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Quantification of Some Metals in Commonly Consumed Canned Foods in South-west Nigeria: Probable Pointer to Metal Toxicity

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ABSTRACT: Canned foods are one of the most commonly consumed products, due to benefits like the taste, handiness and convenience derived from them. On the other hand, these dietary products may be a means of heavy metal exposure and toxicant. This study aimed to quantify metals content in some frequently consumed canned foods in Nigeria as a possible source of toxicity. Twenty-two different commonly consumed brands of canned foods (Sweet corn, Green peas, Corned beef, Hotdog, Mushroom, Tin tomato, Mixed fruit, Baked beans, Mackerel (tomato sauce canned fish), Sardine (canned fish in vegetable oil) and Red kidney were analyzed for Ni, Cr, Cu, Pb and Al using Atomic Absorption Spectrophotometer after wet digestion. The results showed that the heavy metals concentration in the samples under study ranged from 0.55 to 0.86mg/kg (Ni), 0.00 to 0.41mg/kg (Cr), 1.40 to 1.76 mg/kg (Pb), 0.07 to 0.2mg/kg (Cu) and 4.71 to 16.4mg/kg (Al). The levels of Pb, Ni and Al were above FAO/WHO recommended limit of 0.01mg/kg, 0.05mg/kg and 7mg/kg respectively. The presence of heavy metals like lead (Pb) above the permissible limit calls for caution during production and in the frequent consumption of canned foods which may lead to accumulation of metals, toxicity and the sequelae.

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Food ingestion is an apparent route of exposure to metals, not just because many metals are natural components of foodstuffs, but also because of the possibility of contamination during processing (Dallatu *et al*., 2013). Canning, one of the methods of food preservation, involves processing and sealing the content in an airtight container thereby extending the content's shelf life. The aim is to make the food content readily available, palatable and eatable long period far from the processing day. Canned food is frequently and largely consumed in Nigeria. In recent years, there has been an inflow of different types of canned food into the Nigerian market. Canned foods such as canned fish and tomato paste which make up a significant portion of ingredients used in preparation of stews and different delicacies in Nigeria and many other countries are packed in (an air-tight container) cans made of steel or tin, for distribution, storage, preservation and also availability for consumption by humans living distal from the production areas (Iwegbue, 2010). Heavy metals presence in canned foods may be via plants uptake in contaminated soil, heavy metals polluted water and from applied agrochemicals. In canning toxicology, fruits harvested for processing may also become contaminated during canning processes or through leaching from the metal containers into the canned product during storage (Bakircioglu *et al*., 2011). Furthermore, corrosion and leaching of lacquered cans may lead to a high metal content of canned foods. Also implicated is leaching of packaging tin foils (Dallatu *et al*., 2013). The effect of food packaging on food safety cannot be overemphasised given the possibility of movement of chemicals from the contact materials into the food product. This necessitates the extensive study of the metal content of food since some metals are essential for homeostasis while some constitute toxic hazards at low quantity and are remarkably toxic (Chukwujindu *et al*., 2012). The effects of heavy metals on cellular organelles/components and some enzymes responsible for cellular repair, biological detoxification and metabolism have been documented (Beyersmann and Hartwig, 2008). It was observed that the interface of metal ions with nuclear proteins may lead to carcinogenesis, programmed cell death or changes in DNA conformation. The unceasing heavy metals analysis in canned foodstuffs using precise and accurate tools remains vital in controlling the food quality. The present study estimated heavy metals concentration in some common canned foods found in

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Nigerian Market, which are regularly consumed using South West Nigeria as a case study. The selected canned foods are regularly found in the dietary menu of virtually all socio-economic class. The outcome of the study will provide useful information on the degree of heavy metal contamination of commercially available canned foods and the contribution of such dietary sources to the burden of heavy metals in the body.

MATERIALS AND METHODS

Sample Collection: Twenty-two (22) different brands of canned food (red kidney, tin tomato, baked beans, sweet corn, corned beef, hot dog, mackerel (tomato sauce fish), sardine (fish in vegetable oil), mixed fruit, green pea and mushroom considered for analysis were purchased randomly from major food markets in Southwest, Nigeria.

Preparation and Digestion of Sample: All glass wares used were first soaked in a detergent solution overnight before rinsing and soaked in 10% (v/v) HNO_3 overnight, then thoroughly rinsed with distilled water. Analytical grade reagents were used throughout this study. Standard stock solutions of Nickel (Ni), Lead (Pb), Chromium (Cr), Copper (Cu) and Aluminium (Al) were prepared by diluting concentrated solutions to obtain solutions of 1000 mg/L. Samples of canned food were purchased from major food markets. A total of twenty-two (22) canned food samples including red kidney, tin tomato, baked beans, sweet corn, corned beef, hot dog, mackerel, sardine, mixed fruit, green pea and mushroom were used for this study. After opening each can, oil or fluid was drained off and each sample was homogenized. Each sample was then taken and digested promptly, according to a modified method by Pramoda, 2016 (Pramoda *et al*., 2016). The selection of metals to be assayed was based on the outcome of previous studies (Bakircioglu *et al*., 2011; Chukwujindu *et al*., 2012; Dallatu et *al*., 2013). For the determination of selected metals, 10 mL concentrated HNO_3 was poured into a beaker containing homogenized samples of 10g weight. Care was taken to ensure the dissolution of most of the sample. The beaker was subsequently covered and left to stand overnight. Afterwards, it was heated for 45 minutes. After cooling, a volume of 5 mL $HClO_4$ was added. The resultant mixture was then boiled until a white fume was observed. A volume of 2 mL of hydrogen peroxide (H_2O_2) was then added into the clear solution and heated for 2 to 3 minutes. Finally, after cooling, the mixture was filtered with Whatman 42 paper and then transferred into a 50 mL volumetric flask and diluted to the mark with distilled water (Pramoda *et al*., 2016). Heavy metals concentrations were analysed in the solutions so obtained. Each analysis was carried out in triplicates.

Metals analysis: The samples were aspirated into bulk Atomic Absorption Spectrophotometer (VGP 210). The standards were prepared in concentrations of 2 mg/L, 4 mg/L, 6 mg/L, 8 mg/L and 10mg/L for each metal and the AAS gave the standard plot for each metal. Samples analysis for Cr, Pb, Al, Cu and Ni were carried out using Atomic Absorption Spectroscopy manufacturer specified procedure. From the respective salts, the metal solution of 1000 mg/L known concentration was prepared (Abdulrahman *et al*., 2012). For each run, a triplicate sample was done throughout. This includes two blanks samples and for the recovery, spiked samples. In order to ascertain the validity of the methods for analysis, the samples were spiked with various heavy metals concentration for the recovery. To determine metals' recovery, increasing quantities of the metals were added to each sample and digested thereafter.

$$\% \, Recovery = \frac{Metal\ conc.from\ re - analysis - original\ metal\ conc.}{Level\ of\ increase\ achieved\ by\ spiking}\ x\ 100$$

All statistical analyses of data were performed using SPSS 20 software. The data are reported as mean values ±standard deviation (SD).

RESULTS AND DISCUSSION

The percentage recovery of some selected metals in some of the canned food sample is presented in Table 1. The percent recovery ascertained the validity of the methods used in this study.

Mean concentrations of Cr in canned foods: Figure 1 showed the mean concentration of Cr in each canned food sample. The Cr levels for all the canned food samples were below the WHO recommended limit of 13 mg/kg. The Cr level of this study was found to be in the range of 0.00±0.00-0.41±0.09 mg/kg. Chronic exposure to high levels of Cr has been correlated with lung cancer in humans and kidney damage in animals (Seyed *et al*., 2015). In a study, Cr was observed to be in the range of 1.74-2.55 mg/kg in canned mushroom marketed in Sakarya market, Turkey (Altıntığ *et al*., 2016) which was higher than the result obtained in the present study. The reported level of Cr in hot dog consumed in Lebanon was found to be within the range of 0.04-0.06 mg/kg with a mean concentration of 0.05 mg/kg (Samira *et al*., 2012). These values are lower than the present values.

Table 1: Average percent recovery for metal determination in Sardine, Mushroom, Sweet Corn and Mixed Vegetables

Metal	% Recovery in Sardine	% Recovery in Mushroom	% Recovery Sweet corn	% Recovery in mixed vegetable
Al	83.2±8.5	105.2±16.1	99.4±14.5	106±12
Cd	101±16	96±10	102.8±6.8	99.8±9.9
Pb	90±9	102.6±14.8	88±8	105.8±10.2

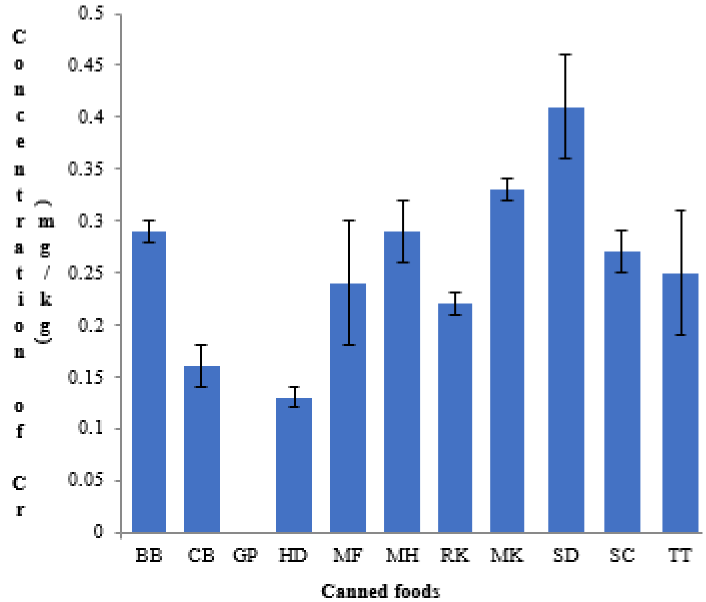

Fig 1: Mean concentrations of Cr in selected canned foods
KEY: BB=Baked beans, CB= Corned beef, GP= Green peas, HD= Hot dog, MF=Mixed fruits, MH= Mushroom, RK= Red kidney, MK= Mackerel, SD= Sardine, SW= Sweet corn, TT= Tin tomato, WHO=World Health Organization.

Chromium (Cr) is essential for human health. Cr (III) in an adequate amount, is an essential nutrient that aids the body to utilize sugars, proteins and fats. However, Cr (VI) is carcinogenic when consumed above recommended dietary intake (WHO/FAO/IAEA, 1996). The recommended dietary intake in adults is between 0.50 and 2.00 µg (Tarley *et al*., 2001). An excessive amount of Cr (III) above the recommended limit may cause adverse health effects. Cr is broadly distributed in human tissues in concentrations that are both variable and exceedingly low.

Mean concentrations of Pb in canned food samples: Figure 2 shows the mean concentration of lead (Pb) in the selected canned foods. The result obtained from this study revealed that the levels of Pb in all canned foods were higher than the WHO standard of 0.01 mg/kg. The highest level of Pb (1.76±0.01 mg/kg) was observed in hot dog sample (HD) as shown in Figure 2, while the lowest was 1.40±0.02 mg/kg in mushroom sample (MH). A source of Pb lead contamination in the canning process is soldering. Hence, this makes lead concentration monitoring in canned food produced for human consumption vital for human health (Voegborlo *et al*., 1999). The concentration of Pb in canned fish consumed in Lebanon ranged 0.02-0.60mg/kg, (Samira and Weam, 2012). Studies on lakes in Tokat, Turkey by Mendil *et al.*, (2005) gave the level of Pb as 2.8mg/kg. Also, reported level of Pb in Turkey's marketed canned fish was in the range 0.08-2.80 mg/kg (Tuzen and Soylak, 2007). The level of Pb in corned beef samples in Egypt was found to be 0.334mg/kg (Khalafalla *et al*., 2016) and the value obtained in samples consumed in Lebanon was in the range of 0.001-0.032mg/g (Samira and Weam, 2012) which was lower than the result obtained in the present study (Figure 2). These results, however, are higher than the WHO recommended limit of 0.01mg/kg (FAO/WHO, 2006). Report showed the level of Pb in canned mushroom (MH) marketed in Sakarya market, Turkey to be in the range of 15.73-16.03 mg/kg (Altıntığ *et al*., 2016) while the result of MH consumed in Lebanon was found to be in the range of 0.001-0.018 mg/kg (Samira and Weam, 2012). These results, however, are higher and lower (respectively) than the obtained value of 1.40±0.02 mg/kg in this study which is higher than the WHO recommended limit. The result obtained for Pb level in canned hot dog (HD) consumed in Lebanon was found to be in the range of 0.001-0.018mg/g (Samira and Weam, 2012) which is lower than the obtained value of this study. The result obtained in this study for sample HD was higher than the recommended standard. In their study, Itodo and Itodo, (2010) opined that the method employed in sealing was a major determinant of the quantity of lead in the canned food product. Lead (Pb) is known for its toxicity manifesting as decreased intelligence and cognitive development in children. In adults, it has been linked to cardiovascular disorders like high blood pressure (Iwuoha *et al*., 2013). A blood Pb level greater than 1.0 μg/cm^3 is dangerous to health (Itodo and Itodo, 2010). The FAO/ WHO noted the toxic nature of Pb, further highlight the importance of interest in heavy metals' presence in food.

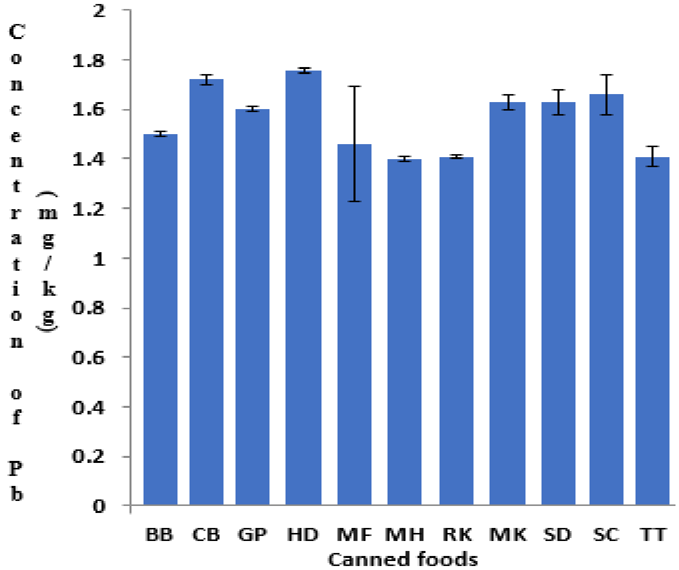

Fig 2: Mean concentrations of Pb in selected canned foods
KEY: BB=Baked beans, CB= Corned beef, GP= Green peas, HD= Hot dog, MF=Mixed fruits, MH= Mushroom, RK= Red kidney, MK= Mackerel, SD= Sardine, SW= Sweet corn, TT= Tin tomato, WHO=World Health Organization.

Mean concentrations of Al in canned foods: The canned food samples concentrations of Al in the present study as presented in figure 3 were generally above the WHO standard of 7.0mg/kg except for tin tomatoes (TT) and baked beans (BB) samples which were below the recommended limit. The concentration of Al in the samples were found to be within the range of 4.70±0.88-16.4±1.32 mg/kg with the highest level in samples hot dog (HD) and sweet corn (SC) and the lowest level in sample tin tomatoes (TT). The range of Al level in canned sardine (SD) in this study (7.22±1.02-14.8±2.32mg/kg) was higher than the reported level of Al in canned sardine consumed in India which was 3.16mg/kg (Mahalakshmi *et al*., 2012). They were also above the reported value of 0.98mg/kg (Tuzen and Soylak, 2007) and 3.12mg/kg (Samira and Weam, 2012) in Turkey and Lebanon respectively. Aluminium level in canned meat consumed in Lebanon was in the range of 0.09-7.5mg/kg (Samira and Weam, 2012) which was below the result obtained in this study for the corned beef (CB) sample. The concentration of Al in mushroom (MH) in this study (11.6±2.31 mg/kg) was higher than that obtained in Lebanon and Turkey which were 1.25mg/kg (Samira and Weam, 2012) and 2.86 mg/kg (Tuzen and Soylak, 2007) respectively. Values of Al obtained in sweet corn consumed in Lebanon and Turkey were found to be 1.2 mg/kg (Samira and Weam, 2012) and 1.73 mg/kg (Tuzen and Soylak, 2007), respectively.

Aluminium is known to be used extensively in the production of food contact materials (CAC, 1995). Al and its various alloys exhibit high corrosion resistance (ECEN, 2004). On exposure to air, Al develops a non-flaking, colourless thin film. The film has been shown to be Al_2O_3, tough and can only be dissolved by a few chemicals (Peter and Ulrich, 2007). Comparatively, pure Al cannot withstand attack by most dilute acids. The hydroxide of Al, at pH 7, is limited in its solubility. However, at alkaline and acidic pH, it shows an increase in solubility. Hence, the acidity of foodstuffs influences the migration of aluminium when used in contact materials that are uncoated. Another factor that influences this migration is the dissolving power of the salt formed. For instance, when in contact with, 1 % phosphoric acid, a protective Aluminium phosphate layer prevents dissolution of Aluminium acetate. On the other hand, 3 % acetic acid easily dissolves Aluminium acetate.

Mean concentrations of Cu in canned foods: The Cu levels in all the canned food samples were within the WHO recommended limit of 0.2 mg/kg as observed in Figure 4. The highest Cu level was observed to be the same (0.20±0.02mg/kg, 0.20±0.01mg/kg and 0.20±0.03mg/kg) in baked beans (BB), mixed vegetables (MF) and sardines (SD) respectively while the lowest level was found in hotdog (HD) (0.07±0.02 mg/kg). Values of Cu in canned mushrooms marketed in Sakarya market, Turkey has been reported to be in the range of 40.8-71.89mg/kg (Tuzen and Soylak, 2007; Altıntığ *et al*., 2016) while values obtained in canned mushrooms consumed in Lebanon was found to be 1.42mg/g (Samira and Weam, 2012). According to literature, Cu levels in canned sweet corn consumed in Turkey and Lebanon were found to be 3.5mg/g (Tuzen and Soylak, 2007) and 0.88mg/g (Samira and Weam, 2012), respectively. The results of studies of canned sardines (Brasilia and the USA) showed the Cu content to be between 1.31- 2.25 mg/kg and 0.50-1.75 mg/kg respectively (Ikem and Egiebor, 2005). Also, the average concentration of Cu in canned sardines sold in Saudi Arabia and Turkey was quoted to be 2.26 mg/kg (Ashraf *et al*., 2006) and 1.96 mg/kg (Tuzen and Soylak, 2007) respectively. These concentrations are higher than those observed in the present study.

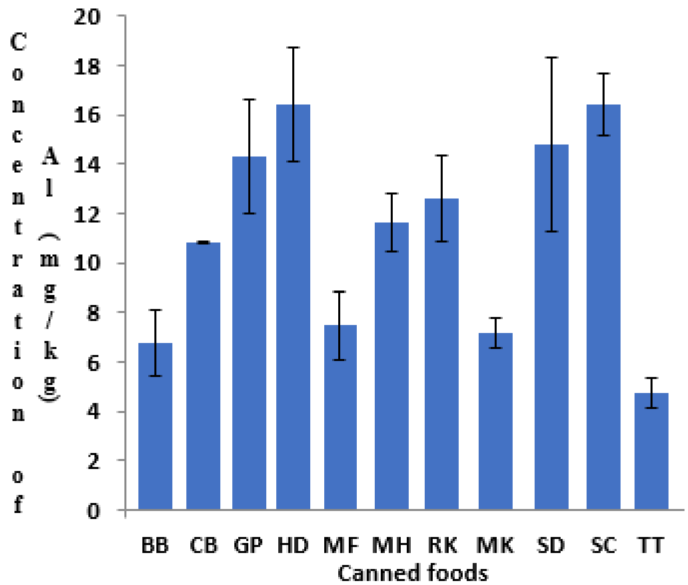

Fig 3: Mean concentrations of Al in selected canned foods
KEY: BB=Baked beans, CB= Corned beef, GP= Green peas, HD= Hot dog, MF=Mixed fruits, MH= Mushroom, RK= Red kidney, MK= Mackerel, SD= Sardine, SW= Sweet corn, TT= Tin tomato, WHO=World Health Organization

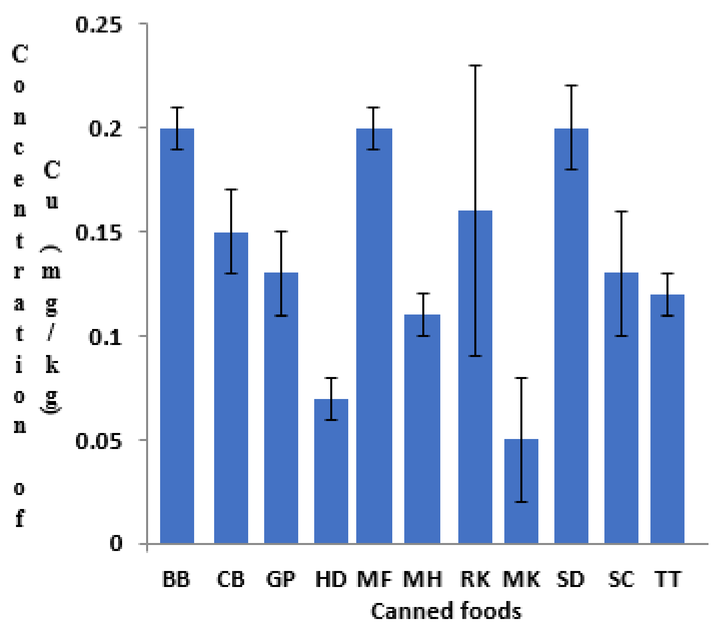

Fig 4: Mean concentrations of Cu in selected canned foods
KEY: BB=Baked beans, CB= Corned beef, GP= Green peas, HD= Hot dog, MF=Mixed vegetables, MH= Mushroom, RK= Red kidney, MK= Mackerel, SD= Sardine, SW= Sweet corn, TT= Tin tomato, WHO=World Health Organization.

Copper plays important roles in bone formation, mineralisation of the skeleton, preventing damage to cell structure and as an antioxidant assisting in free radical scavenging (Salama and Radwan, 2005).

Mean concentrations of Ni in canned foods: Ni levels in all the canned foods in this study were observed to be generally above the WHO recommended limit of 0.05mg/kg (FAO/WHO, 2006) as shown in Figure 5. The lowest and highest Ni levels were found in red kidney (RK) and hot dog (HD) as 0.55±0.22mg/kg and 0.86±0.17 mg/kg respectively.

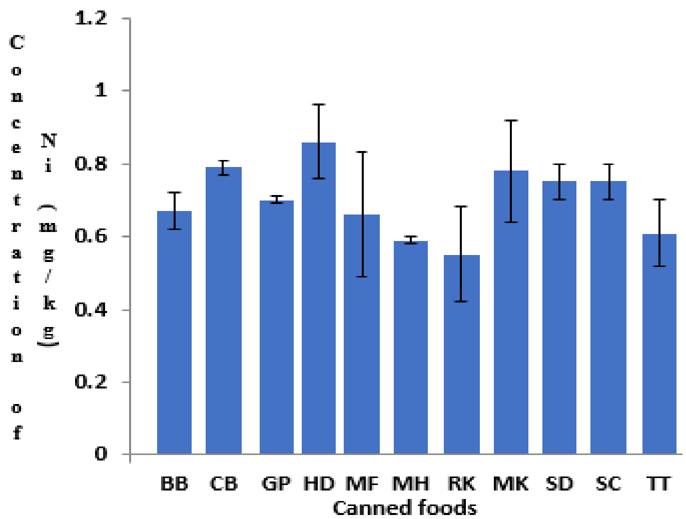

Fig 5: Mean concentrations of Ni in selected canned foods

KEY: BB=Baked beans, CB= Corned beef, GP= Green peas, HD= Hot dog, MF=Mixed fruits, MH= Mushroom, RK= Red kidney, MK= Mackerel, SD= Sardine, SW= Sweet corn, TT= Tin tomato, WHO=World Health Organization.

Nickel concentration in canned fish consumed in Thailand, Pakistan were 1.33mg/g, and 0.52mg/g respectively (Chukwujindu *et al*., 2009) while results obtained in Turkey was in the range of 0.50-0.85mg/g (Tuzen and Soylak, 2007). In the present study, Ni levels were significantly higher than these reported levels except for the result of Pakistan and Turkey which were at par. From literature, Ni concentration in canned mushroom sold in Sakarya market and Turkey were in the range of 3.49-3.59mg/kg (Altıntığ *et al*., 2016).

Conclusion: This study revealed that the metal concentration (Pb, Ni, Al) in the canned food samples were above the WHO recommended limits. This may be sources of metal toxicity, health risk and sequelae especially in the high-risk groups (pregnant mothers and children). The low-risk groups (adolescent and adults) may suffer the same fate due to accumulation resulting from frequent consumption. There is the need, therefore, for consumers to be educated of the inherent dangers and producers to take steps in minimizing levels of these metals in the products.

REFERENCES

Abdulrahman, FI; Akan, JC; Chellube, ZM; Waziri, M (2012). Levels of heavy metal in human hair and nail sample from Maiduguri metropolis Borno State, Nigeria. *World Environ.* 2(4): 81-89.

Altıntığ, E; Hişir, ME; Altundağ, H (2016). Determination of Cr, Cu, Fe, Ni, Pb and Zn by ICP-OES in mushroom samples from Sakarya, Turkey. *Sakarya. Univer. J. Sci.* 21(3): 496-504.

Ashraf, W; Seddigi, Z; Abulkibash, A; Khalid, M (2006). Levels of selected metals in canned fish consumed in Kingdom of Saudi Arabia. *Environ. Monit. Assess.* 117(1-3): 271-9.

Bakircioglu, D; Kurtulus, YB; Ucar, G (2011). Determination of some trace metal levels in cheese samples packed in plastic and tin containers by ICP-OES after dry, wet and microwave digestion. *Food Chem. Toxi.* 49: 202-207
.

Beyersmann, D; Hartwig, A (2008). Carcinogenic metal compounds: recent insight into molecular and cellular mechanisms. *Archi. Toxi.* 82(8): 493–512.

Chukwujindu, MAI; Chukwudumebi, IO; Sarah, ON; Nwajei, GE (2012). Trace metal contents in some brands of canned tomato paste in Nigeria market. *American J. Food Techno.* 7: 577-581.

Chukwujindu, MAI; Nwajei, GE; Arimoro, FO; Osa, E (2009). Characteristic levels of heavy metals in canned sardines consumed in Nigeria. *Environ*. 29: 431

Codex Alimentarius Commission (CAC). (1995). Codex general standard for contaminants and toxins in foods, Joint FAO/WHO Food Standards Programme. FAO, Rome. Document no. CX/FAC 96/17. www.fao.org. Accessed January 2019

Dallatu, YA; Abechi, SE; Abba, H; Mohammed, US; Ona, EC (2013). Level of heavy metals in fresh and canned foods consumed in North Central Nigeria. *Sch. J. Agric. Sci*. 3(6): 210-213.

European Committee for Standardisation (ECEN) (2004). Aluminium and aluminium alloys – Castings – Chemical composition of castings for use in contact with foodstuff. *CEN, Brussels.* EN 601. www.standardsglobalspec.com. Accessed January 2019.

FAO/WHO (2006). Expert Committee on Food Additives (JECFA). Sixty-seventh meeting, Rome. http://www.who.int/ipc/food/jecfa/summaries/summary67.pdf. Accessed November, 2020.

Ikem, A; Egiebor, NO (2005). Assessment of trace elements in canned fishes (mackerel, tuna, salmon, sardines and herrings) marketed in Georgia and Alabama (United States of America). *J. Food Com. Anal*. 18(8): 771-87

Itodo, UA; Itodo, UH (2010). Quantitative specification of potentially toxic metals in expired canned tomatoes found in village markets. *Nat. Sci.* 8(4): 54-58

Iwegbue, CMA (2010). Composition and daily intake of some trace metals from canned beers in Nigeria. *J. Inst. Brew.* 116: 312-315

Iwuoha, G N; Uporo, VB; Onwuachu, UI (2013). Variation of Heavy Metals in Canned Geisha and Founty Mackerel fish brands obtained from Choba market Port Harcourt, Nigeria. *J. Appl. Sci. Environ. Manage.* 17(4): 577-580

Khalafalla, FA; Ali, FHM; Hassan A R (2016). Residues of Lead, Cadmium, Mercury and Tin in canned meat product from Egypt: An emphasis on permissible limits and sources of contamination. *Journal fur Verbraucherschutz und Lebensmittelsicherheit.* 11(2): 137-143.

Mahalakshmi, M; Balakrishnan, S; Indira, K; Srinivasan, M (2012). Characteristic levels of heavy metals in canned tuna fish. *J. Toxicol. Environ. Health Sci*. 42(2): 43-45.

Mendil, D; Uluozlu, OD; Hasdemir, E; Tüzen, M; Sari, H; Suicmez, M (2005). Determination of trace metal levels in seven fish species in lakes in Tokat, Turkey. *Food Chem.* 90(1-2): 175-179.

Peter, KTO; Ulrich, N (2007). Metal packaging for foodstuffs. Packaging Materials. ILSI (International Life Sciences Institute), Belgium.

Pramoda, R; Weerasinhge, S; Migelhewa, N(2016). Determination of heavy metals in Tilapia using various digestion methods. *Intern. J. Sci. Res. Innovat. Technol.* 3(6): 38.

Salama, AK; Radwan, MA (2005). Heavy metals Cd and Pb and Trace metals Cu, Zn contents in some foodstuffs from the Egyptian market. *Emirate J. Food Agricul.* 17: 34-42.

Samira, I. K.; Weam, A. H. (2012). Essential and toxic metals in Lebanese marketed canned food. Impact of metal cans. *J. Food Res.* 2(1): 19-30.

Seyed, VH; Fereidoon, A; Soheil, S; Shaghayegh, BL (2015). Selected Metals in Canned Fish Consumed in Iran. *Iranian J. Toxicol.* 8(27): 1-5.

Tarley, CR; Coltro, WK; Matsushita, M; De Souza, NE (2001). Characteristic levels of some heavy metals from Brazillian canned sardines (*Sardinella brazillensis*). *J. Food Compos. Anal.* 14(6): 611-617.

Tuzen, M; Soylak, M (2007). Determination of trace metals in canned fish marketed in Turkey. *Food Chem.* 101: 1378-1382.

Voegborlo, RB; El-Methnani, AM; Abedin, MZ (1999). Mercury, cadmium and lead content of canned tuna fish. *Food Chem*. 67: 341–345.

WHO/FAO/IAEA. (1996). World Health Organization. Switzerland: Geneva; Trace Elements in Human Nutrition and Health. www.fao.org. Accessed September 2020.