



Assessment of Heavy Metal Concentrations in Tomatoes (*Lycopersicum esculentum*) Cultivated in Horticultural Farms of Nakuru County, Kenya

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Abstract

The objective of this study was to assess the heavy metal concentrations in tomatoes (*Lycopersicum esculentum*) cultivated in horticultural farms of Nakuru County, Kenya. Tomatoes samples were randomly collected from selected areas in Njoro, Naivasha, Nakuru East, Nakuru West, Subukia, Rongai and Gilgil sub-counties. The samples were collected in clean polythene ziplock bags and stored frozen at -10°C . In the laboratory, the samples were sliced and dried to constant weight in an oven at 70°C . They were then ground separately using an electric miller to pass through a $150\text{-}\mu\text{m}$ sieve and preserved in khaki bags for further analysis using atomic absorption spectrophotometry. The overall mean ranges of concentrations of heavy metals were: $0.23\pm 0.00\text{--}0.38\pm 0.06$ mg/kg for Cu; $0.18\pm 0.00\text{--}0.31\pm 0.02$ mg/kg for Zn; $0.69\pm 0.20\text{--}0.91\pm 0.01$ mg/kg for Cr; $0.08\pm 0.00\text{--}0.13\pm 0.01$ mg/kg for Mn and $0.71\pm 0.05\text{--}0.87\pm 0.04$ mg/kg for Fe. The results indicated that the levels of heavy metals in tomatoes were within the WHO accepted levels. Also, there was a significant difference ($p\leq 0.05$) in the levels of Zn and Mn in tomatoes across 7 regions. These findings suggest that while overall heavy metal levels in tomatoes are deemed safe for consumption, localized factors may influence metal accumulation, highlighting the importance of continued monitoring and localized interventions to ensure food safety. The study



recommends that there need to implement routine monitoring programs to assess heavy metal concentrations in tomatoes and other agricultural produce from Nakuru County. Continuous surveillance will help identify any emerging trends or localized contamination issues.

Keywords: Tomatoes, Heavy Metals, Agricultural Soil, Concentration, Horticultural Farms

Introduction

Vegetables form an integral portion of the human diet and humans require large volumes of vegetables in their diet as a source of vital vitamins, essential minerals, other nutrients, and fiber (Butt & Sultan, 2018; Lal et al., 2020). People who eat more vegetables and fruits as part of an overall healthy diet are likely to have a reduced risk of chronic diseases including stroke, cancer, heart diseases, and type-2 diabetes (Schwingshackl et al., 2019). Tomatoes (*Lycopersicum esculentum*) are one of the most widely cultivated and consumed vegetables in the world, with global production surpassing 180 million metric tons in recent years (FAO, 2021). They are a key ingredient in various cuisines, contributing significantly to dietary intakes of vitamins A and C, potassium, and antioxidants such as lycopene, which has been linked to numerous health benefits, including reduced risks of heart disease and cancer (Willcox et al., 2003). Major producers of tomatoes include China, India, and the United States, with these countries collectively accounting for over half of the global production (Heuvelink, 2018). The economic importance of tomatoes extends beyond direct consumption, as they are also processed into products like sauces, pastes, and juices, supporting substantial agro-industries worldwide.

In Africa, tomatoes are a key horticultural crop, integral to both food security and income generation for smallholder farmers. The continent's production is concentrated in countries such as Nigeria, Egypt, and Tunisia. Nigeria, for instance, is one of the largest producers in sub-Saharan Africa, with tomatoes being a staple in Nigerian cuisine (Olayide et al., 2012). Despite the high production, post-harvest losses remain a significant challenge due to inadequate storage and processing facilities (Affognon et al., 2015). Additionally, African farmers face issues related to pests, diseases, and climate change, which can adversely affect yield and quality. The use of agrochemicals to combat these challenges raises concerns about the potential contamination of tomatoes with residues of pesticides and heavy metals (Adenuga et al., 2013).

In Kenya, tomatoes are a vital component of the horticultural sector, contributing to both domestic food supply and export earnings. It is estimated



that 96% of urban households in Kenya purchase tomatoes respectively for their everyday consumption (Van der Lans *et al.*, 2012; Gemechis *et al.*, 2012). Nakuru County, in particular, is a key region for tomato cultivation due to its favorable climatic conditions and fertile soils (KARI, 2013). Tomatoes are grown by smallholder farmers and larger commercial enterprises, making them accessible to a wide range of consumers. However, Kenyan farmers also grapple with issues similar to those in other African countries, including pest and disease pressures and the extensive use of agrochemicals (Gogo *et al.*, 2014). A study by Wambugu *et al.* (2016) highlighted the presence of pesticide residues in tomatoes from Kenyan markets, raising food safety concerns. Furthermore, the potential for heavy metal contamination, especially in areas near industrial activities or where untreated wastewater is used for irrigation, has been noted as a public health concern (Ngure *et al.*, 2014). Heavy metals can accumulate in edible crops, posing serious health risks to consumers over time. Chronic exposure to heavy metals has been documented to cause severe health problems, including neurological, renal, and skeletal damage, and an increased risk of cancer (Al Osman, Yang & Massey, 2019; Fu & Xi, 2020). Several studies have documented elevated levels in tomatoes (Bounar, Boukaka & Leghouchi, 2020). Despite the nutritional importance of tomatoes and their widespread consumption in Kenya, there is insufficient information on the levels of heavy metals in tomatoes grown in Nakuru County. This lack of data poses a significant public health risk, as consumers may be unknowingly exposed to hazardous levels of heavy metals. Therefore, this study assessed the heavy metal concentrations in tomatoes (*Lycopersicon esculentum*) cultivated in horticultural farms of Nakuru County, Kenya.

Methodology

Nakuru County has nine sub-counties including Nakuru North, Gilgil, Nakuru, Rongai, Naivasha, Subukia, Njoro, and Kuresoi (Hussein & Wanyoike, 2015). The total population of Nakuru County was approximated at 2.162 million people in 2019 (Kenya National Population and Housing Census, 2019). Nakuru County is well endowed with economic resources that include; small and large scale agriculture, livestock production, fisheries management, forestry and agroforestry, mining, textile industries, food processing, sawmills, and engineering works others are manufacturing industries and tourism activities. It is a major producer of food, cash, and horticultural crops. The leading food crops include maize, wheat, beans, potatoes, and various fruits and vegetables whereas the main cash crops are: tea, coffee, pyrethrum, and flowers. Types of fruits and vegetables which include grown are tomatoes, peas, carrots, onions, French beans, citrus fruits, peaches, apples, asparagus,



and leeks. Most of these are grown in Bahati, Rongai, Mbogoini, Olenguruone, Njoro, Molo, Nakuru Municipality, and Gilgil Divisions (Ogeto *et al.*, 2013).

All the standard solutions used were prepared from analytical reagent grade materials in doubly distilled water. These reagents include; zinc (II) chloride (ZnCl_2); iron (III) chloride ($\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$); chromium (III) nitrate ($\text{Cr}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$); concentrated nitric acid (HNO_3); hydrochloric acid (HCl), distilled water, All the reagents were obtained from Kobian chemicals Ltd, Nairobi.

An oven (model ULM-400, Germany), was used in sample drying; while an electric miller (MP-45E, Appleton, USA) was used in pulverizing the dry samples. An atomic absorption spectrometer, AAS, (spectra-AA 200, Australia) was then used in the measurement of metal ion concentrations; digestion block (PB512L, Tamil Nadu, India), was used in the digestion of tomato samples. Analytical balance (model AUW220, Shimadzu Corporation, Japan) was used to determine the weights of the dried tomato samples.

Tomatoes were obtained from study areas in cross-sectional study design where 41 sample were randomly sampled from Njoro, Naivasha, Nakuru East, Nakuru West, Subukia, Rongai and Gilgil sub-counties as indicated in table 1.

Table 1: Tomatoes collected from the study area for fluoride and heavy metal analysis

Sampling region	Tomatoes
Njoro	3
Naivasha	4
Nakuru East	10
Nakuru West	11
Subukia	2
Rongai	6
Gilgil	5
Total	41

In the study, ground tomato samples weighing 1.25 g each were treated by adding 10 mL of 6 M sodium hydroxide solution and heating the mixture over a water bath for 30 minutes until complete dissolution occurred. Subsequently, the solutions were cooled, neutralized with 8 M sulphuric acid, filtered, and diluted to 50 mL with double distilled water. Total ionic strength adjustment buffer (TISAB) solution was added to stabilize the pH and maintain constant ionic strength. Fluoride content was measured using a fluoride ion-selective electrode, and concentrations were determined using a standard curve. For selenium analysis, a mixture was prepared by adding selenium powder and lithium sulfate to hydrogen peroxide and concentrated sulfuric



acid, then stored at 4°C. Vegetable samples weighing 0.3 g were digested with a mixture, and after cooling, diluted to 50 mL. The resulting solutions were analyzed for zinc (Zn), copper (Cu), chromium (Cr), manganese (Mn), and iron (Fe) concentrations using Atomic Absorption Spectroscopy (AAS). Descriptive analysis and analysis of variance (ANOVA) was performed using the Statistical Package for Social Science (SPSS) to assess differences in heavy metal concentrations tomatoes from 7 regions in Nakuru County.

Results

Mean Concentration of Heavy Metals in Tomatoes from Different Sampling Regions in Nakuru County

Tomatoes collected from 7 different regions of Nakuru County were analyzed for the presence of heavy metals. The overall mean levels for each element are tabulated in Table 2.

Table 2: Mean concentration of heavy metals in tomatoes from different sampling regions in Nakuru County

Sub-county	n=7	Mean metal concentrations $\pm$ S.E (mg/kg)				
		Cu	Zn	Cr	Mn	Fe
Njoro		0.23 $\pm$ 0.0	0.18 $\pm$ 0.0	0.69 $\pm$ 0.2	0.11 $\pm$ 0.0	0.71 $\pm$ 0.0
		0	0	0	0	5
Naivasha		0.26 $\pm$ 0.0	0.28 $\pm$ 0.0	0.90 $\pm$ 0.0	0.13 $\pm$ 0.0	0.72 $\pm$ 0.0
		1	2	4	1	4
Nakuru east		0.26 $\pm$ 0.1	0.31 $\pm$ 0.0	0.86 $\pm$ 0.0	0.08 $\pm$ 0.0	0.81 $\pm$ 0.0
		1	0	3	0	4
Nakuru west		0.38 $\pm$ 0.0	0.26 $\pm$ 0.0	0.91 $\pm$ 0.0	0.09 $\pm$ 0.0	0.75 $\pm$ 0.0
		6	1	4	1	4
Subukia		0.23 $\pm$ 0.0	0.26 $\pm$ 0.0	0.88 $\pm$ 0.2	0.11 $\pm$ 0.0	0.77 $\pm$ 0.0
		1	1	0	1	7
Rongai		0.26 $\pm$ 0.0	0.31 $\pm$ 0.0	0.89 $\pm$ 0.0	0.05 $\pm$ 0.0	0.87 $\pm$ 0.0
		2	2	4	0	4
Gilgil		0.23 $\pm$ 0.0	0.22 $\pm$ 0.0	0.91 $\pm$ 0.0	0.07 $\pm$ 0.0	0.86 $\pm$ 0.0
		0	2	4	0	1
Overall		0.28 $\pm$ 0.018	0.27 $\pm$ 0.01	0.87 $\pm$ 0.03	0.08 $\pm$ 0.00	0.79 $\pm$ 0.02

Nakuru West recorded the highest concentration of Cu with 0.38 $\pm$ 0.06 mg/kg, while Gilgil, Njoro, and Subukia had the lowest concentration of Cu with the same mean of 0.23 $\pm$ 0.00 mg/kg. Zinc levels were highest in Nakuru East and Rongai with a mean of 0.31 $\pm$ 0.01 mg/kg, while Njoro recorded the lowest level of 0.18 $\pm$ 0.00 mg/kg. The highest chromium



concentration was recorded in Gilgil and Nakuru West with the same mean of 0.91 ± 0.04 mg/Kg, while the lowest was recorded in Njoro with a mean of 0.69 ± 0.20 mg/kg. Naivasha on the other hand, recorded the highest concentration of Mn 0.13 ± 0.04 mg/kg, while Rongai had the lowest Mn concentration with a mean of 0.05 ± 0.00 mg/kg. The highest Fe concentration was in Rongai with a mean of 0.87 ± 0.04 mg/kg, while Njoro recorded the lowest levels of 0.71 ± 0.05 mg/kg.

Results of the analysis of variance (ANOVA)

To determine whether there existed significant differences in the spatial distribution of the heavy metals, a one-way analysis of variance was conducted. Results are indicated in table 3.

Table 3: One-Way ANOVA for the concentrations of heavy metals in tomatoes from 7 regions

	Sum of Squares	Df	Mean Square	F	Sig.
Cu	0.130	6	0.022	1.950	0.101
Zn	0.067	6	0.011	12.529	0.000
Cr	0.166	6	0.028	1.021	0.428
Mn	0.019	6	0.003	18.653	0.000
Fe	0.135	6	0.022	1.931	0.104

According to the results of the analysis of variance presented in Table 3, the p values of Zn and Mn were both 0.000. They were below 0.05 significance level indicating a significant difference at 95% in the heavy metals content. The p values of Cu, Cr, and Fe were 0.101, 0.428, and 0.104 respectively as shown in Table 3.

Discussion

The highest levels of Cu were recorded in tomato samples from Nakuru West (0.38 ± 0.06 mg/kg) and the lowest (0.23 ± 0.00 mg/kg) was recorded jointly in Gilgil, Njoro, and Subukia as shown in Table 2. Osma *et al.*, (2012) while determining heavy metal levels in tomato grown in different station types reported 0.08–0.014 mg/kg concentrations for copper which were lower compared to the results of the present study. One-way ANOVA indicated that there was no significant difference in concentration of Cu in tomatoes for the 7 regions ($p > 0.05$). This is attributed to the same levels of Cu in the parent rocks related to the normal background concentrations of the metal in natural soil samples. Moreover, the overall mean concentration for Cu in tomato samples from 7 regions of the current study area was 0.28 ± 0.018 mg/kg and in all cases, the mean regional levels of Cu in the tomato fruits



were lower than the accepted level of 20.00 mg/kg, which showed that tomatoes from the current study area were not contaminated with undue levels of Cu.

The overall mean concentration for zinc in tomatoes from the 7 regions was 0.27 ± 0.01 mg/kg. Zinc level was highest in Nakuru East and Rongai with a mean of 0.31 ± 0.02 mg/kg, this was due to anthropogenic activities such as industrial waste and municipal waste dumping. Nonetheless, the concentrations of zinc in tomatoes were within the accepted levels of 60 mg/kg as per (WHO/FAO, 2001); (Kibet *et al.*, 2019) requirements. Similarly, one-way ANOVA indicated that the difference in concentration of zinc in tomatoes was not statistically significant ($p > 0.05$), this could be attributable to similar geological distribute of parent rock containing zinc.

The overall mean concentration for Fe in tomatoes from the 7 regions was 0.79 ± 0.02 mg/kg. Iron level was highest in Rongai with a mean of 0.87 ± 0.04 (mg/kg) this is attributed to different soil type influencing the pH and the pH effects on the absorption of Fe. Rongai area is known to have planosolic soil while Njoro with latosolic soil recorded the lowest level of 0.71 ± 0.05 (mg/kg) as shown in Table 2. Mean concentrations of Fe in tomatoes were within accepted levels of 48 mg/kg (WHO/FAO, 2001). These values of Fe in the present study were slightly higher than those reported by Adegbola (2013) with mean content of Fe ranges from 0.03 – 0.07 (mg/Kg) in fresh tomatoes sold in different markets and farms. One-way ANOVA indicated not significant difference ($F=1.931$, $df=6$, $p=0.104$ in concentration of Fe in tomatoes for 7 regions. This is attributed to the same levels of Fe in the parent rocks.

The overall mean concentration for chromium in tomatoes from the 7 regions was 0.87 ± 0.03 mg/kg. Chromium levels in Gilgil and Nakuru West had (0.91 ± 0.04 mg/kg). This could be due to anthropogenic activities such as use of paints in vehicles industry and engineering works whereas, as shown in Table 2, the lowest was recorded in Njoro with a mean of (0.69 ± 0.20 mg/kg). The concentrations of chromium in all the tomatoes were lower than the accepted level of 1 mg/kg as per WHO/FAO (2001) requirements. Adetogun, (2013) while investigating chromium uptake in tomato plants from Glen Valley farm Gaborone, Botswana, recorded the highest uptakes of chromium in tomato plant to be 0.819 mg/kg. Hellen & Othman (2014), on the other hand, recorded 0.20 mg/kg concentrations of Cr in tomatoes. Banerjee *et al.*, 2010 recorded high concentrations of Cr in cauliflower (2.45 mg/kg) and cabbage (1.35 mg/kg) compared to their respective soils. Results from these studies are abit higher compared to those of the present study.

Manganese in tomatoes, from the 7 regions had overall mean concentration of 0.08 ± 0.00 mg/kg. Naivasha recorded the highest Mn concentration 0.13 ± 0.01 mg/kg as compared with other regions. Rongai, on



the other hand, had the lowest Mn concentration with a mean of 0.05 ± 0.00 mg/kg. Ndinwa et al., (2014) while determining heavy metals in tomato (*Solanum lycopersicum*) leaves, fruits and soil samples collected from Asaba Metropolis, Southern Nigeria recorded the highest of 3.83 mg/kg in tomato fruit which was higher than those in the present study. The concentrations of Mn in tomatoes were within the accepted level of 0.2 mg/kg as per WHO/FAO (2001) requirements. One-way ANOVA indicated no difference in concentration of manganese in tomatoes which was not statistically significant ($p > 0.05$). This could be attributed to different geological distribution of parent rock and also low leaching of Mn in Naivasha due to low rainfall.

Conclusion and recommendation

The results revealed that the levels of copper (Cu), zinc (Zn), chromium (Cr), manganese (Mn), and iron (Fe) in the tomatoes fell within the acceptable limits set by the World Health Organization (WHO). However, significant variations were observed in the concentrations of zinc and manganese across the different regions sampled. These findings suggest that while overall heavy metal levels in tomatoes are deemed safe for consumption, localized factors may influence metal accumulation, highlighting the importance of continued monitoring and localized interventions to ensure food safety. The study recommends that there need to implement routine monitoring programs to assess heavy metal concentrations in tomatoes and other agricultural produce from Nakuru County. Continuous surveillance will help identify any emerging trends or localized contamination issues.

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