equal to one (l) Cr which is greater in some of the markets in spaghetti indicating that there is no serious potential health risk. Precautionary measures should be taken to avoid bioaccumulation of these heavy metals. Therefore, it is concluded that these, pasta are partially safe for public consumption as they contain high amount of heavy metals that would constitute danger of metals poisoning.

INTRODUCTION

Pastas are a firm wheat product manufactured from non-leavening dough. They are often cooked and can be formed into thin strips, tubes, or shells, among other configurations. It captures a substantial portion in human nutrition because of its vitamin, carbohydrate and mineral contents (Salama and Radwan, 2005). The most common types of pasta eaten in Nigeria are noodles, macaroni, and spaghetti. These dishes have gained popularity due to their low preparation time, cost, and convenience of preparation.

Cereals that are widely consumed include wheat (Titicum). It is frequently processed to create wheat flour, which is a basic ingredient in baked goods like cakes and pastries (Khalid and Tahir, 2023; Salama and Radwan, 2005). The pastas produced in Nigeria are wheat-based. This commodity is mainly produced by processing wheat which involves sorting and milling of dry grains, and addition of some adjuncts; sugar, honey and dried raisins (Tejera *et al.*, 2013). Products of cereal like wheat flour, bread and pasta are part of the biggest group in food chain. These group of foods are being consumed on daily bases and can affect human health directly (Charles *et al.*, 2018).

In their normal form, cereals are rich in source of vitamins, minerals, fats, oils, carbohydrates and protein. However, the metallic content in wheat varies depending on the variety, the type of land where it has been cultivated, the fertilizer that has been used and the weather conditions (Tejera *et al.*, 2013). As a result of rapid industrial development across the world, there has been an increase in environmental pollution; and consequently

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in agricultural raw materials. This has led to high levels of food contamination across the world (Itodo *et al*., 2009). Cases of environmental pollution confronted very frequently and threatening food safety is due to heavy metals. Heavy metals are persistent in the environment and are subject to bioaccumulation in food chains. Monitoring the concentrations of various metals in food is critical because these contaminants have deleterious effects on humans. Many illnesses and diseases such as hypertension, cancer, depression and metal disorders have been associated with increased concentrations of heavy metals such as cadmium, lead, copper, chromium, nickel, manganese and zinc in human organs (Adekunle *et al.*, 2009).

Concentration of heavy metals found in food products are continuously need to be monitored for safety and quality assurance. Hence, this study aimed at assessing some heavy metals (As, Hg, Cd and Pb) levels in spaghetti consumed in Makurdi, Benue State and any potential health hazards consuming such amounts poses to human health. This study also reports the daily intakes of metals and potential health risk implications using the hazard quotient and total hazard index.

Health Risk Assessment Analysis

The health risk associated with the consumption of wheat-based food products (pastas) may be predicated on the levels of hazard potentials posed by heavy metals they contain as these may induce many health challenges including carcinogenic and non-carcinogenic health disorders. The implications of such hazard parameters are factored into the health risk assessment baseline of this work.

Health risk assessment

Estimation of daily intake

Estimated daily intakes of the metals (EDI) were calculated as follows

$$EDI = C\ x\ MI/BW \qquad 1$$

Where C is the mean concentration of metal in the pasta Consumed (mg/kg), MI is the estimated quantity of pasta Consumed (g/person/day), BW is the average body weight of adult (70kg) and children (27kg) respectively.

Hazard Quotient (HQ)

HQs was determined using USEPA Region III Risk-based concentration described by

$$HQ = \frac{EF_r\ x\ ED_{tot}\ x\ MI\ x\ MC}{RfD_o\ x\ BW\ x\ AT_n\ x\ 10^{-3}} \qquad 2$$

Where EF_r is the Exposure Frequency C350 days /year); ED_{tot} is exposure duration total (70years); MI is pasta ingestion (g/person/days): MC is the metal concentration in pasta (µg/g): RfD_o is the oral reference dose (mg/kg/ day): BW is the average body weight adult and children AT_n is averaging time for non- carcinogens (365 days/year ED_{tot}) oral reference dose for different metals (mg/kg per day); Cd= 0.001, Pb= 0.004, Cu= 0.004,No= 0.002,Mn = 0.14 and Zn= 0.3

Total Hazard Index (THI)

THI was calculated to evaluate the potential risk of adverse health effects from a mixture of chemical constituent in each pasta.

$$THI = HQ_1 + HQ_2 + \cdots + HQ_n \qquad 3$$

The magnitude of the total hazard index is assumed to be proportional to the extent of adverse effects or toxicities of the pasta Consumed.

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Daily Metal Intake

The following formula was used to calculate the daily intake of metals in human body;

$$DIM = \frac{M \, x \, K \, x \, I}{W} \qquad 4$$

Where M represents concentration of heavy metals in packaged pasta (mg/kg), I represent the amount of intake of packaged pasta on daily basis, W is average body weight and K is conversion factor.

MATERIALS AND METHODS

Sample Collection

Packaged consumed pastas samples were purchased randomly from different brands in (Wadata, Modern, Wurukum, High level and North Bank) Markets in Makurdi, Benue State and taken for analysis in the laboratory.

Sample Preparation

The sample was crushed with wooden Mortar/pestle and about 50.00g of the crushed samples were further pulverized into powder with porcelain mortar and pestle, sieved through a thin fine cotton (Muslin) cloth and stored in a desiccator prior to digestion using AAS (Atomic Adsorption Spectrometer).

Sample Digestion

A 1.00g mass of the ground sample was weighed with a weighing balance (mettler -2500) into a conical flash and 20mL of 1:1 HNO_3:$HClO_4$ was added. The mixture was heated om a heating mantle (Labtech Technology, India for 20-30 minutes) until a clear colourless digest was obtained. The digest was transferred to a 50mL standard flask and made up to the mark with de- ionized water (Milacic and Kralj,2003). Analysis were carried out using an Agilent technology (USA) model: 240FS Atomic Absorption Spectrometer. Sample blanks were analyzed for Cd, Cr, Mn, Zn, Cu, Pb and Ni by taking 20mL of the digestion mixture through the same procedure.

Detection of Heavy Metals

An Atomic Absorption Spectrophotometer (Agilent technology (USA) model: 240FS) was used to analyse all the digested samples. The spectrophotometer was calibrated by analysing three standard and blank solutions, before the commencement of analyses for the selected metals. The official method of analysis according to the Association of Official Analytical Chemists (AOAC, 1990) was followed. The heavy metals analysed were Lead, Cadmium, Chromium, Nickel and Zinc. The samples were analysed in triplicates for quality assurance.

Statistical Analysis

Data generated from analysed samples were subjected to ANOVA using Statistical Package for Social Scientists (SPSS, version 21.0) to test for statistical significance set at $P < 0.05$.

RESULTS AND DISCUSSIONS

Level of Potential Toxic Metals in Pastas

The Levels of Pb, Ni, Zn, Cr, and Cd in pasta samples collected from five major Markets in Makurdi Metropolis are presented in the Table 1 and their maximum permissible limit (WHO and FAO).

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Table 1: Level (mg/kg) of potentially Toxic Metals in Pastas

Markets	**Pb**	**Ni**	**Zn**	**Cd**	**Cr**
Modern	1.52	3.57	0.39	0.40	19.95
Wadata	ND	ND	0.35	0.46	14.33
Wurukum	ND	0.53	0.18	0.38	17.06
High Level	ND	4.73	0.29	0.29	23.52
North Bank	ND	5.24	0.19	0.27	34.16
WHO	0.30	5.00	3.30	0.20	2.30
FAO	0.30	4.00	4.00	0.01	2.30

WHO = World Health Organization Maximum Permissible Limit

FAO = Food and Agricultural Organization

ND = Not Detected

The current study was conducted to analyze the content and also health risk assessment of heavy metals (Pb, Ni, Zn, Cd and Cr) through the consumption of some pastas marketed in the city of Makurdi, Benue State in 2023.

Cadmium: Cadmium is a ubiquitous metallic element found in the environment due to severe anthropogenic activities such as the application of fertilizers, sewage sludge agricultural application, and myriad industrial processes. Human exposure to cadmium has been traced to food consumption much more than its occurrence in water and air (Olabimpe *et al*., 2015).

The mean levels of Cd detected in spaghetti presented in Table 1 are (0.40, 0.46, 0.38, 0.29 and 0.27) mg/kg which ranges from 0.29 mg/kg – 0.46 mg/kg respectively. Wadata market recorded the highest mean level (0.46 mg/kg) of cadmium in spaghetti. The cadmium concentration values obtained in this study was found to be above the permissible limits stated by WHO/ FAO (2001). This indicates potential risks and not safe for consumption. However, the mean values in this study is higher than the mean values recorded by Usman *et al*. (2023) which ranges from 0.0007 – 0.0012 mg/kg in the Determination of Heavy Metals in some Selected Pastas in Nasarawa State Markets. On the other hand, the mean concentration of Cd in this research work is lower than the values reported by (0.058 ± 0.0330mg/kg) reported by Filon *et al*. (2013) and within the values presented by (0.28 ± 0.23mg/kg) reported by Olabimpe *et al*. (2015).

Cadmium has no known biological functions. It interferes with some vital function of Zn, thereby inhibiting enzyme reactions and nutrient utilization. It catalyzes oxidation reactions, creating free-radical tissue damage (Afiukwa,2013). Cadmium is known as a human carcinogen and its critical target is the kidney for general population. Cadmium bioaccumulation inside the body causes kidney damage and lung dysfunction in infected individual (Judilyn *et al.,* 2013). Cadmium even at lower levels over a long period of time can lead to a buildup cadmium in the kidney causing a serious damage. It's also responsible for decalcification and deformation of bones, hypertension and impotence (Filon *et al.,* 2013).

Chromium: The mean concentration of Cr from this study ranged from 14.33 mg/kg – 23.52mg/kg respectively in Table 1. The chromium values obtained in this study exceeded the WHO/FAO (2001) maximum permissible limits. The mean value concentration of chromium in this research study is higher than the mean concentration (0.063 – 0.118) mg/kg reported by Odukoya *et al.,* (2016) in Nigeria market lower than those reported by Sobhanardakani, (2020) which ranges from 211.11±92.80 and 677.78±393.0 mg/kg, respectively in the Health Risk Assessment of Heavy Metals Via the Consumption of pasta.

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Chromium is an important heavy metal which is relevant in human nutrition for healthy living, and has a wide range of industrial applications. According to Rana. (2011), Cr has the ability to reduce blood glucose, and is used to control certain cases of diabetes. While industrially it can be used in electroplating, metal finishing, magnetic tapes, pigments, leather tanning, wood protection, chemical manufacturing, brass, electrical and electronic equipment and catalysis. High contents of Chromium causes severe chlorosis, necrosis, and a host of other growth abnormalities and anatomical disorders in plants (Samantaray *et al.,* 1998).

Zinc: Zinc is naturally found in soil, but Zn concentrations are rising unnaturally due to man-made activities, especially mining, coal, and waste combustion, industrial activities, and steel processing. Numerous foodstuffs contain certain concentrations of Zn. Plants often have a Zn uptake that their systems cannot handle due to the accumulation of this element in soils (Wuana and Okieimen 2011). The results showed that the mean concentrations of Zn in this research work ranged from 0.18 mg/kg – 0.39 mg/kg respectively in Table 1. The mean concentration values of Zinc are below the maximum permissible limit set by WHO/FAO (2001). Moreover, the obtained result is much lower than the findings of Cuadrado *et al.* (2000) who reported that the concentration of Zn in pasta samples collected from Spain was 14100 µg/kg (Cuadrado *et al.*,2000).

Nickel: The mean Ni levels recorded ranged from ND – 5.24 mg/kg respectively in Table 1. All samples gotten from the markets were detected expect the sample from Wadata. The values recorded in this work were within the WHO/FAO, (2001) maximum permissible limits except for samples from (Modern, Wadata and Wurukum) market. The values obtained in this study is higher than the values (0.145 mg.kg-1 and 0.062 mg.kg-1) reported by Santos *et al.* (2004) and Ahmed *et al.,* (2015).

Nickel is a metallic element widely distributed in the environment due to its use as liquid and solid fuels, and industrial applications. It is an essential heavy metal, whose specific function in the human system is unknown, but it is known to be present in many enzymes in the body.

Chronic human exposure to nickel can lead to cardiovascular and kidney diseases, lung fibrosis, and lung and nasal cancer (Santos *et al.*,2004).

Lead: Lead is well known for its toxic and adverse health effects. In this regard, the absorption of ingested lead may constitute a serious risk to public health. Some chronic effects of Pb poisoning are anemia, constipation, and colic (Duran *et al.,* 2009). The mean contents of Pb detected ranged from ND – 1.52 mg/kg respectively in Table 1. The samples gotten from (wadata, wurukum, high level and north bank) markets were not detected. The results showed that the mean concentrations of Pb in spaghetti samples were above it maximum permissible limit set by WHO/FAO, (2001).

Besides, the obtained results are lower than the findings of Alberti-Fidanza_*et al.* (2002) who reported that the concentrations of Pb in raw spaghetti samples consumed by students in Italy were 2120 µg/kg and also Cuadrado *et al.* (2000) who reported that the concentrations of Pb in pasta samples collected from Spain were 18.70 µg/kg.

The high concentrations of lead (Pb), cadmium (Cd) and chromium (Cr) in the selected spaghetti samples takes it source from the agricultural soil that propagates the plant (Wheat) used in processing the flower from which the spaghetti is produced. Another important source of these high concentrations represents the foodstuff contact with the processing machineries, high intensity of industrial activities within the manufacturing region and of course, the influence of processing factors. Results from this study is quite alarming since cadmium (Cd), lead (Pb) and Chromium (Cr) are known as human carcinogen and their critical targets are kidney and liver for general population (Judilyn *et al.*, 2013).

Human Health Risk indices of potentially Toxic Metals in Spaghetti

Some human risk indices via: daily dietary intake (DDI), daily intake of metals (DIM), health risk index (HRI) and target hazard quotient (THQ), arising from Pb, Ni, Zn, Cr, and Cd in Spaghetti samples collected from different markets in Makurdi were calculated and are presented in Tables 2-6.

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Table 2: Some Human Health Risk Parameters of Potentially Toxic Metals in Spaghetti from Modern Market, Makurdi.

Heavy Metal	**Conc. in spaghetti**	**DDI (mg/person/day)**	**DIM (mg/kg Person/day**	**HRI**	**THQ**
Pb	1.52	1.2×10^{4}	3.2×10^{4}	6.4×10^{5}	1.7177
Ni	3.57	7.6×10^{3}	2.1×10^{5}	4.2×10^{5}	43.86
Zn	0.39	6.9×10^{6}	1.9×10^{4}	6.3×10^{4}	1.5971
Cd	0.40	4.2×10^{3}	1.2×10^{5}	$I.2 \times 10^{6}$	2457.1
Cr	19.95	2.5×10^{5}	7.1×10^{6}	5.6×10^{10}	11438.0

ND = NOT DETECTED

Table 3: Some Human Health Risk Parameters of Potentially Toxic Metals in Pasta from Wadata Market, Makurdi.

Heavy Metal	**Conc. in Pasta**	**DDI(mg/person/day)**	**DIM(mg/kg/person/day**	**HRI**	**THQ**
Pb	ND	ND	ND	ND	ND
Ni	ND	ND	ND	ND	ND
Zn	0.35	6.2×10^{1}	7.7×10^{4}	2.6×10^{5}	50.17
Cd	0.46	4.9×10^{3}	3.0×10^{4}	3.0×10^{7}	19780
Cr	14.33	1.8×10^{5}	3.2×10^{5}	1.1×10^{8}	205396.6

ND =NOT DETECTED

Table 4: Some Health Risk Parameters of Potentially Toxic Metals in Pasta from Wukurum Market, Makurdi.

Heavy Metal	**Conc. in Pasta**	**DDI (mg/ person/day)**	**DIM (Mg/kg/ person/day)**	**HRI**	**THQ**
Pb	ND	ND	ND	ND	ND
Ni	0.53	1.1×10^{2}	6.8×10^{2}	136000	455.8
Zn	0.18	1.9×10^{3}	2.3×10^{3}	7666.67	25.8
Cd	0.38	6.7×10^{2}	8.2×10^{1}	273.33	1634.0
Cr	19.06	2.4×10^{5}	4.1×10^{6}	133333	273193.33

ND = Not Detected

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Table 5: Some Human Health Risk Parameters of potentially Toxic Metal in Pasta from North Market, Makurdi.

Heavy Metal	**Conc. in Pasta**	**DDI (mg/person/day)**	**DIM (mg/kg/person/day)**	**HRI**	**THQ**
Pb	ND	ND	ND	ND	ND
Ni	5.24	1.1×10^{4}	6.9×10^{3}	138000	4506.4
Zn	0.19	3.4×10^{1}	4.1×10^{1}	13667.00	27.233
Cd	0.27	2.9×10^{3}	1.8×10^{4}	1.8×10^{8}	11610.0
Cr	32.16	4.1×10^{5}	7.1×10^{5}	2366666.6	460960

ND = Not Detected

Table 6: Some Human Health Risk Parameters of Potentially Toxic Metals in Pasta from High level Market, Makurdi.

Heavy Metal	**Conc.in Pasta**	**DDI (mg/person/day)**	**DIM (mg/kg/Person/day)**	**HRI**	**THQ**
Pb	ND	ND	ND	ND	ND
Ni	4.73	1.0×10^{4}	6.3×10^{3}	4.1×10^{3}	8.2×10^{4}
Zn	0.29	5.2×10^{2}	6.3×10^{1}	4.1×10^{1}	1.4×10^{2}
Cd	00.29	3.1×10^{3}	1.9×10^{4}	1.2×10^{1}	1.2×10^{5}
Cr	23.52	3.0×10^{5}	5.1×10^{5}	3.4×10^{5}	6.0×10^{8}

ND = NOT DETECTED

As shown in Table 2-6, the DDI (mg/person/ day) the daily dietary intake of Ni metal recorded the highest level concentration in spaghetti 7.1×10^{6} and 7.7×10^{8} (mg /kg/person/day) respectively. DIM as a function of body weight and intake recorded Zn and Cd as the highest values of DIM in spaghetti which are 7.7×10^{4} and 8.2×10^{1} (mg/kg/ person/day) respectively.

Therefore, the results showed presented in Tables 2-6 showed that the mean HRI values of some analyzed metals for the consumption of spaghetti are lower than 1. In this regard, the HRI of the analyzed metals were minimal. Except for some samples collected from (High Level, Wadata and Modern) markets which were greater than 1 and not fit for consumption.

THQ; Cr has the highest value of THQ in spaghetti which are 273193.33 the THQ value of Cr in spaghetti are greater than one (1) therefore, there is potential health risk of Cr, related disease example headache, irritability, and abdomen pain and various related to nervous system. Pb in spaghetti. Therefore, there is potential health risk associated with Pb. From the foregoing, this study shows that spaghetti have high concentration of metals analyzed.

CONCLUSION

The toxicity of heavy metals in living organism and their associated health risks/ hazards cannot be over emphasized as they cannot be taken out of such systems easily due to their Bioaccumulation, bioconcentration and Biomagnification tendencies.

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This study showed the occurrence of five heavy metals in pasta products with their average contents occurring in increasing order of Cr > Ni > Pb> Cd >Zn. In this study, the concentration of Cd, Cr and Pb content reported exceeded the WHO/FAO permissible limits but those of Zn and Ni were below the FAO/WHO permissible limits (2001). Heavy metals (lead, cadmium and chromium) contaminants have a potential to bioaccumulate inside the human body. Therefore, consumption of such spaghetti should be monitored to avoid the adverse effects brought about by metals (lead, cadmium and chromium).

Hence, this work is significant in understanding the level of heavy metals taken into the human system by consumption of pasta in Makurdi, their potential human health risks and how to regulate their intake so, as to reduce the impending danger they can inflict on health. Most of the HR and THQ values of these metals were above 1 which implies that the consumers of spaghetti in Makurdi are at risk of potential toxicity as a result of heavy metal poisoning especially children.

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