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Assessment of some heavy metals concentration in selected cereals collected from local markets of Ambo City, Ethiopia

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The concentrations of nine heavy metals (Fe, Zn, Cu, Mn, Ni, Co, Cr, Pb and Cd) in four varieties of cereals (wheat, barley, sorghum and maize) purchased from Ambo market, Ethiopia were determined using Atomic Absorption Spectrophotometers (AAS). Dry ashing method was used to destroy the organic matter to determine the content of nine heavy metals. The results showed that the concentrations of heavy metals in mg kg^{-1} dry weight were in the range of: Cu (0.13 - 1.72), Fe (0.40 - 36.45), Zn (0.66 - 8.54), Mn (0.42 - 7.67), Co (0.14 - 0.45), Ni (ND - 0.43), Cr (0.29 - 0.95) and Pb (non-detectable - 0.08), respectively. Cadmium was not detected in any of the cereal samples. In addition, the mean concentrations of heavy metals in cereals purchased from Ambo market decreases in the following order: Fe > Zn > Mn > Cu > Cr > Co > Ni > Pb > Cd. The trace metals Fe, Zn and Mn were higher than the entire heavy metals in the samples investigated while Cd and Pb were in minor quantities and hence the cereals were free from toxic heavy metals. The author concluded that the levels of heavy metals determined in the analyzed cereal samples were found below the permissible limits set by FAO/ WHO; hence they are safe for human consumption and can be considered as good sources of essential trace metals to the individuals.

Key words: Cereals, heavy metals, atomic absorption spectrophotometers (AAS).

INTRODUCTION

The cereals most commonly cultivated in Ethiopia are wheat, maize, barley, sorghum and rice. Cereals are the important crops that serve as stable food for most people in Ethiopia. Cereals are the main source of food in many countries. Generally speaking, cereals are necessary for a healthy diet and nowadays a daily consumption of between 4 and 6 portions of cereals derived products is recommended due to their content in fiber, trace minerals and vitamins, which are supposed to prevent various diseases. All cereal derived products are rich in carbohydrates, and therefore, the base of a well-balanced and healthy diet. This is the reason for the importance of this group of food (Doe et al., 2013).

The increasing demand for food safety stimulated

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research regarding the risk associated with consumption of foodstuffs contaminated by pesticides, heavy metals and/or toxins. Food safety issues and potential health risks make as one of the most serious environmental concerns (Gebregziabher and Tesfaye, 2014). Heavy metals are among the major contaminants of food supply and may be considered the major problem to our environment (Radwan and Salama, 2006). Heavy metals may enter the human body through inhalation of dust, consumption of contaminated drinking water and consumption of food plants grown in metal contaminated soil (Gebregziabher and Tesfaye, 2014).

Heavy metals are potential environmental contaminants with the capability of causing human health problems if present in excess in the food we eat. They are given special attention throughout the world due to their toxic effects even at very low concentration (Haware and Pramod, 2014). Heavy metals are persistent and non-biodegradable, have a long biological half-lives and they can be bioaccumulated through the biologic chains: soil-plant-food and seawater-marine organism-food leading to unwanted side effects. So, the presence in high amount of heavy metals in environment represents a potential danger for human health and for environment due to their extreme toxicity. Heavy metal contamination may be occurred due to irrigation with contaminated water, the addition of fertilizers and metal-based pesticides, industrial emissions, transportation, harvesting process, storage and/or sale. Crops and vegetables grown in soils contaminated with heavy metals have greater accumulation of heavy metals than those grown in uncontaminated soil (Bempah et al., 2011).

Toxic effects of heavy metals have been widely described by many workers. Elements such as Cd, Cr and As are considered carcinogenic, while Fe, Cu, Zn, Ni and Mn are considered as essential metals, however, if the concentrations of the later elements are higher than their permissible limits they may create toxic effects in human (Edem et al., 2009). Heavy metal accumulation may pose a direct threat to human health (Turkdogan et al., 2003). Lead toxicity in the body can cause musculoskeletal, renal, ocular, immunological, neurological, reproductive, and developmental effects. Excess Cd intake is known to result to bone fracture, cancer, diarrhea, stomach pains, severe vomiting, reproductive failure and damage of central nervous system (Oti, 2015). Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Radwan and Salama, 2006; Khan et al., 2008; Aklilu et al., 2013).

A complete profile of mineral and heavy metals must be available for the nutritionist and consumers. A lot of work has been done on metal determination in food stuffs. Data regarding the mineral contents is still lacking in developing countries like Ethiopia. Quality of cereals affects consumers. Excessive levels could imply a risk as cereals represent a high percentage of Ethiopians' diet. However, there are no published literature reports on the heavy metal content of the commonly consumed cereals from local markets in Ethiopia. Thus, the aim of this study was therefore to evaluate and compare the concentrations of heavy metals in the cereals available in local markets for the consumers in Ambo city, Ethiopia with the view of knowing the health effect associated with the consumption of these cereals.

MATERIALS AND METHODS

Reagents

All the reagents used were of analytical grade. Double distilled water was used for dilution and preparation of reagents and standards. All glassware and plastic containers used were washed with liquid soap, rinsed with water, soaked in 10 % nitric acid for 24 hrs, cleaned thoroughly with double distilled water and dried in such a manner to ensure that any contamination does not occur.

Study area

The study was conducted in the local market of Ambo city which is located 112 km south of Addis Ababa, the capital city of Ethiopia. It lies between latitude 8°59'N, longitude 37°51'E and an elevation of 2101 m above sea level (Figure 1). The selection of the study area was based on availability of the sample, proximity to the study area and sampling cost.

Sample collection

Samples of four different kinds of cereals (wheat, barley, sorghum and maize) were collected from the local markets of Ambo town. Sampling was done at random from different retailers and vendors within these market areas. All the samples were collected and stored in polythene bags according to their type and brought to Ambo University the laboratory for preparation and treatment.

Sample treatment

The samples were placed in clean acid-washed porcelain crucibles and oven-dried at 105°C for 24 h in drying oven. The dried samples were then grounded in to a fine powder form by using acid washed mortar and pestle, and passed through a 2.0 mm sieve. The powdered samples were kept in polythene packets for further analysis.

Sample digestion

5.0 g of grounded powder samples were weighted and transferred to a clean crucible, which is labeled according to the sample number and dry-ashing process was carried out in a muffle furnace by stepwise increase of the temperature up to 550°C and then left to ash at this temperature for 6 h. The sample were removed from the furnace and allowed to cool. The ash was wetted with water and 2.5 ml of concentrated HNO_3 was added. The crucible was covered with watch glass and placed on hot plate. The digestion performed at a temperature of 90 to 95°C for 1 h. The ash was dissolved in 5 ml of 9.25% HCl and digested again on hot plate until the white fumes ceased to exist and sample reached to 2 ml. After cooling 20 ml of distilled water was added and filtered using Whatman filter No.41. The filtered sample was then diluted up the mark of 50 ml

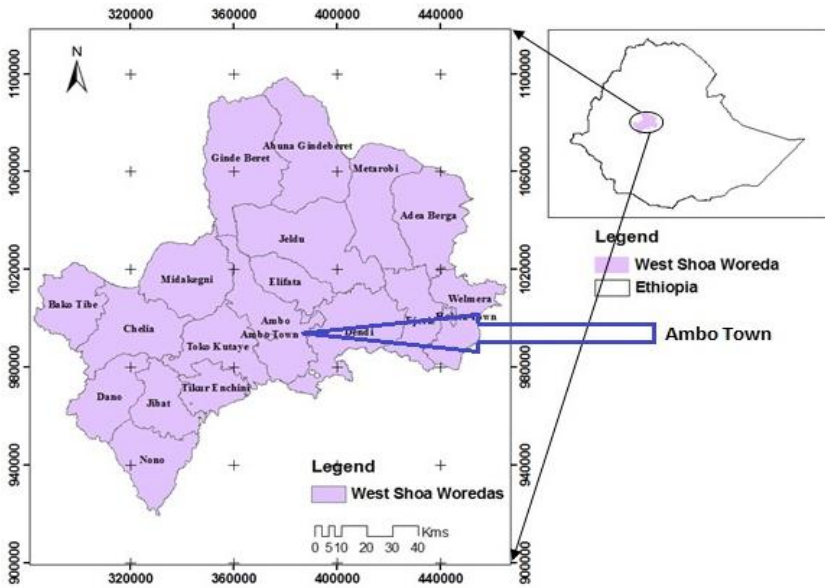

Figure 1. Location of the study area.

Table 1. Instrument operating conditions for the determination of heavy metals in cereal samples by AAS.

Element	Wavelength (nm)	Lamp current (mA)	Slit width (nm)	Flame type
Cu	324.7	5.8	1.00	Air-acetylene
Fe	248.3	6.4	0.75	Air-acetylene
Zn	213.9	5.0	1.00	Air-acetylene
Mn	279.8	6.0	0.50	Air-acetylene
Co	240.7	7.0	0.75	Air-acetylene
Ni	232.0	5.0	1.00	Air-acetylene
Cr	357.9	6.0	0.50	Air-acetylene
Pb	217.0	5.0	1.00	Air-acetylene
Cd	228.8	4.2	0.50	Air-acetylene

standard volumetric flask, and stored in polyethylene container until analysis. All samples were prepared identically in triplicates. Blanks were prepared to check for background contamination by the reagents used.

Preparation of standards and analysis of samples

Working standard solutions of copper (Cu), iron (Fe), zinc (Zn), manganese (Mn), cobalt (Co), nickel (Ni), chromium (Cr), lead (Pb) and cadmium (Cd) were prepared from the stock standard solutions containing 1000 ppm of element in 2N HNO_3. The instrument was calibrated with calibration blank and three series of calibration standard solutions, measurements of elements was done by using the atomic absorption spectrophotometer (AAS) (Model: ELICO SL-194). The atomic absorption spectrophotometer working conditions are given in Table 1.

Statistical analysis

All the samples analyses in this study were carried out in triplicate and the results were reported as mean ± standard deviation. Statistical analyses were carried out using SPSS software, version 16. ANOVA was used for comparing mean concentration of heavy metals between the cereals.

RESULTS AND DISCUSSION

The mean concentrations of heavy metals in the selected cereal samples collected from Ambo market are shown in Table 2. Results are expressed as mean ± SD of the three replicate analyses.

Copper

Copper is one of the essential micronutrients and its adequate supply for growing plants should be ensured through artificial or organic fertilizers (Itanna, 2002). Cu occurs in the compounds with no known functions as well as enzymes having vital function in plant metabolism

Table 2. Average concentration of heavy metals (Mean ± SD, n = 3, mg kg^{-1} dry weight) in cereal samples.

Metal	Cereal samples				FAO/WHO
	Wheat	Barley	Sorghum	Maize	Safe limit
Cu	1.72 ± 0.02	0.15 ± 0.02	1.29 ± 0.03	0.13 ± 0.02	73.3
Fe	10.64 ± 0.04	31.85 ± 0.04	36.45 ± 0.06	0.40 ± 0.06	425.5
Zn	8.54 ± 0.09	3.85 ± 0.04	5.40 ± 0.05	0.66 ± 0.03	99.4
Mn	7.67 ± 0.06	1.67 ± 0.02	2.34 ± 0.07	0.42 ± 0.03	500
Co	0.35 ± 0.05	0.14 ± 0.07	0.45 ± 0.03	0.24 ± 0.04	50
Ni	0.27 ± 0.02	ND	0.43 ± 0.05	0.07 ± 0.01	67
Cr	0.43 ± 0.02	0.29 ± 0.02	0.95 ± 0.02	0.52 ± 0.05	2.3
Pb	0.05 ± 0.03	0.03 ± 0.06	0.08 ± 0.05	ND	0.3
Cd	ND	ND	ND	ND	0.2

ND = Not detected.

(Kabata-Pendıas and Pendias, 2001). As can be seen from Table 2, the concentration of copper in wheat, barley, sorghum and maize ranged from 0.13 to 1.72 mg kg^{-1} in the cereals analyzed. The highest and the lowest concentration of Cu were accumulated by wheat (1.72 mg kg^{-1}) and maize (0.13 mg kg^{-1}) respectively. Considering the mean values, order of Cu concentration was wheat > sorghum > barley > maize. One-way ANOVA revealed that there was no significant difference ($p > 0.05$) between the values of Cu in the barely and maize samples but there was significance ($p < 0.05$) difference between the other cereals.

Iron

Iron (Fe) is an essential element in man and plays a vital role in the formation of haemoglobin, oxygen and electron transport in human body (Kalagbor and Diri, 2014). Iron (Fe) was found to have the highest concentration in all the samples analyzed (Table 2 and Figure 2). The maximum concentration of iron was found in sorghum (36.45 mg kg^{-1}) and the minimum in maize (0.40 mg kg^{-1}) in sample. The FAO/WHO (2001) maximum limit for Fe concentration in food is 425 mg kg^{-1}. The result obtained in this study is lower than the recommended limit. The total accumulation of iron was in the order of sorghum > barley > wheat > maize. One-way ANOVA revealed that there was significant difference ($p < 0.05$) in levels of Fe in the cereals.

Zinc

Zinc is essential to all organisms and has an important role in metabolism, growth, development and general well being. It is an essential co-factor for a large number of enzymes in the body. Zinc deficiency leads to coronary heart diseases and various metabolic disorders (Saraf and Samant, 2013). As can be seen from Table 2, the levels of zinc were 8.54 mg/kg in wheat, 5.40 mg kg^{-1} in sorghum, 3.85 mg kg^{-1} in barley and 0.66 mg kg^{-1} in maize (Table 2). The content of Zn reported in this study is generally lower than the permissible levels set by FAO/WHO (2001). One-way ANOVA revealed that there was significant difference ($p < 0.05$) in levels of Zn in the cereals. Deficiency of zinc can also result from inadequate dietary intake, impaired absorption, excessive excretion or inherited defects in zinc metabolism (Öztürk et al., 2011).

Manganese

Manganese is essential element required for various biochemical processes. The kidney and liver are the main storage places for the manganese in the body. Mn is essential for the normal bone structure, reproduction and normal functioning of the central nervous system. Its deficiency causes reproductive failure in both male and female (Saraf and Samant, 2013). Manganese showed maximum concentration in wheat (7.67 mg kg^{-1}) and the minimum in maize (0.42 mg kg^{-1}). The concentration of manganese in the cereals increased as follows: wheat > sorghum > barley > maize respectively (Table 2). One-way ANOVA revealed that there was significant difference ($p < 0.05$) in levels of Mn in the cereals.

Cobalt

Cobalt is an integral component of the vitamin B-12 molecule. It is required in the manufacture of red blood cells and in preventing anemia. An excessive intake of cobalt may cause the overproduction of red blood cells (Kalagbor et al., 2014). The maximum concentration of Co was found in sorghum (0.45 mg kg^{-1}) and the minimum in barley (0.14 mg kg^{-1}) in the cereal samples. The concentration of cobalt in the cereals increased as follows: sorghum > wheat > maize > barley respectively (Table 2). One-way ANOVA revealed that there was significant difference ($p < 0.05$) in levels of Co in the cereals.

Nickel

Nickel plays some roles in body functions including enzyme functions. In very trace amounts it may be beneficial to activate some systems, but its toxicity at higher levels is more enzyme prominent (Onianwa et al., 2000). As can be from Table 2, the concentration of Ni ranged from non-detectable to 0.43 mg kg^{-1}in cereal samples collected from Ambo market. The highest concentration of Ni is found in sorghum 0.43 mg/kg and lowest concentration was recorded as ND in barely sample. The total accumulation of nickel was in the order of sorghum > wheat > maize > barley. One-way ANOVA revealed that there was significant difference ($p < 0.05$) in levels of Ni in the cereals.

Chromium

Cr (III) is an essential element required for normal sugar and fat metabolism. It is effective to the management of diabetes and it is a cofactor with insulin. Cr (III) and its compounds are not considered a health hazard, while the toxicity and carcinogenic properties of Cr (VI) have been known for a long time (Kalagbor et al., 2014). The concentration level of chromium in sorghum, maize, wheat and barley were found to be 0.95, 0.52, 0.43 and 0.29 mg kg^{-1}. These values are lower than the maximum permissible limit of 2.3 mg/kg by FAO/WHO (2001). Statistical test of significance using one-way ANOVA revealed that there was significant difference ($p < 0.05$) in levels of Cr in the cereals.

Lead

Results obtained showed that high concentration of Pb were obtained in sorghum 0.08 mg/kg, followed by wheat 0.05 mg kg^{-1}, barley 0.03 mg kg^{-1} and not detected in maize. The concentration of lead in the cereals increased as follows: maize < barley < wheat < sorghum respectively. The Pb contents of the cereals in this study are lower when compared to the FAO/WHO (2001) safe limit of 0.3 mg kg^{-1}. Thus, the study showed that, in the cereals, Pb contents are within the permissible limit. So the levels of Pb obtained in the present study do not indicate a potential health hazard to consumers. Lead toxicity is known to cause musculo-skeletal, renal, ocular, neurological, immunological, reproductive and developmental effects (Ambedkar and Muniyan, 2012). One-way ANOVA revealed that there was no significant difference ($p > 0.05$) in levels of Pb in wheat and barley the cereals but there was significance ($p < 0.05$) difference between the other cereals.

Cadmium

Cadmium is highly toxic Non-essential heavy metal and it does not have a role in biological process in living organisms. Thus even in low concentration, cadmium could be harmful to living organisms (Ambedkar and Muniyan, 2012). Cd poisoning in man could lead to anaemia, renal damage, bone disorder and cancer of the lungs (Edward et al., 2013). As can be seen from Table 2, cadmium was not detected in any of the cereal samples. However, in general, the results indicate that the order of the concentration of heavy metals in cereal samples was found to follow decreasing order: Fe > Zn > Mn > Cu > Cr > Co > Ni > Pb > Cd. When the present concentrations of heavy metals were compared with permissible limits by FAO/WHO (2001), it was found out that all the levels were within the safe limit (Table 2).

As human health is directly affected by ingestion of cereals, which is the main source of food for man, bio-monitoring of trace elements in the cereals should be continued to prevent possible consumption of contaminated cereals or foodstuff. Agronomic practices such as the application of fertilizer, pesticides and water managements on growing these cereals could be affecting the accumulation of these heavy metals. Therefore; it is essential that the farmers should be educated and encouraged to reduce such contamination by controlling the use of pesticides, avoiding cultivation in fields far away from highways and industrial areas. This study thus showed cereals consumed in Ambo district are safe for human consumption.

Conclusion

Consuming the cereals contaminated with heavy metals has different detrimental effects on human health; therefore, monitoring contamination of heavy metals will allow for avoiding unnecessary exposures. The result of this study has revealed that the various concentrations of the heavy metals Cu, Fe, Zn, Mn, Cr, Co, Ni, Pb and Cd in cereals sold in Ambo town, West Shewa zone, of the Oromia Regional State, Ethiopia. The concentrations of heavy metals determined were in sequence Fe > Zn > Mn > Cu > Cr > Co > Ni > Pb > Cd. Generally, the levels of heavy metals obtained in all cereals are within the acceptable range and do not pose any health hazard to the health of their consumers in the study area but the study has helped to show that cereals from Ambo market serve as good dietary sources for essential trace metals. Further studies are being carried out on soil samples on the possible transfer of these heavy metals from soil to cereals.

Conflict of Interest

The authors have not declared any conflict of interest.

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