A Comparative Assessment of Concentrations of Heavy Metals in Un-soaked and Soaked Maize (*Zea mays*) and Guinea Corn (*Sorghum bicolor*) sold in Port Harcourt, Rivers State, Nigeria

Edori, O. S.
Department of Chemistry, Faculty of Natural and Applied Sciences,
Ignatius Ajuru University of Education Rumuolumeni,
PMB 5047, Port Harcourt, Rivers State, Nigeria.
Email: onisogen.edori@yahoo.com

D.O.I: 10.56201/ijccp.v9.no1.2023.pg17.26

Abstract
Food is the most vital component of human existence. Maize and guinea corn purchased from open market in Port Harcourt, Rivers State, Nigeria were divided each into two group. One group was soaked in distilled water for four days and the other group remain unsoaked. After four days, they were both even dried to constant weight and digested using nitric acid and hydrogen peroxide. The digest were analyzed for heavy metals using atomic absorption spectrophotometer model model SN – SG 10960. The result obtained showed higher value of metals in the unsoaked grains as against the soaked grains. The percentage removal of metals in maize was 22.999, 19.867, 100, 1.252, 9.953, 10.198, 7.007 and 4.412% for Pb, Cr, As, Fe, Zn, Ni, Cu and Mn respectively. For guinea corn, the percentage removal of the metal after soaking were; 51.592, 25.491, 100, 1.139, -8.365, 23.292, 7.585 and 22.661% for Pb, Cr, As, Fe, Zn, Ni, Cu and Mn. However, Cd was not detected in any of the samples and Zn content in guinea corn slightly increased in value. The result implied that soaking of cereals before preparation for human consumption could be an important source of removal of toxic metals from food.

Keywords: *Cereals, food preparation, nutrition, human health, maize, guinea corn*

Introduction

Food is an important ingredient essential for nourishment and continuation of life for all living organisms. For life to continue, the consumed food must be associated with certain functions, such as growth, development, and maintenance of the body (Mohammed and Ahmad, 2014). In general, food materials are mostly obtained from plants (fruits, vegetables, cereals, tuber, grains etc.) and animals. Food make available to the body needed elements like vitamins and minerals which help to keep the body healthy and well-nourished (Huang *et al.*, 2007). Foods are characteristically categorized according to readiness and convenience to intake. Some are eaten raw without additional preparation, while others require additional processing before consumption.

Cereals are commonly consumed in different parts of Nigeria. They are grown in different parts of the country and are eaten using different preparatory methods. They serve for various nutritive purposes such as energy, therapeutic and mineral requirements of the human body (Salihu *et al.*, 2014). The nutritive composition of cereals vary from specie to another, but they are basically enriched naturally with carbohydrate, macro and micro elements, vitamins, oil and protein (Doe *et al*., 2013). The safety of Food presupposes that if there is the presence of contaminants, it is at concentrations that will not be harmful to human health (Sulyman *et al*., 2015). The acceptability of food by consumers depends on quality of the food. The presence of heavy metals in any plant species is a natural occurrence, which is dependent of certain environmental conditions prevalent in the area the plant is. Such factors may result from the nature of the soil (Mertz, 1980), genetic factor (lnoti *et al*., 2012), plant species, weather and climatic variables (Salihu *et al*., 2014), the metal type, the environment and age of the plant (Ismail *et al*., 2011; Tangahu *et al*., 2011).

In several unindustrialized nations of the world, the requirement for minerals for daily intake is insufficient (is not met) for the ever increasing population of human beings and agricultural farms (for ranched animals and poultry birds). Minerals are produced from plants and water enriched with minerals (Anjorin *et al*., 2010). These minerals from plants are potential sources of minerals, which serve for pharmaceutical and healing purposes (Al- kharusi *et al*., 2009).
Mineral components are important to humans because of numerous functions they play in the body. Minerals are components of the skin, transports proteins and protein hormones, acts as cofactors of enzymes and electrolytes in body fluids and cells (Okoye, 1992) and as such has become very important in both human and animal nutritional requirements (Mohammed and Ahmad, 2014).

One of the ways by which humans are affected by heavy metals is due to excess intake of either food or water which contains metals in excess of what is required for human use (Haware and Pramod, 2011). The heavy metal content of plants are also influenced by different anthropogenic input sources, which may be fertilizer application, water used for irrigation, proximity to industrial sites where metallic elements are constantly discharged, pesticides application, during movement of the crop from one point to the other, storage or sale (Omeje *et al*., 2021).

Cereals commonly eaten in Nigeria are generally produced locally, even though some are imported. Some cereals produced locally in Nigeria include maize (*Zea mays*), wheat (*Triticum aestivum*), guinea corn (*Sorghum bicolor*), millet (*Penisetum typhiodes*). However, the choice of cereals depends on individuals, locality and availability. The methods of preparing these cereals for consumption varies from place to place, therefore the need to examine the level of some heavy metals in some processing methods of food from maize and guinea corn. This information may serve as a guide to the nutritional value and pollution potential of some processed food from grains due to their mineral contents.

Materials and Methods

Source of Maize and Guinea Corn

Samples of maize and guinea corn were purchased from the open market within Port Harcourt metropolis. They were taken to the Chemistry Department Laboratory for preparation.

Sample Preparation and Treatment

Each of the cereals (guinea corn and maize) were divided into two portions. Two hundred grams of each of the portions were soaked for four days in the laboratory with 500 cm^3 of borehole water. The other portion was air dried for four days. The essence of soaking the samples for four days is to mimic the manner of the locals that prepare these cereals for akamu. The soaked maize and guinea corn were removed from the water at the end of the fourth days and dried to constant weight using oven set at a temperature of 60 ^oC. Both the soaked and the unsoaked cereals were heated to constant weight. Thereafter, they were powdered separately with mortar and pestle. The samples were sieved after grinding to obtain a fine powder.

Acid Digestion

Five grams (5g) of each sample was placed in 100 ml reflux flask. The samples were digested with 15 ml of concentrated HNO_3 and 5ml of concentrated H_2O_2. The mixture was allowed to stand for 48 hours without applying heat. It was refluxed on a heating mantle at 90 ^oC to obtain a clear colour and allowed to cool. Again, 5ml of 60% of $HClO_4$ was added to the mixture and further refluxed for 30 minutes. The digest was allowed to cool to room temperature and was filtered into a 100 ml sample bottle and made up to 50 ml mark with de-ionized water.

Analysis:

The digests were analyzed for heavy metals content using atomic absorption spectrophotometer model SN – SG 10960 at a private laboratory, Jaros Inspection Services Limited along Iwofe Road, Port Harcourt

Results and Discussion

The results of the experiment are given in Tables 1 and 2.

The concentrations of Pb in unsoaked maize was 0.119 mg/kg, while the soaked maize was 0.091 mg/kg. The amount removed as a result of soaking was 0.02 mg/kg, which was 22.999%. The concentrations of Pb in unsoaked guinea corn was 0.031 mg/kg, while the soaked guinea corn was 0.015 mg/kg. The amount removed as a result of soaking was 0.016 mg/kg, which was 51.592%. The concentrations of Pb observed in both unsoaked and soaked maize and guinea corn were higher than the RDA value of 0.0038-0.0081 mg/Kg (Korfali *et al.*, 2013) and 0.01mg/Kg limit recommended by WHO (Toroni *et al.*, 2019) and also the values observed in some cereals and fruit crops in Minna, Niger State, Nigeria. The values of Pb observed in the processed cereals were lower than those of Toroni *et al* (2019) in maize and millet in Rubi community, Nasarawa State, Nigeria.

High values of Pb is harmful to humans due to its effect on several body functions. It impedes brain enzymes, affects the transport of electrical impulse and transmission of information by nerve cells (thereby reducing their activity) (Edori and Edori, 2012), affects the kidney leading to memory loss, confusion, loss of cell coordination and misperception (FAO, 2002; FAO/WHO, 2006). Pb has not been found to be of any health importance in man, but rather known to be a poisonous metal that can cause different types of damages to body tissues such as the liver, kidneys, brain, central nervous and reproductive systems (Lovei and Ley, 2000) and high blood pressure (Okoye et al., (2009). For infants, it can cause deep and enduring aggressive health consequence, which include retardation of the development of brain and nervous system (Ahmed and Mohammed, 2005).

Cadmium (Cd) was undetected in both soaked and un-soaked maize and guinea corn. This values falls with the FAO (2002) and FAO/WHO (2006) acceptable value of 0.3 mg/Kg. The non-observation of Cd in the present work is in agreement with the observation of Aliyu *et al* (2020) in some cereals harvested around gold mine in Kuchiko-Hausa, Gurara LGA, Niger State, Nigeria. However, Chunhabundit (2016) and Toroni *et al* (2019) observed the presence of Cd in cereals. The non-detection of Cd in the examined foods implies that it is safe for consumption with regard to RDA requirements. Human exposure to Cd toxicity is through intake of food contaminated by the metal, through smoking of cigarette and through smelting and mining activities. The presence of Cd in human body effects human fluid system such as blood and urine. Furthermore, when it is consumed orally through water intake could perturb necessary tissue mechanisms and pathways that can result in short term or prolonged ailments in humans (Jiang *et al*., 2015; Cao *et al*., 2018). Cd is a confirmed carcinogen to human being (Kim *et al*., 2020).

The concentrations of Cr in unsoaked maize was 3.161 mg/kg, while the soaked maize was 2.533 mg/kg. The amount removed as a result of soaking was 0.628 mg/kg, which was 19.867%. The concentrations of Cr in unsoaked guinea corn was 2.510 mg/kg, while the soaked guinea corn was 1.875 mg/kg. The amount removed as a result of soaking was 0.642 mg/kg, which was 25.491%.

Cr can exist in several oxidation states which ranged from +2 to + 6. Of all the oxidation states, the +3 and +6 state are the most stable and therefore more common (Shekhawat et al., 2015). Cr^{6+} (VI) is linked to a sequence of ailments, although Cr^{3+} is essential for the natural production of fat and protein and also functions as a cofactor with other substances to facilitate the action of insulin (Cefalu and Hu, 2004; Vincent, 2019). However, the Cr^{6+} type or specie has been classified as a serious work-related carcinogen (Loomis *et al*., 2018).

The concentrations of As in unsoaked maize was 0.014 mg/kg, while in the soaked maize it was not detected. The amount removed as a result of soaking was 0.014 mg/kg, which was 100% removal. The concentrations of As in unsoaked guinea corn was 0.0024 mg/kg, while in the soaked guinea corn, it was not detected. The amount removed as a result of soaking was 0.0024 mg/kg, which was 100%. As is a toxic heavy metal which play negative roles in human body especially at high levels of accumulation. The concentrations of As observed in both maize and guinea corn was low. The non-detection of As on the soaked samples may be as a result of diffusion of As metal from the crop to the water in the soaked ones. Based on intake requirements of As by different stages of humans (15-25 µg/day for adults and 2-25 µg/day for children) (Mukesh et al., 2008), it follows that soaked maize and guinea corn as observed in this work cannot be a source of As toxicity to humans. Arsenic is detrimental to human health, therefore its consumption constitute risk to the public. Human exposure to As may be work-related or through eating of contaminated food and drinking of contaminated water. According to Gupta et al (2017), As is a notorious poison known as the king of poisons.

The concentrations of Fe in unsoaked maize was 9.843 mg/kg, while the soaked maize was 9.719 mg/kg. The amount removed as a result of soaking was 0.123 mg/kg, which was 1.252%. The concentrations of Fe in unsoaked guinea corn was 11.589 mg/kg, while the soaked guinea corn was 11.457 mg/kg. The amount removed as a result of soaking was 0.132 mg/kg, which was

1.139%. The values of Fe observed in both soaked and unsoaked maize and guinea corn were within the limits of RDA daily consumption requirement. In the present study, the level of Fe slightly decreased in the soaked maize and guinea corn, which pre-supposes that soaking could be used to remove the metal from the cereals in case of excess iron.
The values of Fe observed in the examined cereals were within the range of values observed in six different grains sold in Kaduna markets (Sulyman *et al.*, 2015), but lower than the values observed in maize milled through different methods in Samaru, Nigeria (Israila and Halima, 2016), whose values were higher than the requirement for daily consumption and also lower than the values of Fe observed in maize harvested from industrial areas of Ogun state, Nigeria (Malomo *et al.*, 2012). Fe is present in the body as heme in hemoglobin and myoglobin, which responsible for transportation of oxygen to other body cells for respiratory purposes. It is also a component of heme enzymes which include cytochromes, catalases and peroxidizes and some non-iron central compounds (McDowell, 1992). Although the RDA requirement for iron is 8mg/day – 18mg/day (NIH, 2013), depending on the age and sex, yet those who consume maize or millet whose values are within the range of this research, need to consume a very large quantity above 1 Kg/day, which is quite impossible, thus the maize and millet can easily and safely consumed

The concentrations of Zn in unsoaked maize was 7.967 mg/kg, while the soaked maize was 7.174 mg/kg. The amount removed as a result of soaking was 0.793mg/kg, which was 9.953%. The concentrations of Zn in unsoaked guinea corn was 6.288 mg/kg, while the soaked guinea corn was 6.814 mg/kg. The amount added as a result of soaking was 0.526 mg/kg, which was 8.365%.
Zinc is an abundant indispensable element which is needed for regular development of animals. Zinc is found in a number of human enzymes and various nutriments differ in their natural content of Zinc. The ranges of Zn observed in the present work was slightly higher than the values observed in an earlier work (Malomo et al., 2012). Also the observed values for both soaked and unsoaked maize and guinea corn were within the Recommended Dietary Allowance for Zn is 11 mg. The WHO/FAO safe level for Zn is put at 0.06 mg/kg. Risky content of Zn can cause respirational impairment, tension and restraint of regular growth and maturing (Weatherley et al., 1988). The value considered to be dangerous to pregnant mothers is put at 1.5 mg/kg. However, intake of zinc to meet-up body requirements has been identified to be a good therapy to reduce the effect of diarrhea (WHO/UNICEF, 2004).

The concentrations of Ni in unsoaked maize was 1.618 mg/kg, while the soaked maize was 1.453 mg/kg. The amount removed as a result of soaking was 0.165 mg/kg, which was 10.198%. The concentrations of Ni in unsoaked guinea corn was 1.391 mg/kg, while the soaked guinea corn was 1.067 mg/kg. The amount removed as a result of soaking was 0.324 mg/kg, which was 23.292%.
The values of Ni observed in both unsoaked and soaked cereals were lower than the RDA value of 1.0 mg. However, elevated concentrations of Ni hinders mitosis, thereby causing a reduction the rate of plant growth and also reduced fruit yield and quality (Gajewska et al., 2006; Edori and Marcus, 2016). Ni is toxic to blood, disruptions body immune resistance, neurotoxic, affects reproduction, the veins, kidney and liver and also considered a carcinogen. The ability of Ni to induce toxicity on organisms is based on its ability to produce oxygen species that helps on the

production of free radicals which is consequent on DNA malfunction. Although, Ni is an indispensable element in animals, yet its health threat cannot be overruled. These risks or challenges comprises fibrosis, prolonged bronchitis, compromised respiratory role, and emphysema. Deficiency of Ni leads to reduction in plasma lipid, elevated lipids in the liver, and alteration in structure of liver cells, jagged hair, reduced reproduction, and reduced development of young children.

The concentrations of Cu in unsoaked maize was 3.211 mg/kg, while the soaked maize was 2.986 mg/kg. The amount removed as a result of soaking was 0.225 mg/kg, which was 7.007%. The concentrations of Cu in unsoaked guinea corn was 4.311 mg/kg, while the soaked guinea corn was 3.984 mg/kg. The amount removed as a result of soaking was 0.327 mg/kg, which was 7.585%.
Although Cu deficiency is seldom, yet when it occurs may cause circulatory and vascular diseases. Cu is mostly present in body tissues such as liver, brain, heart and skeletal muscles. It major function in the body is to help in the formation of collagen and absorption of iron and further facilitate the role of energy production in body cells (Okoye et al., 2009)

The concentrations of Mn in unsoaked maize was 4.692mg/kg, while the soaked maize was 4.485 mg/kg. The amount removed as a result of soaking was 0.207 mg/kg, which was 4.412%. The concentrations of Mn in unsoaked guinea corn was 3.875 mg/kg, while the soaked guinea corn was 2.997 mg/kg. The amount removed as a result of soaking was 0.878 mg/kg, which was 22.661%.
Manganese is considered as the least toxic when compared with all other essential metals. The toxicity to a very great extent is dependent on the ion type and the oxidation state. Developmental hindrance, non-specific anemia, metal emission disease, mental and neural disarrays are some of the warning signs of manganese intoxication. Lingering human toxicity with Mn is due to continuous contact by breathing and assimilation through food intake. The persistence of intake or exposure to Mn will result in a diseased condition that affects the central nervous system (CNS) called manganism, which linked with psychic and neurological condition (Edori and Marcus, 2016). A unusual slurping posture, spasms or vibrations of the body, incoherent speaking, delusions, sleeplessness, and psychological misperception are notable symptoms of the disease.

Table 1: Concentration of heavy metals in un-soaked and soaked maize (*Zea mays*)

Heavy metals (mg/kg)	Unsoaked maize	Soaked Maize	Amount Removed	% Removed
Pb	0.119	0.091	0.027	22.999
Cd	ND	ND	-	-
Cr	3.161	2.533	0.628	19.867
As	0.014	ND	0.014	100
Fe	9.843	9.719	0.123	1.252
Zn	7.967	7.174	0.793	9.953
Ni	1.618	1.453	0.165	10.198
Cu	3.211	2.986	0.225	7.007
Mn	4.692	4.485	0.207	4.412

Table 2: Concentration of heavy metals in soaked and un-soaked guinea corn (*Sorghum bicolor*)

Heavy metals	Un-soaked guinea corn	Soaked guinea corn	Amount Removed	% Removed
Pb	0.031	0.015	0.016	51.592
Cd	ND	ND	-	-
Cr	2.510	1.875	0.642	25.491
As	0.0024	ND	0.0024	100
Fe	11.589	11.457	0.132	1.139
Zn	6.288	6.814	-0.526	-8.365
Ni	1.391	1.067	0.324	23.292
Cu	4.311	3.984	0.327	7.585
Mn	3.875	2.997	0.878	22.661

Conclusion

The analysis of the unsoaked maize and millet showed the presence of Pb, Cr, As, Fe, Zn, Ni, Cu and Mn, while the soaked showed the presence of Pb, Cr, Fe, Zn, Ni, Cu and Mn. There was reduction of the metal contents in both maize and guinea in the soaked groups. The percentage removal of heavy metals from the cereals indicated very high percentage for the non-essential metals when compared to the essential metals. This observation points out that soaking of cereal will be an important factor for removal of toxic metals that may have been taken up from the soil during cultivation processes. This method should therefore be considered as an appropriate and cost effective method to reduce intake of unwanted quantity of metals in human and animal systems.

References

Al-kharusi, L. M., Elmardi M. O., Ali, A., Al-Said, F. A. J., Abdelbasit K. M. and Al-Rawahi, S. (2009). Effect of Mineral and Organic Fertilizers on the Chemical Characters and Quality of Date Fruits. International Journal of Agriculture and. Biology, 11: 290- 296.

Aliyu, Y., Abdullahi, I. O., Whong, C. Z., Olalekan, B. O. and Reuben, C. R. (2020). Occurrence and antibiotic susceptibility of methicillin-resistant Staphylococcus aureus in fresh milk and milk products in Nasarawa State, North-Central Nigeria. Journal of Microbiology and Antimicrobes, 12:32–41.

Anjorin, T. S., Ikokoh, P. and Okolona, S. (2010). Mineral Composition of Moringa oleifera Leaves, Pods and Seeds from two region in Abuja, Nigeria. International Journal of Agriculture and. Biology, 12: 431- 434.

Cao, Z. R., Cui, S. M., Lu, X. X., Chen, X. M., Yang, X., Cui, J. P., et al. (2018). Effects of occupational cadmium exposure on workers' cardiovascular system. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi, 36(6), 474–477. doi:10.3760/cma.j.issn.1001-9391.2018.06.025.

Cefalu, W. T. and Frank B Hu, F. B. (2004). Role of chromium in human health and in diabetes. Diabetes Care, 27(11):2741-51. doi: 10.2337/diacare.27.11.2741.

Doe, E. D., Awua, A. K., Gyamfi, O. K. and Bentil, N. O. (2013). Levels of selected heavy metals in wheat flour on the Ghanaian market, a determination by atomic absorption spectrophotometer, *American Journal of Applied Chemistry, 1*(2), 17-21

Edori, O. S. and Edori, E. S. (2012). Effect of Automechanic Works on Lead and Iron in Two Mechanic Villages in Port Harcourt, Rivers State Nigeria. Journal of Applied Science and Environmental Management, 16 (4): 317-321.

Edori, O. S. and Marcus, A. C. (2016). Phytochemical Screening and Physiologic Functions of Metals in Seed and Peel of Citrullus lanatus (Watermelon). International Journal of Green and Herbal Chemistry, B, 6(1): 35-46.

FAO (2002). Food Energy – Methods of analysis and conversion factors. Report of a technical workshop. Rome, 3-6, December, 2002.

FAO/WHO (2006). The Role of food safety in health and development- Summary of evaluations Performed by the Joint FAO/WHO Expert Committee on Food Additives (JECFA); 2006.

Gajewska, E., Sklodowska, M,. Slaba, M. and Mazur, J. (2006). Biological Plant, 50, 653–659.

Gupta, D. K., Tiwari, S., Razafindrabe, B. H. N. and Chatterjee, S. (2017). Arsenic contamination from historical aspects to the present. doi: 10.1136/oemed-2017-104944.

Haware, D. J. and Pramod, H. P. (2011). Determination of specific heavy metals in fruit juices using Atomic Absorption Spectrophotometer (AAS), *International Journal of Research in Chemistry and Environment*, *4*(3), 163-168.

Huang, Z., Li, X. L., Wang, J. S., Tu, X. D. and Liu, W. (2007). Vertical variations of particle number concentration and size distribution in a street canyon in Shanghai, China. *Science of the Total Environment*, *378*,306–316.

Inoti, K. J., Kawaka, F., Orinda, G. and Okemo, P. (2012). Assessment of heavy metal concentrations in urban grown vegetables in Thika Town, Kenya. *African Journal of Food Science*, *6*, 41-46

Ismail, F., Anjum, M. R., Mamon, A. N. and Kazi, T. G. (2011). Trace Metal Contents of Vegetables and Fruits of Hyderabad Retail Market. *Pakistan Journal of Nutrition*, *10*, 365-372.

Israila, Y. Z. and Halim, S. (2016). Effect of Grinding Plates (GUK, Parpela and Premier) on Maize Flour Milled within Samaru, Nigeria. *International Journal of Biochemistry Research & Review, 12*(1), 1-7.

Jiang, J. H., Ge, G., Gao, K., Pang, Y., Chai, R. C. and Jia, X. H. (2015). Calcium signaling involvement in cadmium-induced astrocyte cytotoxicity and cell death through activation of MAPK and PI3K/Akt signaling pathways. Neurochemistry Research, 40 (9): 1929–1944.

Kim, T. H., Kim, J. H., Le Kim, M. D., Suh, W. D., Kim, J. E., Yeon, H. J., et al. (2020). Exposure assessment and safe intake guidelines for heavy metals in consumed fishery products in the Republic of Korea. Environmental Science Pollution and Research International, 27, 33042–33051. doi:10.1007/s11356-020-09624-0

Korfali, S. I., Tamer, H. and Mohamad, M. (2013). Evaluation of heavy metals content in dietary supplements in Lebanon. *Chemistry Central Journal*, 7(10), https://doi.org/10.1186/1752-153X-7-10.

Loomis, D., Guha, N., Hall, A. L., and Straif, K. (2018). Identifying occupational carcinogens: an update from the IARC monographs. Occupational and Environmental Medicine, 75 (8), 593–603. doi:10.1136/oemed-2017-104944.

Lovei, M. and B.S. Levy (2000). Lead exposure and healh in Central Eastern Europe. Evidence

from Hungary, Poland and Bulgaria. World Bank, Washington D.C.

Malomo, O., Ogunmoyela, O. A. B., Oluwajoba, S. O. and Adekoyeni, O. O. (2012). Evaluation of chemical and heavy metal concentrations in maize (Zea mays) from industrial area of Ogun state, Nigeria.

McDowell L. R. (1992). Minerals in Animal and Human Nutrition. Academic Press Inc., CA, USA.

Mertz, W. (1980). The Essential Trace Elements. *Science, 213*:1332.

Mohammed, M. I. and Ahmad, U. M. (2014). Mineral elements content of some coarse grains used as staple food in Kano Metropolis, Nigeria. *Bayero Journal of Pure and Applied Sciences, 7*(1): 85 – 89.

Mukesh, K. Raikwar, Punect Kumar, Manog Sigh and Anamed Singh (2008). Veterinary World, 1 (1): 28-30.

NIH (National Institute of Health), (2013). Health Professional Fact Sheet. Office of Dietary, pp 544–553. Supplements. Available at http://www.ods.od.nih.gov/factsheets.

Okoye Z.S.C (1992) Biochemical Aspects of Nutrition Prentice-Hall of India, New Delhi pp 147-195.

Omeje, K.O., Ezema, B.O., Okonkwo, F., Onyishi, N.C., Ozioko, J., Rasaq, W.A., Sardo, G. and Okpala, C.O.R. (2021). Quantification of Heavy Metals and Pesticide Residues in Widely Consumed Nigerian Food Crops Using Atomic Absorption Spectroscopy (AAS) and Gas Chromatography (GC). *Toxins*, *13*, 870-887.

Salihu, S. O., John O. J., Matthew, T. K. (2014) Heavy Metals in Some Fruits and Cereals in Minna Markets, Nigeria. *Pakistan Journal of Nutrition*, *13*(12): 722-727.

Shekhawat, K., Chatterjee, S., and Joshi, B. (2015). Chromium toxicity and its health hazards. International Journal of Advanced Research, 3 (7), 167–172

Sulyman, Y. I., Abdulrazak, S., Oniwapele, Y. A. and Ahmad, A. (2015). Concentration of heavy metals in some selected cereals sourced within Kaduna state, Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *9*(10): 17-19

Tangahu, B. V., Abdullah, S. R. S., Basri, H., Idris, M., Anuar, N. and Mukhlisin, M. (2011). *International Journal of Chemical Engineering 2011*, 1-31.

Toroni, A.O., Aguoru, C.U., Ogbonna I.O. and Olasan, J.O (2019). Comparative Studies of Heavy Metals and Mineral Residues in Some Farm Crops around Mining Community of Ribi, Awe Local Government Area of Nasarawa State. *International Journal of Environment, Agriculture and Biotechnology*, *4*(3), 789-796.

Vincent, J. B. (2017). New evidence against chromium as an essential trace element. Journal of Nutrition, 147 (12), 2212–2219. doi:10.3945/jn.117.255901.

Weatherley, A.H., Lake, P. S. and Stahal, P. L. (1988). Zinc in the environment and ecological cycling. John Wiley New York, pp: 337-417.

WHO/UNICEF, (2004). Chemical management of acute diarrhoea (Joint statement) WHO and UNICEF, Geneva and New York.