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Consumer Risk Exposure to Chemical and Microbial Hazards Through Consumption of Fruits and Vegetables in Kenya

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Abstract
Recently, there has been public outrage and media report on presence of heavy metal residues and pathogenic contamination in commonly consumed commodities including fruits and vegetables in Kenya. Chemical and microbial contaminants in food value chains pose serious health risk to the consumers hence the need for regular surveillance of these hazards to protect the public. This study provides insight into prevalence and levels of chemical and microbial pathogens in selected fruits and vegetables commonly consumed in urban and peri-urban areas in Kenya. Structured interviews, market observations and analytical determinations were used for data collection. Chemical and microbial analysis of randomly selected fruit and vegetable samples including kales, amaranth leaves, tomatoes and mangoes were analyzed using standard methods. Microbial analysis included *total aerobic counts, anaerobic bacteria, yeast and moulds, coliforms, Enterobacteriaceae, Staphylococcus aureus, Listeria Monocytogenes, Escherisia coli* and *Clostridium botulinum* while chemical analysis consisted of pesticides residues and heavy metals as well as nitrates. The results were evaluated against national and global standards for maximum residue limits (MRLs) for each commodity and pesticide. The findings demonstrated that fruit and vegetable samples were contaminated with pesticides residues some of which were beyond the allowed limits such as *Dimethoate (>0.02mg/kg), Bifenthrin (>0.05mg/kg), Metribuzin (0.05mg/kg), Cyromazine (>0.05mg/kg), metalaxyl (>0.05mg/kg) and Pyrimethamil (>0.02* while mango had *thiabendazole (0.031mg/kg)* and contained heavy metals with Lead concentration ranging from < 0.01 mg/100g to >0.06 mg/100g compared to Cadmium levels of 0.01mg/100g. Nitrate content ranged from 100-200 mg/100g in vegetables and 120-210 mg/kg in fruit. Total aerobic counts ranged from 1.42x103 - 9.56x104 in the mango, 1.32x103 - 7.01x104 in tomato, 9.50x104 - 9.40x106 in kale and 2.46x106 - 7.60x107 in amaranth leaves. Anaerobic bacteria counts ranged from <1 - 7.74x104 in the mango, 1.83x103 - 5.65x103 in tomato, 9.50x102 - 1.18x106 in kale and 1.83x106 - 9.20x107 in amaranth leaves. Samples also showed presence of pathogenic microbes including *Staphylococcus aureus* and *Escherishia coli*. These findings show that compliance to food safety standards should be enforced so that the quality of Kenya's food supply meets the highest safety requirements to satisfy domestic and international demands. Control measures should emphasis on good agricultural practices, better postharvest handling practices, improved traceability and good hygienic practices in the markets.
Keywords: chemical residues, consumer risk, heavy metals, fruits and vegetables, microbial hazards, pesticide residues

1. Introduction

Food security entails the access to safe, acceptable and affordable nutritious food for all citizens at all time. However, the access to safe and acceptable foods in the local markets at retail level has been curbed with numerous reports of chemical and microbial contaminants leading to food borne illness and toxic effects in the human body (Tango *et al*. 2018). Food security is of such national importance to Kenya, that the current government has made it one of its four key deliverables within the next five years by President Kenyatta in 2018 (GOK 2018). It is also the second sustainable development goal of the United Nations (UN), to end hunger, achieve food security and improved nutrition and promote sustainable agriculture. Food security is core to the Kenyan's Vision 2030 and the strategy for revitalizing agriculture (GOK 2018). The presence of chemical and microbial hazards in commonly or frequently consumed food products poses health risks to consumers especially the vulnerable population leading to huge economic and social impacts (Alegbeleye *et al*. 2018; Chlebicz & Śliżewska 2018; Nawab *et al*. 2018). Many studies have reported presence of chemical contaminants especially heavy metals and nitrates in fruits and vegetables especially leafy vegetables exceeding recommended standards by regulatory bodies (Ali & AL-Qahtani 2012; Hattab *et al*. 2019; Ilić *et al*. 2014; Piglowski 2018; Romeh *et al*. 2018; Zhong *et al*. 2018). Pathogenic contamination such as *E. coli* and *Salmonella* in fruits and vegetables has been reported in many studies which show that the microbes contribute to food borne illnesses. The foodborne pathogens are able to efficiently invade/replicate intracellularly in the human epithelial cells and have distinct virulence traits which could be linked to consumption of plants and food safety issues (Verma *et al*. 2018; Tango *et al*. 2018; Markland *et al*. 2017). Consumption of contaminated foods especially fruits and vegetables have been shown to pose health risks to consumers' especially vulnerable populations such as children and pregnant women (Botttex *et al.* 2008; Chiu *et al*. 2018; Cockburn *et al*. 2013).

Fruits and vegetables play an important role in the nutrition and health of many populations and current research focus has been on health promoting properties of these foods (Kunyanga *et al*. 2012; Kunyanga *et al.* 2011a; Kunyanga *et al*. 2011b). Fresh fruits and vegetables constitute 25% and >80 % of the diets in the urban and the rural areas of Kenya, respectively (Mungai *et al.* 2000). In addition, horticulture sector in Kenya has been a key income and foreign earner for many farmers. The country is able to produce a wide range and diversity of horticultural produce i.e. fruits and vegetables from its agro-ecological zones with over 2.57 million small-scale producers of which 70% are involved directly and indirectly in the horticultural activities of production, processing and marketing (Mungai *et al.* 2000). However, poor postharvest handling of fruits and vegetables by farmers, traders and other value chain actors has been reported to the rise of food safety issues posing risk to the consumers (Pangal *et al.* 2018). It has been shown that if enforcement of good agricultural and good manufacturing practices was effectively implemented, the chemical residues could be reduced to a minimum limit especially with incorporation of household preparation methods such as soaking, washing, peeling and blanching (Chung 2018; Markland *et al.* 2017).

The recent emergence of many reports of contaminants especially of heavy metals in the food value chain has caused a lot of concern in the food safety systems and official controls in Kenya (*Newspaper article on "How mercury finds itself in your sugar". Published on Wednesday, June 20th 2018 in the The Standard*.

https://www.google.com/amp/s/www.standardmedia.co.ke/mobile/amp/article/2001284742/how-mercury-finds-itself-in-your-sugar; Newspaper report, "*Study warns of highly contaminated fruits and vegetables in open markets and supermarkets: Poisoned vitamins (Concern over pesticides, lead in vegetables)". The Standard Newspaper, Monday, June 9, 2014)*.

Questions have arisen on compliance and enforcement of food safety and quality standards and consumers continue to mount concerns regarding the health risks posed by consumption of these foods. Reports of food-borne diseases also remain a problem in Kenya. Approximately 70% of all episodes of diarrhea are attributable to ingestion of contaminated food and water (FAO/WHO 2005). Food is considered to be safe if there is reasonable demonstrated certainty that no harm will result from its consumption under anticipated conditions of use (FAO/WHO 2003; Romeh *et al*. 2018). Although Kenya lacks a defined and published policy on food safety as part of a wider National Food and Nutrition Policy, there exists food laws designed to protect the consumers. Food safety control agencies operate under various government ministries who are tasked with implementation. Standards for food and agricultural products are developed by technical committees with their secretariats at Kenya Bureau of Standards (KEBS 2005). Food standards give specifications for the compositional requirements, microbial requirements, the tolerance limits for contaminants, packaging, labeling and the hygiene conditions necessary for manufacture of products (KEBS 2005). The functions of these agencies include sensitization and implementation of codes of hygiene and agricultural practices by stakeholders throughout the food chain (FAO/WHO 2005). Despite these, Kenya experiences major problems of non-compliance with basic food safety and agricultural health practices in local markets. The major prerequisite for ensuring food quality and safety is that all stakeholders in the food supply chain recognize that primary responsibility lies with those who produce and process as well as trade, and that public control should be scientific based risk assessment (Piglowski 2018; Romeh *et al*. 2018).

This study was therefore designed to establish and report the presence and levels of chemical residues and microbial contaminants in commonly consumed fruits and vegetables in Kenya. The findings can be used as baseline information to inform the public, government and other stakeholders on the risks posed by presence of contaminants in the food value chain. The findings can be leveraged by risk managers to ensure strict adherence and compliance to food safety standards/regulations and stringent implementation of proper official controls within and outside the Kenyan borders.

2. MATERIALS AND METHODS

2.1 Sample collection

Fruits and vegetables samples were collected from markets and retail outlet in urban and peri-urban towns including Urban retail outlets (Nairobi and Thika) and Peri-urban retail outlet 1 (Nakuru) and Peri-urban retail outlets 2 (Machakos). The samples included kales (*Brassica oleraceae var acephala*), amaranth leaves (*Amaranthus palmeri* and *A. Caudatus*), tomatoes (*Solanum lycopersicum*), and mangoes (*Mangifera indica*). Samples were collected and prepared in triplicates after three different random visits to the common and large open air markets, supermarkets and retail centers in 4 major urban towns (Nairobi, Thika, Nakuru and Machakos) of Kenya. A total of 48 samples were collected, preserved and transported under sterile and cold conditions to avoid sample deterioration and changes.

2.2 Analytical methods

2.2.1 Pesticides residue analysis

Samples were analyzed for all possible pesticide residues using both Gas chromatography (GC) and liquid chromatography (LC) methods. The samples were weighed, cut and homogenized, and a known volume of polar extraction solvent containing internal standards added. The mixture was macerated and then turrax added for homogeneity purposes. Extraction was followed by a salting-out step. Co-extractives were removed by passing a portion of the acetonitrile extract through an octadecyl (C18) solid-phase extraction cleanup cartridge and then, in a second cleanup, through a carbon cartridge coupled to an amino propyl cartridge. Gas chromatography (GC) was done using mass-selective detection in the selected-ion monitoring mode, and for liquid chromatography (LC) with post-column reaction and fluorescence detection for N-methyl carbamates (Fillion *et al*. 2000). The quality process involved analysis of blank sample, duplicate sample and spiked sample in three point calibration standards.

2.2.2 Heavy metals analysis

Analysis of heavy metals in edible parts of vegetables and fruits was determined in hydrochloric solution from plant ash solubilization. Lead and Cadmium levels were analyzed in all the samples using Atomic Absorption Spectrophotometer (AAS) (Unicam 939/959, Pye-Unicam, Cambridge, UK) equipped with an air-acetylene flame and a hollow cathode lamp, and using lamps specific for each element. The device was operated under standard conditions using wavelengths and slit-widths specified for each element (AOAC 2005). In this analysis, 1g of dried and finely ground sample was accurately weighed and incinerated to constant weight. The ash was extracted with 10 ml of HCl:water (1:1) and the extract was quantitatively transferred to 50 ml volumetric flask and made up to the mark. Dilutions were made and the elements analyzed against their standards.

2.2.3 Nitrates analysis

For determination of nitrates, the samples were ground to pass through a 60μm sieve then re-dried in an air oven at 70^oC overnight. Then 0.1g was weighed accurately and suspended in 10ml distilled water. The suspension was incubated at 45^oC for 1 hour to allow complete leaching of the nitrate and then filtered through Whatman No. 41 filter paper. The filtrate was used for analysis of nitrate-N by the method of Cataldo *et al.* (1975)**.** Means and standard deviations were used to assess the contamination levels of nitrates in the vegetable and fruit samples.

2.2.4 Microbial analysis

Microbial contaminants of the samples were evaluated using ISO standard methods. Aerobic meosphiles were analyzed using ISO 4833 method, *Listeria monocytogenes* was analyzed using ISO 11290-1 and ISO11290-2 method, *E. coli* using ISO 16649-1-3:2001 method, *Staphylococcus aureus* using ISO 6888-1:1999 method, *Salmonella* spp using ISO 6579 method, *Clostridium botulinum* using KS 05 220, *Enterobacteriaceae* using ISO 4833 and ISO 21528-2 method. Spread plating was done for individual organisms while pour plating was done for Total Plate Count only. Ten grams (10g) of each sample was aseptically placed into a stomacher bag then homogenized with 90 mL of sterile 0.1% peptone water in a masticator blender for 2 min at room temperature. The microbiological data was then transformed into logarithms of the number of colony forming units (CFU/g). Standard Plate Count (SPC). Yeast and Mold Count (YC) were done on GYEA and Malt Extract Agar respectively by Spread Plate Technique, while Coliform Count (CC) was studied on VRBA by Pour Plate Technique.

2.3 Statistical analysis

All analyses were performed in triplicate (n=3), and the data was presented as means standard error of deviation (±SEM). GraphPad PRISM® version IV software, San Diego, CA was used for statistical analysis. Duncan multiple test at $p<0.05$ was used to compare the least significance of the means.

3. Results and discussion

3.1 Chemical contaminants in fruits and vegetables

3.1.1 Pesticide residues (maximum residue levels, MRLs)

Findings showed that there is a heavy use of pesticides in tomato, kale and amaranth (Figure 1 and 3). The pesticide residues were found all the crops that were assessed. Majority of the residues were found in tomatoes followed by kale, amaranth and lastly mango (Figure 1 and 2). Most of the residues found in the vegetables were within the allowable limits except those of *Dimethoate (>0.02mg/kg), Bifenthrin (>0.05mg/kg), Metribuzin (0.05mg/kg), Cyromazine (>0.05mg/kg), metalaxyl (>0.05mg/kg)* and *Pyrimethamil (>0.02)*. In mangoes only thiabendazole (0.031mg/kg) was detected in all the samples. Thiabendazole is not considered to be acutely toxic and is applied to the peel of the mango which is normally not consumed. The number of pests and diseases that attack vegetables including tomatoes explain the highest use of pesticides in agriculture thus threatening both the environment and consumers' health. Repeated and high doses of pesticide applications to deal with serious pests and diseases that attack vegetables, particularly tomato, may be the major cause of accumulation of pesticide residue beyond allowable limits. Tomato, for example, has in the recent past has faced the occurrence of *Tuta* *absoluta*, a serious pest reported in Kenya, Tanzania, Ethiopia and Eritrea, which has necessitated an increase in pesticide use (Kariathi *et al.* 2016). Similar results were reported in fruits and vegetables collected from markets in Argentina which were analyzed for 35 pesticides, where pesticides were detected in 65% of the total samples of which 56% exceeding the MRLs while chlorpyrifos being the highest residue (Mac Lughlin *et al*. 2018). Further, studies done in Ghana also reported that levels of dimethoate exceeded MRLs in tomato and eggplant samples (Akoto *et al.* 2015). The chemical residues and in particular the derivatives of chlorinated pesticides, exhibit bioaccumulation which can build up to harmful levels in the body as well as in the environment. Tomatoes and kales which were found to contain pesticide residues levels in excess of the MRLs are commodities that are of major importance to the Kenyan population. Majority of the consumers eat for example raw tomatoes without washing as either whole fruits or salads on a daily basis, the residue levels are of concern. In the event of exposure to an acutely toxic pesticide where there are single instances of high pesticide intake could lead to illnesses or even death. Chui *et al.* (2018) in a recent study determined the associations of maternal intake of fruits and vegetables with regard to pesticide residue concentration with fetal growth. The study reported heterogeneity in the relationship between first trimester high pesticide FVs intake and risk of preterm birth by race/ethnicity (Chui *et al*. 2018). Therefore, there is a need for strict implementation of the sanitary and phytosanitary regulations especially on pesticide use to safe guard the health of the Kenyan population.

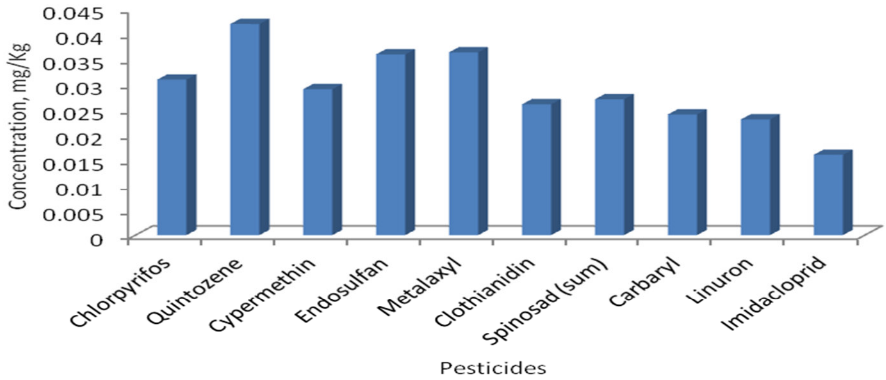

Figure 1. Pesticide residue levels in Kale

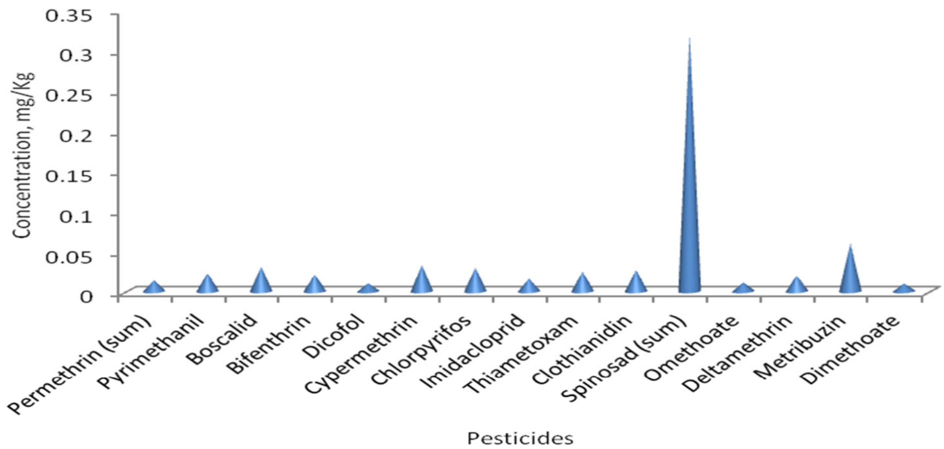

Figure 2. Pesticide residue concentration levels in Tomato

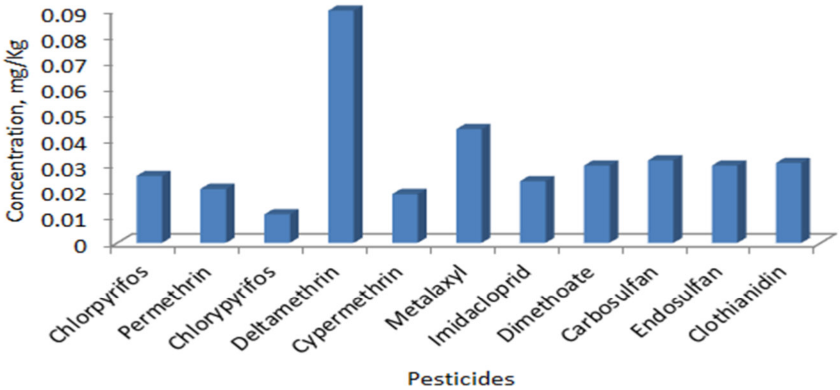

Figure 3. Pesticide residues concentration in Amaranth leafy vegetable

3.1.2 Heavy metals contaminants (Pb and Cd)

Among the heavy metals, lead and cadmium were present in the selected fruits and vegetable sample (Figure 4). Lead concentration ranged from < 0.01 mg/100g to >0.06 mg/100g compared to lower Cadmium concentration of less than 0.01mg/100g dwb in all samples (Figure 4). Vegetable samples contained more Lead than mango fruit while amaranth contained more Lead than kale and tomato. Accumulation of heavy metals varies with plant species and age, environmental conditions in which the plant is grown, part of the plant analyzed and soil mobility of the particular metal ions involved. Recent reports have shown presence of heavy metals (Fe, Mg, Mn, K, Ca, Na, Zn, Cu, Ni and Cd) in edible parts of two vegetables (*Solanum lycopersicum cv. Amal*) and (*Lactuca sativa L. cv Augusta*) and a fruit (*Fragaria x ananassa cv. Sabrina*) from conventional and organic farming in the Eastern-central region of Tunisia (Hattab *et al*. 2018). The accumulation of heavy metals differ according to plant species, the age of the plant, the environmental conditions in which the plant is grown and the part of the plant analyzed and the soil mobility of the particular metal ions involved. Nawab and others (2018) reported similar findings in a recent study showing significant heavy metal concentration of Cr, Zn, Pb, As and Cd in fruits at 45-54% and 43-50% in vegetables which exceeded their respective permissible limits set by FAO/WHO (2001). Similar findings were reported for leafy vegetables which were found to contain the highest metals values especially parsley (543.2 and 0.048. µg/g for Fe and Hg respectively), Jews mallow (94.12 and 33.22. µg/g for Mn and Zn respectively), spinach (4.13. µg/g for Cd) which exceeded the recommended maximum acceptable levels proposed by the Joint FAO/WHO Expert Committee on Food Additives (Ali & Al-Qahtani 2012; FAO/WHO 2003).

It has also been reported that heavy metals represent the fourth most often notified hazard category in the Rapid Alert System for Food and Feed (RASFF) from 1980-2016 mostly in fish and food contact materials, in addition to fruits and vegetables (Piglowski 2018). A risk assessment of heavy metals (Fe, Mn, Zn, Cu and Pb) in common plantain (*P. major L.)* grown in meadowland sites in Egypt showed that *P. major* can be used as a bioindicator and a biomonitor for ecotoxicological risk assessment of heavy metals in urban areas (Romeh *et al*. 2018).

As Lead and Cadmium are relatively immobile in the soil (http://www.atsdr.cdc.gov/toxprofiles/tp13-c6.pdf), leafy crops are most susceptible to contamination from atmospheric deposition of Lead from industrial and automotive sources. The US Food and Drug Administration Advisory Panel suggest that no more than 1 mg of Lead per day be consumed from food (Gordon and Wayne 1993). The majority of dietary Lead results from environmental pollution, especially if the food is grown near roads due to exhaust gases from automobiles, from processing equipment and storage containers fabricated using lead containing materials such as solder (Hattab *et al.* 2018).

Heavy metals are currently of much environmental concern. They are harmful to humans, animals and are susceptible to bioaccumulation in the food chain (Hattab *et al.* 2019). Heavy metals may come from many different sources in urban areas. Atmospheric pollution is a major contributor to heavy metal contamination (Zhong *et al.* 2018). One of the most important sources of air pollution is vehicle emission. Heavy metals are known as non-biodegradable, and persist for long durations in aquatic as well as terrestrial environments. They might be transported from soil to ground waters or may be taken up by plants, including agricultural crops. For this reason, the knowledge of metal-plant interactions is also important for the safety of the environment. Recently, some studies have highlighted the heavy metal accumulation in plants (Nawab *et al.* 2018; Romeh *et al.* 2018). In today's environment, food safety and quality are most important in human health problems, especially in the developing country. Subsequently, food safety has been recognized as such by FAO/WHO/EU Codex Alimentarius Commission (Cockburn *et al.* 2013; FAO/WHO 2003).

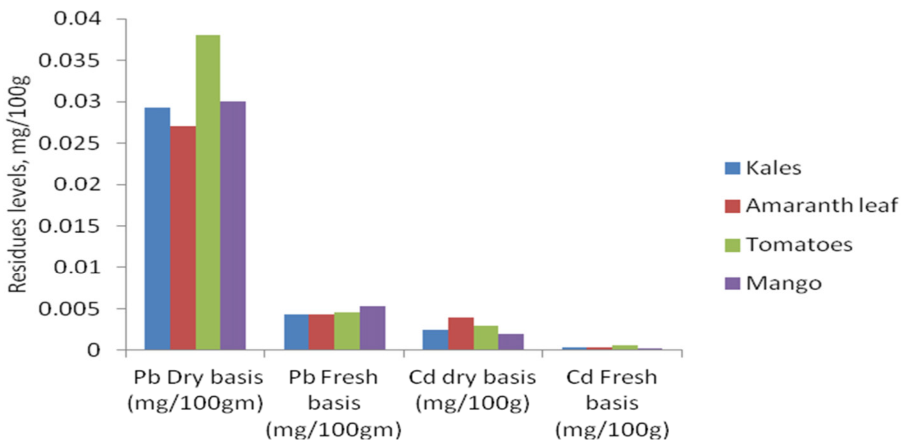

Figure 4. Lead (Pb) and cadmium (Cd) residue levels (mg/100g) in selected fruits and vegetable

3.2 Nitrates levels in selected fruits and vegetables

The nitrate content in fruit and vegetable samples ranged from 100–160 mg/100g fwb in amaranth, 180-200 mg/100g in kale, 120-180 mg/kg in tomato and 195-210 mg/100g in mango sold in the peri-urban and urban retail outlets (Figure 5). Among the vegetable samples the highest content of 200mg/100g fwb was recorded in kales sold in Nairobi urban retail outlets. The study determined the amount of nitrate consumed daily by an adult consuming kale purchased at retail outlet in Nairobi town as an example since kale is one of the most consumed vegetable in Kenya. The determination considered consumption of about 200g per day of vegetable by adults and therefore, the daily intake of nitrates from kale will be 400mg. This amount is far much higher than the maximum safe daily intake of nitrate recommended by WHO for adults of 220mg. However, Nitrates are water soluble and therefore some loss through leaching is possible in cooked vegetables if the cooking water is discarded (Ilić *et al.* 2014).

Nitrate and nitrite are widely consumed by animals and humans, and are also formed endogenously. It is been reported that usually nitrate is metabolized to nitrite and has been shown to be about 10-fold more toxic (Cockburn *et al.* 2013). A risk assessment carried out by the European Food Safety Authority for nitrate in food and nitrite in feed reported that at the current levels of exposure there is no concern for human or animal health. The current acceptable daily intake (ADI) for nitrates is 3.7 milligrams per kilogram of body weight per day (mg/kg bw/day). The safe level for nitrites was re-established at 0.07 mg/kg bw/day, close to the slightly more conservative existing ADI of 0.06 mg/kg bw/day. It has been established that in a risk-benefit assessment that beneficial effects outweigh the risks when nitrate toxicity and benefits of vegetable consumption is compared (Bottex *et al.* 2008). A consequence of nitrogenous fertilization in vegetable production is that if supplied in excess some of the N taken up will accumulate as nitrate in the vacuoles instead of being converted to amino-nitrogen (Romeh 2018). Therefore the benefits of increased yield and increased protein content of leafy vegetables arising from nitrogenous fertilization need to be balanced against the risk of excessive nitrate contents. The nitrate contents of vegetables are therefore a determinant of their quality and there are recommended limits for the nitrate content of vegetables (Bottex *et al.* 2008; FAO/WHO 2003).

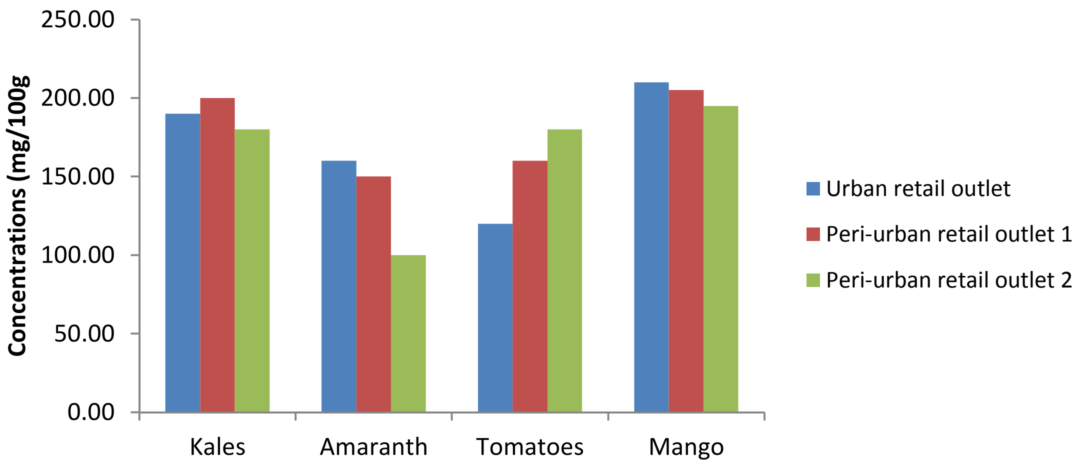

Figure 5. Nitrate levels (mg/100g) of selected fruit and vegetables

3.3 Microbial contamination

Total aerobic counts, Anaerobic bacteria, yeast & moulds, coliforms, Enterobacteriaceae*, Staphylococcus aureus, Listeria Monocytogenes, Escherisia coli* and *Clostridium botulinum* were analyzed in mango, tomato, kale and amaranth samples (Tables 1& 2). *Total* aerobic counts ranged from $1.42x10^3$ - $9.56x10^4$ in the mango, $1.32x10^3$ - $7.01x10^4$ in tomato, $9.50x10^4$ - $9.40x10^6$ in kale and $2.46x10^6$ - $7.60x10^7$ in amaranth leaves. Anaerobic bacteria counts ranged from <1 - $7.74x10^4$ in the mango, $1.83x10^3$ - $5.65x10^3$ in tomato, $9.50x10^2$ - $1.18x10^6$ in kale and $1.83x10^6$ - $9.20x10^7$ in amaranth leaves. The yeast and moulds counts ranged from <1 - $7.26x10^3$ in the mango, <1 - $4.13x10^2$ in tomato, $4.50x10^0$ - $1.24x10^4$ in kale and $3.60x10^2$-$6.10x10^4$ in amaranth leaves (Tables 1-2). The coliforms counts ranged from <1 - $8.50x10^1$ in the mangoes, <1 - $4.03x10^2$ in tomatoes, <1 - $1.22x10^5$ in kales and $9.40x10^3$ - $1.93x10^6$ in amaranth leaves. *Enterobacteriaceae* counts ranged from $1.07x10^3$ - $8.60x10^1$ in the mango, <1 - $8.14x10^3$ in tomato, <1 - $1.13x10^6$ in kale and $1.00x10^2$ - $1.00x10^7$ in amaranth leaves. The *S. aureus* counts ranged from $1.40x10^2$ - $8.51x10^2$ in the mangoes, $2.00x10^1$ - $9.35x10^3$ in tomatoes, $1.92x10^3$ - $3.34x10^5$ in kales and <1 - $4.74x10^6$ in amaranth leaves. Findings show that samples were heavily contaminated and showed high microbial counts showing poor hygienic and handling practices. Among the pathogens analyzed, *Salmonella* was detected in 7 samples mainly tomato, mango, kale and amaranth leaves collected in open air markets in Nairobi, an urban center.

Table 1: Microbiological contamination of selected fruit and vegetable samples in retail outlets in urban centers

Commodity	**Microorganism**	**Open air market**		**Supermarkets**	
		Counts cfu/cm²	***Log 10 cfu/cm²***	***Counts cfu/cm²***	***Log 10 cfu/cm²***
Mango	*Total aerobic counts*	$6.57x10^3$	3.82	$8.95x10^4$	4.95
	Anaerobic bacteria	$3.95x10^3$	3.60	<1	<1
	Yeast & moulds	$4.20x10^1$	1.63	$1.70x10^1$	1.23
	Coliforms	$8.50x10^1$	1.93	<1	<1
	Enterobacteriaceae	$3.67x10^2$	2.56	$8.60x10^1$	1.94
	Staphylococcus aureus	$3.67x10^2$	2.56	$5.49x10^2$	2.74
Tomato	*Total aerobic counts*	$1.32x10^3$	3.12	$1.55x10^3$	3.19
	Anaerobic bacteria	$1.83x10^3$	3.26	$1.02x10^4$	4.01
	Yeast & moulds	<1	<1	<1	<1
	Coliforms	$1.15x10^2$	2.06	<1	<1
	Enterobacteriaceae	$2.60x10^2$	2.41	<1	<1
	Staphylococcus aureus	$5.28x10^2$	2.72	$2.00x10^1$	1.30
Commodity	***Organisms***	***Counts cfu/g***	***Log 10 cfu/g***	***Counts cfu/g***	***Log 10 cfu/g***
Kales	*Total aerobic counts*	$6.25x10^5$	5.80	$9.50x10^4$	4.98
	Anaerobic bacteria	$6.05x10^5$	5.78	$9.50x10^2$	2.98
	Yeast & moulds	$3.30x10^3$	3.52	$1.24x10^4$	4.09
	Coliforms	$6.40x10^4$	4.81	<1	<1
	Enterobacteriaceae	$5.80x10^5$	5.76	<1	<1
	Staphylococcus aureus	$3.34x10^5$	5.52	$1.92x10^3$	3.28
Amaranth leaves	*Total aerobic counts*	$2.46x10^6$	6.39	$2.27x10^6$	6.36
	Anaerobic bacteria	$1.83x10^6$	6.26	$1.90x10^6$	6.28
	Yeast & moulds	$1.94x10^4$	4.29	$6.10x10^4$	4.79
	Coliforms	$4.90x10^4$	4.69	$7.80x10^4$	4.89
	Enterobacteriaceae	$6.20x10^5$	5.79	$1.13x10^6$	6.05
	Staphylococcus aureus	$1.01x10^5$	5.00	$1.05x10^5$	5.02

Similar studies have reported pathogenic contamination of fruits and vegetables in retail markets in Korea with high prevalence of *L. monocytogenes* (0.6%)*, E. coli* O157:H7 (0.8%), *Cl. perfringens* (13.3%) and *Staphylococcus aureus* 1.4% of the fresh produce (Tango *et al.* 2018). A wide spectrum of fresh produce vehicles have been associated with *Salmonella* infections. *Salmonella* is the pathogen most frequently linked to consumption of fruit and vegetables (Verma *et al*. 2018). Several large-scale outbreaks have been linked to consumption of tomatoes (Verma *et al.* 2018). Our findings also reported *E. coli* which was detected in two of the samples i.e. kales and amaranth leaves collected from retail outlets mainly supermarket in Nairobi, an urban center. Several studies have reported produce-associated outbreaks of *E. coli* O157 infections linked to consumption of leafy green vegetables and these have been increasingly recognized (Chanseyha *et al.* 2018; Tango *et al.* 2018). *E. coli*, especially the STEC O157:H7 adhere strongly to tomato skin, spinach leaves and roots of alfalfa sprouts and can be a serious pathogen in vegetables.

L. Monocytogenes and *Cl. botulinum* were absent in all the fruit and vegetable samples collected (Table 1 & 2). *Campylobacteriosis, Salmonellosis, Yersiniosis, Listeriosis* and *botulinusm* have been shown to cause serious health effect in human and animals (Chlebicz & Śliżewska 2018). *Cl. botulinum* is the most serious cause of food poisoning. The toxin produced by this bacterium is extremely toxic and lethal. Being a spore former, this bacterium can survive in harsh conditions such as low water activity and pH. Recent investigations have identified fruits and vegetables as the source of many food borne disease outbreaks especially foodborne illnesses associated with multidrug resistant bacteria (Chanseyha *et al.* 2018; Chlebicz & Śliżewska 2018). *Salmonella* was the most commonly reported bacterial pathogen, accounting for nearly half of the outbreaks due to bacteria (Tango *et al.* 2018).

Many factors have been showed to contribute to high microbial counts in fresh fruits and vegetables (Chanseyha *et al.* 2018; Markland *et al.* 2017). Water sources used for agriculture have been shown to be important source of contamination of foods (Markland *et al.* 2017). Use of water in postharvest processing has also played a key role in the high contamination in fruits and vegetables. This is made worse by poor water supply and sanitation in most markets. Dirty water is also used to wash the fruits and vegetables before display. In addition, other possible sources are run-off from nearby animal pastures and irrigation from a contaminated source. The risk associated with using water from a range of sources that vary in microbiological quality for irrigation of produce has been assessed and the need for improved guidelines recognized (Markland *et al.* 2017). Pathogens may also be transferred to the environment by application of inadequately composted or raw animal manures or sewage (Alegbeleye *et al.* 2018; Chlebicz & Śliżewska 2018). This is more prevalent in urban and peri-urban towns in Kenya where there are poor sewage systems where most of the vegetables are grown. The faeces of wild animals may also be a source of contamination (Alegbeleye *et al.* 2018). For fruits, insects are also a possible source of contamination. Studies have shown that contaminated flies can directly transfer bacteria to plant leaves or fruits (Alegbeleye *et al.* 2018; Chlebicz & Śliżewska 2018). The postharvest handling practices in all the towns for both the supermarket and open air markets was poor leading to high contamination levels in the produce. Post harvesting processes, ranging from storage and rinsing to cutting, have been shown to be common sources of contamination with best practices in household preparation methods being shown to reduce the levels significantly (Chung 2018).

Table 2: Microbiological contamination of selected fruit and vegetables in retail outlets in peri-urban centers

Commodity	**Microorganism**	**Open air market**		**Supermarket**	
		Counts cfu/cm²	***Log 10 cfu/cm²***	***Counts cfu/cm²***	***Log 10 cfu/cm²***
Mango	*Total aerobic counts*	$7.81x10^4$	4.89	$9.56x10^4$	4.98
	Anaerobic bacteria	$3.49x10^4$	4.54	$7.74x10^4$	4.89
	Yeast & moulds	$2.97x10^3$	3.47	$7.26x10^3$	3.86
	Coliforms	$1.50x10^3$	3.17	$4.49x10^3$	3.65
	Enterobacteriaceae	$4.37x10^4$	4.64	$5.67x10^3$	3.75
	Staphylococcus aureus	$8.22x10^3$	3.92	$4.49x10^4$	4.65
Tomato	*Total aerobic counts*	$7.01x10^4$	4.85	$1.28x10^4$	4.11
	Anaerobic bacteria	$2.86x10^4$	4.46	$3.86x10^3$	3.59
	Yeast & moulds	$4.13x10^2$	2.62	$3.49x10^2$	2.54
	Coliforms	$1.16x10^2$	2.07	$4.03x10^2$	2.61
	Enterobacteriaceae	$5.84x10^4$	4.77	$8.14x10^3$	3.91
	Staphylococcus aureus	$2.51x10^3$	3.40	$3.19x10^3$	3.50
Commodity	***Organisms***	***Counts cfu/g***	***Log 10 cfu/g***	***Counts cfu/g***	***Log 10 cfu/g***
Kales	*Total aerobic counts*	$4.90x10^5$	5.69	$3.20x10^5$	5.51
	Anaerobic bacteria	$5.20x10^4$	4.72	$4.40x10^4$	4.64
	Yeast & moulds	$4.50x10^0$	0.65	$8.50x10^0$	0.93
	Coliforms	$3.50x10^4$	4.54	$1.28x10^4$	4.11
	Enterobacteriaceae	$3.10x10^5$	5.49	$1.17x10^5$	5.07
	Staphylococcus aureus	$4.90x10^3$	3.69	$9.35x10^3$	3.97
Amaranth leaves	*Total aerobic counts*	$3.95x10^6$	6.60	$5.20x10^6$	6.72
	Anaerobic bacteria	$4.05x10^6$	6.61	$3.20x10^6$	6.51
	Yeast & moulds	$1.22x10^4$	4.09	$3.60x10^2$	2.56
	Coliforms	$9.40x10^3$	3.97	$4.80x10^5$	5.68
	Enterobacteriaceae	$3.70x10^5$	5.57	$1.00x10^2$	2.00
	Staphylococcus aureus	$1.50x10^4$	4.18	<1	<1

4. Conclusion

Fruit and vegetables sold locally in urban (Nairobi and Thika) and peri-urban retail outlets (Machakos and Nakuru) have high levels of chemical and microbial contaminants. The results show that raw fruits and vegetables are contaminated by microorganisms including human pathogens. Heavy use of pesticides in tomato, kales and amaranth production was also evident in the foods as indicated by the high level of pesticide residues some of which were above the recommended maximum limits. Levels of Heavy metals found in the samples were within the limits allowed in plant samples. The study also showed that there is lack of compliance to food safety standards and hygienic practices, thus predisposing consumers to health risks. Government agencies mandated to ensure compliance and enforcements of food safety regulations should have stringent control measures to address consumer risks to hazards. The public should be sensitized on potential exposure to hazards in fruits and vegetables and some of the control measures that can be used to minimize risk exposure. Capacity building and training of small holder farmers and traders handling fruits and vegetables in retail outlets should be initiated to educated farmers on control measures that can be used to minimize risks in the food chain.

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