Erzincan Üniversitesi
Fen Bilimleri Enstitüsü Dergisi
2016, 9 Özel Sayı I, 86-94
Araştırma Makalesi

Erzincan University
Journal of Science and Technology
2016, 9 Special Issue I, 86-94
Research Article

Element Content Analysis of Edible Insect of Ghana (Curculionidae: *Sitophilus zeamais*) Using EDXRF Spectrometer

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(Geliş Tarihi/Received: 20.12.2015, Kabul Tarihi/Accepted: 11.03.2016)

ABSTRACT

The overall study objective was to develop baseline information on the heavy elements concentration in edible insect *Sitophilus zeamais* (Coleoptera: Curculionidae) and to evaluate the contamination levels of this insect. Twelve heavy elements (V, Mn, Fe, Cu, Zn, Br, Sn, Sb, I, La, Ce, Pb) were analyzed by using an Energy Dispersive X-ray Fluorescence (EDXRF). The element concentration showed trend of Cu>Zn>Sn>Sb>Mn>Fe>I=La>Ce>Br>V>Pb. Cu and Zn were maximally accumulated metals in *Sitophilus zeamais*, whereas Pb had the lowest level.

Keywords: Curculionidae, Edible insect, EDXRF, Ghana, Heavy element.

Ghana'nın Yenilebilir Böceğinde (Curculionidae: *Sitophilus zeamais*) EDXRF Spektrometresi Kullanarak Element İçeriği Analizi

ÖZET

Bütün bu çalışma, yenilebilir böcek *Sitophilus zeamais* (Coleoptera: Curculionidae) türündeki ağır element konsantrasyonuna temel bir bilgi sağlamayı ve bu böceğin kontaminasyon seviyesini belirlemeyi amaçladı. Enerji Dağılımlı X Işını Flouresans (EDXRF) spektrometresinde on iki ağır element analiz edildi. Element konsantrasyonu sıralaması Cu>Zn>Sn>Sb>Mn>Fe>I=La>Ce>Br>V>Pb şeklindedir. *Sitophilus zeamais* türünde Cu and Zn en çok biriken, Pb ise en az biriken metal oldu.

Anahtar kelimeler: Curculionidae, Yenilebilir Böcek, EDXRF, Ghana, Ağır element.

1. Introduction

There are numerous publications and reports on metal pollution in marine, freshwater and terrestrial ecosystems in the last decades. Many elements are essential to living organisms but some of them are highly toxic or become toxic at high concentrations. In these days living organisms expose environmentally to high element concentrations. Because of their oxidative and carcinogenetic potential, element pollution is considered hazardous to biological systems (Chang et al., 1996; Bal and Kasprzak, 2002).

Insects are eaten in many parts of the world and have played an important part in the history of human nutrition in Africa, Colombia, Venezuela, Asia and Latin America (Chavunduka, 1975; Adeduntan and Bada, 2004; Alamu et al., 2013). About 2000 insect species are eaten worldwide, mostly in tropical countries. Up till now, most of this

ISSN: 1307-9085
e-ISSN: 2149-4584
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DOI: 10.18185/eufbed.77067

food has been collected from nature (Huis, 2014). As a food source, insects are highly nutritious. Many insect species contain as much or more protein as meat or fish (Durst and Shono, 2010). In general, insects tend to be a rich source of essential proteins and fatty acids, as well as dietary minerals and vitamins. Accordingly, today, insects play important roles in traditional diets (Bukkens, 2005; Ramos-Elorduy, 2005). Local people, who consume edible insects, choose to eat insects not only they are nutritious or taste good but also they are cheap compared to meat.

In Tamale, *Sitophilus zeamais* is popularly known as Salga by local people. This insect is an important part of human nutrition in Ghana, it serves as a source of dietary carbohydrate for humans (Ojo and Ogunleye, 2013) and most of this insect is collected from nature. But in contrast to its taste, *Sitophilus zeamais* is one of the world's most serious stored maize pest, that also attacks all other cereal grains and cereal products. It is an insect pest of economical importance, because it infests stored grains and damages crops of apples, grapes, and peaches (Conti et al., 2010; Sousa and Conte, 2013). *S. zeamais* is the most widespread and destructive primary insect pest of stored cereals. Infestations not only cause significant losses due to the consumption of grains; it also results in elevated temperature and moisture conditions that lead to an accelerated growth of molds, including toxigenic species (Liu et al., 2011). For this reason, the maize weevil, *Sitophilus zeamais* is a major stored grain pest currently controlled by chemical pesticides (Conti et al., 2010; Liu et al., 2011; Sousa and Conte, 2013).

Generally, many researchers studied the potential of insects as food, and made numerous investigations on the micronutrient, amino acid and fatty acid content and nutritional value of insects (Mbata, 1995; Defoliart, 1999; Bukkens, 2005; Banjo et al., 2006; Jongjaithet et al., 2008; Bukkens, 2010; Belluco et al., 2013). But heavy element availability in edible insects needs further investigation. Chemical hazards in insects depend, in most cases, on habitat and plant feed contamination and can be controlled by selected farming and dietary conditions. In this study we want to determine heavy element content of edible insect *Sitophilus zeamais* Motschulsky 1855.

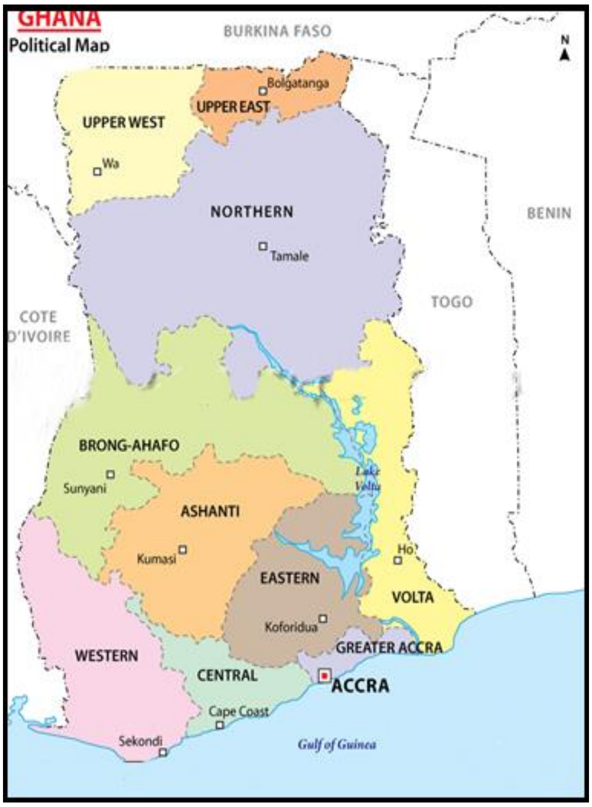

Figure 1. Location of the sampling site.

2. Materials and Methods

The Northern Region is the largest area of Ghana. As of 2009, it is divided into 20 districts. The region's capital is Tamale. Beetle samples were colleted from Northern Ghana (Tamale), savana zone of Ghana. Figure 1 shows the location of Tamale. Here is a place of intense agriculture, but there is no industry. These group insects are known as "Salga" traditionally. The photo of edible insect *Sitophilus zeamais* is shown Figure 3.

Firstly, the sample *S. zeamais* was dried at 80˚C for 36 hours. Secondly, insects were pulverised and then cellulose was added as a binder. Five tons of pressure applied to make 13 mm diameter pellets of the specie. An EDXRF spectrometer with 1 Ci 241Am radioactive source and an HPGe detector with resolution ~180 eV at 5.9 keV was used to determine the heavy elements in *S. zeamais*. Sample was excited by using 59.5 keV photons, emitted from 241Am radioactive source. Measurements of heavy element content were carried out under vacuum. Measurement time for this insect was twenty-four hours.

The concentration of elements in sample was determined by WinAXIL software, which uses Fundamental Parameters Method (FPM) for quantitative analysis. The analysis of X-ray spectra is the most critical step in X-ray analysis due to the complexity of it; e.g. overlap of different elemental lines, presence of escape and sum peaks, different and complex type of continuum, etc. WinAXIL software has a database in which there are necessary data to correct the complexity of the spectra. The spectrum evaluation is based on building a mathematical model with which analyst trying to describe the experimental data. This is done by specifying the region of the spectrum to be fitted, the selection of a suitable continuum compensation method, the selection of X-ray lines to be included in the model and by establishing approximately correct values for energy and resolution parameters of the spectrometer. The model parameters are then optimized by means of a non-linear least squares strategy, using a modified Marquardt algorithm to minimize the weighted (optional choice) sum of differences $\chi 2$ between the experimental data and the mathematical model. Elemental concentration of the insect sample was given in Table 2. The concentration presented in this Table has some uncertainties (maximum ~5%). Possible error sources for these uncertainties are listed in Table 1. A typical EDXF spectrum is shown Figure 2.

Table 1. The error sources in the experimental results.

Nature of Uncertainty	Uncertainty (%)
Counting Statistics	~1.00
Systematic errors	~2.00
Peak evaluation procedure	~3.00
Fundamental parameter methods	~3.00

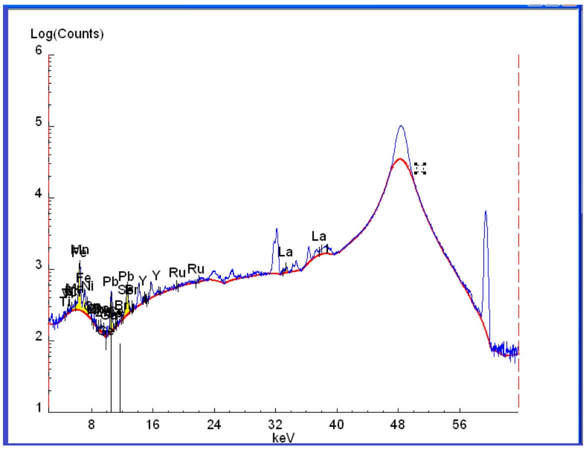

Figure 2. The typical spectrum of samples in EDXRF.

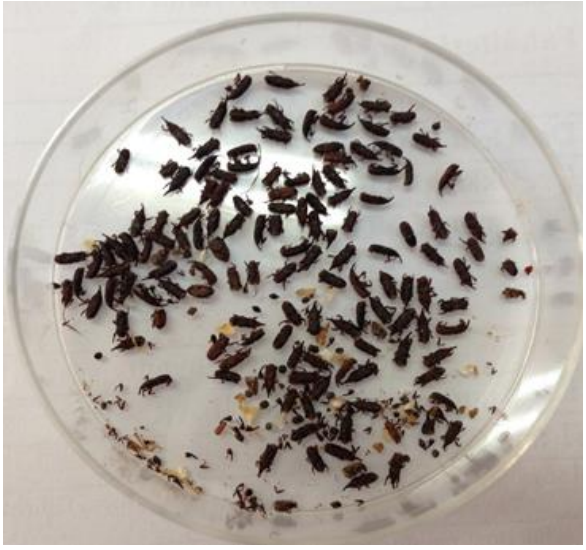

Figure 3. Photo of edible insect *Sitophilus zeamais*.

3. Results and Discussions

In these days, contamination of food products by heavy metals is becoming an unavoidable problem. In the present study, the concentration of heavy elements (V, Mn, Fe, Cu, Zn, Br, Sn, Sb, I, La, Ce, Pb) were measured in edible insect (*Sitophilus zeamais*) which were collected from Tamale (Northern Region), savanna zone of Ghana. These twelve heavy elements in edible insect *Sitophilus zeamais* were determined by EDXRF. Table 2 shows elemental concentration of the edible insect *Sitophilus zeamais*. As it seen Table 2, the analysis of heavy elements in this insect indicated that among the twelve heavy elements tested, Cu (589 ppm) had the highest concentration, followed by Zn (400 ppm), whereas Pb (0.0129 ppm) had the lowest concentration. The metal concentration showed a general trend of Cu>Zn>Sn>Sb>Mn>Fe>I=La>Ce>Br>V>Pb.

Table 2. Result of heavy elements analysis from edible insect *S. zeamais* in Ghana (ppm)

Heavy Elements	***Sitophilus zeamais***
V	0.0439
Mn	2.8
Fe	2.4
Cu	589
Zn	400
Br	0.24
Sn	61
Sb	5
I	2
La	2
Ce	1
Pb	0.0129

It is evident that both the essential and non-essential metals are toxic to living organisms when subject to high concentrations. Further work is required to determine the accumulation levels of these twelve elements in this insects and also its environment. The potential of insects to bioaccumulation chemical substances must be well investigate because of when use insects as food or feed, this may pose a risk for people eating *Sitophilus zeamais*. The measured elements and their daily intakes or risk are given in below:

Vanadium (V): Seafood generally contains higher concentrations of vanadium than meat from land animals. Daily intakes of vanadium from food have been reported ranging from 0.01 to 0.02 mg. Approximately 0.0004 mg of vanadium is released in the smoke of one cigarette. You cannot avoid exposure to vanadium. Elemental vanadium does not occur in nature; however, vanadium compounds exist in 65 different mineral ores and in association with fossil fuels (ATSDR, 2012). Measured level of edible insect *Sitophilus zeamais* is 0.0439 ppm. This concentration nearly similar to daily intakes of V from food.

Manganese (Mn): The major anthropogenic sources of Mn are: municipal wastewaters, sewage sludge, and metal smelting processes. Mn uptake is metabolically controlled. However, passive absorption of Mn is also occur, especially in the high and toxic range of its concentrations in the soil solution (Kabata-Pendias, 2011). According to institute of medicine, adequate Mn intakes for adults are 2.3 mg/day males and 1.8 mg/day females (IOM, 2001). According to these values, in this study, the Mn concentration is within the normal limits (2.8 ppm).

Iron (Fe): Iron is an essential element for living plant and animal metabolism. But the excess amount of iron is toxic for both the plants and animals (Kabata-Pendias, 2011). Many edible insects are an excellent source of iron. Most of them boast equal or higher iron contents than beef. For comparison, beef has an iron content of about 6 mg/100 g dry weight (2.1 mg/100 g fresh weight), while the iron content of most food insects lies well above this value (Bukkens, 2005). In our study the measured concentration of iron in edible insect *Sitophilus zeamais* is 2.4 ppm.

Copper (Cu): Cu concentration in surface soils reflects its bioaccumulation as well as its anthropogenic sources. Copper is an essential nutrient that is incorporated into a number of metalloenzymes involved in hemoglobin formation, drug/xenobiotic metabolism, carbohydrate metabolism, catecholamine biosynthesis, the cross-linking of collagen, elastin and hair keratin, and the antioxidant defense mechanism. Due to its bacteriostatic properties, it is added to animal fodder (Kabata-Pendias, 2011). It is also an essential nutrient but at higher level may cause human disease. The estimated daily intake of copper is 900μg/d for adults (IOM, 2001). In our study, measured concentration in edible insect *Sitophilus zeamais* is 589 ppm.

Zinc (Zn): Zinc is extraordinarily useful in biological systems. Numerous proteins, enzymes and transcription factors depend on zinc for their function. Therefore, certain levels of zinc intake are recommended. Millions of people are currently being exposed to various levels of zinc such as food supplements and additives, medicines, disinfectants, antiseptic and deodorant preparations and in dental cement. WHO and the US environmental protection agency has set a reference dose of 0.3 mg/kg^{-day} for zinc. This reference dose corresponds to 21 mg zinc for 70 kg male and 18 mg for a 60 kg female. Also, the US food and nutrition board has set the tolerable upper intake level at 40 mg/day for adults older than 19 years (Nriagu, 2007). According to these values, the Zn concentration in this study were higher than normal limits (400 ppm).

Bromine (Br): Anion form of bromine is known as bromide (Br^-). The limit for Bromide concentration for drinking water is specified as 0.5 mg/L (WHO, 2004a). Bromide ion has a low degree of toxicity; thus, bromide is not of toxicological concern in nutrition. Limited findings suggest that bromide may be nutritionally beneficial; for example, insomnia exhibited by some hemodialysis patients has been associated with bromide deficiency. Doses of bromide giving plasma levels of 12 mmol/l (96 mg/l plasma) produce bromism (the chronic state of bromide intoxication), and plasma levels greater than 40 mmol/l (320 mg/l plasma) are sometimes fatal (Chennaiah et al., 2013). In this study, Br concentration within the normal limits (0.24 ppm).

Tin (Sn): Sn is a common component of ship paints, which is of an environmental concern. Also, its elevated emission to the atmosphere, mainly from coal combustion, refuse incineration, and Cu/Ni production facilities may be of a local serious problem (Kabata-Pendias, 2011). Tins as single atoms or molecules are not very toxic to any kind of organism and the toxic form is the organic form. Organic tin compounds are from human-made sources and do not occur naturally in the environment (Eisler, 1989). Food, particularly canned food, represents the major route of human exposure to tin. Low tin levels have been found in flour (10 ng/g), dried milk (50 ng/g), spinach (20 ng/g) and fish (4–8 µg/g); higher levels were reported in canned fruit (30–100 µg/g) and canned grapefruit juice (245–260 µg/g). Diets consisting of fresh vegetables, meat and cereals contributed less than 1 mg to the daily intake (WHO, 2004b). Our finding (61 ppm) is nearly same to the canned fruits.

Antimony (Sb): Recently, Sb and its compounds are considered by the USEPA and the EU to be serious pollutants and its concentration in sewage sludge is recently of a concern (EPA, 2011). Especially Sb released from coal combustion is of environmental concern due to its high solubility and reactivity. Sb is considered a nonessential metal, it is relatively easily taken up by plants if present in soluble forms (Kabata-Pendias, 2011). Antimony does not bioaccumulate, so exposure to naturally occurring antimony through food is very low. The concentrations in drinking-water appear to be less than 5 µg/litre (WHO, 2003a). In our study Sb concentration in edible insect is 5 ppm.

Iodine (I): Iodine is applied in a number of chemicals and pharmaceuticals. The Iodine Deficiency Disorders (IDD) is a relatively common health problem, especially in Africa and Asia. In alkali soils of arid and semiarid regions, I is known to be greatly accumulated (e.g, in solonchak, up to 340 mg/kg) due to both salinity processes and a low degree of the I mobilization under alkaline pH conditions (Kabata-Pendias, 2011). Iodine is an essential element for the synthesis of thyroid hormones. Estimates of the dietary requirement for adult humans range from 80 to 150mg/day (WHO, 2003b). In this study level of iodine is 2 ppm.

Lanthanum (La): Lanthanum and lanthanum salts are not on the National Occupational Health and Safety Commission (NOHSC) List of Designated Hazardous Substances (NOHSC, 1999). The bioavailability of lanthanum is extremely low, ≤0.0007% in animals, with the majority of an oral dose being excreted in the faeces. In the human body, the absolute bioavailability of lanthanum (administered as lanthanum carbonate) was also extremely low (0.00127% ± 0.00080%), with individual values in the range of 0.00015% to 0.00224% (Afsar and Groves 2009). In this study level of iodine is 2 ppm.

Cerium (Ce): Of all Ce minerals, cerium dioxide has received much attention in the global nanotechnology market due to their useful applications for catalysts, fuel cells, and fuel additives. The impact of CeO_2 nanoparticles on ecosystem health (e.g, toxicological effects on aquatic-terrestrial organisms) has not been well understood (Dahle and Arai, 2015). In this study level of cerium is 1 ppm.

Lead (Pb): Lead is a major chemical pollutant of the environment, thus, its concentration in vegetation in several countries has increased in recent decades due to anthropogenic activities. The largest worldwide use of Pb is for lead-acid batteries. Nowadays, the use of Pb in petrol as an antiknock additive in developed countries has been phased out in order to reduce the atmospheric Pb pollution. When Pb is present in soluble forms in nutrient solutions, plant roots are able to take up great amounts of this metal, the rate increases with increasing its concentration in the solutions and with time. The biological half-life of lead is approximately 16–40 days in blood and about 17–27 years in bones (Kabata-Pendias, 2011). All forms of lead are toxic. There is no thresholds have been demonstrated because any exposure is potential concern. In this study, measured Pb level in edible insect *Sitophilus zeamais* is 0.0129 ppm.

4. References

Adeduntan, S. A. and Bada, F. A. "Socio-Economic Importance of Local Silkworm (Anaphe venata) to the Rural Dwellers in Ondo State, Nigeria". Book of Abstracts, 35th Annals of the Entomological Society of America, Pp: 7, 2004, Nigeria

Afsar, A. and Groves, S. 2009.Toxicity assessment of Phoslock® & Lanthanum to human health. Phoslock Water Solutions Report Number: TR 023/09, pp. 12.

Alamu, O. T., Amao, A. O., Nwokedi, C. I., Oke, O. A., Lawa, I. O. 2013. Diversity and nutritional status of edible insects in Nigeria: A review. International Journal of Biodiversity and Conservation, 5 (4), 215-222.

ATSDR, 2012. Toxicological profile for vanadium. Division of Toxicology and Human Health Sciences, pp: 200, Atlanta.

http://www.atsdr.cdc.gov/toxprofiles/tp58.pdf (Accessed 17.12.2015)

Bal, W., Kasprzak, K. S. 2002. Induction of oxidative DNA damage by carcinogenic metals, Toxicology, 127, 55-62.

Banjo, A. D., Lawal, O. A. and Songonuga, E. A. 2006. The nutritional value of fourteen species of edible insects in Southwestern Nigeria, African Journal of Biotechnology, 5 (3), 298-301.

Belluco, S., Losasso, C., Maggioletti, M., Alonzi, C. C., Paoletti, M. G., Ricci, A. 2013. Edible insects in a Food Safety and Nutritional Perspective: A Critical Review, Comprehensive Reviews in Food Science and Food Safety, 12, 296-313. doi:10.1111/1541-4337.12014

Bukkens, S. G. F. (2005). Insects in the human diet: nutritional aspects. In "Ecological implications of minilivestock; role of rodents, frogs, snails, and insects for sustainable development" (M. G. Paoletti, ed.). Science Publishers, 545–577, New Hampshire.

Bukkens, S. G. F. 2010. The nutritional value of edible insects, Ecology of Food and Nutrition, 36, 2-4, 287-319, DOI: 10.1080/03670244.1997.9991521.

Chang, L., Magos, L., Suzuki, T. 1996. Toxicology of Metals, CRC Press, Boca Raton, FL.

Chavunduka, D. M. 1975. Insects as a Source of Protein to the Africa. The Rhodesia science news, 9, 217-220.

Chennaiah, J. B., Rasheed, M. A., Lakshmi, M., Srinivasa Rao, P. L., Dayal, A. M., Patil, D. J. 2013. Assessment of ground water quality in Ghatkesar and Bibinagar areas of Andhra Pradesh, India. Int. J. of Plant, Animal and Environmental Sciences, 3 (4), 123-130.

Conti, B., Canale, A., Cioni, P., Flamini, G. 2010. Repellence of essential oils from tropical and Mediterranean Lamiaceae againist Sitophilus zeamais, Bulletin of Insectology, 63 (2), 197-202.

Dahle, J. T., Arai, Y. 2015. Environmental geochemistry of Cerium: Applications and toxicology of Cerium oxide nanoparticles, International Journal of Environmental Research Public Health, 12, 1253-1278.

Defoliart, G. R. 1999. Insects as food: why the Western attitude is important, Annual Review of Entomology, 44, 21-50.

Durst, P. B. and Shono, K. 2010. Edible forest insects: exploring new horizons and traditional practices, FAO of the United Nations Regional Office for Asia and the Pacific, pp 1-4, Bangkok, Thailand.

Eisler, R. 1989. Tin hazards to fish, wildlife, and invertebrates: A synoptic review, Biological report 85 (1.15), Contaminant hazard reviews, report no: 15.

EPA, 2011. Strontium. http://www.epa.gov/rpdweb00/radionuclides/strontium.html.

Huis, A. V. 2014. The global impact of insects. Researchgate. http://www.researchgate.net/publication/271270540 (Accessed 17.12.2015).

IOM, 2001. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.

Jongjaithet, N., Wacharangkoon, P., Paomueng-Prapasiri, P. 2008. Protein quality and fat content in common edible insects. Division of Nutrition, Ministry of Public Health http://nutrition.anamai.moph.go.th/temp/main/view.php?group=3&id=120 (accessed 5.12.2008).

Kabata-Pendias, A. 2011. Trace elements in soils and plants. CRC press, 4th Eds, pp. 534, USA.

Liu, Z. L., Chu, S. S., Jiang, G. H. 2011. Insecticidal activity and composition of essential oil of Ostericum sieboldin (Apiaceae) againist Sitophilus zeamais and Tribolium castaneum, Records of Natural Products 5 (2), 74-81.

Mbata, K. J. 1995. Traditional uses of arthropods in Zambia: I. the food insects, The Food Insects Newsletter, 8 (3), 5-7.

Nriagu, J. 2007. Zinc toxicity in humans. Encyclopedia of environmental health, Elseiver, Ann Arbor, MI, 2010.

NOHSC. 1999. List of Designated Hazardous Substances, Australian Government Publishing Service, Canberra, Australia.

Ojo, D. O. and Ogunleye, R. F. 2013. Comperative effectiveness of the powders of some underutilized botanicals for the control of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae), International Journal of Pure and Applied Sciences and Technology, 16 (2), 55-62.

Ramos-Elorduy, J. 2005. Insects: a hopeful resource, “Ecological implications of minilivestock” (M. G. Paoletti, ed), pp. 263-291. Science Pub, Enfield, N. H., USA.

Sousa, G., Conte, H. 2013. Midgut morphophysiology in Sitophilus zeamais Motschulsky, 1855 (Coleoptera: Curculionidae), Elsevier, Micron, 51, 1-8.

WHO, 2003a. Antimony in Drinking-water, Background document for development of WHO Guidelines for Drinking-water Quality. pp. 22.

WHO, 2003b. Hydrogen sulfide in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality. Geneva, World Health Organization (WHO/SDE/WSH/03.04/7).

WHO, 2004a. Guidelines for Drinking Water Quality. 1.

WHO, 2004b. Inorganic Tin in Drinking-water Background document for development of WHO Guidelines for Drinking-water Quality. pp. 14.