IMPACT OF COOKING UTENSILS ON TRACE METAL LEVELS OF PROCESSED FOOD ITEMS

Emmanuel Udo Dan, Godwin Asukwo Ebong*
Chemistry Department, University of Uyo, P. M. B 1017, Uyo, Nigeria.
*E–mail: g_ebong@yahoo.com

Abstract
Levels of trace metals namely: iron (Fe), aluminium (Al), copper (Cu), chromium (Cr) and nickel (Ni) were analyzed spectrophotometrically in rice, beans, yam and plantain cooked in aluminium and stainless steel pots. These metals were also determined in uncooked rice, beans, yam and plantain which served as Controls. Results obtained indicated that, the lowest concentrations of all the metals analyzed for were recorded in uncooked food items (Controls). It was also noticed from results recorded that, the highest mean concentration of Fe (4.45 ± 0.36 mg/kg) was obtained in plantain boiled in stainless steel pot, Al recorded its highest mean level (0.44±0.04mg/kg) in rice cooked in aluminium pot while the highest mean concentration of Cu (7.26 ± 0.06mg/kg) was indicated in beans cooked with aluminium pot. Chromium recorded the highest mean concentration (0.98 ± 0.04mg/kg) in rice boiled in stainless steel pot whereas; Ni indicated the highest concentration in plantain boiled with stainless steel pot. Results obtained in this study further revealed that, cooking utensils can leach some quantities of trace metals into food during processing, hence resulting in slight increase in the concentration of these metals in processed foods. The general results showed that levels of Fe and Al obtained were within their recommended safe limits whereas, concentrations of Cu, Cr and Ni were above their maximum acceptable levels. The study has also shown that, rice and plantain have high potentials of leaching these metals from cook wares examined. These results have discussed based on their environmental and health implications.

Keywords: cooking utensil, trace metal, Uyo, stainless steel pot, aluminium pot

Submitted: 01.08.2013 Reviewed: 2.09.2013 Accepted: 17.09.2013

1. INTRODUCTION

Environmental pollution is a major cause of the elevated levels of micro and macro elements in food chain (Nnorom *et al*., 2007). When soil environment is polluted by trace metals, plants grown on them absorb these toxic metals and transferred same directly to human and grazing animals when these plants are taken up by them (Raphael *et al*., 2010). The soil–plant transfer of trace metals is a part of chemical element cycling in nature but a very complex process governed by several factors, both natural and artificial (Kabata-Pendias, 2004).

Trace metals are potential environmental contaminants/pollutants with the capabilities of causing human health problems if present in foods at high concentrations (Fair-weather Tait, 1988; Graham *et al*., 1976). However, trace metals are significant in nutrition especially if its concentration is within the safe limit. Food can be contaminated during different stages of agricultural production particularly in the soil where these metals are naturally present (Zhuang *et al*., 2009). Trace metals due to their persistence, non-biodegradability and toxicity even at low concentrations, are given special attention by researchers throughout the world (Das, 1990). Studies have shown that the nature of cook wares, cooking process, storage and processing methods can increase trace metal levels in foods (Anderson *et al*., 1992; Ebong *et al*. 2010). Cabrera *et al*. (2003) reported that, the type of cooking utensil used may contribute some considerable amounts of trace metals into our foods by way of leaching in addition to the ingredients used. In Akwa Ibom State and Nigeria in general, the most commonly used cooking pots are those made of aluminium and stainless steel. The choice of these pots is because, they are the most popular and economical cookware commonly found in most Nigerian markets in addition to the fact that they are easy to clean, have unique surfaces that cannot crack easily, difficult to rust and high life expectancy. This study aimed at assessing the impacts of these cook wares on the metal levels of food items processed using them thereby creating awareness on the attendants health implications associated with the applications of these cooking utensils in food processing.

2. MATERIAL AND METHODS

Food items (Rice, Beans, Plantain fruit, and yam seeds) utilized for this research work were bought from Akpan Andem market in Uyo metropolis, Akwa Ibom State, Niger Delta region of Nigeria. In the laboratory,1kg each of rice and beans were washed with distilled water to remove dust particles and divided into three (3) equal parts each, two (2) of which were cooked differently in aluminium pot and stainless steel pot 30mins for rice, and 45mins for beans using electric stove. The soft samples were then sieved to remove water, dried in oven at 105^0C for 12hrs then ground into fine powdery form. The uncooked samples were oven dried at 100^oC for 24hrs and grinded using mixer grinder (model 33750). These ground samples were preserved for digestion and trace metal analysis. The other samples (yam and plantain) were peeled manually, cut into pieces and cooked with distilled water in aluminium and stainless steel pots respectively for 40mins. These samples were drained, oven dried for 48hrs at about 105^0C, ground and stored in plastic containers. The uncooked samples were sliced into pieces, oven dried for 48hrs at 120^0C and ground into fine powder (Adeniji *et al.*, 2007).

Sample Digestion and trace metals Determination: 1g of each of the ground samples was weighed into a 125cm^3 Erlenmeyer flask, 4cm^3 of perchloric acid was added followed by 25cm^3 conc. HNO_3 and 2cm^3 conc. H_2SO_4 in a conical flask under perchloric acid fume hood to almost dryness. The content was continuously heated at 180-220^{o}C for about 35mins until dense white fumes appeared on the topmost part of the flask. The solution was heated again for about 10mins until a clear yellow solution was obtained. The resulting solution was allowed to cool, after which 40cm^3 of distilled water was added, re-boiled for 30seconds on the same plate at medium heat. The solution was cooled and then filtered with Whatman filter paper No. 42 into a 100cm^3 Pyrex volumetric flasks and made up the volume with distilled water. The trace metal determination was done using Atomic Absorption Spectrophotometer (AAS) model GBC Aranta Pm according to the methods of Sobukola *et al.* (2009).

3. RESULTS AND DISCUSSION

The mean levels of trace metals analyzed for in cooked and uncooked rice, beans, yam and plantain obtained from Urua Akpan Andem in Uyo metropolis, Akwa Ibom State using Aluminium and stainless steel pots are presented in Table 1. Results obtained revealed that the different food items studied recorded variable levels of trace metals with aluminium recording the lowest metal level in all the samples analyzed.

Results obtained also indicated that, iron recorded the highest mean metal concentration with a range of 1.83 – 4.45mg/kg, the lowest Fe level was recorded in uncooked rice (1.83mg/kg) and the highest in plantain cooked with stainless steel pot (4.45mg/kg). The high level of Fe recorded in this study may be attributed to the availability of the metal in the earth's crust and its importance for both plant growth and human (Ebong *et al.*, 2006). The result also revealed that food cooked with stainless steel pot recorded more of the Fe than those cooked with aluminium pot or their uncooked counterparts. This may be attributed to the fact that stainless steel is a metal alloy that contain more than fifty percent (50%) Fe be it ferritics or martensitic which are the most common constituent in almost all stainless steel cooking utensils found in homes and industries among other factors (Elinder, 1986). However, the range of Fe obtained in this study is within the recommended safe limit for the metal in food (0.8mg/kg) by JECFA (1983).

Table 1: Levels of trace metals (mgkg^{-1}) in cooked and uncooked rice, beans, yam and plantain.

Cooking Utensils	Mean Conc. in mg/kg dry weight ± S.D				
	Fe	Al	Cu	Cr	Ni
				Rice	
Uncooked	1.83±0.03	0.20 ± 0.01	1.05 ± 0.35	0.37 ± 0.13	1.86±0.05
Aluminium pot	2.67±0.02	0.44±0.04	1.47±0.12	0.48±0.01	3.37±0.11
Stainless Steel	3.46 ± 0.12	0.10 ± 0.01	1.14 ± 1.03	0.98 ± 0.04	4.32 ± 0.21
				Beans	
Uncooked	2.12 ±0.23	0.09 ± 0.00	4.34±0.32	0.31 ± 0.06	1.44 ± 0.01
Aluminium pot	2.88 ± 0.15	0.16 ± 0.02	7.26 ± 0.06	0.52 ±0.04	2.62 ± 0.03
Stainless Steel	4.17 ± 0.86	0.07 ± 0.01	5.11 ± 0.23	0.77 ± 0.14	4.22 ± 0.50
				Yam	
Uncooked	1.89±0.03	0.07 ± 0.02	1.35 ± 0.23	0.46 ± 0.01	1.96 ± 0.03
Aluminium pot	2.34 ± 0.05	0.24 ± 0.01	2.34±0.11	0.58 ± 0.11	3.30±0.21
Stainless Steel	2.98 ± 0.14	0.05 ± 0.02	2.24 ± 1.10	0.78 ± 0.03	4.65 ± 0.11
				Plantain	
Uncooked	2.13 ± 0.19	0.04 ± 0.00	1.59±0.12	0.43 ± 0.01	1.84±0.31
Aluminium pot	3.01±0.21	0.18 ± 0.01	2.43 ± 0.05	0.58±0.02	2.32 ± 0.13
Stainless Steel	4.45 ± 0.36	0.06 ± 0.01	1.85 ± 0.43	0.97 ± 0.12	5.29 ± 1.00

Values are mean ± SD of samples analyzed in triplicate.

This is in agreement with the findings by Accominotti *et al.* (1998) who reported in his study that the amount of metals released into food during cooking or processing were still less than the tolerable daily intake (TDI) recommended. The low concentrations of Fe recorded in the Control samples have shown that, some amounts of Fe have been leached from the cooking utensil into the food items cooked. Thus, a periodic assessment of the level of this metal in human body is recommended to avoid bioaccumulation and its attendant's effects in future. A range of 0.04 – 0.44mg/kg was obtained for Al in this study with the highest level recorded in rice cooked in aluminium pot while the lowest concentration was obtained in uncooked plantain. The Results recorded for Al indicated that, the metal was leached from the cooking utensil into the food items cooked since high levels were obtained in samples cooked in aluminium pot. This is in agreement with reports by Dobonne *et al.* (2010) that, the level of aluminium increased from 1.60 mg/g in uncooked rice to 18.1mg/g in rice cooked with traditional cooking pot made of aluminium during their research work. However, the range of Al recorded in cooked and uncooked food items are within the safe limit in food (7.00mg/kg) by JECFA (1989). This is in agreement with reports that, cooking in aluminium vessels increases the content in the foodstuffs less than 1 mg/kg for about half the foodstuffs examined, and less than 10 mg/kg for 85% of the foodstuffs examined (Pennington and Jones, 1989). Studies have also shown that, acidic foodstuffs and soft fruits most frequently take up more Al from the containers than their basic counterparts (Hughes, 1992). Greger *et al.* (1985) reported that, the longer the cooking time, the greater the accumulation of aluminum and about 3.5 mg/day quantity of Al is added to the daily diet through the use of aluminium for food processing. Based on results obtained, cooking of rice in aluminium pot should be discouraged since this metal present a risk for the consumers especially in the prolonged exposure even at low concentrations. Several complications have been reported on toxicity of aluminium in human like Alzheimer's disease (Harrigton, 1994; Martyn *et al.*, 1989), Neurons alteration diseases (Crapper *et al.*, 1976; Bharathi *et al.*, 2008) among others.

Copper according to Codex (1995) is naturally present in most foodstuffs in the form of copper ions or copper salts. It is among the most effective of metal biochemical oxidizing agents. Copper though needed in our body can be harmful if present in excess amount as it acts as a hemolytic agent (Aaseth and Norseth, 1986). Copper recorded a range of 1.05 – 7.26mg/kg in this study with the highest level in beans cooked with aluminium pot while uncooked rice showed the lowest Cu concentration. The obtained results also indicated that, levels of Cu in all the food items cooked with aluminium pot were higher than their corresponding levels in food items cooked in stainless steel pot and uncooked ones. This confirmed that, aluminium cook wares may contain alloying elements such as magnesium, silicone, iron, manganese, copper and zinc (European Standard EN 601; European Standard EN 602). The high and low Cu levels reported for beans and rice respectively in this study is in agreement with results obtained by Onianwa *et al*. (1999) in beans (6.87mg/kg) and rice (1.53mg/kg). On comparing the results obtained for copper with the provisionally maximum tolerable daily intake (PMTDI) for the metal (0.5 mg/kg) by JECFA (1982), it was observed that Cu concentrations obtained in this study in both the cooked and uncooked samples were higher than the standard required by the human body. This revealed that, copper level in unprocessed foods can be as high as 2mg/kg or less as reported by Aaseth and Norseth (1986). It was also inferred from the results that, consumption of foodstuffs cooked with copper or copper related pots can cause Cu toxicity and its implications such as migraine headaches, hypotension, anxiety, premenstrual syndrome, nausea, vomiting, renal and liver damage, increased respiratory rates etc (Flemming and Trevors, (1989). Thus, this practice should be discouraged and discontinued to avoid a devastating effects associated with it. Chromium is an essential nutrient required by the human body to promote the action of insulin in the body tissue hence helping in the utilization of glucose, protein, and fat (Anderson, 1992, 1995; O'Fleherty, 1993) especially if within the allowable limit. Studies have shown that, most foodstuffs contain less than 0.1 mg chromium per kg (Nordic Council of Ministers, 1995). Reports have also indicated that, chromium is present in the diet mainly as Cr (III) since it has the potential of forming strong, inert complexes with a wide range of naturally occurring organic and inorganic ligands (Codex, 1995; Florence and Batley, 1980; Guglhofer and Bianchi, 1991). This work recorded a range of 0.31 – 0.97mg/kg for Cr, the highest Cr level was obtained in rice cooked with stainless steel pot while the lowest value was indicated by uncooked beans. Results obtained indicated that, food items cooked with stainless steel pot recorded higher Cr levels than those cooked with aluminium pot and uncooked counterparts. This revealed that some quantity of Cr may have been leached from stainless steel cooking utensil into foodstuffs cooked with it. The range of Cr obtained is consistent with reports that, chromium does not migrate significantly from articles made of stainless steel and any released Cr is Cr (III) since Cr (III) can not migrate significantly at neutral pH in foodstuffs (Cunat, 1997). Nevertheless, the obtained range is higher than 0.025-0.2mg/day stipulated by Codex (1995). These results showed that consuming foodstuff cooked with stainless steel cook wares may cause Cr toxicity and its attendant's health implications in human. Nickel is known to be essential to the health of some species; but it has not been proven to be essential to the health of humans (Barceloux, 1999; ATSDR, 1995).

Notwithstanding its unknown essentiality, humans are exposed to the metal through food. In this research work, Ni indicated a range of 1.44 – 5.29mg/kg with the highest concentration recorded in plantain cooked with stainless steel while the lowest level was obtained in uncooked beans. This high Ni content in cooked plantain may be attributed to the leaching of the metal from stainless steel pot into the sample. This is consistent with the findings by several researchers that, some quantity of Ni is always transferred into foodstuffs cooked with stainless steel utensils Agarwal *et al*., 1997; Berg *et al*., 2000; Kumar *et al*., 1994). However, the obtained results is not consistent with the report by NiDI (1994) that, the release of nickel ions from stainless steel cooking pots into foodstuffs is generally less than 0.1 mg/kg. The range of Ni reported in this study is higher than 0.15-0.7 mg/day recommended by Codex (1995) as the daily intake of nickel via foodstuff. Even though, the use of stainless steel utensils by nickel sensitized persons does not bring forth an allergic reaction, some patients with certain types of nickel dermatitis may have eczema when exposed to high levels of Ni through foodstuffs rich in nickel (Veien, 1989; Veien and Menné, 1990). Therefore the level of Ni in human body should be regulated to forestall the associated health implications.

4. CONCLUSIONS

Results obtained in this study has revealed that different food crops have different potential of accumulating trace metals in addition to supplying valuable information about the trace metal levels in food crop commonly eaten in Akwa Ibom State, Southern Nigeria. It has also shown that different cooking utensils like aluminium pot and stainless steel pot which are commonly utilize in food processing have different impact on the metal levels of different foodstuffs processed. The variations in the concentrations of the same metal by different food items may also be as a result of variations in enzymatic reactions with the different food items examined. Although, the levels of iron and aluminium were within their safe limits, further studies should be done on other food items not assessed in this study to avoid metal toxicity in human. This work has also indicated that, Ni and Cr sensitive persons who suffer from contact allergy should avoid the frequent use of stainless steel pot for cooking. The high potential of plantain and rice in absorbing these toxic metals should be noted and examined further to establish the factors that may have accelerated the process.

5. REFERENCES

[1] Aaseth, J. and Norseth, T. 1986. Copper. In: Friberg, L., Nordberg, G.F., Vouk, V.B. *Handbook on the toxicology of metals.* Second edition. Elsevier, Amsterdam, New York, Oxford.

[2] Accominotti, M., Bost, M.; Haudrechy, P.; Mantout, B.; Cunat, P. J.; Comet, F.; Mouterde, C.; Plantard, F.; Chambon, P. and Vallon, J. J. 1998. Contribution to chromium and nickel enrichment during cooking of foods in stainless steel utensils. Contact Dermatitis. 38 (6): 305-10.

[3] Adeniji, T. A., Sanni, L. O., Barimalaa, I.S. and Hart, A. D. 2007. Anti-nutrients and heavy metals in some new plantain and banana cultivars. Nigerian Food Journal 2:25.

[4] Agarwal, P. and Srivastava, S., 1997. "Studies on leaching of Cr and Ni from stainless steel utensils in certain acids and in some Indian drinks." Science of the Total Environment 199(3): 271-275.

[5] Anderson, R. A. 1995. Dietary and metabolic effect in trivalent chromium retention and distribution in rats. Biol. Trace Elem Res. 50:97-108.

[6] Anderson, R. A., Bryen, N. A., Polansky, M. M., 1992. Dietary chromium intake. Freely chosen diets, institutional diet and individual foods. Biol. Trace Elem. Res., 31:117-121.

[7] ATSDR 1995. *Toxicological profile for nickel.* Draft for public comment. US Department of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry.

[8] Barceloux, D. G. 1999. "Nickel." Journal of Toxicology-Clinical Toxicology 37(2): 239-258.

[9] Bharatti, P., Govindaraju, M., Palanisamy, A., Sambamurti, K., Rao, K., 2008. Molecular toxicity of aluminium in relation to neurodegeneration. India J. Med. Res., 128(4): 545-556.

[10] Flemming, C. A., Trevors, J. T., (1989). "Copper toxicity and chemistry in the environment: a review". Water, Air, & Soil Pollution 44 (1-2): 143–158.

[11] Cabrera, C., Lloris, F., Gimenze, R., Olalla, M., Lopez, C., (2003). Mineral content in legumes and nuts: Contribution to the Spanish dietary intake. Sci. Total Environ. 308:1-14.

[12] Capar, S. G. and W. C. Cunningham 2000. "Element and radionuclide concentrations in food: FDA total diet study 1991-1996." Journal of AOAC International 83(1): 157-177.

[13] Codex Alimentarius Commission 1995. Doc. no. CX/FAC 96/17. Joint FAO/WHO food.
standards programme. Codex general standard for contaminants and toxins in foods.
Technical Report Series 776.

[14] Crapper, D., Krishman, S. and Quittkat, S. 1976. Aluminium, neurofibrillary degeneration and Alzheimer's disease. Brain, 99 (1): 67-80.

[15] Cunat, P. J. 1997. *Healthy eating and drinking with stainless steel.* 1st SS congress,Thailand, Dec. 1997.

[16] Dabonne, S., Koffi, B., Kouadio, E., Due, E. and Kouame, L. 2010. Traditional Utensils: Potential sources of poisoning by heavy metals. British Journal of Pharmacology and Toxicology, 1(2): 90-92.

[17] Das, A. (1990). *Metal ion induced toxicity and detoxification by chelation therapy.* In; 1st (ed). A

textbook of medical aspects of bio-inorganic chemistry, CBS, Delhi. pp. 17-58.
[18] Ebong, A., Chapel, A., Matinus, N. and Alexander, D. 2006. Foliar fertilization stuttgar. Fischer-verlag
[19] Elinder, C.G. 1986. Iron. In: Friberg, L., Nordberg, G.F., Vouk, V.B. *Handbook on the toxicology of .metals*. Second edition. Elsevier, Amsterdam, New York, Oxford.
[20] European Standard CEN EN 601. Aluminium and aluminium alloys - Castings – Chemical composition of castings for use in contact with food.
[21] European Standard CEN EN 602. Aluminium and aluminium alloys-Wrought products -Chemical composition of semi products used for the fabrication of articles for use in contact with food.
[22] Fairweather-Tait, S. (1998). Zinc in human nutrition. Nutrition Research Review 1: 23-27.
[23] Florence, T.M. and Batley, G.E. (1980). Chemical speciation in natural waters. CRC Critical Reviews in Analytical chemistry. p. 219-296.
[24] Godwin Ebong, Ime Obot and Helen Etuk (2010). Copper Impacting Potential of Boiling Ring during Water Heating, International Journal of Chemical, Environmental and Pharmaceutical Research 1(3):16-22.
[25] Graham, G., and A. Cordano (1976). *Copper deficiency in human subjects*. In Prasad A., Oberleas, D.,The Nutrition Foundation. Trace elements in human health and diseases. Vol 1. Zinc and copper, New York: Academic press.
[26] Greger, J.L. 1985. Aluminum content of the American Diet. Food Technol. 39:73-80.
[27] Greger, J.L., Goetz, W., and Sullivan, D. 1985. Aluminum levels in foods cooked and stored in aluminum pans, trays and foil. J. Food Protect. 48 (9): 772-777.
[28] Guglhofer, J. and Bianchi, V. 1991. *Metals and their compounds in the environment*. VCH. Verlag, Weinheim, Germany.
[29] Harrigton, C., (1994). Alzheimer's disease-like changes. Lancett, 343: 993-997.
[30] Hughes, J.T. (1992). Aluminium and your health. British Library Cataloguing in Publication Data, Rimes House.
[31] JECFA (1982). Evaluation of certain food additives and contaminants. Twenty-sixth report of the Joint FAO/WHO Expert Committee on Food Additives. World Health Organization,Technical Report Series 683.
[32] JECFA (1983). Evaluation of certain food additives and contaminants. Twenty-seventh report of the Joint FAO/WHO Expert Committee on Food Additives. World Health Organization, Technical Report Series 696.
[33] JECFA (1989) in 1988 established a PTWI at 7 mg/kg body weight for the total intake, including food additive uses of aluminium salts.
[34] JECFA (1989). Evaluation of certain food additives and contaminants. Thirty-third report of the Joint FAO/WHO Expert Committee on Food Additives. World Health Organization,Technical Report Series 776.
[35] Kabata-Pendias, A. (2004). Soil-plant transfer of trace elements-an environmental issue. Geoderma 122: 143-149.
[36] Kumar R, Srivastava P. K, Srivastava S. P. Leaching of heavy metals (Cr, Fe and Ni) from stainless steel utensils I food stimulants and food materials, Bull Environment Contam. Toxicol. 1994 53 (2): 259 – 266.
[37] Martyn, C.N., Osmond, C., Edwardson, J.A., Barker, D.J.P., Harris, E.C. and Lacey, R.F.1989. Geographical relation between Alzheimer's Disease and aluminium in drinking water. Lancet i, 59-62.
[38] Marzec, Z., A. Marzec, et al. (2006). "Study of Metal Release from Cookware." Polish Journal of Environmental Studies 15(2A): 139-142.
[39] NiDI (1994). Status report. Nickel Development Institute. SR-0003.
[40] Nnorom, I. C. (2007). Trace of heavy metal level of some bouillon cubes and food condiments readily consumed in Nigeria. Pak. J. Nutr., 6(2).
[41] Nordic Council of Ministers (1995). Risk evaluation of essential trace elements – essential versus toxic levels of intake. Report of a Nordic project group. Ed.: Oskarsson, A. Nordic Council of Ministers, Copenhagen, Denmark.
[42] O'flaherty, E. J. (1993). A physiologically based model for the ingestion of chromium (iii) and chromium (iv) by humans. Toxicol. Appl. Pharmacol. 118: 16-29.
[43] Onianwa, P., Adetola, I., Iwegbue, C., Ojo, M., Tella, O., (1999). Trace heavy metals composition of some Nigerian beverages and food drinks. Food Chemistry 66: 275-279.
[44] Pennington, J. A., Jones, J. W., (1989). Dietary intake of aluminium. Aluminium and Health- A Critical Review. Gitelman, pp. 67-70.
[45] Raphael, E.C.; Eunice, O. E. and Frank, E. O. (2010). Trace metals distribution in some common tuber crops and leafy vegetables grown in the Niger Delta Region of Nigeria. Pakistan Journal of Nutrition, 9(10): 957-961
[46] SCF (1993). Reports of the Scientific Committe for food. Thirty-first series. Nutrient and energy intakes for the European Community.
[47] Sobukola, O. P., Adeniran, O. M., Odedaira, A. A., Kajihausa, O. E. (2009). Heavy metal levels of some fruits and leafy vegetables from selected markets in Lagos, Nigeria. African Journal of Food Science. 4(2):389-393.
[48] Veien, N. K., 1989. Nickel dermatitis: Its relationship to food and experimental oral challenge. In: Maibach, H. I., Menne, T. Nickel and the skin: Immunology and toxicology, PP 165-178. CRC Press, Inc. Boca Raton, Florida.
[49] Veien, N.K. and Menné, T. 1990. Nickel contact allergy and a nickel-restricted diet. Seminars in Dermatology, 9(39):197-205.
[50] Zhuang, P., H. Zou and W. Shu 2009. Biotransfer o heavymetas alog a soil-plant-insect- chicken food chain: Field Study. J. Environ. Sci. (china), 21(6): 849-853.