Assessment of Selected Heavy Metal Concentrations in Selected Fresh Fruits in Eldoret Town, Kenya

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Abstract
This study assessed levels of selected heavy metals (Lead, Chromium and Cadmium) in oranges and mangoes sold in Eldoret town and their health implications to consumers. A total of one hundred and eighty (180) samples were collected for analysis from randomly selected market sites within Eldoret town. Samples were wet digested using a mixture of 1:3 (65% HCl: HNO3) and analyzed using Atomic Absorption Spectrophotometer version 200. One Way Analysis of Variance (ANOVA) was used to test the significance of selected heavy metal levels in consideration of market sites at 5% significance level. There was insignificant variance in mean chromium levels in mango fruits among market sites (f=2.1, df=3, p=0.10) with the highest mean level occurring at 2.43±0.24 mg/kg. Lead levels in orange fruits were significant (f=13.3, df=3, p=0.00) with the highest mean level occurring at 0.65±0.03 mg/kg. Cadmium levels were significant in mango fruits among market sites (f=6.5, df=3, p=0.00) with the highest level at 0.09±0.05 mg/kg. Risk Assessment in terms of values of Daily Intake of Metal (D.I.M) had chromium levels in mango fruits with the highest at 0.05mg/day, lead in orange fruits was at 0.02mg/day with the least D.I.M occurring in cadmium levels in mango fruits at 0.002mg/day. Mango and orange fruits sold in Eldoret town posed no health risks to consumers based on their D.I.M levels, as the values were within Provisional Daily Tolerable Intake standards of World Health Organization (WHO). The elevated chromium D.I.M levels in mango fruits in this study meant that environment in which mango fruits are grown were high in chromium content. There is need to initiate and sustain continued monitoring of heavy metals in fruits and food sold to consumers due to their different sources where contamination of heavy metals varies to ascertain food safety.

Keywords: Daily Intake of Metal, Hazard Quotient and Heavy metal.

1. Introduction
Consumption of fruits on a regular basis is critical in providing health promoting nutrients to the human body. Protective antioxidants and phytoneutrants in fresh fruits including: flavonols, anthocyanins and phenyl propanoids are critical to best functioning of human immune system, protecting against communicable and non-communicable diseases such as cancer and other degenerative diseases (Dauchet et al., 2010). Additionally, other vital components in fresh fruits such as vitamin C, carotenoids, minerals and dietary fiber are vital requisites to body’s optimum immunity functions. These protective functions derived from fresh fruits necessitates that every human meal serving be accompanied with fresh fruit intake in providing a balanced diet and boosting of the body’s immune system (Maggini et al., 2010). Inadequate intake of fruits is increasingly becoming recognized as one of the key risk factors for cardiovascular diseases and some form of cancers, the two leading causes of death in the world today (WHO/FAO, 2012). Compared to vegetables and their nutrient contribution to the human body, fresh fruits are usually taken in large quantities whereas vegetables are usually consumed in relatively small amounts as side dishes or relished with staple foods (Stewart et al., 2011).

Despite extensive documentation on the importance of consumption of fresh fruits, fresh fruit consumption can be associated with some health risks arising from elevated levels of heavy metals emanating from various environmental sources (Sobukola et al., 2010). These sources include: use of synthetic fertilizers in fruit farming, use of pesticides and waste water in food crop farming and contaminated transport modes involved in transporting fresh fruit products from farms to markets (Sudhakar et al., 2012). Heavy metals may be of particular concern in fruit tree production because of the importance of foliar spray which deposits fertilizer directly on fruits, some foliar fertilizers used in fruit production could be laden with heavy metals (Thomas et al., 2012). Low but measurable amounts of heavy metals occur in agricultural commodities because of uptake by plants from trace amounts in the soil and these levels can be of health risk to consumers (Heshmat et al., 2012). Other sources of heavy metal contamination in fruits are from rapid unorganized urban and industrial developments (Doherty et al., 2012). Food safety is a major public concern worldwide. During the last decades,
increasing demand for food safety has stimulated research regarding the risk associated with consumption of foodstuffs contaminated by pesticides, heavy metals and toxins (WHO/FAO, 2012).

High lead level in human food chain is associated with development of abnormalities in children including: teratogenesis and mutagenesis (Carlisle et al., 2009). Exposure of lead to young children, generally of the age below 5 yrs has been linked to low Intelligence Quotients and increased levels of blood pressure (Carlisle et al., 2009). Lead is also linked to condition of anemia in humans (Kavita et al., 2010). Uptake of Cadmium levels exceeding recommended level is associated with renal, prostrate and ovarian cancers (Satarug et al., 2010). Cadmium is known to be a bioaccumulator heavy metal whose target body organs includes: reproductive system and bones. Cadmium has been classified as a probable carcinogen and as an endocrine disruptor (Shimphei et al., 2012). The consequences of ingesting hexavalent chromium are damages to nose lining and irritation of lungs and gastrointestinal tract. When swallowed, chromium inflicts damages to stomach, liver and kidneys. Environmental Protection Agency in United States classifies hexavalent chromium as a human carcinogen (Ashraff et al., 2011).

International and national regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of risks these metals pose to food chain contamination (WHO/FAO, 2012). Presently research on fresh fruit contamination by heavy metals has been extensively reported on temperate fruits such as: strawberries, raspberries, blackcurrant and food crops namely asparagus, peanuts and tomatoes have been reported. There is need to also investigate the levels of heavy metals in tropical fruits that are consumed in developing countries. Safety in consumption of fresh fruits due to their trace elements has to be guaranteed as fruits are significant sources of critical vitamins to human health and are relatively affordable to large proportion of the population (Fernando et al., 2012).

2. Materials and Methods
This study was carried out in Eldoret town, Kenya. The town is located at Longitude 35ºN 12ºE and Latitude 0º35’N (Figure 1). Eldoret town serves as a regional commercial centre where fresh fruits are sold to consumers. 180 replicates of Mangos and Oranges were sampled on monthly basis for 3 months from four (4) market sampling sites located in Eldoret town. The fruits upon collection from sampling sites were packaged in clean, dry, high density clear plastic bags immediately after purchase and then stored in refrigerator at 4ºC awaiting further analysis for heavy metals (Cui et al., 2010).
2.1 Heavy Metal Analysis

Fresh fruit samples were extracted using acid digestion method (Cui et al., 2010). Three aliquots of 30mls each representing three replicates for each fruit were accurately measured and placed in a 200 ml flask beaker to which 30 mls of 10% concentrated HNO₃ was added and left to settle for 15 minutes. Wet acid digestion followed in 10mls of 1:3 mixture of concentrated 65% HCl: HNO₃ (Merck) using a hotplate, till clear solution was obtained. Digested samples were allowed to cool off at room temperature. Digested samples were then acidified with 10mls of 1:1 mixture of HCl: H₂O and filtered through 0.45 micron filter paper and the final volume made up to 50ml with distilled water. The resultant filtrate was then transferred to cleaned dried plastic bottles awaiting heavy metal level analysis (Cui et al., 2010).

2.2 Quality Control

All glass and non-glassware (with no metal liners) used in this study were washed with deionized distilled water and immersed in 2% Nitric acid (HNO₃) for 24 hours prior to use to avoid heavy metal contamination (Wang et al., 2012). Fruit samples were cleaned with distilled water and peeled with stainless steel knife, sliced to get edible parts and homogenized to juice for analysis using an electric blender with stainless steel rotor knives (Cui et al., 2010). Glasswares were properly cleaned and reagents used for heavy metal analysis were of analytical grade (MERCK sourced from Darmstadt, Germany). De-ionised water was used throughout sample preparation and analysis. Reagent blank determinations were used to correct analysis readings. All samples were analyzed in triplicates and three quality control samples consisting of: reagent blank, sample duplicate and spiked sample were run for every batch of 5 samples. Mean fractional recoveries were satisfactory being in excess of 90% for the analyzed metals (Lead, Cadmium and Chromium).

2.3 Statistical Analysis

The statistical significance in mean concentrations of heavy metals in the fruits vis a vis Market sites was tested
using SPSS version 16, One Way analysis of variance (ANOVA). A probability level of P<0.05 was considered significant.

3. Results and Discussion

3.1 Lead levels in Oranges and Mangos

Lead levels in Oranges and Mangos had significant variance in mean concentration levels between market sites in Eldoret Town; Oranges (f=13.33, df=3, p=0.00) and Mangos (f=21.87, df=3, p=0.000) respectively. Mean lead levels were significant in oranges and mangos sampled in market A in comparison to Market C; Oranges (q=4.14, p=0.00) and Mangos (q=7.84, p=0.00) respectively. Significant mean variance in lead levels were also noted in oranges sampled between market sites B and C (q=6.18, p=0.00); Markets C and D (q=2.99, p=0.02). Mango fruit samples had significant lead concentrations between market sites: A and B (q=5.25, p=0.00) and A and D (q=5.43, p=0.02) respectively. Oranges sourced from Market site B (Open Market) had the highest mean concentrations of lead at 0.651±0.032mg/kg while Mangos sourced from market site A had highest mean concentrations of lead at 0.606±0.039mg/kg (figure 2). Lead levels were highly reported in Orange than in Mango fruits. High lead levels above the recommended limit of 0.3 mg/kg (WHO/FAO, 2012) found in sampled fresh fruits in this study may be related to their environmental points of production.

Another possible explanation to high levels of lead in fresh fruits in this study could be the use of pesticides, fertilizer and wastewater in farming of fruit crops. Orange fruit plants could be having a greater affinity of lead uptake from the soil compared to mangos (Anju et al., 2011). Works of Krejpcio et al., (2005) agrees to this finding by reporting that lead contents of fruits grown in non-polluted areas of Poland were generally low and did not exceed maximum permissible level (0.3 mg/kg fresh weight). The highest content of lead was detected in black current fruits at 0.073 mg/kg and lowest in pears at 0.044 mg/kg. Most significant was that lead content of strawberries was regionally dependent to places within Poland with lowest lead level in strawberries reported at 0.03 mg/kg in central part of the country, higher in Northern Eastern Poland at 0.06 mg/kg with the highest level of lead in southern region of Poland at 0.20 mg/kg Krejpcio et al., (2005).

![Comparison of lead levels between Oranges and Mangos among market sites](image)

**Figure 2.** Comparison of lead contents in Oranges and Mangos among market sites

3.2 Cadmium levels in Oranges and Mangos

Cadmium concentrations in oranges had no significant variance in mean concentrations between market sites in Eldoret Town (f=1.85, df=3, p=0.14) whereas Mangos sampled in different market sites had significant variance in mean concentrations (f=6.50, df=3, p=0.00). Mean Cadmium concentrations were significant in Mangos sampled between markets A and C (q=4.09, p=0.00), Markets A and D (q=2.70, p=0.00) and Markets B and C (q=3.05, p=0.02). Oranges sourced from market site B had highest mean concentration of Cadmium at
0.057±0.004mg/kg whereas Mangos sourced from site C had the highest concentration at 0.052±0.004mg/kg. The least Cadmium Concentration in Oranges was found in samples sourced from market site D at 0.046±0.004mg/kg as the least level of cadmium in mangos occurred from samples sourced in market site A 0.066±0.005mg/kg (Figure 3). Cadmium levels were reported to occur in high concentration in Mangos compared to Orange fruits.

Low levels of Cadmium analyzed in the fruits sampled occurred within recommended level of 0.2mg/kg (WHO/FAO, 2012) posed insignificant health risk to consumers. Cadmium levels in fresh fruits sold in Eldoret town could be multiple sources of environmental pollution exposed to fruit trees during growth period. In agreement to this, Sobukola et al., (2010) reported a mean value of 0.090mg/kg of Cadmium in fluted pumpkin in a study conducted on some fruits and leafy vegetables from selected markets in Lagos, Nigeria. Krejpcio et al., (2005) reported a mean level of Cadmium contents in fruits in Poland being similar in all the three regions of Poland ranging from 0.018 to 0.023 mg/kg with the lowest in apples within a range of 0.003 to 0.005 mg/kg. Cadmium levels in fruits are dependent on plant fruit type and its affinity to uptake cadmium from the environment in which the fruits are grown. Environment is rich in cadmium content correlates with elevated uptake of the same by fruit plants (Tuan et al., 2012). Seyed et al., (2008) reported concentrations of 1.8 mg/kg of cadmium in oranges and 2.14 mg/kg in mangos fruits collected in India city market with high concentrations of 15.39 mg/kg of cadmium in oranges and 16.9 mg/kg in mangos collected at Yeshwantur market. Fruits sourced from Yeshantupur market had high concentration of heavy metals due to a combination of several environmental factors including uptake from soil due to use of fertilizers, use of waste water and pesticides in fruit farming.

3.3 Chromium levels in Oranges and Mangos
Chromium concentrations in oranges had significant variance in mean concentrations between market sites in Eldoret Town (f=3.5, df=3, P=0.02). Mean Chromium concentrations were significant in oranges sampled between markets A and B (q= 2.62, p=0.048), Markets A and D (q=2.69, p= 0.040). Mangos samples sourced in different market sites had no significant variance in mean concentrations (f=2.14, df=3, p=0.10). Orange sourced from market site A had the highest mean levels of chromium at 1.741±0.060mg/kg whereas mangos sourced from market site D had highest mean level of chromium at 2.429±0.243mg/kg. The least level of chromium in sampled oranges occurred at market site D at 1.393±0.115mg/kg respectively while in mangos chromium concentrations in mangos, followed by market site C level at 2.283±0.149mg/kg, market site B had a mean concentration of 2.014±0.145mg/kg, with market site A at 1.915±0.054mg/kg respectively (Figure 4).

High concentration of Chromium levels in oranges sampled in market sites could be hypothesized to the fact that oranges sold in these market sites may have originated from different growing regions. This could have impacted on uptake of heavy metals from the soil to deposition in the orange fruit. In contrast to this study, Erum et al., (2009) in a study of market basket survey of selected metals in fruits from Karachi city in Pakistan found out that chromium metal exhibited high concentrations in mango fruits at an average value of 4.09 mg/kg whereas this
The present study had the highest chromium concentration in mangos at 2.428 mg/kg. The probable explanation to this is the different environments where the fruits are grown (Krepjcio et al., 2005). Chromium as a heavy metal is the most bioavailable heavy metals in fresh fruits signifying that the uptake of chromium from soils by plants is at a more magnified level than other heavy metals (Fernando et al., 2012). Depending on the richness of the environment in terms of heavy metal concentration, chromium can be a health concern especially to fresh food products. Prolonged consumption of unsafe concentrations of chromium through foodstuffs may lead to the chronic accumulation of heavy metals in kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (Satarug et al., 2010).

![Comparison of Chromium levels between Oranges and Mangos among market sites](image)

**Figure 4. Chromium Mean levels in Oranges and Mangos within market sites**

### 4. Conclusion and Recommendations

Fresh fruits are known to contain levels of metals that are essential to well-being of human health but these levels of metals can be toxic when they exceed the recommended health levels (Orish et al., 2012). Elevated levels of these heavy metals arise from many sources in the environment; Uptake by plants from soils and subsequent deposition in fruits and application of fertilizers and pesticides laden with heavy metals. Heavy metal occurrence in fresh fruit sampled in markets in Eldoret Town had the following order: Cr>Pb>Cd. Elevated chromium levels in fresh fruits sampled were of concern. Sources correlating strongly to high levels of chromium in fruit samples include: use of pesticides, use of wastewater for irrigation farming and use of fertilizers that are of industrial manufactured in nature (Karanja et al., 2012). High levels of lead above the recommended limits (WHO/FAO, 2012) as assessed in the fresh fruits was a health concern due to the potential risks it might pose to consumers.

In assurance of safety to consumers against health risk of heavy metal uptake it would be in the interest that regular assessment of sources of heavy metals from areas that can impact on food safety. This study has brought forth baseline data on heavy metal contamination of fresh fruit sold in Eldoret Town. The hypothesis that consumers of fresh fruits in Eldoret town were at no health risk of heavy metal contamination has been proved through this study with the exception of elevated levels of lead in the fruits which could pose health risks. Contamination of fresh fruits in Eldoret town is thought to be enhanced by environment in which fresh fruits are grown. There is a need to ascertain soil content for presence of the analyzed metals in the environment under which these fruit plants are grown. This information is vital especially to specialists in crop production who will devise best crop farming practices, disseminate to relevant stakeholders so that safety of fresh fruits and food is guaranteed. There is need also to ascertain levels of other toxicants in fresh and processed food products currently flooding markets based on the dynamic lifestyles. There is concern that process in manufacturing can impact levels of these toxicants in the final products; of concern are soft drinks and beverages being sold in markets.
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