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Fish a Delicacy from Lake VictoriaSafe or Contaminated: Quantification of Heavy Metals in *OreochromisAureus* from Kasenyi, a Lake Victoria Landsite, in Uganda

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Abstract

This paper discusses the heavy metals in fish, *Oreochromisaureus* from Kasenyi landing site on Lake Victoria sampled between December 2015 and March 2016.The study aimed at investigating the constituent of chromium in relation to the other heavy metals in the *Oreochromisaureus* from Lake Victoria with the aim of ascertaining quality of fish from Lake. Fish is a chromium-rich delicacy. The results showed that the mean concentration of heavy metals were highest in the liver (0.793 μg/g for copper,0.347 μg/g for manganese,0.843 μg/g for zinc,0.167 μg/g for chromium and 0.023 μg/g for lead than the muscle that is (0.543 μg/g for copper,0.2 μg/g 7 for manganese,0.583 μg/g for zinc,0.1 μg/g for chromium and 0.038 μg/g for lead) from the ten fish samples collected in months of December 2015, January 2016 and February 2016. The undetectable concentration of cadmium in all the samples implied that the fish is good for consumption. This can also be supported by the low quantities of lead. Both cadmium and lead are not good to human health. The mean concentration of chromium of 0.617 μg/g in the whole fish was lowenough for use of the fishfor human food.

Keywords: Heavy metals; Pollutants;Exposure period; Gills; Liver; Muscle

Introduction

Macro- and micro-minerals are inorganic elements necessary in the diet for normal body functions the knowledge of role of trace elements in fish is mainly limited to iron, copper, manganese, zinc and selenium as components of body fluids, cofactors in enzymatic reactions, structural units of non-enzymatic macromolecules and fish takes up minerals via diet and water [1].

Fish may derive these minerals from the diet and also from ambient water. Characteristic concentrations and functional forms of the minerals need to be maintained within narrow ranges for ordinary metabolic activities in cells and tissues. Fish have been considered good indicators for heavy metal contamination in aquatic systems because they occupy different trophic levels with different sizes and ages.Fish are widely consumed in many parts of the world by humans, and polluted fish may endanger human health [2]. The minerals are responsible for skeletal formation, maintenance of colloidal systems, regulation of acid-base equilibrium and for biologically important compounds such as hormones and enzymes. Mineral deficiencies can cause biochemical, structural and functional pathologies which depend on several factors, including the duration and degree of mineral deprivation.

The diverse functions of wetlands are being adversely affected by human activities. Aquatic ecosystems are highly polluted with heavy metals arising from anthropogenic and terrigenous sources and water and sediments from Nakivubo Channel a stream in Kampala, Uganda when analyzed showed that it had been polluted with lead, cadmium, zinc, manganese and iron [3, 4]. However, fish is known to bioaccumulate Hg through methylation, may cause increase in the Hg in the food chain. Industries which release effluents with high heavy metal contents should treat them before discharge [5].

The concentrations of heavy metals like zinc, chromium, cadmium, lead, and iron were determined in many fish species, lake or ocean sediments and different waters over many years. The results of the several experiments and analyses have shown relation between the mineral compositions of the environment and fish tissue mineral compositions in different waters of the world[6]. Heavy metals like Pb, Cd and Cr era the commonest toxicants found in marine environment including fish [7] consumed by humans.

In Iran, three species of most-consumed fishes, water and sediments when analyzed showed that the highest concentration of heavy metals in water and fish and sediment samples were related to Pb and Zn. The minimal and maximal concentrations of these metals in fishes, water and sediments were below recommended limits [6]. However, the results showed elevating levels of Zn, Pb, Cd and Cr in fish, water and sediments sampled form Southern Caspian Sea, Iran.

In the evaluation of the chromium contamination from tannery discharges into rivers in the State of Minas Gerais, Brazil, samples of fluvial sediment, vegetation and fish were collected and analyzed.It was found that chromium levels in fish exceeded 35 times the Brazilian recommendation value for human intake [8].

Consumption of vegetables and fish contaminated with the heavy metals Cu, Zn, Pb, Cd, Hg, and Cr is the most likely route for human exposure to heavy metals in Tianjin, China. Health risks associated with these heavy metals were assessed based on the target hazard quotients (THQs), which can be derived from concentrations of heavy metals in vegetables and fish consumed in four districts of China [9]. The risk contribution from Cr was minimal compared to the other elements. The health risk to adults in Ding Li is ascribed mainly to the intake of Cd by vegetables and fish consumption, which contributes a substantial fraction to the total THQ (about 51%) [9].

In polluted aquatic ecosystems the transfer of metals through food chains can be high enough to bring about harmful concentrations in the tissues of fish may lead to reduction of species diversity. When susceptible species are eliminated, metal-tolerant food organisms may become dominant[10].

Analysis of fish muscle for content of heavy metals like Zn, Pb, Bi, Cd, Ni, Co, Fe, Mn, Mg, Cu, Cr, Ca, Sr, Na, Li, K in five species *Cyprinuscarpio* (from Işıklı dam), *Scardiniuserythrophthalmus* (from Işıklı dam), *Tincatinca* (from Işıklı dam), *C. carpio* (from Karacaören dam), *Carassiuscarassius* (from Karacaören dam) caught from Işıklı and Karacaören [11] revealed the highest metal was Na (466.95 μg/g) in *C. carassius*, while the lowest levels were Fe (0.37 μg/g) and Cu (0.37 μg/g) in *C. carpio* from Işıklı dam[11].Fish tissue analyzed for heavy metalsrevealed that gills had the highest accumulation of copper after a period of six weeks as compared to other metals. In general, the order of accumulation of metals in tissue after six weeks in Nakivubo channel was in order; copper > zinc > chromium > manganese and gills > liver > muscle [12].

The presence of heavy metals in our environment has been of great concern because of their toxicity when their concentration is more than the permissible level. These metals enter in the environment by different ways like industrial activities. The fish samples Rahu (*Labeorohita*), Tilapia (*Tilapia zilli*) and Catfish (*Chrysichthysnigrodigatatus*) from Yamuna River in Delhi showed presence of several metals as Al, B, Ba, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Sb, Sn, Si, P and Zn[13].

The finding of heavy elements in river Muhazi showed that the concentrations of Cadmium, Iron and Lead far exceeded the recommended levels for aquatic life at all sampling points and this was attributed to the riparian landuse practices such as uncontrolled agriculture, urban runoff and mining activities [14]. Fish constitute a major source of heavy metals in food. Concentration of Cd, Pb, Hg, Cr, As, Zn, Cu, Co, Mn, Ni and Se in commercially important species of fish, shellfish and fish products from fish markets in and around the Cochin area was evaluated[15]. The plankton samples showed a metal concentration gradient consistent with a gradient from the source of pollution in northern Lake George, along the Kazinga Channel to Lake Edward as*Oreochromisleucostictus* and *Bagrusdocmac*had highest yet the lowest occurred in *Oreochromisniloticus*[16].

As lake ecosystems are vulnerable to heavy metal pollution, tissues of *Tilapianilotica* of different ages from Khor El-Ramel in Nasser Lake (Egypt) showed that of all the fish parts, fish liver accumulated the highest levels of Cu and Zn. Manganese presented in the intestine and stomach in the highest concentration. Scales exhibited the highest levels of Co, Cr, Ni and Sr, while the gill and vertebral column contained the lowest level of the studied elements[17].Nile tilapia (*Oreochromisniloticus*)gills, liver and muscle showed significantly higher concentrations of heavy metals in fish than in water in the Nakivubo channel [12] this showed the efficiency of Nakivubo channel in sieving out Zn, Cu, Cd and Pb has shrunk from 89.7–98.3% in December 2006 to 79.4–92.1% in December 2008,over a period of three consecutive years indicating the growing in effectiveness of the wetland to absorb heavy metals[3] a feature threatening quality of Ugandan fish and water quality. A person will acquire the same quantity and effect of the heavy metal by consuming fish [7].

The gills of *Tilapia zilli*contained the highest concentration of Pb, As, Cd and Cu, followed by the intestine while the muscle tissues appeared to be the least preferred site for the bio accumulation of metals [18]. Similarly, the gills of *Clariasgariepinus* contained the highest concentration. Silver fish (*Rastreneobolaargentea* from 10 landing sites on Lake Victoria, and from five control sites along Lake Kyoga contained significantly higher levels of Zn, Cu, Cd and Pb compared with those from the control sites [19].Different organs of the fishes *Labeorohita* and *Ctenopharyngodonidella* of Upper Lake of Bhopal accumulated varying quantities of different heavy metals. In *L. rohita*, accumulation of heavy metals was in the sequence liver > kidney > gills > muscles, and in *C. idella*, it was gills > liver > kidney > muscles [20].*Tilapia nilotica* grown in polluted water with some heavy metals showed highest concentrations in all examined metals were in visceral tissues followed by the head. The lowest value was found in fish flesh. The heavy metal content in all fish parts decreased on steaming and baking. The reduction in the metal content on baking was much greater than on steaming[21] indicating volatilization of heavy metals[22]. Fish constitute a major source of heavy metals in food [15] but Cr is micro-nutrient.

Water from Lake Qarun, and Sanhour River contained Zn, Fe, Mn, Cu, Cd, Cr, Pb and Cd at concentration levels lower than those found in fish from the Fayoum Governorate and the levels vaied with seasons. The relative accumulation of total heavy metals in the studied fish showed the following pattern: “Mousa fish” (*Soleaaegyptiaca*) < “Bolti fish” (*Tilapia* sp.) < the shrimp (*Penacus* sp.) < “Bouri fish” (*Mugil* sp.) for metals like zinc, iron, manganese, copper, cadmium, chromium, nickel, lead, cobalt, tin), lead and cadmium were found in fish at mean concentrations above the permissible limits proposed by FAO [23].

Under certain environmental conditions, Cr, Cd, As may be accumulated to a toxic concentration,and cause ecological damage. Heavy metals were of particular concern due to their toxicity and ability to be bioaccumulated in aquatic ecosystemsas well as persistence in the natural environment. Among the different metals analyzed, Cr, Cd, As are classified as chemical hazards and maximum residual levels have been prescribed for humans(FAO,1983; EC,2001).Heavy metals pollution in aquatic environmental has become a serious problemand also an important factor in the decline of water sediments and fish quality.

Chromium (III) is an essential nutrient for humans and shortages may cause heart conditions, disruptions of metabolisms and diabetes. But the uptake of too much chromium (III) can cause health effects as well, for instance skin rashes. The functions of chromium in our bodies include; the glucose tolerance factor which stimulates insulin activity, controls the uptake of glucose by the muscles and organs, stimulates glucose metabolism, controls blood cholesterol levels, controls fat levels in the blood, reduces atherosclerosis, stimulates the synthesis of proteins increases resistance to infection and suppresses hunger pains [24].

The trivalent chromium is an essential in the human body where it helps in the treatment of certain diseases like diabetes as chromium is used by our bodies to process sugar and its shortages may cause heart conditions.The hexavalent chromium is found to be one of the major components of the slimming products for those people whose aimis to lose weight. The chromium (III), found in most foods and nutrient supplements for example fruits, meat, grains and yeast, foods including egg yolks, whole-grain products, high-bran breakfast cereals, coffee, nuts, green beans, broccoli, meat, brewer’s yeast, and some brands of wine and beer, is an essential nutrient with very low toxicity [25]. Fish too contains chromium and other heavy metals.

Study Objective

In this study, 10 selected samples of fish, *Oreochromisaureus*were collected in months of December2010, January 2011 and February 2011from Kasenyi landing site on Lake Victoria were used to assess environmental variance and quality of fish. The aim of the study was to determine the levels of heavy metals (Cr,Zn,Cu,Cd,Mn,Pb) in the muscle and gills and liver in order to assess fish quality.

Methodology

Study Area and Sampling

Kasenyi landing site spans about0.4 km along the shores of Lake Victoria. See figure 1 for the landing site. The fish caught from far and near is brought and offloaded at the site. The periods of sample collection was December 2009, January 2010 and February 2010. The collection of fish was by buying 10 fish from the landing boat. The elected fish were collected in sterile polyethylene bags and kept in the laboratory deep freezer at -20°C to prevent deterioration before analysis.

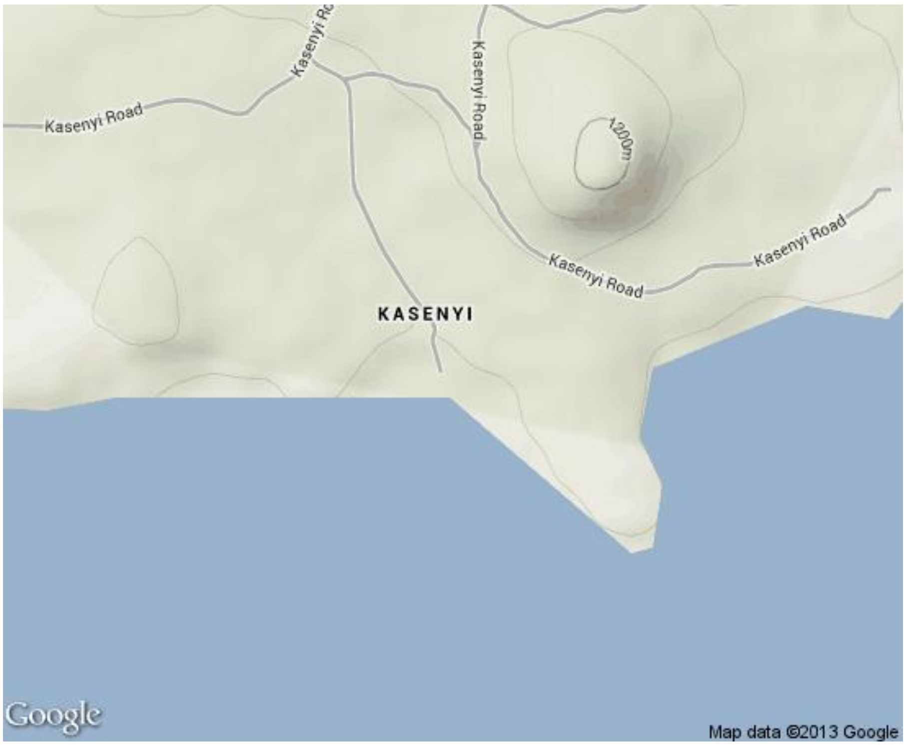

Figure 1: Map of Kasenyi on Lake Victoria

Sample Preparation

Each selected fish sample was washed thoroughly, drained and separated into desired parts: gills, liver and muscle.

Digestion in Acid

5g of each separated fish samples (gills, liver muscle) was separately digested in 10mL of concentrated nitric acid in open glass flask for 24 hours at room temperature. On the following day, the digested samples were heated at 80°C for 5 hours. The solutions made were cooled to room temperature and volume of solution made up to 50mL with distilled water. The solutions were stored in polyethylene bottles. The solutions were analyzed using flame atomic absorption spectroscopy.

Sample Analysis

The heavy metal content of fish samples collected from Kasenyi landing site of Lake Victoria, Uganda were analyzed using flame atomic absorption spectrophotometer (ShmadzuAA-6300). Standard solutions of lead, cadmium, manganese and chromium were prepared in varying concentrations of 0.2, 0.5, 1.0 and 2.5ppm and used to calibrate the spectrophotometer prior to analysis using distilled water as control. All chemicals and reagents used in this study were procured from the British Drug House (BDH) and were of AnalaR grade

Results and Discussion

Samples of gills, muscle and liver of fish digested in nitric acid were subjected to determination of Cr, Cd, Cu, Mn and Zn using flame atomic absorption spectroscopy, yet was determined using and the results tabulated as shown in Tables 1, 2 and 3 below.

Table 1: The mean (±SD) concentrations (µg/g) of heavy metals in gills

Metal	Dec 2009	Jan 2010	Feb 2010
Pb/µg/g	0.057±0.040	0.045±0.030	0.054±0.037
Cd µg/g	ND	ND	ND
Cr µg/g	0.35±0 071	0.31±0 060	0.25±0 065
Cu µg/g	0.42±0.041	0.350±0.031	0.380±0.040
Mn µg/g	0.267±0.070	0.23±0.060	0.24±0.065
Zn µg/g	0.503±0.015	0.50±0.010	0.49±0.017

Table 2: The mean (±SD) concentrations (µg/g) of heavy metals in muscle

Metal	Dec 2009	Jan 2010	Feb 2010
Pb/µg/g	0.038±0.030	0.03±0.028	0.029±0.031
Cd/µg/g	ND	ND	ND
Cu/µg/g	0.543±0.015	0.48±0.013	0.49±0.017
Cr/µg/g	0.1±0.010	0.09±0.011	0.1±0.012
Mn/µg/g	0.27±0.044	0.30±0.042	0.26±0.043
Zn/µg/g	0.583±0.050	0.57±0.052	0.55±0.048

Table 3: The mean (±SD) concentrations (µg/g) of heavy metals in liver

Metal	Dec 2009	Jan 2010	Feb 2010
Pb/µg/g	0.023±0.015	0.025±0.017	0.027±0.013
Cd/µg/g	ND	ND	ND
Cu/µg/g	0.793±0 .086	0.81±0 .082	0.79±0 .078
Cr/µg/g	0.167±0.021	0.17±0.020	0.16±0.023
Mn/µg/g	0.347±0.050	0.32±0.047	0.35±0.051
Zn/µg/g	0.843±0.051	0.86±0.053	0.85±0.049

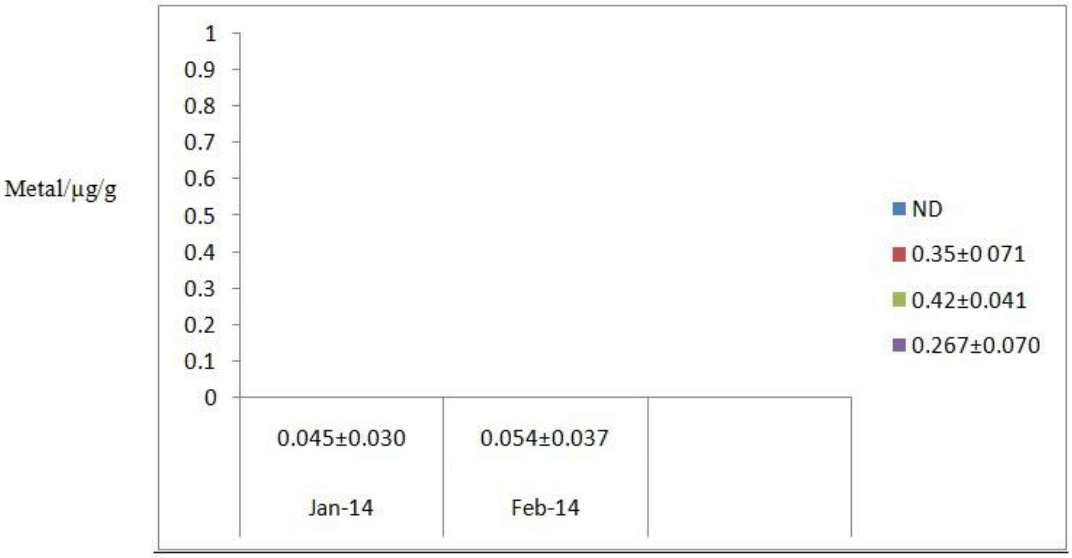

Figure 2: Representation heavy metals in gills

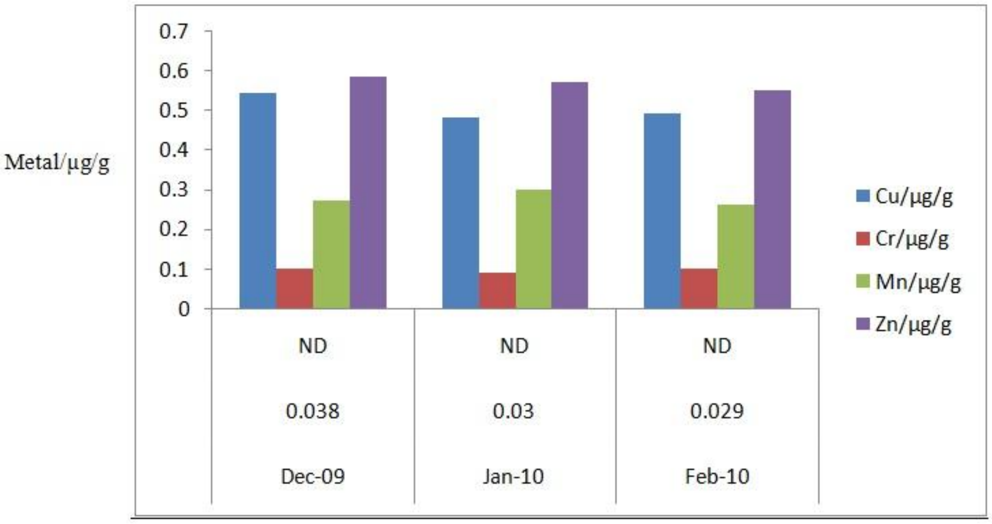

Figure 3: Representation of heavy metals in muscle

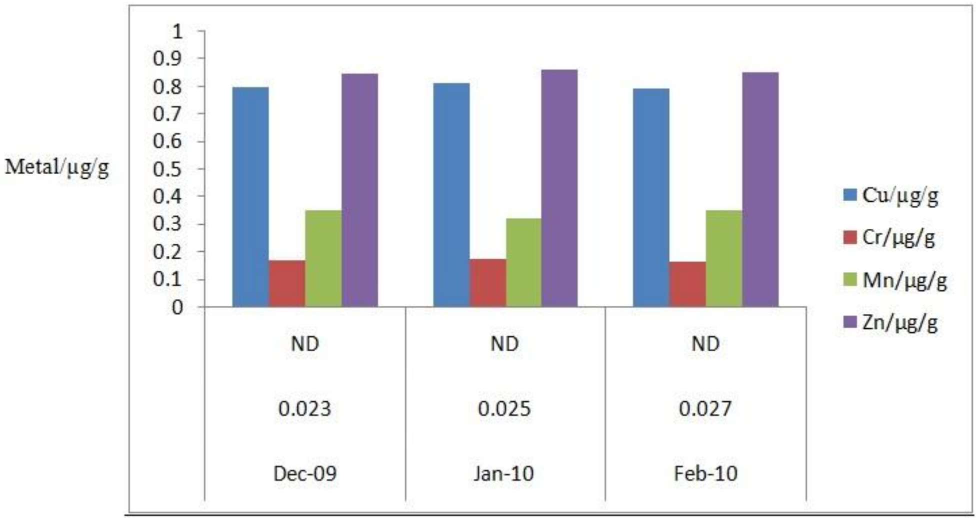

Figure 4: Representation of heavy metals in liver

The mean concentrations of copper were found to be 0.793 μg/g, 0.543 μg/g and 0.42 μg/g in liver, muscle and gills respectively. Copper concentrations ranged from 0.38 μg/g to 0.46 μg/g in gills, 0.53 μg/g to 0.56 μg/g in muscle and from 0.7 μg/g to 0.81 μg/g in liver. The highest concentrations of copper were found in the liver whereas the lowest concentration was found in the gills.

The mean levels of manganese in liver, muscle and gills were 0.347 μg/g, 0.27 μg/g and 0.267 μg/g respectively. The concentrations ranged from 0.3 μg/g to 0.4 μg/g in the liver, 0.24 μg/g to 0.32 μg/g in the muscle and 0.2 μg/g to 0.34 μg/g in the gills. The concentrations of manganese were maximum in the liver and minimum in the muscle.

The mean zinc concentrations were 0.843 μg/g, 0.583 μg/g, and 0.503 μg/g in the liver, muscle and gills respectively. Zinc values in *Oreochromisaureus* varied from 0.8 μg/g to 0.9 μg/g in the liver, 0.53 μg/g to 0.63 μg/g in the muscle and 0.49 μg/g to 0.52 μg/g in the gills. The maximum zinc level was in the liver while the minimum value of zinc was found in the gills just like the varying concentration of copper.

The concentrations of chromium in the liver, muscle and gills were different with a mean concentration of 0.167 μg/g, 0.1 μg/g and 0.35 μg/g respectively. Chromium was detected in all the samples and the concentrations were found to be 0.15 μg/g -0.19 μg/g in the liver, 0.09 μg/g -0.11 μg/g in the muscle and 0.3 μg/g -0.4 μg/g in the gill. The highest concentration was detected in the gills well as the lowest concentration was detected in the muscle.

On average, the content of lead in fish was lowest in muscle and highest in the gills. The mean values for Pb were 0.023 μg/g in the liver, 0.038 μg/g in the muscle and 0.057 μg/g in the gills. This revealed the highest concentration of lead was in the gills while the lowest concentration was in the liver.

Interestingly, cadmium was not detected in any of the samples prepared. Thisindicated that either the concentrations of cadmium were too low to be detected or the Lake Victoria fish are safely uncontaminated with cadmium.

The cadmium can be bioaccumulated from metallothioneins which is toxic to humans. Cadmium injures kidneys and cause symptoms of chronic toxicity, including impairment of kidney function, poor reproductive capacity, hypertension, tumours and hepatic dysfunction. Absence of this metal in fish indicates Ugandan fish is safe for human consumption. So chromium needed in human diets can be derived from fish safely.

Copper contents in all the examined fish samples was found to be much less than the FAO permitted level of 30 μg/g. Excessive intake of copper may lead to liver damage, dermatitis and neurological disorders. So fish from Lake Victoria can be used for food.

In general, lead values are low in all the fish samples examined in the laboratory. The Chinese food standards acceptable limit is 1 μg/g.The Turkish and EU acceptable limit is 0.4 μg/g.The range of international limits for Pb in fish is 0.5 μg/g to 10 μg/g. Lead and when causes renal failure and liver damage in humans exceeded.

The content of manganese is relatively high in the fish liver but does not exceed the recommended manganese intake limit which is 3mg per day. Manganese is good for our health especially for the functioning of the brain, production of urea and necessary for normal bone structure.

Zinc concentrations were found to be the highest results as compared to the quantity of other elements in the three parts of fish. Comparing our values with Chinese food standards (50 μg/g).Canadian food standards (100 μg/g) and a range of international limits lie in the range 40-100 μg/g), the results got in this research are less than the international limits showing the fish is safe for human consumption. Thus the zinc content poses no threat for fish consumption by man.

The chromium contents were within the limits prescribed by the FDA. As the concentration of chromium is fairly low, it can be asserted that fish can provide the chromium needed to helpin functions like the glucose tolerance factor, controlling the uptake of glucose by the muscles and organs, stimulating glucose metabolism, controlling blood cholesterol levels, controls fat levels in the blood, reduces atherosclerosis and stimulating the synthesis of proteins.

Heavy metals such as lead and cadmium are dangerous for human health because of their accumulation properties. Metals bioaccumulation through aquatic food webs to fish and humans. Although there are no high levels of heavy metals in fish, a potential danger may occur in the future, depending on agricultural and industrial development in this region. The concentrations are below the limit values for fish proposed by FAO.

The concentrations of heavy metals in the liver were relatively higher than those in the muscle and gills. This organ has a relatively higher potential for metal accumulation. Although fish liver is seldom consumed, it has been shown to have accumulated more heavy metals than any other part of fish used in this study and may represent good biomonitors of metals present in the surrounding environment.

Some metals are natural constituents of the environment for example Zn and Cu.Other metals such as cadmium and lead in contrast, have no biological role. At higher concentrations, heavy metals can become toxic for living organisms. In this study, the results obtained especially for chromium that the concentration of chromium is good the human health in a positive way. So fish can be used in place of chromium food supplements.

Conclusions

Fish from Lake Vitoria is safe for human consumption. The water in which the fish live is not highly polluted by toxic heavy metals. All concentrations of heavy metals investigated in this study were below the limits for fish proposed by Chinese standard for fish. The fish studied is fit for human consumption and the water in which the fish live is not highly polluted. The high levels of heavy metals in the liver indicate bioaccumulation.

Recommendations

Water and sediments in the Lake Victoria should be studied to identify the sources of the heavy metals in fish.

Rivers and swamps (wetlands) draining into Lake Victoria need to be strongly protected from encroachers so that they continue sieving the minerals from water before it enters the lake.

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