HEAVY METAL INTAKE ASSOCIATED WITH CONSUMPTION OF FREE RANGE CHICKEN PRODUCTS IN KENYA: A CASE OF EMBAKASI SUB-COUNTY, NAIROBI COUNTY

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DEPARTMENT OF FOOD SCIENCE, NUTRITION AND TECHNOLOGY

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DECLARATION

This dissertation is my original work and has not been presented for a degree in any other University

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DEDICATION

To my Father and Mother whose guidance in life on good values and importance of education are unchallenged.

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LIST OF ACRONYMS

AAS	-	Atomic Absorption Spectroscopy
ADI	-	Acceptable daily intake
AOAC	-	Association of Official Analytical Chemists
Bw	-	Body weight
CAC	-	Codex Alimentarius Committee
CDC	-	Center for Disease Control
Con	-	Concentration
EDI	-	Estimated daily intake
EFSA	-	European Food Safety Authority
EOSQC	-	Egyptian Organization for Standard and Quality control
EPA	-	Environmental Protection Agency
ESRD	-	End Stage Renal Disease
EWI	-	Estimated weekly intake
FAO	-	Food agriculture organization
FR	-	Free range Chicken
FSANZ	-	Food Safety Australia and New Zealand
FSSAI		Food Safety Systems Authority of India
HM	-	Heavy Metal
IARC	-	International Agency for Research on Cancer
ICP/AES	-	Inductively coupled plasma optical emission spectrometry
ICP/MS	-	Induced coupled plasma mass spectroscopy
IOSHIC	-	International Occupational Safety and Health Information Centre.
JECFA	-	Joint Expert Committee on food additives

JKIA	-	Jomo Kenyatta International Airport
KARLO	-	Kenya Agriculture and Livestock Organization
KEBS	-	Kenya Bureau of Standards
KNBS	-	Kenya National Bureau of Statistics
KS	-	Kenya Standard
MoALAD	-	Ministry of Agriculture and Livestock Development
MoH	-	Ministry of Health
NAG –N	-	Acetyl-β-D-glucosaminidase
NCR	-	National Research Council
ND	-	Non-Detectable
NOEAL	-	No-Observed-Adverse-Effect Level
NS	-	Not set
PMTDI	-	Permissible maximum tolerable daily intake
PTWI	-	Provisional tolerable weekly intake
WHO	-	World health organization
WI	-	Weekly intake

GENERAL ABSTRACT

Enormous volumes of waste in form of water effluent, solid domestic waste or e-waste is generated in urban set up raising environmental concerns as they eventually end up in the food chain. Some of these are heavy metal contaminants which are common in peri-urban agriculture practices of free-range chicken that may lead to unsafe exposure to consumers yet limited information on the same exist in Kenyan scenario. The current study was carried out to determine the levels of heavy metals in free range chicken products and exposure of their consumers. A base line survey was carried out to assess the production and consumption of chicken products in the study area while heavy metals levels were determined by use of Atomic absorption spectroscopy. Consumption data and contamination were fit in @risk Palisade software to estimate exposure by chicken consumers in Embakasi area, exposure levels and distribution of heavy metals were determined with overall lead and copper in poultry exhibiting Laplace distribution, while cadmium and mercury had an exponential distribution. The consumption of free range chicken was found to be 78.1 % compared to exotic broilers (15.7 %) with more male consuming chicken (60.7 %) compared to the females (39.3 %). The muscle part of the chicken was found to have the highest preference (85.1 %), followed by gizzard at 4.5 %, liver at 1.7 % and other chicken parts at 2.5 %.

The mean levels of all metals varied significantly ($P<0.05$) in the different chicken products. Average cadmium was found to be 0.04 ± 0.004 mg/kg in liver, 0.03 ± 0.004 mg/kg in muscle, 0.04 ± 0.01 mg/kg in gizzard and 0.04 ± 0.00 mg/kg in eggs. The level of lead was 0.26 ± 0.01 mg/kg in muscle, 0.28 ± 0.01 mg/kg in liver, 0.21 ± 0.02 mg/kg in gizzard and 0.04 ± 0.00 mg/kg in eggs. Copper levels were 0.52 ± 0.02 mg/kg in muscle, 0.79 ± 0.05 mg/kg in liver, 0.50 ± 0.03 mg/kg in gizzard and 0.53 mg/kg in eggs. Levels of mercury were 0.029 ± 0.01 mg/kg in liver, 0.027 ± 0.0293 mg/kg in muscle, 0.027 ± 0.00 mg/kg in gizzard and 0.0186 ±

0.00 mg/kg in eggs. The mean cadmium levels in environmental samples were 0.715 ± 0.22 mg/kg in soil and 0.12 ± 0.10 mg/kg in vegetation; lead was 1.64 ± 0.55 mg/kg in soil, 0.205 ± 0.04 mg/kg in water and 0.21 ± 0.02 mg/kg in feed. Mercury levels were 0.55 ± 0.20 mg/kg in soil and was not detected in water. Copper was found to be < 3.28 ± 0.78 mg/kg in all samples. Dietary intake would not exceed levels of 0.004 mg/kgbw/day for mercury, 0.0025 mg/kgbw/month for cadmium, and 0.5 mg/kgbw/day for copper in free range chicken products. However, the safety levels were exceeded for lead which was 1.1 µg/kgbw/day at 95 percentiles against EFSA 0.5 µg/kgbw/day. In general, the risk of heavy metals was low except with lead in free range chicken products which indicated likelihood of high intake levels. This raises concerns in levels of lead in the environment necessitating the need for urgent interventions by agencies to check levels of lead in the environment.

CHAPTER ONE: GENERAL INTRODUCTION

1.1 Background information

Rearing of free range poultry is considered a substitute to the supply of poultry meat in major urban cities in Kenya to meet dietary needs as well as serving as an employment for a considerable population in the informal and formal habitats in urban centers Bett *et al*. (2012). Rapid industrial growth, advances in Peri- urban agriculture, fertilizer use, raw sewer discharge into water channels and other human activities are the genesis of heavy metal contamination within the County of Nairobi (Akoto, 2008). Besides pollution from heavy metals, the dispersion of metal by-products has evidential health impact on human beings either during production, recycling or disposing (King'ori *et al*., 2010).

In Nairobi and other urban centers free range chicken are reared in small flocks of up to 30 birds (Nyaga, 2007) which are marketed in Street Side kiosks along the highways, estate roads, food joints or in dedicated market centers while some Peri urban farmers keep their flocks in enclosure providing feeds in form of commercial feeds and homestead left overs. Others leave their chicken to forage and scavenge for food in the open environment thereby exposing chicken to heavy metal contamination (King'ori *et al*., 2010). According to Ghadimi *et al.* (2013) and Khairy (2009), not only does dioxin and heavy metal contamination cause significant problem to the environment, they are the main agents of pollution through their discharge from urban centers and homestead into rivers.

According to King'ori *et al.* (2010), Kenya has an estimated population of 22 million free range chickens. About 90 % of the population in up-country use free range system to rear the chicken usually in small flocks, of 30 chicken per flock. The poultry industry is flexible and requires a small piece of land to be practiced as compared to other industries like dairy and beef (Ayieko *et al.*, 2015). This is best explained by Kenyans who consider to rear chicken upon their dismissals or retirements (Nyaga, 2007). There has been a growing trend by city dwellers to engage in Peri-urban activities to substitute salaries and business earning. With limited space, feeding of free-range chicken involves the provision of commercial feed or letting the chicken free in the neighborhoods (Oforka, 2012). There has also been indication of peri-urban free range chicken rearing in the dumpsite in Dandora with intention to commercially avail the chickens to the wider population for economic gains (Ayieko *et al*., 2015).

World Health Organization (WHO) and Kenya government through KEBS-2017 have set out heavy metal maximum contamination levels for dressed chicken intended for the market, WHO levels are as follows: mercury maximum levels is set at 0.03 mg/kg, cadmium 0.05 mg/kg, lead at 0.1 mg/kg while copper has no restriction since it is a microelement necessary for cell development even though Australia and New Zealand authority has set a limit of 200 mg/kg on copper. Heavy metals according to Williams (2017) bio-accumulate in livestock that include free range chicken as a result of scavenging for food from waste disposal, along traffic, feeding in dumpsites in addition to other harmful chemical substances. The current study therefore aimed to establishing the levels and intake of heavy metal contamination in products sourced from such agricultural production activities.

1.2 Statement of problem

Peri-urban poultry farming is increasingly being used as an alternative supply of free range poultry meat source, nutrients, food security and a source of employment (FAO, 2011). The poultry in such areas that are also informal slum settlement feed on contaminated water sources such as along effluent diversions that are likely to be contaminated by heavy metals (King'ori *et al.*, 2010). According to Rehman *et al*. (2012), chicken products from free range chicken that are reared under free range system have higher concentration of heavy metal than those produced conventionally because of consuming feeds on the ground (soil) that contains traces of heavy metals. However, there is little or no information on the possible accumulation of heavy metals in poultry reared in Embakasi area that has high peri-urban production of free-range chicken with wide spread market of free-range chicken indicating high consumption. It is therefore important to establish the safety of free-range chicken product due to indications of environmental contamination and establish potential linkages since Embakasi Sub County is composed of river networks, industries and is the largest municipal dumping site for Nairobi County which may be a source of food chain contamination.

1.3 Justification

According to FAO (2011), among the rapidly growing and adopted production concept in agriculture is Peri- urban agriculture which recognized by city residents as an alternative source of income and nutritious food. Despite peri-urban poultry production being considered as an alternative urban farming system in Kenya, scanty knowledge regarding safety of the end products is known, thus still a potential health risk to Nairobi (Bukar, 2014).

Several chemical contaminants from industrial effluent, raw sewage, pesticides and other industrial chemical wastes that find their way into water channels or drainage system, have been reported to have the capability to impact negatively on the quality aspects of natural feeds available for poultry (Chauhan *et al.,* 2014). There is little understanding on constraints faced in poultry Peri-urban poultry farming, for instance, mortality level that might have been caused by toxins, due to prolonged intake and exposure to feeds contaminated with heavy metal residues and likely transfer of heavy metals to human diet Johri (2010).

Majority of Nairobi county dwellers believe that poultry is safe due to recent debates on food safety antibiotics concerns in exotic broiler poultry supplied in Nairobi city Kirui (2014). The information and data will be useful in advising policy makers if there are risks associated with consumption of poultry, ways to mitigate and improve health of Nairobi county Embakasi sub-counties population.

1.4 Aim

The aim of the study is to contribute towards reduction of health risks associated with consumption of free range peri- urban poultry laced with heavy metals.

1.5 Purpose

The purpose of the study is to contribute towards food safety knowledge on risks associated with consumption of peri-urban chicken products in Embakasi area of Nairobi County.

1.6 Objectives of the study

1.6.1 Overall Objective

The overall objective of this study was to determine the intake of heavy metal contaminants by consumers in Embakasi Sub-County, Nairobi Kenya.

1.6.2 Specific Objectives

1. To determine consumption patterns and characteristics of free range chicken consumers in Embakasi.
2. To determine levels of cadmium, copper, mercury and lead in chicken muscles, gizzards, liver and eggs in relation to environmental contamination levels in Embakasi Sub-county.
3. To estimate dietary intake of heavy metal residues from chicken consumption in Embakasi sub counties and compare with WHO and EFSA guidelines in order to assess potential food safety hazards.

1.7 Hypothesis

1. Consumption of free range chicken in Embakasi Nairobi does not differ with chicken parts.
2. There are no significant residues of Lead, cadmium, copper and mercury in free-range poultry produced and marketed in Embakasi area of Nairobi County.
3. Intake of lead, mercury, cadmium, and copper through consuming free-range poultry products produced in Embakasi area higher than WHO or EFSA standards.

CHAPTER TWO LITERATURE REVIEW

2.1 Poultry farming in Kenya

The high rate of human population growth has spurred the increased demand for high quality and versatile protein food leading to high demand for poultry products. This has also been facilitated by the increased income level of the population (FAO, 2011). According to Bett et *al*. (2012), among poultry, chicken is the most reared across the globe and also the leading in terms of population. In the rural areas, as well as peri-urban areas, free range chicken are reared as source of livelihood and nutrients. Almost 90 % of Small-scale farmers in Kenya rear free range poultry, a large percentage being chicken. Chicken are reared for economic benefits and source of protein in the home stead at times used for cultural rites during occasions (Adoum *et al.*,2015). According to Nyaga (2007), the poultry sub-sector has become a source of employment, therefore playing a role in the general economic development.

Kenya had an approximate of 31 million heads of poultry back in the year 2016, Seventy-six percent of this population were indigenous chickens reared under free range (FAOSTAT, 2016).

Poultry keeping is especially attractive to poor households as they require low start-up capital and have low maintenance costs.

2.1.1 Free range Poultry production system

According to Bett *et al*. (2012), managing chicken under free range system relies on the indigenous technical skills available. Birds are released during the day to scavenge for feeds, such as grains, insects and grass and are confined in the evening until morning (Omiti and Okuthe, 2010).

2.1.2 Semi-intensive Poultry production system

This system of production is adopted by well-off households as compared to families that rear poultry under free-range system. Chickens that are kept using this system are both free range and exotic; they scavenge for feed during the day just like those under free range system. The only difference is that during evening they are confined in a shelter that is a bit costly (Mongothe, 2012). According Omiti (2010) a semi-intensive system is a combination of both extensive and intensive poultry productions. The semi-intensive system is common in urban, peri-urban and rural areas whereby birds are sheltered at a particular time of night while being provided with feed and water.

2.1.3 Commercial – Intensive Poultry production system

This system of production involves use of highly mechanized equipment, which makes production easy to run, with high returns. According to Mongothe *et al*. (2012), commercial poultry production systems are more common in urban areas as opposed to rural areas. The system involves rearing of flocks numbering as much as 500 birds which are fully sheltered and fed throughout. The intensive production system has higher returns both for eggs and free range chicken (FR) meat production with better controls in form of health care for birds while limited losses due to theft and predators (Mongothe *et al.*, 2012). Some of the producers involved in integrated production system include Muguku poultry in central province and Kenchic in Nairobi. Kenchic requires contracted farmers contract farmers to be within 50km around the city with a capacity of 3000-12000 birds (Omiti, 2011).

2.2 Occurrence of heavy metals in food products

The exposure of mankind to heavy metals is a major threat to human health (Sharma, 2015). Several studies have been conducted on the effects of such heavy metals on the health of human. International bodies like WHO conduct regular studies to find out any development with regards to the heavy metals (Flora, 2012). Man has exploited heavy metals for economic purposes for years and still exploits them to date. According to Sharma (2015), Documentation of the potential hazards and effects of heavy metals on one's health has not been able to bring sanity over the exploitation of heavy metals. Ahmed *et al.* (2017) noted exposure of these heavy metals to human still persist and is considered as part of the ecosystem especially in nations that are less developed, while in the last 100 years' nations that are developed have witnessed decline in emissions.

A concrete definition of heavy metals has never been developed, however density has been used to determine a heavy metal. Based on the density of a metal, if it exceeds a density of 5 g/cm^3 it is regarded as a heavy metal. Therefore, this type of metal or metalloid is linked to environmental contamination as well as toxicity (Sparks, 2005).

Dangerous chemicals, biological and/or physical substances contained in air, water and/or food endangers human species. Berglund (2001), argues that the critical determinant on the toxicity level depends on the contact time an individual is exposed to substances containing heavy metals. According to Berglund (2001), a contact must occur between the perceived contaminated substance and outer parts of an individual's body such as the mouth, airways, and/or the skin.

As far as toxicity level is concerned, exposure can be defined as the time one is subjected to a toxic substance of a given concentration (EFSA, 2012). It can be further defined or elaborated as an incident where the external part of the body gets into contact with contaminated substances of a specified concentration in the environment for a given period (NCR, 1991). For exposure to happen, a co-existence of heavy metals and human population must happen. According to Sharma *et al. (*2009), the intake of mercury, lead and other heavy metals by human population via the food chain occurs across the globe. Soil has its capacity that it can withstand the toxicity associated with the accumulation of heavy metals (Singh and Agrawal, 2010).

2.2.1 Occurrence of Cadmium in food

Along with copper, zinc and lead, cadmium occurs in ores naturally. The compounds of Cadmium are used for various economic reasons, for instance, as color pigment, in rechargeable nickel-cadmium batteries, phosphate fertilizer and stabilizers in PVC products Adamse(2017). Persons who do not smoke are exposed to hazards associated with cadmium via food (WHO, 2011). According to Karanja *et al. (*2012), most food consumed contains cadmium; however, the concentration varies sharply, and depending on one's dietary habit. Under the Environmental protection Agency (EPA), Cadmium is a regulated heavy metal used as anti-corrosion and decorative coatings on metal alloys (Shama *et al*., 2015).

Among notable characteristics include soft, silvery, ductile and faint bluish tinge. Cadmium is a mixture of eight isotopes with an atomic weight of 112.40. Among the likely entry points in the food chain include waterways via industrial discharges and brakeage of galvanized pipes (Jinadasa *et al*., 2014). When ingested, cadmium poses a health risk through displacement of zinc due to its similarities in chemical characteristics (Colasanti *et al*., 2013). According to International occupational safety and health information center- IOSHIC (2010), low exposure results in kidney damage and in some instances cancer (IARC, 2010).

2.2.2 Occurrence of Mercury in food

The use of mercury compound cinnabar (HgS), is dated back in the ancient times by the Greeks commonly referred to as white lead for cosmetic purposes especially bleaching the skin, while in pre-historic era it was used to paint caves with red colors (Robin *et al.*, 2011). Mercury compound has been used in the provision of healthcare, for instance, curing syphilis (Robin *et al*., 2011), mercury amalgam and calomel (Hg_2Cl_2), used in many nations to fill teeth, not forgetting mercury compounds have also been used as diuretics (WHO, 2010).

Mercury is normally converted from inorganic mercury into organic compounds, such as poisonous methyl mercury, that is considered to be stable and predominantly found in fish and other sea food products while organic forms is predominantly found in other food stuff (Arnich *et al*., 2012). Its tendency to accumulate in the food chain was realized in 1970s after its methyl mercury was used as a means to control seeds from being attacked by fungi while the first know deaths as a result of exposure to organic mercury in the form of dimethyl mercury as cited in St. Bartholomew hospital in London (Zhuang, 2015). According to WHO (2010), humans are exposed to the various compounds of mercury through food. Studies conducted have indicated mercury amalgam fillings emit mercury vapors and the rate is enhanced during food chewing process.

2.2.3 Occurrence of Lead in food

Air and food are the main source for lead exposure to human (Zhang, 2015). Pots made of lead used for cooking and storing food were considered to be the source of lead in meals served to people. Pot wine was also made sweet through the use of lead acetate. Lead accumulates in the skeleton and is released from the compartment of the body slowly (Odhiambo *et al.*, 2010). According to WHO (2011) lead in blood has an approximate half-life of one month; while that in body skeleton has half-life of 20-30 years (WHO, 2010). According to Mania (2015) uptake of Lead is more in children than adult due to the relatively higher gastrointestinal uptake and the permeable blood-barrier making children more susceptible to exposure than adults. Among other uses of lead include manufacture of storage batteries, cables, protection clothing against radiation and tetraethyl lead used in gasoline as antiknock agent. According to Tsafe (2012), heavy metals that are most abundant and toxic include Lead and Cadmium.

2.2.4 Occurrence of Copper in food.

Copper is an important macro nutrient in animal body, however, extreme amounts may be detrimental to human health, Copper has been isolated from chicken liver in amounts meeting WHO set standards Ahmed (2017). According to Haleelu *et al.* (2015), copper being an essential trace element is important in human diet include normal constitute of animal tissues and fluids critical in hemoglobin synthesis and other enzyme functions with both deficiency and excess having undesirable effects. Copper is included in chicken diet in recommended proportions, a basil level of 8mg/kg is ideal (Samanta *et al.*, 2011) copper has various functions in biological systems among them is maintenance of cytochrome. Enzyme tryosinase, ascorbic acid oxidase and ferroxidase are critical in iron metabolism and collagen formation while melatonin production is key central nervous system functioning of which copper is a constituent (Samanta *et al*., 2011).

2.3 Occurrence of heavy metals in poultry products

2.3.1 Occurrence of heavy metal in Eggs

Eggs are considered to be a complete diet based on the number of vital nutrients available in a fresh egg. In addition, different food products use eggs in the production process to serve various purposes (Ahmed, 2017). Some of the sources of these elements (heavy metals) are water and feeds as reported. Bukar *et al.* (2012) and Hashish *et al.* (2012) argued that an increased cadmium content in a feed has a positive correlation with increased cadmium content in an egg. A review conducted recently by Kan *et al*. (2007), gave depth on the transferability of poisonous substances to eggs from the consumed feeds.

According to Waegeneers *et al*. (2009), cadmium concentrations in the eggs sampled did not meet the threshold for quantification. This was, however, contrasted by a research conducted by Fakayode *et al*. (2003), that revealed an average concentration of cadmium in eggs to be 0.07mg/kg. This level was found to be higher compared to those found in other international standards as well as local standards (Kan *et al.*, 2007). Chicken have the capability to control the deposition of metals into the eggs by avoiding mineral deposition (Nisianakis *et al.,* 2008). Despite the presence of multiple protection layers that are sufficient against the deposition of chromium and manganese, they are insufficient for minerals like Lead in the egg.

2.3.2 Occurrence of heavy metal in gizzards, liver, muscle and eggs

According to Akoto *et al*. (2014), lead and cadmium are considered the most poisonous heavy metals and have no known biochemical use to human or animals. Felsmann (1998), argued that birds are vulnerable to accumulate much heavy metals in their bodies because of the high rate of metabolism due to their small body size. Cadmium levels in poultry in Egypt were found to be very low. However, in muscle samples from Assiut upper Egyptian province, nickel was found to be the highest metal residue. Poultry muscles have higher tendency of accumulating metals (except Aluminum) than the liver. Such observation was supported by Iwegbue *et al*. (2008) in Nigeria where the levels of cadmium, lead, nickel, copper and zinc were higher in the meat of the chicken than gizzards. Studies done in Bangladesh (Ping Zhuang *et al*., 2014) on different concentration of heavy metals in poultry parts revealed that chicken were successful in sequestering lead and copper in feathers which is in agreement with earlier research that feathers can play a role both in storing and eliminating metals (Tsipoura *et al.,* 2011).

The highest level of mercury in poultry products was discovered in skin and liver of chicks with likely entry source by Mariam *et al.* (2004) attributed to intake of mercury-contaminated feeds. Likely human activities leading to environmental contamination with mercury include heavy use of pesticides and fertilizer, contamination of water bodies, industrial wastes leading to mercury escape into the air, soil thus getting accumulated in fodder plants and hence animal tissues. The codex committee has set acceptable maximum levels of various heavy metals as listed in Table 2.1

Table 2.1. Heavy metal concentration maximum levels in selected foods

Food/Product Group	Lead (Pb) (mg/kg)		Cadmium (Cd) (mg/kg)		Mercury (Hg) (mg/kg)		Copper (Cu) (mg/kg)	
	Min	Max	Min	Max	Min	Max	Min	Max
Brassica vegetables	NS	0.3[b]	-	0.05[b]	-		-	2[a]
Fruit vegetables e.g. Cucumber	NS	0.1[b]	-	0.05[b]	-		-	5[a]
Leafy vegetables broccoli	NS	0.3[b]	-	0.2[b]	-		-	5[a]
Eggs	NS	0.1[b]	-	0.05[b]	-		-	1[a]
Rice polished	NS	0.2[b]	-	0.4[b]	-		-	10[a]
Poultry	NS	0.1[a,ks]	-	0.05[b,ks]	-	0.03[b,ks]	-	7[a]
Muscle of Pig, cattle, sheep and goat	NS	0.1	-	0.05[a]	-	0.03[b]	-	400[a]
Fish	NS	0.3[b]	-	0.1[a]	-	1[a]	-	-
Infant formulae	NS	0.02[b]	-	0.01[a]	-	0	-	-

Source: [a]EC commission No 1881/2006 of 19 Dec 2006, [b]codex Stan 195- 1995, [ks]KEBS-2017, NS-Not set

2.3.3 Occurrence of heavy metals in poultry manure

Copper and other heavy metals have been isolated from the poultry manure according to Osolo, (2015). Levels of lead and mercury were found to be far below what would be considered hazardous in wastes. According to Osolo, (2015) the mercury levels in manure have been found above the minimum limit in salt (food grade). Delgado, (2013) indicated that poultry manure was relatively safe to use on land with respect to heavy metal pollution, however constant monitoring was necessary to reduce possibility of soil toxicity. Sustainable poultry manure management must be implemented to address the entire manure chain from its production point at the poultry house through the storage, transport process and end use points whether as fertilizer, cattle feed or fuel (Osolo, 2015)

2.3.4 Occurrence of heavy metals in vegetables

Famers supplement poultry feed with vegetable left overs such as kales, spinach, amaranths, dark shade and pumpkin leaves. According to Atayese *et al.* (2009), vegetables such amaranths and pumpkin leaves accumulate heavy metals such as lead, copper and chromium in the aerial parts. Studies by Othman (2001) showed more than 60 % higher contents of heavy metal in pumpkin and amaranths compared to Chinese cabbage, leafy cabbage or cow peas leaves. Accumulation of heavy metals differ according to plant species, plant age and environmental conditions in which the plant is grown (Hooda *et al.*,1997). According to Mkamburi (2015), vegetable amaranths sourced from Njiru and Ruai in Kenya were found to have high levels of lead recorded at 2.8 ppm above the recommended by KS 435:2012 which is 2 ppm.

2.3.5 Occurrence of lead, cadmium, copper and mercury in soil

Lead, cadmium and copper among others accumulate in soils (Karanja *et al.*, 2010). High levels of cadmium (14.3mg/ kg), chromium (9.7 mg/kg) and lead (1.7 mg/ kg) were found to accumulate in soils in Kibera and Maili saba in Nairobi, Kenya. Crops grown in these types of soil lead to high phyto-accumulation of cadmium, chromium and lead which are eventually bio-accumulated in vegetation (Kabata and Pedias, 1984). According to Kimani (2010), Dandora dump area contribute significantly to heavy metal pollution with soil samples analyzed indicating high levels of heavy metals lead, cadmium, copper and chromium. According to Njagi (2013), medical assessments of the population around the damping site indicated that children and adolescents experienced medical conditions associated with exposure to high levels of heavy metals.

2.3.6 Occurrence of heavy metal contaminants in poultry feeds

Heavy metal entry into food chain occurs via many routes such as animal feeds among them poultry feed is no exception. According to Ukpe *et al.* (2018), in most cases, heavy metals are transferred from soil to plants, animals and consequently man through bioaccumulation. Copper, zinc, arsenic and cadmium have been isolated from poultry feeds, RASFF alerts and notification have raised concern on high levels of lead in animal minerals of higher than 30 mg/kg while cadmium has been reported in fish meal at 41 % above maximum levels (Riklit, 2017).

2.4 Toxicological and health effects of selected heavy metals in human foods.

The consumption of food contaminated with heavy metals has adverse effects on the health of an individual; the adversity depends on intake level (WHO, 2011). According to Rehman (2013), heavy metals such as cadmium and lead are deposited in the kidney after consumption, resulting into kidney dysfunction as well as a declined reproductive capacity, and hypertension. Inhaling cadmium fumes or its particles is a threat to life, even though cases of acute pulmonary effects and deaths are uncommon, it does not rule out their occurrence (Vengris, 1974).

Cadmium exposure has the potential to impair the kidney. The initial sign of renal lesion is exhibited by excretion of a reduced molecular weight proteins [such as β_2-microglobulin and α_1- microglobulin (protein HC)] or enzymes [such as N-Acetyl-β-D-glucosaminidase (NAG)], a condition regarded as tubular dysfunction (Aiad, 2001). A Linkage between chronic renal failure [end stage renal disease (ESRD)] and cadmium exposure was revealed in a recent study (Nikhil, 2010). Experiments conducted on animals have revealed that cadmium has a potential to cause cardiovascular disease, however studies on humans have not confirmed the risk factor of the cadmium (Aiad, 2001).

According to European food safety authority EFSA (2012), there is consideration for possible future lowering of existing maximum levels for a number of important contributors to dietary exposure (cereals, potatoes and other vegetables), a recommendation focusing on a progressive implementation by food firm operators and farmers' and available mitigation measures for reduction in the levels of cadmium in food (EFSA, 2012). This recommendation encourages further research and investigations to fill any possible gaps in knowledge on mitigation methods. Mercury is launched to the environment using both natural and anthropogenic sources (Chauhan, 2014). Once released into the environment, mercury undergoes numerous complex transformations and cycles between ocean, atmosphere, and land (Cardo, 2014). Methyl mercury is one of the common compounds formed after the series of the transformation that finds itself into the food chain (Robin *et al.*, 2011).

Other than the kidney being the main target for heavy metal toxicity, immune system, nervous system, liver, developmental and reproductive systems are also affected (Robin *et al.*, 2012). Methyl mercury has been proven to have the capability of penetrating the hair follicle, cross the placenta, the blood-brain and finally the blood-cerebrospinal fluid barriers, thus allowing accumulation in hair, the fetus and the brain (Enry,2001). Body irritation, abdominal pain, and headache are some of the symptoms associated with acute lead poisoning (Flora, 2012). Another condition caused by lead exposure characterized by sleeplessness and restlessness is referred to as lead encephalopathy (Flora, 2012). In a serious case, one suffering from this condition experiences reduced consciousness, acute psychosis, and confusion (Flora, 2012). Children who have been subjected to lead toxicity have exhibited instances of behavioral disturbances, concentration and learning difficulties (Flora, 2012).

Numerous published studies have documented the adverse effects of lead in children and grown-up's (IARC, 2010). Multiple studies on the negative effects of lead exposure on human health have been published and documented. According to Flora (2012), studies have indicated the linkage between blood lead, lower intelligence quotient-IQ, impaired hearing capability, neurobehavioral development, retarded growth, anti-social, poor attention and language handicaps (van der Kuijp *et al.*, 2013). According to Gagan and Flora *et al*. (2012), toxicity mechanism of lead is well documented with cellular, intracellular and molecular mechanism manifestation due to toxicological effects of lead in the body, oxidative stress representing imbalance between production of free radicals and biological system capacity to detoxify, rectify or repair resulting damage as a result of exposure. In the presence of lead oxidative stress occurs in two pathways simultaneously that include generation of free radicals (ROS) such as hydro peroxides ($HO_2^{\cdot}$) and hydrogen peroxide(H_2O_2) leading to antioxidant depletion (Flora *et al.*, 2002).

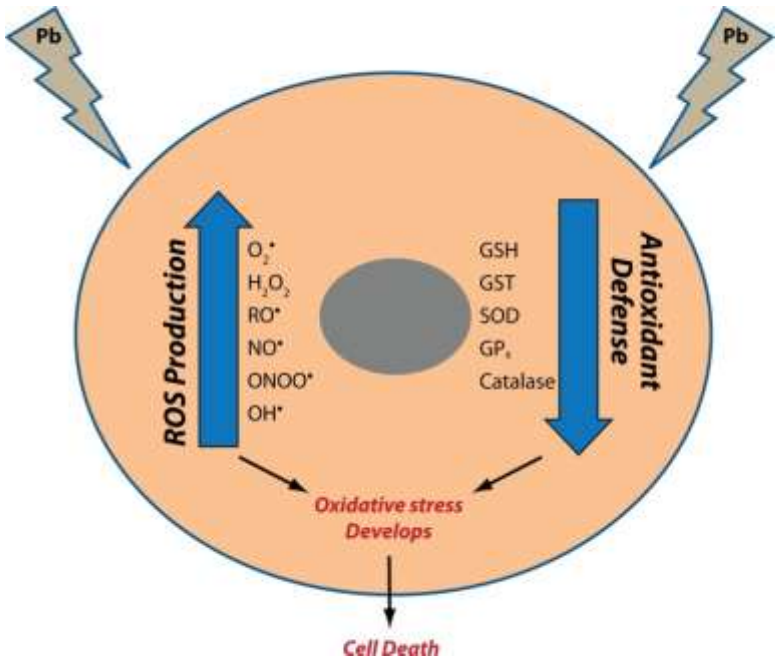

Figure 2.1: Mechanism underlying the development of oxidative stress in a cell on lead exposure (source flora *et al*, 2002)

According to Juberg (2000), despite copper being an essential macronutrient, excess exposure could lead to wilson's disease & Menke's disease with the former being a condition described by excessive accumulation of copper in body organs that include liver, brain kidney and cones. Menkes disease is characterized by peculiar hair, severe mental retardation, neurological impairment and death at 3 years of age (Juberg, 2000).

2.5 Analysis of heavy metals

2.5.1 Atomic absorption spectroscopy (AAS)

AAS is an analytical technique employed to determine the concentration level of a given element present in a specified sample. This technique is robust in determining 70 plus elements in a given sample or solution (FSSAI, 2015). The use of this technique is vast for instance, clinical analysis of metals and biological fluids such as urine, plasma, semen, saliva, liver and muscle (FSSAI, 2015). Some pharmaceutical firms use this technique to monitor the quantity of a given catalyst that remains after production of the final drug, as well, as analyzing water required for its metal content (FSSAI, 2015).

2.5.2 Induced Coupled plasma atomic emission spectroscopy (ICP/AES)

ICPA/AES is an analytical technique that is used to detect traces of metals that are in small quantity in a given sample. This technique is also known as inductively coupled plasma optical emission spectrometry (ICP-OES) (FSSAI, 2015). It relies on spectral emission which uses plasma that have been coupled inductively to generate excited ions and atoms, which are responsible in the emission of electromagnetic radiations at wavelength that characterize a given element (FSSAI, 2015). It can also be regarded as a flame technique since it uses a flame of temperature ranging from 6000 to 10000 K. According to Stefansson *et al. (*2008), it can be referred to as a solution technique if methods of standard silicate dissolution are used. The emission intensity indicates the concentration of an element in the presented sample. (FSSAI, 2015).

2.5.3 Induced coupled plasma mass spectroscopy (ICP/MS)

ICP/MS is a more robust type of mass spectrometry that has the potential to detect metals and numerous non-metal elements in a given sample, even if the concentration is as low as one part in 10 ppq (parts per quadrillion) on non-interfered low-background isotopes (FSSAI, 2015). This capability is realized by ionizing the sample provided with plasma coupled inductively and later separate and quantify the ions using a mass spectrometer (FSSAI, 2015).

2.5.4 Appropriate sample preparation method for heavy metal lead, cadmium, copper and Mercury analysis via AAS method

Metals such as magnesium, zinc, iron, copper, cobalt, and chromium in trace amounts are important in biochemical functions in living organisms, at high concentration effects are disastrous leading potential toxicity. According to Jinadasa (2013), trace metals can cause serious environmental pollution due to their toxicity, non-biodegradability and persistence. Due to health effects such as reduction in cognitive development, increase in blood pressure and induction of renal tumors in adults for lead and cases of liver damage as a result of excessive copper exposure (Jinadasa, 2013). There is therefore need to quantify levels of heavy metal in samples through appropriate sample preparation for realization of credible results to be achieved.

According to Hseu (2004), it is important to prepare samples through simple digestion ahead of quantification of heavy metal through available machinery (digestion) which can either be closed or open digestion system using different combination of acids such include $HCLO_4$, HF, HCL, HNO_3 and some oxidants like H_2O_2. Sample Digestion can either be wet digestion or dry ashing with wet digestion being carried out in either an open system or in a closed vessel (Muinde *et al.*, 2013). According to Ranasinghe *et al.* (2016), dry ashing has better recovery for cadmium, chromium and Copper contents

CHAPTER THREE

CONSUMPTION PATTERNS AND CHARACTERISTICS OF FREE-RANGE CHICKEN CONSUMERS IN EMBAKASI AREA, NAIROBI COUNTY, KENYA

3.1 Abstract

Consumption of free range chicken is on the increase in Kenya and more so in urban set up with sources being Peri-urban or rural areas. Limited information exists on consumption pattern of free range chicken among peri-urban inhabitants in major Kenyan cities, Nairobi included. The current study aimed at determining the consumption pattern among inhabitants in Embakasi Sub-county Nairobi County. This was a cross-sectional survey involving both qualitative and quantitative aspects and data was collected using semi-structured questionnaire. The results showed that there was high consumption of free range chicken (78.1 %) than exotic broilers (15.7 %) among the 242 inhabitants that were surveyed. Consumption was also high among males (60.7 %) compared to females (39.3 %). Those who consumed the free-range chicken once a week accounted for (35.1 %) while those who consumed the chicken once a month accounted for (22.7 %.) The preference for consuming chicken muscle was (85.1 %) while that of gizzard and liver was (4.5 %) and (1.7 %), respectively. The preferred units of packaging ranged from 0.25 Kgs to >1 kg, though the most popular unit of packaging was whole chicken at (47.5 %). Significantly *($p<0.05$)*, high number of respondents (43.8 %) purchased poultry products from the street-side market, kiosks and butchers (40.5 %) while few (8.3 %) purchased products from supermarkets. There was a strong significant association between occupation, education and income levels and consumption frequency ($p<0.001$) while association between age and consumption frequency noted to be significant ($p=0.005$). Consumption of free range chicken is more popular among male gender, frequencies are dependent on disposable income, occupation and perceptions of quality attributes such as taste.

This study provides most current information on free range chicken consumption hence useful to consumer, producer, policy makers, authorities and other stake holders in poultry research.

3.2 Introduction

Agriculture contributes 26 % to Kenyan gross domestic product (GDP) through export earnings (65 %) while livestock production contributes about 25 % of the agriculture contribution to the GDP (Alessandro and WBG, 2015). Chicken is one of the sources of protein with a high demand in the market given the fact that it is white meat hence considered healthier compared to beef. The demand for chicken in urban areas has created business opportunities for several players in the poultry sector. According to the Kenya National Bureau of Statistics (KNBS), 2009 census figures, free range indigenous chicken population is estimated to be 25,756,500 chickens which is about 81 % of the total poultry population (KNBS, 2009). Most currently GoK (2010) reported an increase in numbers of chicken to about 28 million out of which 79 % is free range chicken. According to Nyaga (2007), the poultry sector plays a critical role in fostering the economy of Kenya as it is among those that contributes to 30 % of the total GDP contributed by the agricultural sector. Free range chicken and other exotic chicken are considered luxury by the rural population (Strategia *et al.*, 2016).

Free range chickens (FR) (*Gallus domesticus*) according to National Flock Identification Scheme (NFIS) is defined as chicken that are adopted to harsh environmental conditions that include extensive, small-scale, free range and organic production system. They are also referred to as traditional, scavenging, back-yard, village, local or family chicken (Ayieko *et al*., 2015). Introduction of improved free range chicken breeds has played instrumental role in increasing production. Among those introduced include Kenya Agricultural Research Institute improved Kienyeji, Kenbro by Kenchic limited and Rainbow roosters with reported advantage of early maturity of about 5 months (Otieno *et al.*, 2016). The consumption significance of free range chicken in urban areas is evidenced by increase in bird production estimated to be about 25,756,500 (Kenya National Bureau of Statistics, 2009), daily transportation from metropolis such as Thika, Machakos, Makueni around Nairobi due to ready markets offering better prices with meat being favored due to sweetness and leanness (Omondi *et al.*, 2014).

The free range chicken is mostly preferred among consumers due to its health benefit as compared to the exotic broilers. In addition, the meat of free range chicken is preferred due to its leanness, unique taste, and color (Adoum *et al.*, 2015). Rural areas, as well as peri-urban areas, have increased production of free range chicken to meet the growing demand in urban areas (Kabuge, 2017). Free range chicken, therefore, has a role in enhancing food and nutrition security in Kenya since it satisfies the two main elements of food security, which are, accessibility and availability (Kiilholma, 2007). According to Nyaga (2007), in nearly all rural areas and Peri urban families in Kenya keep on average, 13 birds which contribute to their social, economic and cultural welfare. This notably contributed to the rise in per capita consumption of meat from 14.9 Kgs in 1991 to 16 Kgs in 2007 which is expected to rise to 22 Kgs by year 2050.

According to Bett *et al.* (2012), markets for free range chicken and meat in general in urban set up in Kenya can be categorized into 3 levels which vary in product, operations, location and number of participants at each level. According to Aringa (2008), the 3 levels indicate social and economic stratification of the population, primarily the segmentation being based on income levels of the consumers. The first level is composed of the low-end income, which consumes meats classified as meat on borne, tripes, and liver, where there are no refrigeration facilities. The Second level, also referred to as middle level, has meat products offered in varying proportions and types including steak, meat on borne and tripes. The Third level consists of consumers willing to pay extra for benefits of packaging, safety and quality of product and non-division of free range chicken and meat products into to smaller portions. The three levels exist within Embakasi, the area of study, due to existence of low, mid and few high-end estates.

It is thus vital that the consumption of chicken is studied to understand the dynamics and Food Safety implications. The study was designed to determine current consumption pattern, diversity and preference of free range Chicken in the urban areas of Nairobi Embakasi Sub County.

3.3 Materials and methods

3.3.1 Area of study

Data on the consumption of chicken were purposely collected in selected Embakasi Sub County areas with high population density classified into four main geographical and environmental condition, based on presence of river network, proximity to municipal dump site, high peri-urban farming activity coupled with high residence homesteads and areas with high industrial activities. The considered estates include: Dandora, Kariobangi, Umoja, Buruburu, Mukuru Kwa Njenga, Embakasi Village, Kayole Pipeline, Saika, Nyayo Estate and Imara Daima.

3.3.2 Data collection

A Cross-sectional survey was adopted and a total of 242 respondents randomly interviewed based on population (n) size of area and area coverage involved in the survey. A semi-structured questionnaire (Appendix 1) was utilized to collect data from the respondents with the help of research assistants. Data was collected from 18th June 2018 to 30th June 2018. The questionnaire was pre-tested using one of the sub-county wards to eliminate bias. The questionnaire captured chicken consumption frequency, prices, quantity purchased, gender, age, academic levels, source of chicken, complaints among respondents, average prices, chicken parts and portions preferred and reason for preference.

3.3.3 Sample size determination

The sample size was determined according to Cochran formula (Glenn. 1992).

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}}$$

Where n_{0}= Cochran large population sample size recommended = 385(Glen 1992), N is population size and n is new adjusted sample size. For purpose of this study N=650 was considered as target chicken consumer households considering popularity of chicken consumption among inhabitants in study area (Glen, 1992).

Using small sample Cochran formulae sample size was determined as follows

$$n = \frac{385}{1 + (\frac{384}{650})}$$

$$n = \frac{385}{1.59} = 242.1$$

Respondents were selected randomly across the Embakasi region and consent for their responses sought. Table 3.1 indicates the distribution of the 242 respondents. The sample distribution was based on the area coverage as well as the reception from the respondents.

Table 3.1: Distribution of free range chicken consumer respondents in Embakasi, Kenya

Distribution	**No. Respondents**
Dandora phase; 1,2,3,4, and 5, Kariobangi South and North	56
Mukuru Kwa Ruben, Imara Daima	38
Umoja, Pipeline, Jogoo Road and Nyayo Estate	84
Buruburu, Kayole, Saika, Njiru and Kangundo Road	64
Total respondents	**242**

3.4 Data analysis

Consumption data collected was subjected to analysis of variance using SPSS for windows software version 20 (IBM version 20). Chi square analysis was done to determine levels of various associations and test of significance set at (*P=0.05)*. Data collected using questionnaires was analyzed using SPSS version 20 software by entering the variants namely consumption frequency, levels of education, preferred part, gender, respondents age, income levels, occupation, preferred sources, portions, weights of respondents and respective observed responses. Using descriptive statistics and cross tabulation, frequencies were analyzed to establish percentage, associations and frequencies of the various observations.

3.5 Results and Discussion

3.5.1 Socio-demographic and socio-economic characteristics of free range chicken consumers in Embakasi

The social demographics and social economic characteristics of chicken consumers is represented in Table 3.2. There were more male (61 %) consumers compared to females (39 %). Research carried out by Adoum (2015) reported more male respondents (70 %) compared to female (30 %) in preference of free range chicken. The dominance in male respondents in the study over female can be explained by the fact that family budget decision is predominantly made by male who are working or engage in business activities therefore more endowed (Ndenga *et al.,* 2017).

Table 3.2: Social –demographic and socio-economic characteristics of free range chicken consumers in Embakasi

Characteristics	Frequency (n=242)	Percentages
Female	95	39.3
Male	147	60.7
Age range:		
15-20	47	19.4
21-25	71	29.3
26-30	94	38.8
31-35	25	10.3
36-40	5	2.1
>40	0	0
Education levels		
Primary Education	29	12
Secondary Education	52	21.5
Advanced Secondary	96	39.7
Tertiary Education	65	26.9
Income Levels (USD) (1USD=100ksh)		
<100	31	12.8
100-150	63	26.0
151-250	9	3.7
251-350	21	8.7
351-450	54	22.3
451-550	46	19
551-650	15	6.2
>650	3	1.2
Occupation types		
White color	36	14.9
Business and self employed	86	35.5
Casual worker	91	37.6
Student	14	5.8
Other (Domestic servant, Driver)	15	6.2

The age of respondents ranged from 15 years to over 40 years with majority (38.8 %) being 26-30 years of age. Most of the respondents had attained advanced secondary education (39.7 %) followed by tertiary education (26.9 %) reflective of the general inhabitants of the sub county composed of fairly educated population. Similar findings were noted by Nyanja (2016) with over 66 % of respondents having education above advanced secondary level of education.

Income ranged from < USD. 100 to > USD.650 with the majority (26 %) of the respondents earning between USD.100-150 per month followed by those earning USD.350-450 per month while those earning > USD. 650 constituted only 1.2 % of the respondents. According to KNBS (2018), wages payable to urban workers has continued to increase on average between 2016 to 2017 from an average of Ksh.15980 (USD. 159.8) to Ksh.17423 (USD. 174.23) per month for dwellers in Nairobi, Mombasa and Kisumu. The rates translate to about USD. 5.8 per day payment which is above the recommended a dollar a day baseline for people living below poverty line. From the study findings majority of respondents (Casual labor and Business/self-employment) indicated a mean of USD. 5 per day for the casual labor while the Self- employed indicated a mean on USD. 12 per day. This generally indicates ability of respondents to frequently consume free range chicken based on one's desire.

There is a significant number of population 12.8% in Embakasi that earn less than a dollar a day which is lower than the national poverty level figures of 36.1% (KNBS 2018) the low percentage could be attributed to a higher distribution of people leaving below poverty line mostly found in the rural parts of the country compared to urban areas, this segment of population is unable to afford free range chicken frequently thus only consume either during occasions, during festive seasons or opt to purchase offal parts of broiler chicken from vendors within the informal sectors.

Occupation was diverse with casual workers noted to be highest among the respondents (37.6 %) followed by business or self-employed (35.5 %) while the blue collar accounted for 14.9 % of the respondents. Occupation according to Kenya National Bureau of Statistics (2018) is classified based on the task one performs with general works including sweepers, gardeners, watchmen, house ayaya and messengers among others. In public sectors, occupation is defined based on grades with the lowest grade B1 earning USD.144.4 per month while in private sector occupation types vary with salary scales dependent on tasks performed. Among the most important group to be considered include the youth according to British council (2017) constituting 61 % of the population and mostly engaged in ICT and small business enabling residents earn to consume various services and goods.

3.5.2 Gender, Age and types of chicken consumed in Embakasi area

Among the chicken available for choice, the free range chicken (FR) was the most commonly purchased (78.1 %) followed by exotic breeds (15.7 %) while a population of 6.2 % indicated not to consume chicken (Figure 3.1). The popularity of free range chicken can be attributed to overall improvement and introduction of new early maturity breeds by breeders and proximity of traders of IC to house locations. Bett *et al. (*2012) in his study reported that free range chicken was more popular (43 %) among bird's meat in city of N'Djamena in Chad.

Figure 3.1 indicates the consumption of free range chicken with respect to the age bracket for both men and women.

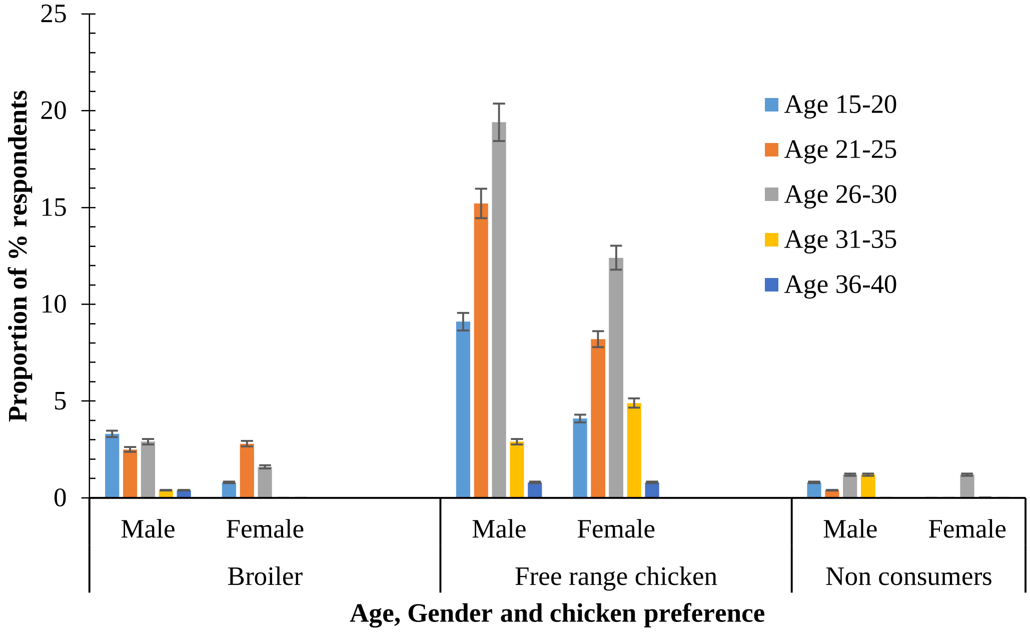

Figure 3.1 Consumption of chicken based on gender and age in Embakasi, Nairobi Kenya. The bars indicate standard error of means

Consumption of free range chicken is slightly lower for both men (9 %) and women (4 %) at the age bracket of 15-20 years. This can be attributed to the fact that most people at this age cannot afford free range chicken which is slightly more expensive. Free range chicken is consumed more for both men (19 %) and women (12 %) at the age of 26-30 years. A similar study conducted by Musyoka (2010) also found out that at this age people are economically empowered hence can afford free range chicken. The high consumption trend among youth is in agreement with work done by Abong' *et al*. (2010) on potato snacks consumption. The decline in the consumption of IC among people between age 36 - 40 years (2.1 %) can be associated with an increased responsibility, for instance paying school fees for secondary school which is expensive thus reduction in purchasing power.

Above 40 years of age recorded low levels of preference for free range chicken. Work done by Ndenga *et al*. (2017), reported a decrease in consumption with increase in age in Makueni, with age among households' head having a negative and significant ($P<0.001$) influence on consumption of free range chicken.

3.5.3 Gender, chicken type and preferred parts of chicken

Figure 3. 2 indicates the consumer gender in relation to chicken type and preferred part of chicken.

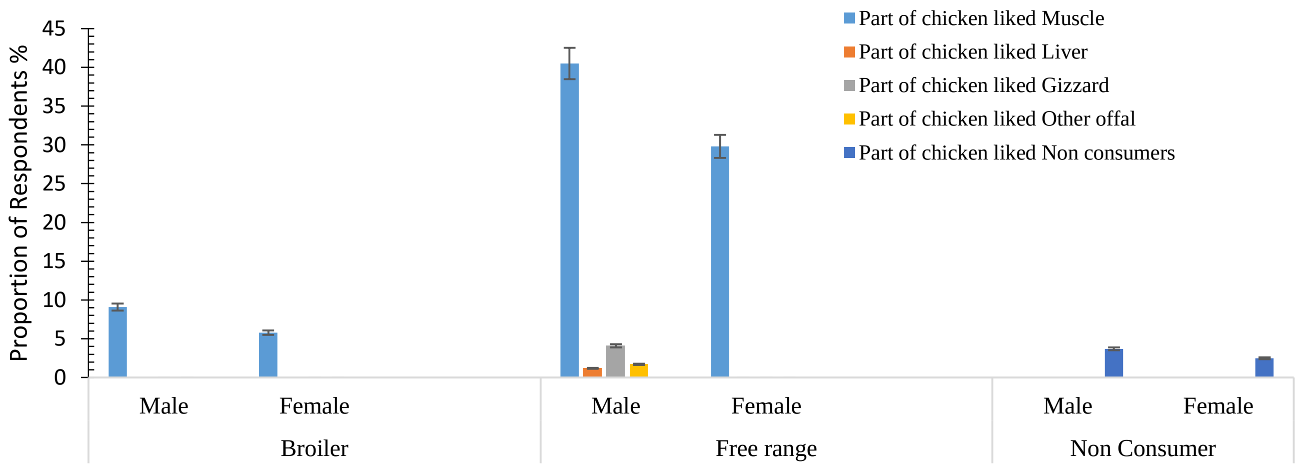

Figure 3.2. Gender, chicken types and preferred poultry part of consumers in Embakasi, Nairobi Kenya. The bar represents standard error of means.

The study showed (Figure 3.2) both male and female prefer the muscle part of chicken at 41 % and 30 % respectively compared to other portions. However, gizzard is only preferred by 4.5 % of the respondent majority being males. Similar studies conducted in Malaysia had similar results (Jayaraman *et al.*, 2012). It can be argued out that muscle parts are more favored as they constitute more of the edible part compared to other parts which are offal.

3.5.4 Education levels and chicken consumption

Figure 3.3 shows the education levels of the respondents and preferred type of chicken.

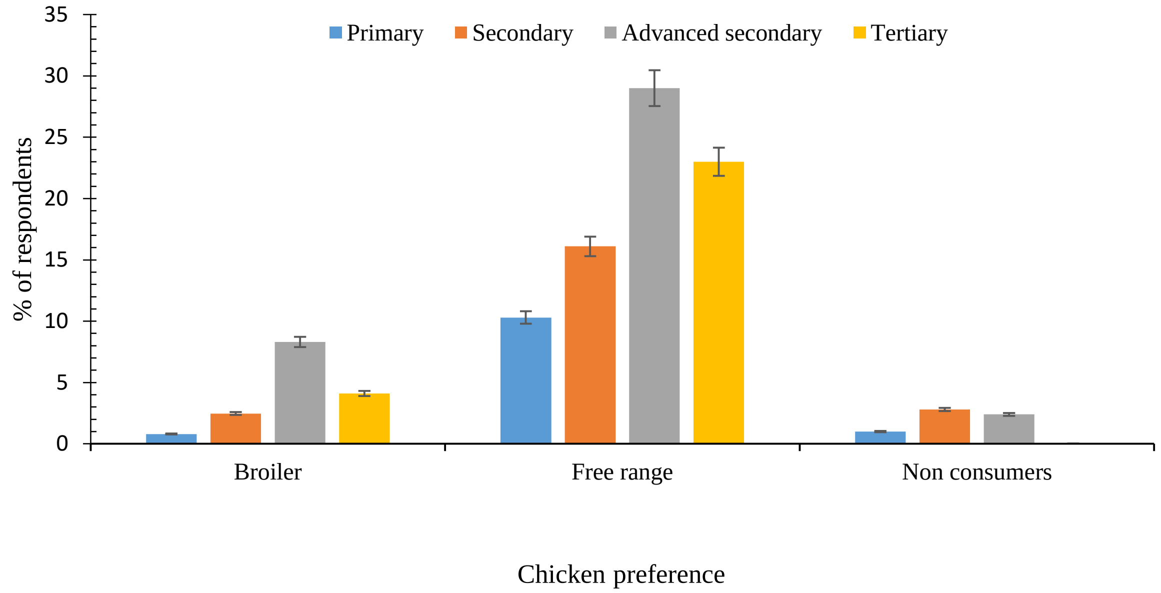

Figure 3.3 Education levels and preferred chicken type in Embakasi, Nairobi Kenya. The bars indicate standard error of means.

The level of education among free range chicken consumers within Embakasi varied with a significant proportion 29 % having achieved advanced secondary education, tertiary accounted for 23 %, secondary 16 % while primary education level accounted for 11 % of free range chicken consumer's respondents.

Within Embakasi area, 8 % of respondents with advanced secondary education indicated they preferred exotic chicken (broiler) while only 1 % of those preferred exotic breeds attained primary school level of education. Education levels in this study agree with a research carried out by Nyanja (2016) on age of respondents participating in free range chicken consumption and value chain enhancement in Baringo. Education levels have an influence of consumption frequency, type of chicken consumed and reason for preference. The results agree with findings by Ndenga *et al.* (2017) indicating better educated family have better nutrition consciousness.

3.5.5 Education level and free range chicken portion in Embakasi area

Figure 3.4 shows the influence of level of education on parts of a chicken consumed. Those that consumed muscles part of the chicken were the highest numbers (83 %) among all categories of level of education while advanced secondary (33 %) had the highest preference of muscle among the education levels. Liver was the least preferred part (2 %) by respondents with advanced secondary with no one with primary education preferring to consume liver. High level of muscle preference can be attributed to size of muscle in relation to size of chicken with offal parts forming a small proportion of overall chicken size.

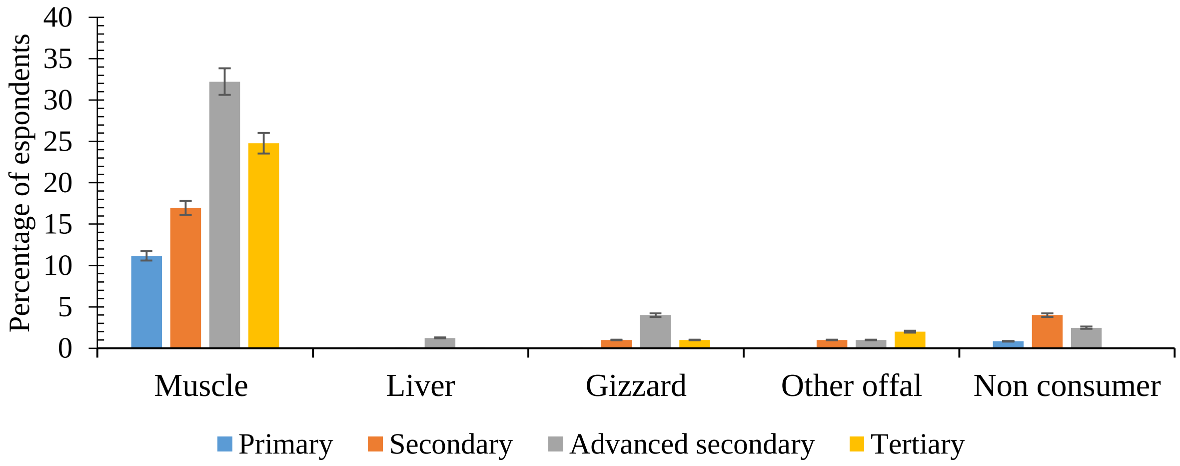

Figure 3.4: Education level and chicken portion consumed. The bars represent standard error means.

The findings indicate overall education level of respondents does not determine what parts of chicken one consumes but has a statistically significant effect on type of chicken consumed. According to Silva *et al.* (2010), price was indicated as the most determining factor for chicken consumption levels.

Table 3.3 gives the reasons for various preferences of chicken types by consumers. The study established relationship between education and reasons for preference of free range chicken (Table 3.3) showing that respondents had various reasons for preference with majority of the respondents (38 %) due to taste, healthy (28 %) while the least 1 % indicated ease of preparation as reason for choice.

Table 3.3 Education levels of respondents in Embakasi and reason for preference of free range chicken

	Reason for preference of free range chicken					
Academic level	Sweet	Healthy	Free of chemicals	Cheap	Easy to prepare	Total %
Tertiary	14	5	4	3	0	26
Advanced secondary	13	10	6	8	0	37
Secondary	7	8	2	2	0	19
Primary	4	5	2	1	1	13
Total %	38	28	14	13	1	95%

A high number of respondents with tertiary level (14 %) and advance secondary level (13 %) of education indicated taste as a driving reason for choice. Even though some (5 %) for tertiary and (10%) for advanced secondary did not consider health as a reason for choice. Bett *et al.* (2012) and Adoum *et al.* (2015) in their study noted that customers make choices based on taste, pigmentation among other preferences. The study findings are further supported by findings by Silva *et al.* (2010) that decision to consume meat products is primarily done due to culinary taste (62%) and not nutritive value. A proportion of respondents (13%) across all levels of education indicated price to be a determining factor for the choice of type of chicken consume.

3.5.6 Income, Occupation levels and chicken consumption

The respondents within the study area of Embakasi region have different sources of income depending on their respective occupation. This influences their living standards and eating habits. Figure 3.5 indicates the income range for the respondents and type of chicken preferred.

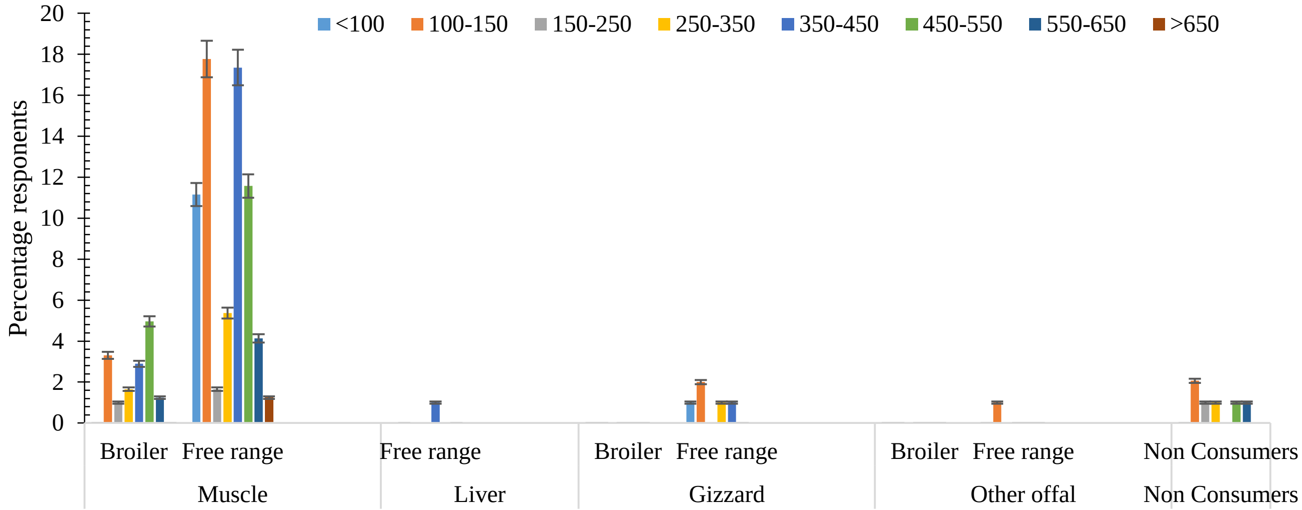

Figure 3.5: Income of respondents, chicken type and part preferred by consumer of free range chicken in Embakasi, Nairobi Kenya. The bars indicate standard error of means.

The findings of this study agree with another study by Omondi (2014) that found out that the income level of people is a determinant of consumption levels. There is a significant association between occupation type and disposable income among free range chicken consumers in Embakasi area. The high number of casual labors is indicative of the salary range among consumers with those within the minimum wage noted as 34.3 %. Most business and self-employed (29 %) indicated a salary range between USD. 150 to 350 per month based on business performance on average within this range. Most consumers indicated a consumption frequency of free range chicken of once in a week while muscle part of free range chicken being preferred over other parts. A significant low number of consumers earn more than USD. 350. It can be argued out that with the few high-end estates within Embakasi area house rent takes a significant portion of disposable income thus reduced intake of free range chicken. Majority of the population within the study area are middle class and low-income earners. The income range among the respondents for this study within the Embakasi region is <10000 -> 65,000Ksh. (USD. 100- 650).

3.5.7 Occupation, consumption frequency and portion sizes of chicken consumers in Embakasi

The respondents within the study area have diverse occupations with different consumption patterns and preferences Table 3.4 indicate various trends that exist in consumption in line with occupation and portion sizes of free range chicken.

Table 3.4 Occupation, consumption frequency, portion sizes of chicken consumers in Embakasi, Nairobi Kenya.

Unit (Grams)	Consumption frequency	Job type: White-collar	Business/self employed	Casual worker	Student	Others occupation	% of respondents
250	Daily	3	1	0	0	0	4.13
	Once a week	1	5	0	0	0	5.79
	Twice a week	0	2	2	0	0	4.96
	Once in a month	0	0	1	0	0	0.83
							0.00
500	Daily	1	0	0	0	0	1.24
	once a week	2	8	0	0	0	9.50
	twice a week	0	1	3	0	0	4.55
	once in a month	0	0	2	0	0	2.48
	Festive and Holiday	0	0	0	0	0	1.24
							0.00
750	Daily	0	1	0	0	0	0.83
	Once a week	2	5	0	0	0	7.02
	Twice a week	0	0	1	1	0	1.65
	Once in a month	0	0	1	0	0	1.65
							0.00

Table 3.4 continued

Unit (Grams)	Consumption frequency	White-collar	Business/self employed	Casual worker	Student	Others occupation	% of respondents
1200	Daily	1	2	0	0	0	2.89
	Once a week	5	8	0	0	0	12.81
	Twice a week	0	1	6	0	0	3.31
	Once in a month	0	0	17	1	0	18.18
	Once in two months	0	0	2	0	0	2.48
	Festive and Holiday	0	0	0	3	2	7.85
							0.00
1500	Daily		1	0		0	0.41
	Non consumers		1	2	0	3	6.20

Consumption frequency based on portions were reflective of price range of various portions or sizes being purchased. From the studies portions of chicken were 0.25 kg, 0.5 and 1.2 kg assumed to be whole chicken (Aringa, 2008). The choice of size to be purchased by residents is strongly determined by occupation which is assumed to be influenced by income. The occupation levels among free range chicken consumers in Embakasi indicates a high level of casual labors (35 %) mostly working in the industrial parts of Nairobi city. JKIA Airport and other logistics linkage business facilities offer employment to the wider population within the study area, offering disposable income to middle class who drive consumption level of free range chicken within the white-collar segment. The business or self-employed workforce constituted 28.9 % and this mainly is composed of business men operating in the Central Business District (CBD) who are attracted in the area by lower housing rents within Embakasi area. Student population was found to be low (7 %) and this can be attributed to the few numbers of educational institutions around Embakasi area while high transportation cost to institution of higher learning forms a significant prohibitive factor among the student population in this area of study.

3.6 Consumption of chicken type and parts

3.6.1 Consumption frequency

Figure 3. 6 shows the consumption frequency of chicken in Embakasi, Kenya. Consumption of free range chicken among those who consumed once per week (35.1 %) was high followed by those who consumed it once per month (22.7 %).

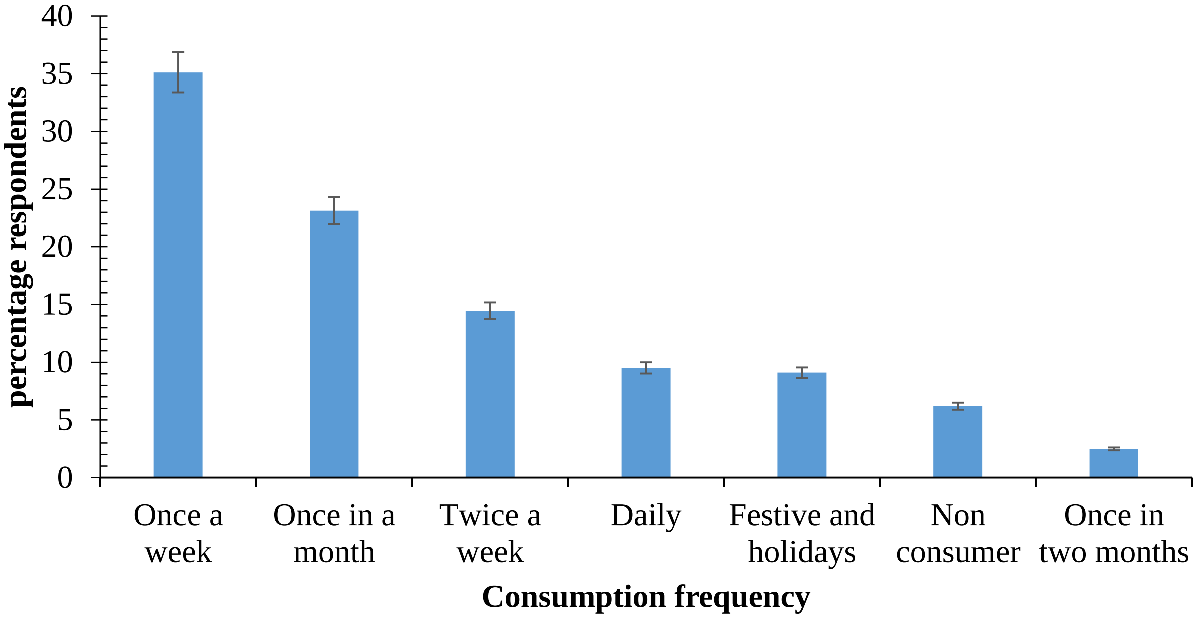

Figure 3.6: Consumption frequency of chicken by residents of Embakasi, Nairobi Kenya. The bars represent standard error of means

The study found out that those who consumed chicken more than once per week bought the chicken in small portions, for instance, 120 grams, 250 grams with the highest portion being 1.2 kg or whole chicken (Aringa, 2008). Consumption of broilers declines sharply when the frequency of chicken consumption declines. A similar trend was found by other researchers (Musyoka, *et al.*, 2010) who reported that among the respondents who consumed chicken once per two months, there were 9.5 % respondents and none of them consumed broilers. The findings of this study indicate that the low price of broilers chicken makes them affordable though free range chicken remains more popular among respondents. A small number of respondents (9 %) consumed free range chicken during occasions such as festive season, family gatherings and wedding functions. The price of a whole broiler chicken across the Embakasi area ranged from USD 4.5 to 5 while the price of a whole free range chicken ranged from USD. 6 to 10. This study finding on price is contrary to Adoum (2015) who reported that broiler prices were found to be higher than reformed and free range chicken. The prices reduced if one purchased in small portions indicating price as a determinate of frequency of consumption since most residents who purchase in butcheries (42 %) make the choice due to flexibility of prices and size they can afford. Overall from the study consumption frequency was found to be influenced by education status, prices, and household income and occupation.

3.6.2 Sources of chicken for consumers in Embakasi area

The most preferred source of the free range chicken among the respondents within Embakasi region are shown in Figure 3.7

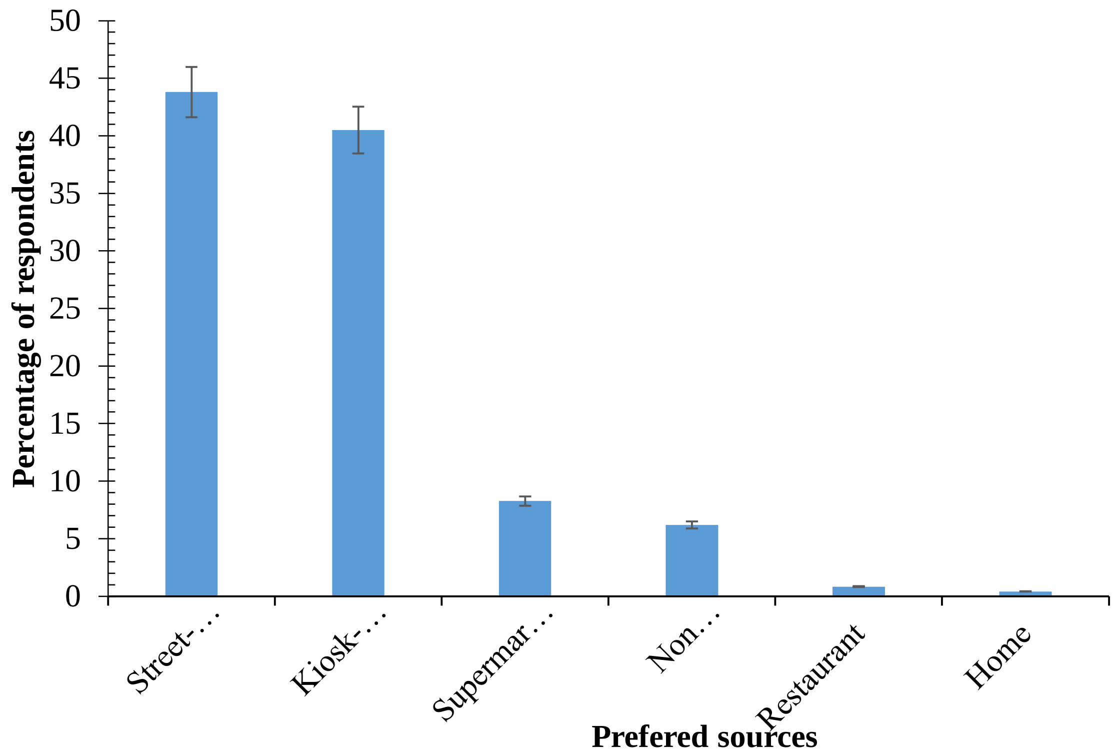

Figure 3.7: Preferred sourcing location for free range chicken in Embakasi, Nairobi Kenya area. The bars indicate standard error of means

Most consumers preferred sourcing chicken products from the roadside street markets (43 %) followed by Kiosk/butchers (40 %). Affordability in terms of price offered the ability to haggle for best price was the reason provided by 43.8 % of the respondents who preferred street road markets. In addition, the respondents in this category indicated after-sale service and cleanliness offered by vendors attracts them. The after-sale services included packaging, slaughtering, de-feathering of flock and credit services. Approximately 40.5 % of consumers preferred the butcheries due to cleanliness, ability to get lower units of measure while supermarkets and restaurants had the lowest preference at 8.3 % and 0.8 %, respectively. This can be attributed to high and fixed prices as compared to other sources. A study conducted in Nairobi on preferred source of chicken by consumers (Otieno *et al.,* 2016) had similar results with findings of this study. Further comparison with other meat sectors indicates preferred location according to Aringa (2008).

3.6.3 Age, occupation, education and gender association with free range chicken consumption frequencies, parts and portions

Table 3.5 shows the association between age, education, gender and the levels of free range chicken consumption. Age, education level and occupation influence consumption frequency of free range chicken within the study area. The more educated the higher the preference towards consumption of free range chicken with respondents of age within 26-30 years (Table 3.4) having the highest preference when all factors are considered.

From the study, consumption of free range chicken is significantly associated with respondent's occupation which is strongly significant with an observed *P=0000* (x^2=336), which is also associated with disposable income *P=0.000* (x^2=247) this can be attributed to availability of disposable income to spend on purchase and consumption of free range chicken. Various social demographic factors also indicate strong significance association with free range chicken consumption with age of respondents indicating significant influence on consumption frequency of free range chicken with *P=0.005* (x^2=45.3).

There was no significant association (Table 3.4 p-value and chi square values) observed between gender and various variables tested. Free range chicken was found to be popular amongst all gender thus not dependent on gender. Education levels amongst respondents had significant association on free range chicken consumption frequency, portions and reasons for preference amongst respondents with *P=0.035* (x^2=26.3) but no effect on parts of chicken favored or chicken type.

Occupation had a significant association (Table 3.4) to chicken portions purchased, chicken type, chicken parts and reason for preference of free range chicken this could be attributed to availability of disposable income while availability of smaller portions make free range chicken easily affordable among the different class of respondents this is further supported by high levels of those that preferred sourcing chicken from butcheries(40%) as they offer sizes depending on respondents ability to pay.

The association between income and chicken portions, chicken type was noted to be significant this is explained by availability of disposable income and flexibility offered by the kiosks/butcheries to respondents.

Table 3.5: Social demographics associations with free range chicken consumption among residents of Embakasi area -Nairobi county

Social demographics factors	Chicken part χ^2	P value	Chicken type χ^2	P-value	Chicken portion χ^2	P Value	Reasons for chicken type Preference χ^2	P-Value	Consumption frequency χ^2	P value
Gender	8.07	0.89	0.05	0.99	6.5	0.16	3.0	0.69	5.1	0.52
Age	14.5	0.57	17.86	0.02	48.8	0.000	41.4	0.003	45.3	0.005
Education	18.5	0.10	13.5	0.042	40.0	0.000	26.3	0.035	197	0.000
Occupation	80.41	0.000	68.01	0.000	95.1	0.000	84.7	0.000	336	0.000
Income	25.5	0.622	30.6	0.006	84.31	0.000	51.2	0.38	247	0.000

3.7 Conclusion

The consumption of free range chicken is higher than that of exotic- broilers and this can be attributed to respondents' perception of healthy and preferred culinary taste. There is also noted significant association between disposable income and consumption frequencies. This study recommends that further research should be conducted to determine the high consumption of free range chicken at households which is contrary to its intake at restaurants across various urban centers, establish the food safety aspect of free range chicken based on identified consumption trends across Nairobi. One of the most common reasons advanced by respondents on choice of purchase is the slaughter and de-feathering services offered by the street-road- side markets vendors. However, the absence of formal abattoirs fully equipped with necessary food safety requirements such as County veterinary inspection services cannot go unnoticed. Therefore, the study recommends that County veterinary inspection services should be enhanced on aspects of food safety.

CHAPTER FOUR

HEAVY METAL CONTAMINATION OF FREE RANGE CHICKEN PRODUCTS AND ENVIRONMENT IN EMBAKASI AREA - NAIROBI COUNTY, KENYA

4.1 Abstract

Due to rapid urbanization, environmental conditions have continued to worsen due to extensive use of pesticide, inorganic fertilizers, effluent, fuel combustions emissions and poor disposal of solid wastes leading to adverse effect on food chains. Free range reared chicken and chicken products have higher concentration of heavy metal than those produced conventionally, because of consuming feeds that is contaminated with traces of heavy metals. However, there is little or no information on the possible accumulation of heavy metals in poultry in Embakasi area that has high peri-urban production of free-range chicken with wide spread market of free-range chicken indicating high consumption. To determine the levels of heavy metal in free range chicken, a total of forty random samples of free range chicken were collected from street vendors, peri-urban farms, kiosks and butcheries within the study area and portioned into muscle, liver and gizzards. Twenty eggs in the same areas were also sampled to analyze for heavy metals. Soil, water, vegetation and feed were collected for analysis using 210 VGT bulk Scientific Atomic absorption spectroscopy. Results showed that there was no significant *($p>0.05$)* variation of cadmium levels in the different free range chicken parts with average levels in liver being 0.04 ± 0.003 mg/kg, in muscle being 0.04± 0.032 mg/kg while in gizzard and eggs were 0.04 ± 0.0031 mg/kg and 0.0398± 0.00261 mg/kg, respectively. Concentration of lead in various parts of chicken were found to range between 0.28 and 0.04 mg/kg, when organs contamination levels were compared lead traces were found to be high in muscle and least in eggs.

Mercury levels in liver considered to be organs of metal contamination was higher compared to other body parts but not significantly different *(P>0.05)* while copper average levels of 0.518 mg/kg were found to be within recommended levels across all chicken parts analyzed. High levels of cadmium, lead and copper were found in soil, vegetation, water and feeds. Levels of cadmium, copper and mercury in chicken products were found to be within the recommended standards by WHO (2011) and Kenya Bureau of Standards. However, lead levels were higher than those recommended by WHO and KEBS therefore posing a risk to consumers.

4.2 Introduction

Desire for rapid industrial, infrastructure development and improved agriculture productivity among developing countries has led to negative effects on the environment, and Kenya is no exception (Bet *et al.*, 2012). The trend has seen entry of heavy metals into the environment and consequently into the food chain either directly through inhalation, skin contact or indirectly through ingestion of contaminated food by animals or human beings. According to Osolo (2015), food chain contamination is one of the common routes for exposure to heavy metals for humans through atmospheric deposition, land application such as application of inorganic fertilizers, agrochemicals and pesticides.

Heavy metals such as lead, cadmium, mercury and arsenic are non-essential elements and toxic when consumed in extreme levels with lead exposure associated with elevated blood pressure and hypertension while cadmium is associated with cancer of the liver, kidney and stomach (Flora, 2012). Africa has seen its contribution to global lead pollution increase from 5 % to 20 % in 1980's to 1986 with limited preparations to protect the environment (WHO, 2010). Copper forms part of the essential micronutrients in human diet and is important in living organisms at low levels of intake while exposure to high doses is known to be harmful with side effects including nose, mouth, and eye irritation, causing nausea, dizziness and diarrhea (Okoye, 2011). Copper has been isolated from local free range chicken with elevated levels compared to exotic breeds of chicken while among the chicken parts, muscles recorded high amount of copper (147.07 ± 60.79 μg/kg) therefore indicating some metals settling more in the muscle of body part of some animal species (Okoye, 2011).

Lead has been isolated from chicken parts with varying concentrations (Oforka *et al.*, 2012) with liver having the highest concentration of 0.17 ± 0.37 mg/kg, compared to gizzards (0.24 ± 0.37 mg/kg) and muscle (0.15 ± 0.26 mg/kg). According to Ahmed *et al.* (2017), lead has been isolated in eggs in Assiut governorate Egypt with levels above the EOSQC recommendation of 0.1 mg/kg and with mean concentration of 0.62 mg/kg and average daily intake rate of about 17.8 % of ADI (0.025 mg/kgbw/day)

Cadmium has a number of industrial applications which include metal plating, pigments, batteries with industrial effluents forming the most of the link with food chain through water contamination (Oforka, 2012). Isolation at different concentrations in various chicken parts has been reported by Sharkawy *et al.* (2002). Cadmium levels in chicken muscle in Assiut governorate were 0.016 ppm while in drumstick was 0.196 ± 0.024 mg/kg (Hanna *et al.*, 2004). Other chicken parts accumulate cadmium at different levels with the liver storing most of the cadmium (Gonzalez *et al.*, 2006). The levels in eggs were found to be 12 % at Assuit with the low levels attributed to low dietary transfer to eggs (Ahmed *et al.*, 2017). Industrial activities including mining, agricultural activities involving extensive use of pesticide and fertilizers have led to migration of mercury to food chain. Mercury exist in food in form of methylmercury. According to Williams (2017), mercury levels in chicken products are reported to be highest in kidneys of chicken in Ikom at 0.05 μg/g while lowest in the muscle tissue at 0.01 µg/g in chicken in Odukpani. According to Samek (1997), highest levels of mercury were noted in skin and liver of chicks. Mercury at levels above WHO (2005) recommendation (0.03 mg/kg) is disastrous to human health. The recommended levels of mercury in food are 0.03 mg/kg (WHO, 2011).

This current study was therefore aimed at determining the level of contamination of chicken products with heavy metals in Embakasi area Nairobi, Kenya.

4.3 Material and Methods

4.3.1 Study area

The study was carried out in Nairobi County Kenya, Embakasi Sub County. The Sub county lies between geographical coordinates 1° 18' 0'' South, 36° 55' 0'' East (Figure 4.1) and was purposely selected for the study. Due to high population, the sub county is composed of middle, high- and low-income population. Additionally, the residents engage in peri-urban agriculture. According to Nyaga (2007), Embakasi had the highest number of chicken population of about 398,000. Within Embakasi Sub County there are industries, river networks and several municipal dump sites which are presumed to have effect on peri-urban agriculture practices. Embakasi Sub County covers 204.1 km^2 with three divisions, six locations and thirteen sub locations comprising of the following administrative units: Embakasi East sub county Embakasi Central, Embakasi North and Embakasi South. Embakasi area has an estimated population of 925,775 (KNBS, 2009).

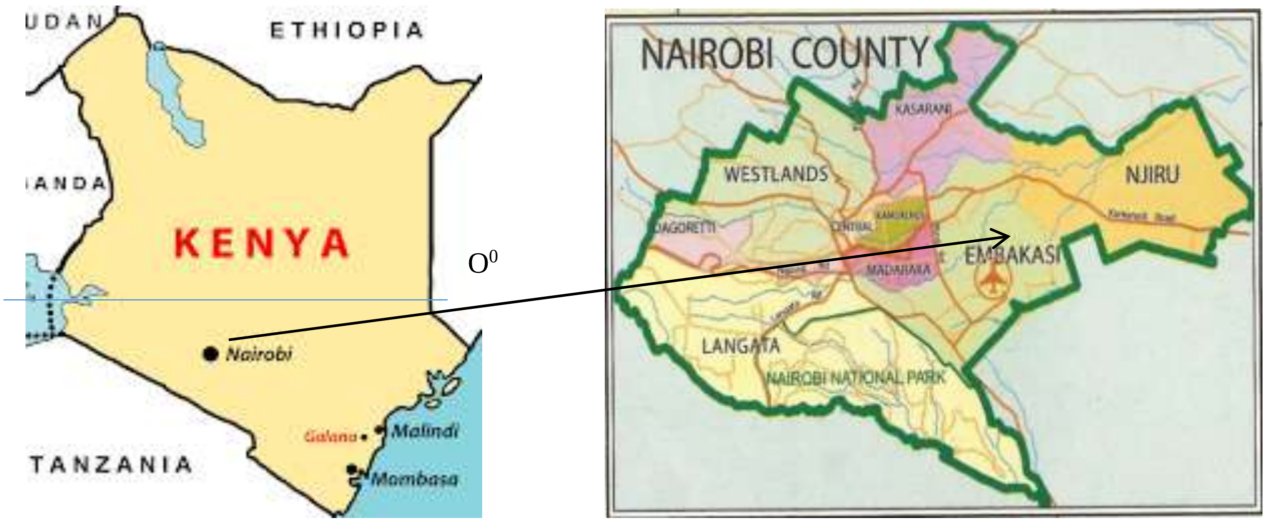

Figure 4.1: Map of Kenya showing Embakasi area within Nairobi. Source Google maps (2018).

4.3.2 Study type and design

The study was a cross sectional survey in design applying quantitative data collection methods through laboratory analysis.

4.3.3 Sampling

Random sampling was employed in purchasing a total of forty chickens (three parts for each), twenty eggs, and collection of four soil samples, four water samples, four vegetation samples and four feeds totaling to one fifty-six samples which were purposely collected across Embakasi sub county distributed in zones, areas with river effluent, areas with high concentration of dump sites and areas with high industrial activities.

The fisher formulae were applied to determine number of samples with degree of desired accuracy set at 0.159 for chicken and for eggs.

$Chicken\ sample\ size = n = \frac{Z^2pq}{d^2} = 1.960^2\ X\ 0.5\ X\ \frac{0.5}{0.1590^2} =$ 38 rounded of to 40 chickens.

Eggs $= n = \frac{Z^2pq}{d^2} = 1.960^2\ X\ 0.5\ X\ \frac{0.5}{0.220^2} = 20$ eggs

Where Z= The standard normal deviation set at 1.96 of the 95% CI

q= Expected contamination proportion (1-P) (1-0.5) = 0.5

d= degree of accuracy desired set at 0.159 significance for Chicken while eggs were set at 0.220

p=proportion in the large population estimated to contain heavy metals (probability)

n = Desired sample size, target population is >10000

For the purpose of this study samples were collected from 8 divisions and distributed equally among the sub units (Table 4.1 and Figure 4.2).

Table 4.1 Sample collection distribution

Distribution of sample collection points/Sites	Zone description	No of chicken samples	No. of samples native to Embakasi area	No of eggs Samples	Environmental (soil, water, feed and vegetation
Mukuru Kwa Ruben, Imara Daima	A=High effluent (river networks)	10	7	5	4
Njiru, Utawala Dandora phase; 1,2,3,4, and 5,	B=Dumping site	10	10	5	4
Kariobangi South, North and Kangundo road	C=High industrial activity	10	4	5	4
Umoja, Pipeline, Kayole, Jogoo road, Nyayo Estate, Komarock and Buruburu	D=High residential population	10	3	5	4
Total		**40**	**24**	**20**	**16**

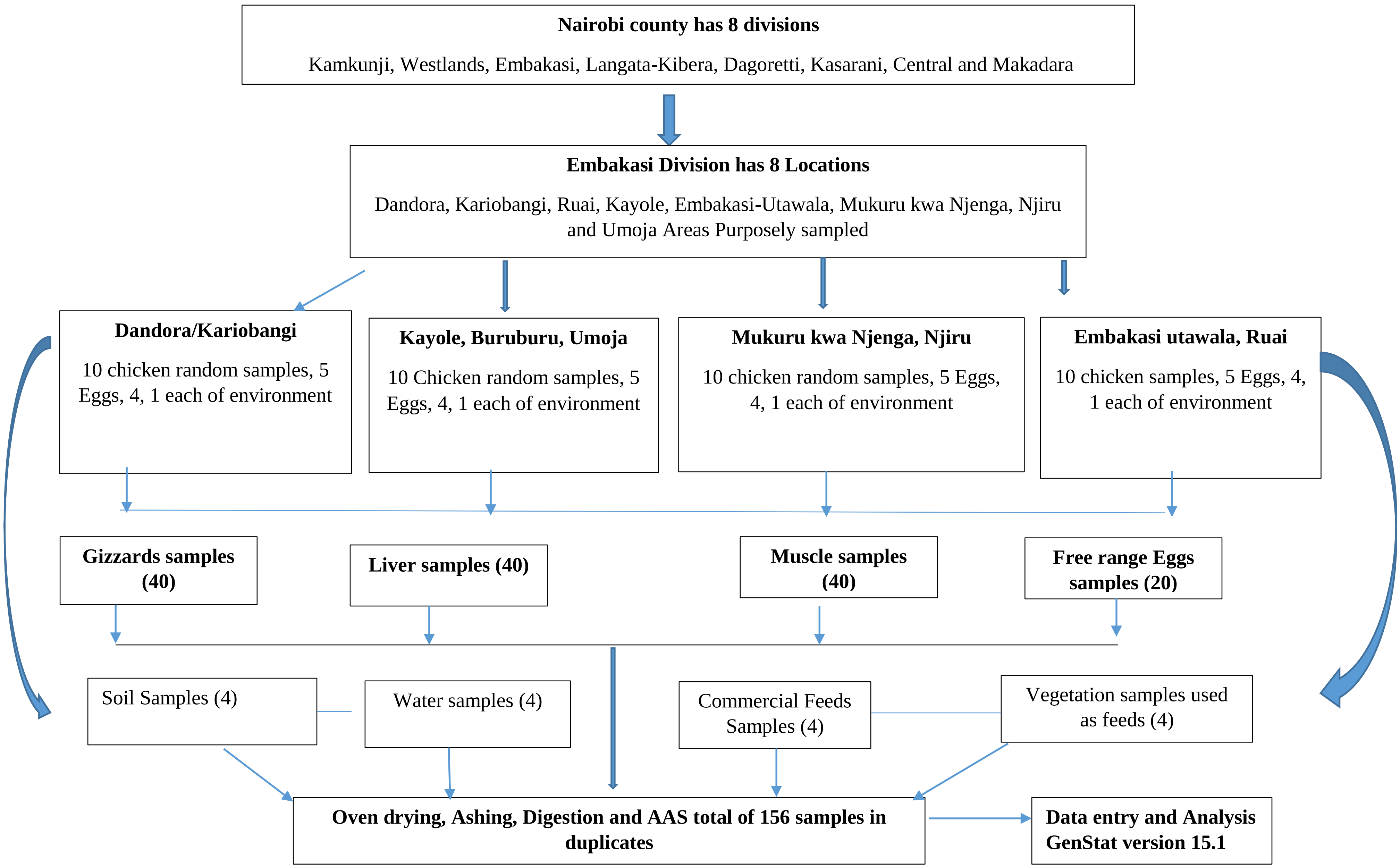

Figure 4.2 Schematic sample collection procedure

4.3.3.1 Sample preparation

Chicken samples based on sample collection zones were purchased from several pre-urban farms, local supermarkets, butcheries and road side street markets were portioned into respective body parts (muscle, liver and gizzards) and stored at -20°C until time of analysis. Every portioned chicken part was weighed and dried using Laboratory oven, at a temperature of 105°C until they attained equal measure for all similar portions of the entire sample. Motor grinder was used to grind the samples into powder and further dried in oven at 105°C for 45 min to remove any residual moisture.

4.3.3.2 Digestion Chemicals

Chemicals used for the entire analysis were of highest purity, analytical grade while solutions were prepared by the use of double distilled water. All chemicals were sourced from Marty enterprises limited Nairobi.

4.4 Analytical methods

4.4.1 Determination of Moisture content of various chicken parts and eggs.

Determination of moisture content of all samples of chicken parts and eggs was done using the method described in AOAC, 930.15. Drying was done in an air oven (Heraeus model 8411060 type T5042) set at 105°C till constant weights were achieved.

4.4.2 Dry ashing and heavy metal determination of various chicken parts, eggs and environmental samples of feeds and vegetation

Portions of chicken muscle, liver and gizzard were ground into powder according to the method described in AOAC 2000 method 999.11. Using crucibles, 1.3 g grounded chicken parts each was transferred into the oven set at 105°C to remove residual moisture. The crucibles were then gradually heated in a muffle furnace (Heraew GMBH HANAU model MR-170 machine no 00005978, Germany) set at 550°C to 600°C and adjusted 50°C for every 30 minutes for a period of 20 hours (Ranasinghe *et al*., 2016). Cooling was done and the residual ash dissolved in 20 % HCL for digestion. The sample solution was then solubilized using 20% hydrochloric acid (HCL) and filtered ready for determination by atomic absorption (210 VGT buck Scientific atomic absorption spectrophotometer). Relative concentrations of metals were obtained from a standards curve

4.4.3 Analysis of heavy metals in water

A Mix grade concentration of nitric acid (HNO_3) and perchloric acid $HClO_4$ was prepared in the ratio of 9:4 and left to cool. Following digestion method adopted by Ranasinghe *et al*., (2016), 10 ml sample water was weighed into 300 ml calibrated digestion tube after which 5 ml concentrated nitric acid (HNO_3) was added. Swirling was done carefully and sample tubes placed in a rack. The pre-digestion was achieved by placing a glass funnel on the calibrated digestion tube and left standing for about 6-8 hours followed by addition of a 10 ml mixture of nitric acid and perchloric acid while carefully swirling. The sample tubes were then placed in a block-digester and a glass funnel inserted in the neck and kept at room temperature to complete digestion. Filtering was done using Whatman No. 1 filter paper, and distilled water added to 50 mL volume. Determination of copper, cadmium, and lead was done using 210 Volt Atomic Absorption Spectrophotometer.

4.4.4 Determination of mercury levels in chicken parts, eggs, and environmental samples

These were analyzed according to the method described in AOAC (2000) official method 971.21. After sample preparation following procedure in section 4.3.2, 25 ml of digested solution was transferred into a new digestion flask and volume adjusted to 100 ml with distilled water. The hydrant output pump was then adjusted to 2: l air/min done by regulating the variable transformer. The spectrophotometer was then zeroed and 20 ml of reducing solution diluted in the aliquot. Determination of mercury content was done through aeration for about 3 minutes for each sample obtaining maximum absorbance.

4.5 Statistical analysis

The data was analyzed for means, standard deviation, correlation and variance statistically using GENSTAT v 15 software. Tukey test was used to determine the significant difference of means values for lead, cadmium, mercury and copper concentration in chicken parts of muscle, liver, gizzards and eggs. Environmental samples were equally analyzed and significant difference of means for respective metals determined.

4.6 Results and Discussion

4.6.1 Moisture content of free-range chicken parts

The moisture content of different chicken parts is as shown in the Tables 4.2. The mean moisture levels for the muscle, liver and gizzard were 76.83%, 80.99%, 83.41% while eggs had 89% moisture content. The difference in moisture content of different chicken parts would be attributed to the age of poultry and difference in mineral composition of various samples. The moisture content of a food product influences texture, taste and shelf life of the food. A slight elevation against set standards may have adverse effect on several properties of food thus affecting consistency of final product (Scaratti, 2016).

According to Rahaman *et al.* (2012), slaughter age has a significant effect on moisture content of meat carcasses with advanced aged meat having less moisture content. A study carried out by Oforka (2012) reported moisture content of 74.30% ± 2.07 in chicken muscle that are similar to the study findings agreeing with the findings that age affects moisture content of poultry products.

According to Yung Lin *et al*.,(2014), significance of moisture levels in food safety dictates the lower the moisture level the higher the shelf life of the product, from the study the liver, eggs and gizzard part of the free range chicken had higher moisture level compared to the muscle part being offal parts they are known to spoil relatively faster compared to other meat parts, the level of spoilage can be attributed to various factors among them high moisture level as an intrinsic contributor to spoilage.

Table 4.2 Moisture content of muscle, liver, gizzard and eggs free range chicken

Sample ID	% Muscle Moisture Content(±Sd)	Sample ID	% Liver moisture Content(±Sd)	Sample ID	% Gizzard moisture Content(±Sd)	Sample ID	% Eggs moisture Content(±Sd)
M1S1	77.7± 0.707^{bcde}	L1S1	80.3± 1.41^{ab}	G1S1	82.85 ±0.50^{b}	E1S1	88.85 ±1.909^{a}
M2S2	76.9± 0.566^{abcde}	L2S2	81± 1.56^{abc}	G2S2	83.85 ±0.50^{b}	E2S2	89.25 ± 2.616^{a}
M3S3,	75.2± 0.849^{abcde}	L3S3	79.65± 0.92^{abc}	G3S3	83.65 ±2.19^{b}	E3S3	88.55 ±2.333^{a}
M4S4	73.95±1.061^{ab}	L4S4	81.65± 0.35^{abc}	G4S4	85.2 ±1.56^{b}	E4S4	88.75 ±0.778^{a}
M5M5	76.7± 0.424^{abcde}	L5S5	80.1 ±1.56^{abc}	G5S5	84.55 ±1.91^{ab}	E5S5	89 ±1.101^{a}
M6S6	75.65± 0.636^{abcde}	L6S6	80.3± 1.56^{ab}	G6S6	83.2 ±1.56^{b}	E6S6	90.45 ± 1.202^{a}
M7S7	77.2± 0.141^{abcde}	L7S7	81.5 ±0.85^{abc}	G7S7	83.9 ±1.98^{b}	E7S7	91.1 ±0.99^{a}
M8S8	76.95± 0.071^{abcde}	L8S8	81.5± 1.13^{abc}	G8S8	84.75 ±1.91^{b}	E8S8	91.15 ± 1.485^{a}
M9S9	75.7± 0.566^{abcde}	L9S9	81.5 ±1.27^{abc}	G9S9	85.9 ±0.28^{b}	E9S9	90.05 ±2.192^{a}
M10S10	76.85± 0.919^{abcde}	L10S10	81.15 ±1.34^{abc}	G10S10	83.5 ±1.13^{b}	E10S10	90.05 ±2.192^{a}
M11S11	76.05± 1.061^{abcde}	L11S11	80.7 ±0.57^{abc}	G11S11	84.05 ± 1.20^{b}	E11S11	91.7 ±0.566^{a}
M12S12	78.15± 0.778^{de}	L12S12	79.65 ±0.78^{ab}	G12S12	84.35 ±2.19^{b}	E12S12	88.6 ±1.838^{a}
M13S13	77.65±0.778^{abcde}	L13S13	80.15 ±1.49^{ab}	G13S13	83.2 ±1.56^{b}	E13S13	90.85 ±1.344^{a}
M14S14	77± 0.566^{abcde}	L14S14	80.6 ±0.42^{ab}	G14S14	83.45 ±1.91^{b}	E14S14	90.45 ±1.061^{a}
M15S15	76.15± 1.061^{abcde}	L15S15	80.35 ± 1.06^{abc}	G15S15	84.55 ±1.91^{b}	E15S15	89.15 ±1.344^{a}
M16S16	74.1± 0.707^{abc}	L16S16	79.95 ± 0.21^{ab}	G16S16	85.45 ±1.06^{b}	E16S16	88.5 ±0.99^{a}
M17S17	75.25± 0.919^{abcde}	L17S17	81.7 ± 0.57^{abc}	G17S17	85.35 ±1.49^{b}	E17S17	90.7 ±0.707^{a}
M18S18	76.15± 0.919^{abcde}	L18S18	82.15 ±0.21^{abc}	G18S18	84.5 ±1.84^{b}	E18S18	90.8 ±0.849^{a}
M19S19	78.55± 0.495^{e}	L19S19	79.85 ± 1.06^{ab}	G19S19	83.8 ±1.41^{b}	E19S19	88.35 ±0.778^{a}
M20S20	76.85± 0.495^{abcde}	L20S20	80.2 ± 1.27^{ab}	G20S20	85.25 ±1.34^{b}	E20S20	88.15 ±0.778^{a}
M21S21	73.8± 1.131^{ab}	L21S21	80.95 ± 1.49^{abc}	G21S21	83.2 ± 0.99^{b}		

*Values are given as mean of duplicate samples ± SD (standard deviation), Chicken parts n=40, Eggs n=20, Values in a column with different superscript letters are significantly different at p<0.05. Letter **M**= Muscle, **L**=Liver **G**=Gizzards **E**=Eggs while **S** represents*

Sample.

Table 4.2 continued

Sample ID	% Muscle Moisture Content(±Sd)	Sample ID	% Liver moisture Content(±Sd)	Sample ID	% Gizzard moisture Content(±Sd)
M22S22	74.25 ± 0.919^{abcd}	L22S22	79.75 ± 0.78^{ab}	G22S22	84.45 ± 1.20^{b}
M23S23	76.6 ± 0.283^{abcde}	L23S23	81.75 ± 0.50^{abc}	G23S23	83.7 ± 2.12^{b}
M24S24	76.1 ± 0.424^{abcde}	L24S24	79.85 ± 1.06^{ab}	G24S24	85.5 ± 1.13^{b}
M25S25	76.7 ± 0.849^{abcde}	L25S25	89.6 ± 11.60^{ac}	G25S25	85.4 ± 0.71^{b}
M26S26	77.35 ± 0.636^{abcde}	L26S26	81.25 ± 0.50^{abc}	G26S26	85.25 ± 1.34^{b}
M27S27	75.65 ± 0.495^{abcde}	L27S27	81.2 ± 1.56^{abc}	G27S27	83.4 ± 1.27^{b}
M28S28	76.3 ± 0.849^{abcde}	L28S28	81.25 ± 1.63^{abc}	G28S28	84.3 ± 1.27^{b}
M29S29	76.15 ± 1.202^{abcde}	L29S29	81 ± 1.56^{abc}	G29S29	86 ± 0.42^{b}
M30S30	76.9 ± 0.990^{abcde}	L30S30	81.5 ± 0.57^{abc}	G30S30	83.8 ± 1.56^{b}
M31S31	77.6 ± 0.849^{abcde}	L31S31	81.15 ± 1.34^{abc}	G31S31	84.7 ± 2.12^{b}
M32S32	77.7 ± 0.424^{bcde}	L32S32	80.5 ± 0.99^{ab}	G32S32	84.2 ± 2.40^{b}
M33S33	76.7 ± 0.283^{abcde}	L33S33	79.65 ± 0.92^{ab}	G33S33	85.4 ± 1.27^{b}
M34S34	76.05 ± 3.465^{abcde}	L34S34	80.25 ± 0.92^{ab}	G34S34	84.95 ± 0.21^{b}
M35S35	73.75 ± 1.202^{a}	L35S35	80.2 ± 0.57^{ab}	G35S35	84.35 ± 2.19^{b}
M36S36	75.7 ± 0.283^{abcde}	L36S36	81.05 ± 1.49^{abc}	G36S36	83.5 ± 1.70^{b}
M37S37	76.4 ± 0.424^{abcde}	L37S37	82.15 ± 0.21^{abc}	G37S37	84.85 ± 2.19^{b}
M38S38	76.3 ± 1.414^{abcde}	L38S38	80.35 ± 0.35^{ab}	G38S38	84.65 ± 2.05^{b}
M39S39	78 ± 0.566^{cde}	L39S39	81.6 ± 0.85^{abc}	G39S39	84.25 ± 2.05^{b}
M40S40	78 ± 0.141^{cde}	L40S40	80.65 ± 0.92^{abc}	G40S40	83.25 ± 1.49^{b}

*Values are given as mean of duplicate samples ± SD (standard deviation), Chicken parts n=40, Eggs n=20, Values in a column with different superscript letters are significantly different at $p<0.05$. Letter **M**= Muscle, **L**=Liver **G**=Gizzards, **E**=Eggs while S represents sample*

4.7 Cadmium concentration in free range chicken parts

Table 4.3 shows the levels of cadmium concentration in chicken liver. Cadmium levels in liver ranged from 0.00 to 0.35 mg/kg with mean of 0.044 mg/kg, however samples collected form areas with high effluent areas had levels above limit averaging 0.1 mg/kg with some sample indicating levels as high as 0.35 mg/kg. According to WHO (2014), among principle sources of environmental cadmium to human body, food forms the greatest route of contamination. The study thus corroborates results finding indicating that liver has primarily more toxic metals in amounts of cadmium compared to other chicken parts. Oforka *et al.* (2012) reported mean concentration of 0.0171 mg/kg - 0.0358 mg/kg cadmium in liver. Similar studies conducted in Spain –Teneriffe Island reported cadmium levels of 4.15 µ/kg in chicken meat and 6.50 µ/kg in pork. The mean concentration of cadmium in liver was found to be within the permissible limits of 0.05 mg/kg set by WHO-Codex Alimentarius and Kenya bureau of standard dressed poultry code KS 1398-2017 (KEBS, 2017) set at 0.05 mg/kg. however, some samples had levels above the recommended minimum > 0.05 mg/kg this could be attributed to environmental pollution in Embakasi area.

Cadmium levels in muscles were ranging from 0.00 mg/kg (ND) to a high of 0.16 mg/kg. High contamination levels were noted in samples collected from high effluent environment with high of 0.16 mg/kg and 0.1 mg/kg noted. Samples from dumpsites, industrial and high residential areas had modest cadmium contamination levels over those collected from zones with high effluent discharge that exceeded the WHO limits of 0.05 mg/kg. Researcher Oforka (2012) observed muscle cadmium levels of 0.0147 mg/kg – 0.0183 mg/kg. Cadmium levels in muscles are found to be transferred into other body organs including bones, in human, skin and feathers in birds which acts as a reservoir of cadmium metals in the body (Oforka, 2012). The levels of cadmium in liver samples were found to be within WHO and KEBS recommended levels of 0.05 mg/kg thus safe for consumption.

Cadmium levels in gizzard ranged from not detectable to detectable with the highest detectable level being 0.505 mg/kg with average of 0.045 mg/kg, high levels of cadmium in gizzard noted in samples collected from zones with high industrial activities 0.5 mg/kg while those in high effluent areas reported 0.37 mg/kg signifying higher levels of cadmium through environmental pollution. Some of the gizzard samples lacked cadmium mainly from samples collected from high residential area an indication of minimal contamination of product. Similar finding of lower levels of cadmium in gizzard than other organs were reported by Okoye (2011) indicating values of 0.003 mg/kg of cadmium in gizzards of local chicken. The reason for the low levels of cadmium in gizzard would be due to well digestive functions of the body part thereby having less absorption of cadmium. It would also be due to environmental bio-accumulation thereby being transferred into animal upon ingestion of contaminated feed such as vegetables (Oforka, 2012). Oforka (2012) reported slightly higher levels (0.0236 ± 0.0016 mg/kg) of cadmium in gizzard than those found in muscles (0.0162 ± 0.0008 mg/kg) of local chicken.

The levels of cadmium in eggs from this study ranged from ND to 0.35 mg/kg, high levels were noted in samples from high effluent areas with levels higher than WHO set limit 0.35 mg/kg WHO (2011b). These results were higher than those reported by Ahmed (2017) which indicated levels of 0.012 mg/kg of cadmium in table eggs. Based on study findings, levels of cadmium in eggs were noted to be high in samples collected in areas of high effluent with mean of 0.156 mg/kg, however the overall mean levels for all zones sampled were below WHO/KEBS recommended maximum levels of 0.05 mg/kg in eggs as such indicative of safe nature of eggs from the study area.

Table 4.3 Cadmium concentrations(mg/kg) in liver, Muscle, gizzards and eggs of free-range chicken

Sample ID	Sample collection zone	Cd in muscle (±Sd)	Sample ID	Cd in Liver(±Sd)	Sample ID	Cd in gizzard (±Sd)	Sample ID	Sample collection zone	Cd in Eggs (±Sd)
M1S1	A	0.10 ± 0.14^{abcd}	L1S1	ND	G1S1	ND	E1S1	A	0.03 ± 0.02^{a}
M2S2	A	0.06 ± 0.04^{abcd}	L2S2	0.26 ± 0.08^{ce}	G2S2	0.37 ± 0.10^{abcd}	E2S2	A	0.02 ± 0.01^{a}
M3S3	A	0.16 ± 0.08^{bd}	L3S3	0.06 ± 0.04^{abcd}	G3S3	ND	E3S3	A	0.03 ± 0.03^{a}
M4S4	A	ND	L4S4	0.05 ± 0.02^{abcd}	G4S4	0.255 ± 0.08^{abcd}	E4S4	A	0.35 ± 0.03^{a}
M5M5	A	ND	L5S5	0.03 ± 0.00^{abc}	G5S5	ND	E5S5	A	0.35 ± 0.2^{b}
M6S6	A	0.04 ± 0.04^{abcd}	L6S6	0.35 ± 0.21^{e}	G6S6	0.18 ± 0.11^{abcd}	E6S6	D	ND
M7S7	D	0.04 ± 0.02^{abcd}	L7S7	0.20 ± 0.14^{bcde}	G7S7	0.03 ± 0.01^{abcd}	E7S7	D	ND
M8S8	D	ND	L8S8	ND	G8S8	0.02 ± 0.01^{abcd}	E8S8	D	0.04 ± 0.03^{a}
M9S9	D	ND	L9S9	ND	G9S9	ND	E9S9	D	0.03 ± 0.01^{a}
M10S10	D	0.05 ± 0.04^{abcd}	L10S10	0.03 ± 0.02^{ab}	G10S10	0.02 ± 0.00^{abcd}	E10S10	C	0.04 ± 0.04^{a}
M11S11	D	0.03 ± 0.03^{abcd}	L11S11	0.03 ± 0.01^{ab}	G11S11	0.0105 ± 0.00^{abc}	E11S11	C	0.03 ± 0.02^{a}
M12S12	D	0.02 ± 0.01^{abc}	L12S12	0.04 ± 0.02^{ab}	G12S12	0.02 ± 0.00^{abcd}	E12S12	B	0.02 ± 0.01^{a}
M13S13	B	0.02 ± 0.01^{abc}	L13S13	0.02 ± 0.01^{ab}	G13S13	ND	E13S13	B	0.04 ± 0.02^{a}
M14S14	B	0.02 ± 0.01^{abc}	L14S14	0.02 ± 0.01^{ab}	G14S14	ND	E14S14	B	0.02 ± 0.01^{a}
M15S15	B	ND	L15S15	0.02 ± 0.01^{ab}	G15S15	ND	E15S15	B	0.03 ± 0.02^{a}
M16S16	B	0.02 ± 0.01^{abc}	L16S16	0.02 ± 0.01^{ab}	G16S16	ND	E16S16	B	0.02 ± 0.01^{a}
M17S17	B	0.03 ± 0.01^{abcd}	L17S17	ND	G17S17	ND	E17S17	D	0.03 ± 0.01^{a}
M18S18	B	0.03 ± 0.01^{abcd}	L18S18	0.02 ± 0.01^{ab}	G18S18	0.01 ± 0.00^{abc}	E18S18	C	0.02 ± 0.01^{a}
M19S19	B	0.03 ± 0.01^{abcd}	L19S19	0.03 ± 0.02^{ab}	G19S19	ND	E19S19	C	0.04 ± 0.01^{a}
M20S20	B	ND	L20S20	ND	G20S20	ND	E20S20	C	0.01 ± 0.01^{a}

Values are given as mean of duplicate samples ± SD (standard deviation), Chicken parts n=40, Eggs n=20, Values in a column with different superscript letters are significantly different at p<0.05. Letter ***M****= Muscle,* ***L****=Liver* ***G****=Gizzards,* ***E****=Eggs,* ***ND****=Not detected* ***A****=high effluent,* ***B****=Dumpsites,* ***C****=high industrial activities,* ***D****=residential areas while* ***S*** *represents sample.*

Table 4.3 continued

Sample ID	Sample collection zone	Cd in muscle (±Sd)	Sample ID	Cd in Liver(±Sd)	Sample ID	Cd in gizzard (±Sd)
M21S21	C	ND	L21S21	ND	G21S21	ND
M22S22	C	ND	L22S22	0.03 ± 0.01^{ab}	G22S22	0.01 ± 0.00^{abc}
M23S23	C	0.03 ± 0.03^{abcd}	L23S23	0.02 ± 0.01^{ab}	G23S23	0.505 ± 0.70^{bd}
M24S24	C	0.03 ± 0.03^{abcd}	L24S24	0.03 ± 0.01^{ab}	G24S24	0.01 ± 0.00^{abc}
M25S25	C	ND	L25S25	ND	G25S25	ND
M26S26	C	0.03 ± 0.03^{abcd}	L26S26	ND	G26S26	ND
M27S27	C	0.03 ± 0.01^{abcd}	L27S27	0.03 ± 0.02^{ab}	G27S27	0.01 ± 0.00^{abc}
M28S28	A	0.02 ± 0.01^{abcd}	L28S28	0.03 ± 0.01^{ab}	G28S28	0.0105 ± 0.00^{abc}
M29S29	A	0.03 ± 0.02^{abcd}	L29S29	0.04 ± 0.01^{ab}	G29S29	0.015 ± 0.01^{abc}
M30S30	A	ND	L30S30	0.02 ± 0.01^{ab}	G30S30	0.05 ± 0.06^{abcd}
M31S31	D	0.03 ± 0.01^{abcd}	L31S31	0.04 ± 0.01^{ab}	G31S31	ND
M32S32	D	ND	L32S32	0.02 ± 0.01^{ab}	G32S32	ND
M33S33	D	ND	L33S33	ND	G33S33	ND
M34S34	D	0.03 ± 0.01^{abcd}	L34S34	0.05 ± 0.01^{abcd}	G34S34	0.02 ± 0.01^{abcd}
M35S35	B	0.04 ± 0.03^{abcd}	L35S35	0.04 ± 0.01^{ab}	G35S35	0.03 ± 0.01^{abcd}
M36S36	C	0.04 ± 0.04^{abcd}	L36S36	0.05 ± 0.01^{abcd}	G36S36	0.02 ± 0.01^{abcd}
M37S37	C	0.05 ± 0.04^{abcd}	L37S37	0.03 ± 0.01^{ab}	G37S37	0.025 ± 0.01^{abcd}
M38S38	C	0.03 ± 0.02^{abcd}	L38S38	ND	G38S38	ND
M39S39	A	0.05 ± 0.02^{abcd}	L39S39	0.16 ± 0.06^{abcde}	G39S39	ND
M40S40	B	0.02 ± 0.01^{abcd}	L40S40	0.02 ± 0.01^{ab}	G40S40	ND

*Values are given as mean of duplicate samples ± SD (standard deviation), Chicken parts n=40, Eggs n=20, Values in a column with different superscript letters are significantly different at p<0.05. Letter **M**= Muscle, **L**=Liver **G**=Gizzards, **E**=Eggs, **ND**=Not detected, **A**=high effluent, **B**=Dumpsites, **C**=high industrial activities, **D**=residential areas while **S** represents sample.*

4.8 Lead concentration in various parts of free range chicken

Lead levels in liver ranged from 0.018 to 0.64 mg/kg with high levels noted from chicken sampled from high industrial area zones at 0.296 mg/kg followed by those from areas with high effluent 0.292 mg/kg as shown in Table 4.4. Similar findings have been reported by other researchers such as Miranda *et al*. (2005) and Korenekova *et al.* (2002) who reported that lead accumulates mostly in the liver compared to other body tissues. The higher amounts of lead reported in the liver is an indication of long-term bio accumulation due to increased exposure to lead from the environment. These results were above the WHO/FAO –Codex Standards 193-1995 and KS 1398-2017 stipulated levels of maximum limits of 0.1 mg/kg indicative of food safety concerns and unsafe nature of free-range poultry products in the in the context of lead contamination in Embakasi areas

The lead concentration in muscles ranged between 0.02 mg/kg to 0.44 mg/kg with residual mean level at 0.26 mg/kg ± 0.01. Muscle samples from all zones under consideration had mean levels >0.1 mg/kg indication of general contamination of products with lead across the sample zones within the study areas. The higher amounts of lead reported in muscle of free-range chicken products is an indication of long-term bio accumulation due to increased exposure to lead from the environment. These results are similar to those reported by Oforka (2012) in which the lead levels in chicken were found to be at a mean of 0.2151 mg/kg ± 0.01. This is an indication of the high levels of environmental contamination as a result of enhanced absorption by plants leading to bio-accumulation.

Results of lead concentration in muscles were above the WHO/FAO –Codex Stan 193-1995 and KS 1398-2017 stipulated levels of maximum limits of 0.1 mg/kg indicating food safety concerns and level of unsafe nature of free-range poultry products in the in the context of lead contamination within study areas.

Levels of lead in gizzard was found to be in a range of non-detectable (ND) to 1.11 mg/kg with a mean of 0.21 mg/kg as shown in Table 4.4. Free range chicken analyzed from different areas within the study area indicate higher lead levels in chicken from high residential areas with mean of 0.272 mg/kg closely followed by free range chicken from high industrial setup this is contrary to previous studies which may be attributed to migration of birds to the study area as a result of road transport (annex iii) leading to transit lead contamination. The levels in gizzard were lower compared to levels of lead in muscles and liver. Oforka (2012) reported higher levels of lead in gizzards (0.2867 ± 0.0176 mg/kg) compared to muscles 0.215 ± 0.0167 mg/kg and associated high levels to highly contaminated feeds. Okoye (2011) on the other hand reported lead levels of 0.066 mg/kg in gizzard and 0.147 mg/kg in muscles. Lead levels in gizzard exceed WHO and KEBS set levels of 0.1 mg/kg and is thus indicative on unsafe nature of poultry products in as far as lead contamination is to be considered.

Lead levels in eggs ranged from 0.02 mg/kg to 0.06 mg/kg as shown in Table 4.4. The lead levels were lower in samples collected in areas with high residential concentration averaging 0.032 mg/kg compared to those from areas with high effluent averaged 0.048 mg/kg, similar studies by Ahmed (2017) reported levels of 0.615 ± 0.03 mg/kg of lead in analyzed eggs. The levels of lead were below those set by WHO and KEBs of 0.1 mg/kg thus indicating that eggs are safe for consumption from the study area.

Table 4.4 Lead concentrations (mg/kg) in muscles, liver, gizzard and eggs of free-range chicken

Sample ID	Sample collection zone	Pb in muscle (±Sd)	Sample ID	Pb in Liver(±Sd)	Sample ID	Pb in gizzard (±Sd)	Sample ID	Sample collection zone	Pb in Eggs(±Sd)
M1S1	A	0.07±0.01^{abc}	L1S1	0.06 ±0.02^{abc}	G1S1	0.02 ±0.01^{a}	E1S1	A	0.06 ±0.02^{a}
M2S2	A	0.4±0.12^{defg}	L2S2	0.64 ±0.07^{i}	G2S2	0.59 ± 0.05^{b}	E2S2	A	0.05±0.01^{a}
M3S3	A	0.2±0.06^{abcdef}	L3S3	0.32 ±0.08^{efgh}	G3S3	0.27 ± 0.08^{ab}	E3S3	A	0.03±0.01^{a}
M4S4	A	0.32±0.05^{cdefg}	L4S4	0.37 ±0.08^{efgh}	G4S4	0.31 ± 0.04^{ab}	E4S4	A	0.04±0.03^{a}
M5M5	A	0.08±0.02^{abc}	L5S5	0.20 ±0.09^{abcde}	G5S5	0.06 ± 0.05^{a}	E5S5	A	0.06±0.03^{a}
M6S6	A	0.2±0.07^{abcdef}	L6S6	0.30 ±0.03^{defgh}	G6S6	0.15 ± 0.04^{a}	E6S6	D	0.03±0.01^{a}
M7S7	D	0.41±0.10^{efg}	L7S7	0.36 ±0.08^{efgh}	G7S7	0.17 ± 0.06^{a}	E7S7	D	0.02±0.00^{a}
M8S8	D	0.44±0.06^{fg}	L8S8	0.38 ±0.05^{efgh}	G8S8	0.15 ± 0.05^{a}	E8S8	D	0.04±0.01^{a}
M9S9	D	0.02±0.01^{a}	L9S9	0.02 ± 0.01^{a}	G9S9	0.05 ± 0.01^{a}	E9S9	D	0.03±0.01^{a}
M10S10	D	0.38±0.04^{defg}	L10S10	0.27 ±0.04^{bcdef}	G10S10	0.35 ± 0.05^{ab}	E10S10	C	0.04±0.03^{a}
M11S11	D	0.35±0.06^{defg}	L11S11	0.29 ±0.03^{cdefg}	G11S11	0.08 ± 0.02^{a}	E11S11	C	0.03±0.01^{a}
M12S12	D	0.23±0.071^{abcde}	L12S12	0.25 ±0.06^{abcde}	G12S12	0.15 ± 0.04^{a}	E12S12	B	0.04±0.02^{a}
M13S13	B	0.26±0.08^{abcde}	L13S13	0.19 ±0.01^{abcde}	G13S13	0.23 ± 0.05^{a}	E13S13	B	0.05±0.02^{a}
M14S14	B	0.14±0.03^{abcd}	L14S14	0.28 ±0.05^{bcdef}	G14S14	0.08 ± 0.01^{a}	E14S14	B	0.05±0.01^{a}
M15S15	B	0.28±0.05^{abcde}	L15S15	0.27 ±0.08^{bcdef}	G15S15	0.19 ± 0.02^{a}	E15S15	B	0.03±0.01^{a}
M16S16	B	0.28±0.05^{abcde}	L16S16	0.28 ±0.07^{bcdef}	G16S16	0.17 ± 0.04^{a}	E16S16	B	0.03±0.01^{a}
M17S17	B	0.17±0.06^{abcde}	L17S17	0.22 ±0.04^{abcde}	G17S17	0.26 ± 0.08^{ab}	E17S17	D	0.04±0.01^{a}
M18S18	B	0.36±0.07^{defg}	L18S18	0.33 ±0.05^{efgh}	G18S18	0.21 ± 0.04^{a}	E18S18	C	0.03±0.01^{a}
M19S19	B	0.28±0.04^{abcde}	L19S19	0.42 ±0.06^{ghi}	G19S19	0.19 ± 0.04^{a}	E19S19	C	0.05±0.02^{a}
M20S20	B	0.04±0.04^{ab}	L20S20	0.08 ± 0.02^{abcd}	G20S20	0.00 ± 0.00^{a}	E20S20	C	0.04±0.01^{a}
M21S21	C	0.21±0.04^{abcde}	L21S21	0.18 ± 0.04^{abcde}	G21S21	0.15 ± 0.07^{a}			

*Values are given as mean of duplicate samples ± SD (standard deviation), Chicken parts n=40, Eggs n=20, Values in a column with different superscript letters are significantly different at $p<0.05$. Letter **M**= Muscle, **L**=Liver **G**=Gizzards, **E**=Eggs, **ND**=Not detected, **A**=high effluent, **B**=Dumpsites, **C**=high industrial activities, **D**=residential areas while **S** represents sample.*

Table 4.4 continued

Sample ID	Sample collection zone	Pb in muscle (±Sd)	Sample ID	Pb in Liver(±Sd)	Sample ID	Pb in gizzard (±Sd)
M22S22	C	$0.35{\pm}0.06^{defg}$	L22S22	0.31 ± 0.04^{defgh}	G22S22	0.25 ± 0.06^{ab}
M23S23	C	$0.25{\pm}0.05^{abcde}$	L23S23	0.29 ± 0.04^{cdefg}	G23S23	0.18 ± 0.02^{a}
M24S24	C	$0.16{\pm}0.06^{abcde}$	L24S24	0.05 ± 0.01^{ab}	G24S24	0.19 ± 0.04^{a}
M25S25	C	$0.18{\pm}0.04^{abcde}$	L25S25	0.27 ± 0.04^{bcdef}	G25S25	0.17 ± 0.08^{a}
M26S26	C	$0.32{\pm}0.06^{cdefg}$	L26S26	0.29 ± 0.04^{bcdef}	G26S26	0.16 ± 0.05^{a}
M27S27	C	$0.37{\pm}0.06^{defg}$	L27S27	0.32 ± 0.06^{efgh}	G27S27	0.29 ± 0.11^{ab}
M28S28	A	$0.21{\pm}0.08^{abcde}$	L28S28	0.25 ± 0.04^{abcde}	G28S28	0.05 ± 0.02^{a}
M29S29	A	$0.15{\pm}0.06^{abcd}$	L29S29	0.23 ± 0.04^{abcde}	G29S29	0.17 ± 0.06^{a}
M30S30	A	$0.2{\pm}0.02^{abcde}$	L30S30	0.27 ± 0.06^{bcdef}	G30S30	0.08 ± 0.02^{a}
M31S31	D	$0.39{\pm}0.04^{defg}$	L31S31	0.38 ± 0.08^{efgh}	G31S31	0.27 ± 0.08^{ab}
M32S32	D	$0.28{\pm}0.06^{bcdef}$	L32S32	0.28 ± 0.08^{bcdef}	G32S32	1.11 ± 0.41^{c}
M33S33	D	$0.31{\pm}0.06^{cdefg}$	L33S33	0.31 ± 0.08^{defgh}	G33S33	0.15 ± 0.04^{a}
M34S34	D	$0.47{\pm}0.06^{g}$	L34S34	0.31 ± 0.04^{defgh}	G34S34	0.24 ± 0.06^{ab}
M35S35	B	$0.15{\pm}0.06^{abcd}$	L35S35	0.27 ± 0.06^{bcdef}	G35S35	0.26 ± 0.08^{ab}
M36S36	C	$0.26{\pm}0.08^{abcde}$	L36S36	0.36 ± 0.08^{efgh}	G36S36	0.27 ± 0.06^{ab}
M37S37	C	$0.34{\pm}0.06^{defg}$	L37S37	0.40 ± 0.08^{fgh}	G37S37	0.18 ± 0.04^{a}
M38S38	C	$0.42{\pm}0.09^{efg}$	L38S38	0.49 ± 0.05^{hi}	G38S38	0.27 ± 0.08^{ab}
M39S39	A	$0.26{\pm}0.07^{abcde}$	L39S39	0.28 ± 0.06^{bcdef}	G39S39	0.16 ± 0.05^{a}
M40S40	B	$0.37{\pm}0.08^{defg}$	L40S40	0.29 ± 0.04^{bcdef}	G40S40	0.21 ± 0.04^{a}

*Values are given as mean of duplicate samples ± SD (standard deviation), Chicken parts n=40, Eggs n=20, Values in a column with different superscript letters are significantly different at $p<0.05$. Letter **M**= Muscle, **L**=Liver **G**=Gizzards, **E**=Eggs, **ND**=Not detected, **A**=high effluent, **B**=Dumpsites, **C**=high industrial activities, **D**=residential areas while **S** represents sample.*

4.9 Copper levels in various parts of free range poultry

Copper levels in gizzards was in a range of no detection to a high of 1.11 mg/kg (Table 4.5). Copper levels were higher in samples collected from zones with municipal dumpsites (mean of 0.57 mg/kg) while levels in high effluent zones had list levels with mean of 0.483 mg/kg. These levels were higher than those reported by Okoye (2011) of 0.037 mg/kg and lower than those reported by Mohamed (2009) of 2.854 ± 2.64 mg/kg. The values of copper noted are lower than set standards by ANZF (2008) of 1 ppm. This is an indication of safe nature of gizzards from poultry products in the study areas in as far as excessive copper contamination is considered.

The copper levels in muscle had a mean of 0.52 mg/kg with a range of between 0.14 mg/kg to 0.90 mg/kg as shown in Table 4.5. Copper levels in muscle were higher in samples collected from areas with high industrial activities with a mean of 0.566 mg/kg while lower levels were noted in samples from areas with high residential concentration averaging 0.465 mg/kg. Copper is an essential micronutrient in cells of living tissues with its functions primarily being catalytic in nature for enzymatic systems within developing cells (Yang, 2011). High levels of copper are known to be toxic according to Hostynek *et al.* (1993). Copper deficiency or excessive levels of are detrimental to the body. Toxic levels of copper may lead to Wilson disease described by excessive accumulation of copper in liver, brain, kidneys and cornea. Work done by Okoye (2011) reported levels of 0.0398 mg/kg of copper in local chicken and attributed the low levels to reduced diet with copper content. The values obtained in the study are lower than set Australia New Zealand Food Authority (2008) of 200 ppm. Thus, indicative of safe nature of free-range muscle in as far as copper content is concerned.

Copper levels varied significantly (*p<0.005*) in the chicken organs as shown in Table 4.5. copper levels in liver were mean of 0.79 mg/kg and 0.18 mg/kg for eggs copper levels in liver ranged from 0.28 mg/kg to 1.75 mg/kg with high levels noted in zones with high effluent discharge averaging 1.084 mg/kg while lower levels were noted in samples collected from areas with high industrial activities averaging 0.57 mg/kg. The sources of copper in animal tissue would be through feeds as an essential nutrient added deliberately into animal feeds or through ingestion of vegetation with high copper content. The level of copper in soil was found to be 5.57 mg/kg while 4.67 mg/kg for the vegetation used to feed chicken from same area. This is an indicator of environmental contamination of chicken products with copper.

WHO and Kenya Bureau of standards have not set maximum allowable levels of copper in chicken products but control is necessary to ensure compliance to recommended dietary intake levels through consumption of various foods. According to Siddiquit *et al.* (2011), Britain has a set limit of 6.6 mg/kg of copper in table eggs, Egypt has a set limit of 1 mg/kg (Azza, 2011) and 1.1 mg/kg limit for Turkey.

Levels of copper in eggs ranged from 0.23 mg/kg to 2.06 mg/kg as shown in Table 4.5 with levels of copper higher in eggs collected from areas with high industrial activities averaging 1.12 mg/kg and lowest in areas with high effluent presence averaging 0.295 mg/kg. The sources of copper in animal tissue would be through feeds, an essential nutrient added deliberately into animal feeds or through ingestion of vegetation. Soils from Dandora recorded copper levels of 5.57 mg/kg while vegetation used to feed chicken from same area recorded levels 4.67 mg/kg demonstrating the environmental influence of copper content in chicken products.

Table 4.5 Copper concentrations (mg/kg) in muscles, liver, gizzard and eggs of free-range chicken

Sample ID	Sample collection zone	Cu in muscle(±Sd)	Sample ID	Cu in Liver(±Sd)	Sample ID	Cu in gizzard(±Sd)	Sample ID	Sample collection zone	Cu in Eggs(±Sd)
M1S1	A	$0.60±0.03^{bcdef}$	L1S1	$1.27 ±0.47^{abc}$	G1S1	$0.62 ±0.13^{bcdef}$	E1S1	A	$0.30±0.05^{a}$
M2S2	A	$0.52±0.13^{abcde}$	L2S2	$0.89 ±0.45^{abc}$	G2S2	$0.45 ±0.08^{abcde}$	E2S2	A	$0.29±0.10^{a}$
M3S3	A	$0.71±0.15^{fghij}$	L3S3	$1.12 ±0.40^{abc}$	G3S3	$0.52 ±0.15^{abcde}$	E3S3	A	$0.31±0.14^{a}$
M4S4	A	$0.33±0.09^{abcde}$	L4S4	$0.73 ±0.11^{abc}$	G4S4	$0.43 ±0.12^{abcde}$	E4S4	A	$0.34±0.088^{a}$
M5M5	A	$0.56±0.08^{abcde}$	L5S5	$0.77 ±0.08^{abc}$	G5S5	$0.29 ±0.05^{abcde}$	E5S5	A	$0.235±0.10^{a}$
M6S6	A	$0.57±0.06^{bcdef}$	L6S6	$1.12 ±0.40^{abc}$	G6S6	$0.69 ±0.06^{bcdef}$	E6S6	D	$0.34±0.11^{a}$
M7S7	D	$0.46±0.07^{abcde}$	L7S7	$0.63 ±0.08^{abc}$	G7S7	$0.46 ±0.06^{abcde}$	E7S7	D	$0.28±0.09^{a}$
M8S8	D	$0.57±0.09^{bcdef}$	L8S8	$0.75 ±0.09^{abc}$	G8S8	$0.30 ±0.03^{abcd}$	E8S8	D	$0.27±0.11^{a}$
M9S9	D	$0.48±0.06^{abcde}$	L9S9	$0.51 ±0.14^{ab}$	G9S9	$0.39 ± 0.04^{abcde}$	E9S9	D	$0.30±0.06^{a}$
M10S10	D	$0.32±0.09^{abcde}$	L10S10	$0.45 ±0.16^{ab}$	G10S10	$0.73 ±0.11^{cdefg}$	E10S10	C	$0.3±0.01^{a}$
M11S11	D	$0.23±0.06^{ab}$	L11S11	$0.37 ±0.08^{a}$	G11S11	$0.74 ±0.11^{cdefg}$	E11S11	C	$0.61±0.04^{a}$
M12S12	D	$0.14±0.06^{a}$	L12S12	$0.55 ±0.11^{ab}$	G12S12	$0.51 ±0.12^{abcde}$	E12S12	B	$0.42±0.13^{a}$
M13S13	B	$0.59±0.05^{bcdef}$	L13S13	$0.50 ±0.04^{ab}$	G13S13	$0.56 ±0.09^{bcdef}$	E13S13	B	$0.31±0.08^{a}$
M14S14	B	$0.31±0.05^{abcd}$	L14S14	$0.54 ±0.11^{ab}$	G14S14	$0.28 ±0.05^{abcd}$	E14S14	B	$0.29±0.04^{a}$
M15S15	B	$0.43±0.05^{abcde}$	L15S15	$0.62 ±0.15^{abc}$	G15S15	$0.52 ±0.08^{abcde}$	E15S15	B	$0.34±0.12^{a}$
M16S16	B	$0.50±0.09^{abcde}$	L16S16	$0.59 ±0.04^{ab}$	G16S16	$0.60 ±0.12^{bcdef}$	E16S16	B	$0.44±0.11^{a}$
M17S17	B	$0.40±0.04^{abcde}$	L17S17	$0.53 ±0.08^{ab}$	G17S17	$0.40 ±0.03^{abcde}$	E17S17	D	$0.75±0.23^{a}$
M18S18	B	$0.70±0.04^{efghij}$	L18S18	$0.72 ±0.13^{abc}$	G18S18	$0.50 ±0.04^{abcde}$	E18S18	C	$0.73±0.11^{a}$
M19S19	B	$0.67±0.06^{defgh}$	L19S19	$0.56 ±0.09^{ab}$	G19S19	$0.41 ±0.15^{abcde}$	E19S19	C	$1.88±0.64^{b}$
M20S20	B	$0.52±0.13^{abcde}$	L20S20	$0.36 ±0.07^{a}$	G20S20	$0.54 ±0.10^{abcde}$	E20S20	C	$2.06±0.71^{b}$

Values are given as mean of duplicate samples ± SD (standard deviation), Chicken parts n=40, Eggs n=20, Values in a column with different superscript letters are significantly different at p<0.05. Letter ***M****= Muscle,* ***L****=Liver* ***G****=Gizzards,* ***E****=Eggs,* ***ND****=Not detected,* ***A****=high effluent,* ***B****=Dumpsites,* ***C****=high industrial activities,* ***D****=residential areas while* ***S*** *represents sample.*

Table 4.5 continued

Sample ID	Sample collection zone	Cu con in muscle(±Sd)	Sample ID	Cu con in Liver(±Sd)	Sample ID	Cu con in gizzard(±Sd)
M21S21	C	0.57 ± 0.08^{bcdef}	L21S21	0.54 ± 0.13^{ab}	G21S21	ND
M22S22	C	0.28 ± 0.04^{abc}	L22S22	0.28 ± 0.06^{a}	G22S22	0.59 ± 0.17^{bcdef}
M23S23	C	0.64 ± 0.010^{cdefg}	L23S23	0.75 ± 0.10^{abc}	G23S23	0.72 ± 0.14^{cdefg}
M24S24	C	0.56 ± 0.09^{bcdef}	L24S24	0.54 ± 0.11^{ab}	G24S24	0.34 ± 0.11^{abcde}
M25S25	C	0.55 ± 0.10^{bcdef}	L25S25	0.50 ± 0.11^{ab}	G25S25	0.45 ± 0.16^{abcde}
M26S26	C	0.60 ± 0.09^{bcdef}	L26S26	0.72 ± 0.09^{abc}	G26S26	0.45 ± 0.01^{abcde}
M27S27	C	0.64 ± 0.08^{cdefg}	L27S27	0.49 ± 0.04^{ab}	G27S27	0.56 ± 0.09^{bcdef}
M28S28	A	0.65 ± 0.09^{cdefg}	L28S28	0.84 ± 0.11^{abc}	G28S28	0.17 ± 0.06^{ab}
M29S29	A	0.27 ± 0.06^{abc}	L29S29	1.75 ± 0.50^{cd}	G29S29	0.42 ± 0.08^{abcde}
M30S30	A	0.43 ± 0.18^{abcde}	L30S30	1.55 ± 0.50^{bc}	G30S30	0.73 ± 0.06^{cdefg}
M31S31	D	0.32 ± 0.14^{abcde}	L31S31	0.61 ± 0.11^{abc}	G31S31	0.26 ± 0.04^{abc}
M32S32	D	0.90 ± 0.11^{k}	L32S32	1.27 ± 0.47^{abc}	G32S32	0.41 ± 0.15^{abcde}
M33S33	D	0.60 ± 0.05^{bcdef}	L33S33	1.18 ± 0.46^{abc}	G33S33	0.96 ± 0.34^{egh}
M34S34	D	0.63 ± 0.11^{cdefg}	L34S34	2.75 ± 0.92^{d}	G34S34	$0.50\ 0.14^{abcde}$
M35S35	B	0.63 ± 0.09^{cdefg}	L35S35	0.98 ± 0.32^{abc}	G35S35	0.81 ± 0.13^{defgh}
M36S36	C	0.57 ± 0.09^{bcdefg}	L36S36	0.63 ± 0.09^{abc}	G36S36	1.11 ± 0.42^{h}
M37S37	C	0.83 ± 0.11^{hjk}	L37S37	0.74 ± 0.08^{abc}	G37S37	0.29 ± 0.04^{abcd}
M38S38	C	0.42 ± 0.09^{abcde}	L38S38	0.54 ± 0.11^{ab}	G38S38	0.39 ± 0.04^{abcde}
M39S39	A	0.58 ± 0.07^{bcdef}	L39S39	0.80 ± 0.16^{abc}	G39S39	0.51 ± 0.08^{abcde}
M40S40	B	0.72 ± 0.13^{ghijk}	L40S40	0.59 ± 0.04^{ab}	G40S40	0.37 ± 0.06^{abcde}

Values are given as mean of duplicate samples ± SD (standard deviation), Chicken parts n=40, Eggs n=20, Values in a column with different superscript letters are significantly different at p<0.05. Letter ***M****= Muscle,* ***L****=Liver* ***G****=Gizzards,* ***E****=Eggs,* ***ND****=Not detected,* ***A****=high effluent,* ***B****=Dumpsites,* ***C****=high industrial activities,* ***D****=residential areas while* ***S*** *represents sample.*

4.10 Mercury concentration in free range poultry parts from Embakasi area

The mean levels of mercury in various chicken tissues is summarized in Table 4.6. The mercury levels in liver averaged 0.029 mg/kg ± 0.01mg/kg and ranged from not detectable to a high of 0.20 mg/kg higher than set limit of 0.03 mg/kg. High levels of mercury was noted in free range chicken samples in residential areas with 40% of samples indicating higher than WHO limits, conspicuously high levels of 0.11 mg/kg contamination levels were noted from samples in residential area while free range chicken samples from areas with high effluent areas had list levels of contamination averaging 0.02 mg/kg. These levels varied significantly *($P<0.05$)* and were agreeing with those reported by William (2017) of 0.03 ± 0.01 mg/kg in liver of chicken from cocoa producing regions in Nigeria. The values of mercury in this study were lower than WHO and KEBS standard of 0.03 mg/kg of mercury in dressed poultry products as such indicative of safety of poultry liver in as far as mercury levels of contamination.

The range of mercury levels in gizzard was between 0.00 to 0.17 mg/kg with a mean of 0.027 mg/kg marginally close to WHO limit <0.03 mg/kg, higher levels of mercury were noted in samples collected from areas with municipal dumpsites averaging 0.033 mg/kg with some samples with a high of 0.17 mg/kg while marginal contamination was noted in samples from effluent zones averaging 0.017 mg/kg. These values of mercury in gizzard are lower than those reported by Williams (2017) in kidney of chicken (0.03 mg/kg). From the study findings levels of mercury in gizzards are lower than set WHO/KEBS levels of 0.03 mg/kg thus indicating that gizzards from poultry from the study area is safe for consumption considering mercury levels.

Egg samples had the lowest mercury levels compared to other products, ranging between 0.00 to 0.039 mg/kg. mercury levels varied significantly depending on the zones, with samples collected at Dandora dumping site having the highest levels of mercury of 0.02 ± 0.25 mg/kg. From the study levels of mercury were within the set maximum limits of WHO-Codex 1995 and KEBS-KS 1389-2017 standard of 0.03 mg/kg for dressed chicken.

Mercury levels in poultry muscles ranged from 0.00 to 0.2 mg/kg, even though the mean level of mercury in all samples average 0.0254 mg/kg, samples collected from areas with municipal dumping sites and areas with high residential areas had mean levels of 0.038 mg/kg and 0.032 mg/kg with 30% and 20% of samples in residential areas and municipal dumping area respectively noted to be >0.03 mg/kg indicating contamination levels above WHO limit. The findings of this study were higher as compared to those reported by Williams (2017) of levels of 0.01 µg/g in muscle tissues. The levels of mercury in chicken muscles would be attributed to the presence of mercury in contaminated poultry feeds and environment as a result of use of contaminated fertilizers and pesticides. The values obtained in this study are below WHO, KEBS standard of 0.03 mg/kg therefore indicative of safety of poultry muscle against mercury contamination.

Table 4.6 Mercury concentrations (mg/kg) in muscles, liver, gizzard and eggs of free-range chicken

Sample ID	Sample collection zone	Hg in muscle (±Sd)	Sample ID	Hg in Liver(±Sd)	Sample ID	Hg in gizzard (±Sd)	Sample ID	Sample collection zone	Hg in Eggs (±Sd)
M1S1	A	ND	L1S1	ND	G1S1	ND	E1S1	A	0.03 ± 0.02^{ab}
M2S2	A	0.03 ± 0.01^{ab}	L2S2	0.03 ± 0.01^{ab}	G2S2	0.03 ± 0.01^{abc}	E2S2	A	ND
M3S3	A	0.04 ± 0.01^{ab}	L3S3	0.04 ± 0.00^{ab}	G3S3	0.03 ± 0.01^{abc}	E3S3	A	0.02 ± 0.01^{ab}
M4S4	A	0.03 ± 0.02^{ab}	L4S4	0.03 ± 0.02^{ab}	G4S4	0.03 ± 0.01^{abc}	E4S4	A	0.03 ± 0.01^{b}
M5M5	A	ND	L5S5	ND	G5S5	ND	E5S5	A	0.03 ± 0.00^{b}
M6S6	A	0.03 ± 0.02^{ab}	L6S6	0.03 ± 0.01^{ab}	G6S6	0.03 ± 0.02^{abc}	E6S6	D	ND
M7S7	D	0.03 ± 0.01^{ab}	L7S7	0.03 ± 0.01^{ab}	G7S7	0.02 ± 0.01^{abc}	E7S7	D	ND
M8S8	D	0.03 ± 0.02^{ab}	L8S8	0.03 ± 0.02^{ab}	G8S8	0.03 ± 0.02^{abc}	E8S8	D	0.03 ± 0.01^{ab}
M9S9	D	ND	L9S9	ND	G9S9	ND	E9S9	D	0.03 ± 0.01^{b}
M10S10	D	0.04 ± 0.01^{ab}	L10S10	0.04 ± 0.01^{ab}	G10S10	0.04 ± 0.01^{abc}	E10S10	C	ND
M11S11	D	ND	L11S11	ND	G11S11	ND	E11S11	C	0.03 ± 0.01^{ab}
M12S12	D	0.02 ± 0.01^{ab}	L12S12	0.02 ± 0.01^{ab}	G12S12	0.02 ± 0.00^{ab}	E12S12	B	0.02 ± 0.01^{ab}
M13S13	B	ND	L13S13	ND	G13S13	ND	E13S13	B	0.03 ± 0.01^{b}
M14S14	B	0.02 ± 0.01^{ab}	L14S14	0.02 ± 0.01^{ab}	G14S14	0.02 ± 0.01^{ab}	E14S14	B	ND
M15S15	B	ND	L15S15	ND	G15S15	ND	E15S15	B	0.02 ± 0.01^{ab}
M16S16	B	0.03 ± 0.01^{ab}	L16S16	0.03 ± 0.01^{ab}	G16S16	0.03 ± 0.01^{abc}	E16S16	B	0.03 ± 0.00^{b}
M17S17	B	ND	L17S17	0.01 ± 0.00^{a}	G17S17	ND	E17S17	D	0.02 ± 0.01^{ab}
M18S18	B	0.03 ± 0.01^{ab}	L18S18	0.03 ± 0.01^{ab}	G18S18	0.03 ± 0.01^{abc}	E18S18	C	ND
M19S19	B	0.03 ± 0.02^{ab}	L19S19	0.03 ± 0.01^{ab}	G19S19	0.03 ± 0.02^{abc}	E19S19	C	0.03 ± 0.01^{ab}
M20S20	B	ND	L20S20	ND	G20S20	ND	E20S20	C	0.03 ± 0.00^{ab}
M21S21	C	ND	L21S21	ND	G21S21	ND			

*Values are given as mean of duplicate samples ± SD (standard deviation), Chicken parts n=40, Eggs n=20, Values in a column with different superscript letters are significantly different at p<0.05. Letter **M**= Muscle, **L**=Liver **G**=Gizzards, **E**=Eggs, **ND**=Not detected, **A**=high effluent, **B**=Dumpsites, **C**=high industrial activities, **D**=residential areas while **S** represents sample.*

Table 4.6 continued

Sample ID	Sample collection zone	Hg in muscle (±Sd)	Sample ID	Hg in Liver(±Sd)	Sample ID	Hg in gizzard (±Sd)
M22S22	C	0.03 ± 0.01^{ab}	L22S22	0.03 ± 0.01^{ab}	G22S22	0.03 ± 0.00^{abc}
M23S23	C	0.03 ± 0.01^{ab}	L23S23	0.03 ± 0.01^{ab}	G23S23	0.02 ± 0.00^{abc}
M24S24	C	0.03 ± 0.02^{ab}	L24S24	0.03 ± 0.02^{ab}	G24S24	0.03 ± 0.02^{abc}
M25S25	C	ND	L25S25	0.00 ± 0.00^{a}	G25S25	ND
M26S26	C	0.04 ± 0.01^{ab}	L26S26	0.04 ± 0.01^{ab}	G26S26	0.03 ± 0.01^{abc}
M27S27	C	0.03 ± 0.01^{ab}	L27S27	0.04 ± 0.01^{ab}	G27S27	0.03 ± 0.01^{abc}
M28S28	A	ND	L28S28	ND	G28S28	ND
M29S29	A	0.03 ± 0.01^{ab}	L29S29	0.04 ± 0.01^{ab}	G29S29	0.03 ± 0.01^{abc}
M30S30	A	ND	L30S30	ND	G30S30	ND
M31S31	D	0.03 ± 0.01^{ab}	L31S31	0.03 ± 0.01^{ab}	G31S31	0.03 ± 0.01^{abc}
M32S32	D	0.04 ± 0.01^{ab}	L32S32	0.04 ± 0.00^{ab}	G32S32	0.04 ± 0.01^{abc}
M33S33	D	0.10 ± 0.11^{ab}	L33S33	0.11 ± 0.11^{ab}	G33S33	0.11 ± 0.12^{abc}
M34S34	D	0.03 ± 0.01^{ab}	L34S34	0.04 ± 0.01^{ab}	G34S34	0.03 ± 0.00^{abc}
M35S35	B	0.07 ± 0.03^{ab}	L35S35	0.07 ± 0.03^{ab}	G35S35	0.05 ± 0.03^{abc}
M36S36	C	0.03 ± 0.00^{ab}	L36S36	0.03 ± 0.01^{ab}	G36S36	0.03 ± 0.01^{abc}
M37S37	C	0.02 ± 0.00^{ab}	L37S37	0.02 ± 0.01^{ab}	G37S37	0.02 ± 0.00^{ab}
M38S38	C	ND	L38S38	ND	G38S38	ND
M39S39	A	0.02 ± 0.01^{ab}	L39S39	0.03 ± 0.01^{ab}	G39S39	0.02 ± 0.01^{abc}
M40S40	B	0.20 ± 0.24^{b}	L40S40	0.20 ± 0.25^{b}	G40S40	0.17 ± 0.20^{bc}

*Values are given as mean of duplicate samples ± SD (standard deviation), Chicken parts n=40, Eggs n=20, Values in a column with different superscript letters are significantly different at p<0.05. Letter **M**= Muscle, **L**=Liver **G**=Gizzards, **E**=Eggs, **ND**=Not detected, **A**=high effluent, **B**=Dumpsites, **C**=high industrial activities, **D**=residential areas while **S** represents sample.*

4.11 Heavy metal concentration in free range chicken from various sampling zones

Table 4.7 shows various concentrations of heavy metals in free range chicken parts from different sample collection zones, lead levels in chicken muscle were significantly higher in samples collected in residential areas (0.328 mg/kg) followed by those collected in areas with high industrial activities (0.286 mg/kg) while lowest in area with high effluent (0.209 mg/kg) the difference can be attributed higher levels of lead in air in the industrial zones while those in residential areas have higher levels attributed to mode of transportation of chicken from areas outside Embakasi with approximately 40% (Table 4.1) chicken collected in Embakasi originated from other counties (Appendix III) and exposure to lead likely to be through air pollution considering the location of street markets that are stationed along busy highways causing fossil fuel emissions. Lead levels in liver were not significantly different ($P<0.05$) in all zones under consideration. Concentration of lead in liver were higher in samples collected from industrial zones (0.296 mg/kg) while least in areas with high dumpsite activities (0.263 mg/kg). Lead levels in gizzard were lowest in chicken part samples analyzed, however, gizzards samples collected from residential areas had lead levels higher (0.272 mg/kg) compared to those collected from dumpsite (0.18 mg/kg). Egg samples had the lowest lead levels across all samples collected with eggs in zones with high residential areas having lower concentration (0.032 mg/kg) compared to areas with high effluent (0.048 mg/kg).

Cadmium contamination levels in muscles, liver, gizzard and eggs were not significantly different ($P < 0.05$). however, contamination levels in liver were higher in samples collected from areas with high effluent discharge (0.1 mg/kg) and least in samples collected from zones with high residential areas (0.041 mg/kg) while samples in industrial zones (0.019 mg/kg) were moderately contaminated. Cadmium contamination in free range chicken is relatively lower due to concerted effects by local authorities and the national environmental authority through enforcement of strict regulations limiting industrial effluent disposal to the environment thus reduction of available environmental cadmium.

Mercury levels in all chicken organs were higher in samples collected from dumpsites (0.038, 0.039, 0.033 and 0.02 mg/kg in muscle, liver, gizzard and eggs respectively) while lower in samples collected from areas with high industrial concentration (0.021, 0.02, 0.019 and 0.018 mg/kg in muscle, liver gizzard and egg respectively. There was no significant difference (*p<0.05*) between chicken sampled from zones with high residential population compared to those in dumpsites in mercury contamination levels, this could be attributed to the fact that most chicken produced in dumping site find markets in the residential areas. The source of mercury in dumpsites could be attributed to contamination from municipal waste that includes e-waste.

Copper is an essential macronutrient levels recorded in samples collected are not of safety concern however higher levels could lead to health concerns from the samples analyzed copper levels were higher in liver samples collected from zones with high effluent discharge while least in gizzard. Copper levels in muscles were not significantly different across all zones sampled.

Table 4.7 Average heavy metal concentration in various free range chicken parts based on different sample collection zones

		Zones of sample collection (mg/kg)			
Chicken organ	**Heavy metal**	**A=High effluent**	**B=Dumpsites**	**C=High industrial activity area**	**D=High residential area**
Muscle	Lead	0.209	0.233	0.286	0.328
	Cadmium	0.046	0.021	0.024	0.02
	Copper	0.522	0.547	0.566	0.465
	Mercury	0.018	0.038	0.021	0.032
Liver	Lead	0.292	0.263	0.296	0.285
	Cadmium	0.1	0.019	0.019	0.041
	Copper	1.084	0.599	0.573	0.907
	Mercury	0.02	0.039	0.022	0.034
Gizzard	Lead	0.186	0.18	0.211	0.272
	Cadmium	0.08805	0.004	0.058	0.01205
	Copper	0.483	0.565	0.49	0.526
	Mercury	0.017	0.033	0.019	0.032
Eggs	Lead	0.048	0.04	0.038	0.032
	Cadmium	0.156	0.026	0.018	0.02
	Copper	0.295	0.36	1.116	0.388
	Mercury	0.022	0.02	0.018	0.016

4.12 Heavy metal concentration in environmental samples

Table 4.8 shows the levels of heavy metals in environmental samples. Based on environmental samples analysis, high levels of Lead in poultry products emanate mainly from a combined source that include soils, vegetation and environmental contamination of air as a result of combustion of fossil fuel. Similar studies done by Marium *et al*. (2004) reported likely sources of lead to poultry products include feeds and water. In her study, lead was reported at 2.18 mg/kg, 4.25 mg/kg and 3.15 mg/kg for beef, mutton and poultry respectively results that are on the high side comparable to results obtained in this study.

Enhanced lead levels in local chicken in Embakasi areas can be attributed to contamination of soils from the area with results indicating levels of 2.4 mg/kg (Table 4.7) from Dandora dump site while soils in Kariobangi indicated a mean level of 1.42 mg/kg ± 0.66 mg/kg (r=0.83). Other studies on soils in Nairobi indicate high levels of lead thus the primary source of lead in poultry products can be attributed to soil and vegetation contamination while also air pollution as a result of fossil fuel combustion play a significant contributor mostly during transportation (see Appendix III- Chicken long distance transportation) of chicken from neighboring counties for ready markets within the city.

Table 4.8 Heavy metal concentration (mg/kg) in environmental samples from Embakasi Nairobi, Kenya

Environmental sample	Lead	Cadmium	Copper	Mercury
Water	0.205 ± 0.04	ND	1.925 ± 0.47	ND
Feed	0.21 ± 0.02	0.02 ± 00	1.19 ± 0.51	0.005 ± 0.00
Soil	1.64 ± 0.55	0.715 ± 0.22	3.28 ± 0.78	0.553 ± 0.20
Vegetation	0.51 ± 0.20	0.12 ± 0.10	2.16 ± 0.85	0.04 ± 0.03

4.13 Heavy metal contamination of chicken feed

Vegetation, water and feeds used for feeding free range chicken within Embakasi areas reported lower levels of lead (Table 4.9) with lead levels from vegetation noted at 1.1 mg/kg maximum and a minimum of 0.065 mg/kg. Feeds had the least levels of lead with a minimum of 0.025 mg/kg and maximum of 0.7 mg/kg. Water showed use of contaminated effluents from rivers as a potential source of lead contamination at levels of minimum 0.025 mg/kg and maximum 0.38 mg/kg indicating potential contributor to lead in free range chicken parts.

According to Osuji and Onojake (2004), there is a correlation between contaminated soils in Niger Delta and high levels of lead in the local poultry products in area of study which is attributed to increased and enhanced absorption by plants leading to possible bio-accumulation of such plants and thus when feed to animals the contamination is transferred to animal tissues.

The study finds significant varying levels of contamination $P<0.005$ on samples analyzed and establish a correlation between levels of soil, water, feed and vegetation contamination with various metals and their presence in poultry product and parts within the study areas.

Table 4.9 Heavy metal concentrations (mg/kg) soil and feed collected in selected Embakasi areas of peri urban chicken production sites

Sample	Lead	Cadmium	Copper	Mercury
Feed 1	$0.03±0.01^{a}$	ND	$1.20±0.36^{ab}$	ND
Feed 2	$0.04± 0.02^{a}$	ND	$0.8±0.25^{a}$	$0.02 ±0.01^{a}$
Feed 3	$0.07±0.02^{ab}$	$0.02±0.014^{a}$	$1.5±0.42^{ab}$	ND
Feed 4	$0.70 ±0.14^{abc}$	ND	$1.24±0.54^{ab}$	ND
Soil 1	$1.15±0.42^{abcd}$	$0.65±0.29^{cd}$	$1.79±0.73^{abc}$	$0.50 ± 0.21^{b}$
Soil 2	$2.4±0.71^{d}$	$0.82±0.22^{d}$	$1.76±0.29^{abc}$	$0.52 ± 0.08^{b}$
soil 3	$1.42±0.66^{bcd}$	$0.62±0.23^{bcd}$	$5.57±0.75^{d}$	$0.52 ± 0.23^{b}$

*Values are given as mean of duplicate samples ± SD (standard deviation), n=4 for soil, water, vegetation and feeds, the Values in a column with different superscript letters are significantly different at $p<0.05$. Letter **Veg** refers to Vegetables while **ND** = No detection.*

Continued Table 4.8

Sample	Lead	Cadmium	Copper	Mercury
Soil 4	1.6 ± 0.42^{cd}	0.77 ± 0.28^{cd}	4 ± 1.13^{bcd}	0.67 ± 0.29^{b}
Veg 2	0.07 ± 0.04^{ab}	0.25 ± 0.21^{abc}	1.62 ± 0.40^{abc}	0.02 ± 0.01^{a}
Veg3	0.08 ± 0.02^{ab}	0.07 ± 0.021^{ab}	1.08 ± 0.42^{ab}	0.04±0.03a
Veg4	1.1 ± 0.71^{abcd}	0.07 ± 0.01^{ab}	1.28 ± 0.42^{ab}	0.05 ± 0.04^{a}
Veg1	0.08 ± 0.03^{ab}	0.09 ± 0.01^{ab}	4.65 ± 2.19^{cd}	0.05 ± 0.02^{a}
Water 1	0.03 ± 0.021^{a}	ND	1.57 ± 0.76^{ab}	ND
Water 2	0.26 ± 0.08^{abc}	ND	1.66 ± 0.35^{abc}	ND
Water3	0.15 ± 0.06^{ab}	ND	2.47 ± 0.21^{abc}	ND
Water4	0.38 ± 0.11^{abc}	ND	2.00 ± 0.57^{abc}	ND

Values are given as mean of duplicate samples ± SD (standard deviation), n=4 for soil, water, vegetation and feeds, the Values in a column with different superscript letters are significantly different at p<0.05. Letter ***Veg*** *refers to Vegetables while* ***ND*** *= No detection.*

4.14 Correlation of environment and chicken part heavy metal concentration

From correlation analysis there was insignificantly weak positive correlation between environmental lead levels and free range chicken part lead content (*r = 0.227, p=0.397*) while copper and cadmium exhibited a negative correlation (*r = -0.365, p=0.244* for Copper, *r = -0.19, p=0.461* for Cadmium) indicating no association between levels found in environment and those in chicken parts. Mercury had a very week correlation (*r = 0.042, p =0.896*) indicating the chicken may not only get mercury from environment but also from other sources not sampled for analysis

The reason for weak correlation could be attributed to type and limited environmental samples (Air samples excluded) collected for analysis thus not reflecting the environment contamination levels in the study area.

The chicken sampled from street market, butcheries in high residential zones are likely to have come from areas away from the study areas (Appendix iii) through long distance movement of birds by vendors thus not reflective of environmental contamination levels from the study area.

The low levels in body parts could be as much as chicken consume and is exposed to the same relative to the presence of heavy metals under study in the environment namely soil, water, feed and vegetation. The levels of heavy metals may be as low as non to α since the amount of heavy metals in chicken part and chicken products will be a reflection of level of contamination in the environment. Therefore, the higher the levels of heavy metals in the environment, the higher the amount of the same in chicken and chicken products.

4.15 Conclusions

Heavy metals concentration of all metals under consideration were higher in liver and muscles and lower in gizzards and eggs. Lead levels in chicken organs were above both WHO and Kenyan standard for dressed chicken in all chicken parts sampled while cadmium, mercury and copper mean levels were within the WHO and KEBs standards though some samples had concentrations above WHO set limit of the metals under study raising concerns on free range chicken safety in respect to mercury, cadmium and copper levels. Environmental samples showed high levels of lead contamination in soils and vegetation in areas of chicken production but with weak correlation on levels in chicken parts.

Although cadmium and mercury were detected, some samples above WHO/FAO set level their average values were below WHO and KEBS maximum limits of 0.05 mg/kg and 0.03 mg/kg respectively in accordance to KS 1389-2017 standard and WHO/FAO.

CHAPTER FIVE

INTAKE OF HEAVY METAL THROUGH CONSUMPTION OF FREE-RANGE CHICKEN IN EMBAKASI, NAIROBI, KENYA

5.1 Abstract

Free range chicken can be a source of dietary lead, cadmium, mercury and copper. The levels are critical aspects of determining if resultant exposure due to intake could cause adverse health effects to consumers. The aim of this study was to estimate dietary exposure to cadmium, lead, copper and mercury from consumption of free-range chicken and eggs. Data for heavy metal contents in various tissues was used to arrive at intake taking into account different consumption frequencies. The heavy metal levels were quantified by use of atomic absorbance spectroscopy. The data was fitted into probabilistic models in @ Risk Palisade software and Monte Carlo simulations run to estimate intake levels. Model fitting simulation showed levels of dietary intake would not exceed 0.004 mg/kgbw/day for mercury, 0.0025 mg/kgbw/month for cadmium, and 0.5 mg/kgbw/day for copper in free range chicken products. However, the safety levels were exceeded for lead which at 0.0011 mg/kgbw/day mean at 95 percentiles against revised values of 0.0005 mg/kgbw/day of lead by EFSA 2010, muscle exposure levels were 0.9 mg/kgbw/day while gizzards and eggs had 1.1 mg/kgbw/day. In general, the risk of heavy metal intake through consumption of free-range chicken was found to be low except in the case of lead in free range chicken products which indicate likelihood of high intake levels with prolonged exposure. This raises concern in levels of heavy metal in the environment necessitating faster interventions by agencies to check levels of lead in the environment.

5.2 Introduction

For any food production system, the general principle is to integrate "Farm to folk approach" which basically protects human as well as animal health. Free range chicken production in peri- urban or semi intensive set up has limitations in monitoring of feed quality especially where chicken is left to scavenge for food. According to Alexander (2012), existence of mycotoxins and inorganic pollutants among them heavy metals and organic pollutants therefore necessitating risk assessment to determine intake levels of various hazards. Risk assessment associated with presence of undesirable chemical substances in poultry parts of free-range poultry system is key in derivation of safe intake levels.

Trace and heavy metals are present in foodstuff and toxicity varies considerably depending on the forms (Nathalie *et al*., 2012). Analysis of food stuff is quite complex therefore for this study only total element available in the sample was considered. Mercury exposure is predominantly in the form of methylmercury which is considered stable and mainly associated with fish and other sea food products (Arnich *et al*., 2012).

Dietary intake for lead in meat have been reported at levels of 3.03 µg/kgbw/day while poultry had a lower intake level of 2.77 µg/kgbw/day (Nasreddine *et al*., 2010). Copper intake levels from meat and poultry are reported in levels of 147.34 µg/kgbw/day contributing about 13.3% of composite food group (Nasreddine *et al*.,2010).

For other food stuff poultry included mercury exist predominantly in inorganic form. According to Arnich *et al*. (2012), French population's mean exposure to cadmium is estimated at 0.16 µg/kgbw/day in adults while for children mean exposure of 0.24 µg/kgbw/day based on total diet study with main contributor of dietary cadmium being potato products and potatoes at 12 and 14% respectively.

Cadmium dietary exposure among European population as a result of poultry products consumption have been found to contribute 22.1%, 13.1%,8.3%, 8.1%, 6.1% 4.4% 5.3% among the following age groups toddlers, other children, adolescents, adults, elderly and very elderly respectively with an average exposure of 2.74 µg/kgbw/week at 95 percentiles as rough estimate for infants (EFSA, 2012).

Poultry and meat products form an important dietary contribution for copper in USA while for Britain, black beans form 60 % of dietary contribution of copper in foods (Nasreddine *et al*, 2010). Risk characterization is an important aspect in establishing exposure significance. For this study both EFSA, CAC and WHO recommended levels for poultry meat and products were considered benchmarks for safety of products. Margins of exposure were calculated based on the mean and P95 exposures (MOE) (Nasreddine *et al.*, 2010). This study was aimed at determining exposure and intake levels as a result of consumption of free-range poultry parts and eggs.

5.3 Materials and Methods

5.3.1 Consumption data and chicken sampling

The sampling for eventual laboratory analysis was performed between July and September 2018 while consumption data on frequencies was collected between 20th June to 30th June 2018. The procedure for sample collection, distribution and analysis is descried in chapter four section 4.3.3, 4.3.3.1, and 4.4.2 while consumption data is described in chapter three section 3.5.

5.3.2 Exposure assessment

Exposure assessment was performed by combining heavy metals contamination levels and individual consumption using @ Risk Palisade software with 1,000,000 iterations. Mean exposure and 95th percentile (P95) were calculated for each product part of chicken and eggs. The @Risk

TopRank Plaside (UK) Risk analysis software for excel was used to obtain the best fit distributions. Obtained distribution formulae are as indicated in Table 5.1, 5.2, 5.3 and 5.4. To estimate the margins of exposure (MOE) for the purpose of risk assessment the average exposure at 65 kg normal human body weight and exposure at 95th Percentile (P95) were obtained through dividing of NOEAL (intake levels in mg/kgbw/day) by estimated exposure dose of the various heavy metals in free raged chicken in Embakasi Area-Nairobi.

$$MOE = \frac{NOEAL(\frac{mg}{kgbw}/day}{Estimated\ exposure\ dose}$$

NB: NOEAL refer to No-Observed-Adverse-Effect Level

5.3.3 Heavy metals levels, consumptions and exposure from chicken products in Embakasi Nairobi Kenya

Model distribution fit for lead, cadmium, copper and mercury and estimated consumption levels of the same are as shown in Table 5.1,5.2,5.3 and 5.4. The levels of heavy metals in all chicken parts for all metals varied significantly *(P<0.05)*

Table 5.1 Formulae used in quantitative risk assessment simulation model for lead analysis

Unit	Function	Distributions
Chicken consumption (mg/Kg bw/day)	Input Extent	RiskInvgauss (0.0023045,0.0010667, RiskShift (0.0000612686), RiskName ("Chicken consumption (mg/Kgbw/day) 2"))
Overall lead contamination distribution (mg/kg)	Input (levels)	Risk Weibull (1.4905,0.24702, RiskShift (-0.0034749), RiskName ("Overall lead contamination distribution (mg/kg)"))
Lead distribution in eggs(mg/kg)	Input (levels)	RiskExtvalue (0.032655,0.0091796, RiskName ("PB distribution in eggs(mg/kg)"))
Lead distribution in liver (mg/kg)	Input (levels)	RiskLaplace (0.2825,0.10483, RiskName ("PB distribution in liver (mg/kg)"))
Lead levels distribution in muscles (mg/kg)	Input (levels)	RiskTriang (-0.028742,0.35,0.48532, RiskName ("PB levels distribution in muscles (mg/kg)"))
Lead levels distribution in gizzards (mg/kg)	Input (levels)	RiskLoglogistic (-0.097359,0.27657,4.4141, RiskName ("PB levels distribution in gizzards (mg/kg)"))
Lead intake from liver (mg/Kg bw/day)	Output	Risk Output () + B1*B4
Lead intake from muscles (mg/Kg bw/day)	Output	Risk Output () + B1*B5
Lead intake from eggs (mg/Kg bw/day)	Output	Risk Output () + B1*B3
Lead intake from gizzards (mg/Kg bw/day)	Output	Risk Output () + B1*B6
Lead overall intake (mg/Kg bw/day)	Output	Risk Output () + B1*B2

Table 5.2 Formulae used in quantitative risk assessment simulation model for copper analysis.

Unit	Function	Distribution
Chicken consumption (mg/Kg bw/day)	Input Extent	RiskInvgauss (0.0023045,0.0010667, RiskShift (0.0000612686), RiskName ("Chicken consumption (mg/Kg bw/day)"))
Overall Copper contamination distribution (mg/kg)	Input (levels)	RiskLaplace (0.5175,0.33148, RiskName ("Overall lead contamination distribution (mg/kg)"))
Copper distribution in eggs(mg/kg)	Input (levels)	RiskExtvalue (0.032655,0.0091796, RiskName ("Cu distribution in eggs(mg/kg)"))
Copper distribution in liver (mg/kg)	Input (levels)	Risk Loglogistic (0.2091,0.45913,2.812, RiskName ("Cu distribution in liver (mg/kg)"))
Copper levels distribution in muscles (mg/kg)	Input Extent	Risk Normal (0.52275,0.16289, RiskName ("Cu levels distribution in muscles (mg/kg)"))
Copper levels distribution in gizzards (mg/kg)	Input (levels)	Risk Logistic (0.48545,0.11, Risk Name ("Cu levels distribution in gizzards (mg/kg)"))
Copper intake from eggs (mg/Kg bw/day)	Output	Risk Output () + B1*B3
Copper intake from gizzards (mg/Kg bw/day)	Output	Risk Output () + B1*B6
Copper intake from liver (mg/Kg bw/day)	Output	Risk Output () + B1*B4
Copper intake from muscles (mg/Kg bw/day)	Output	Risk Output () + B1*B5
Copper overall intake (mg/Kg bw/day)	Output	Risk Output () + B1*B2

Table 5.3 Formulae used in quantitative risk assessment simulation model for cadmium analysis

Unit	Function	Distribution
Chicken consumption (mg/Kg bw/day)	Input Extent	RiskInvgauss (0.0023045,0.0010667, Risk Shift (0.0000612686), Risk Name ("Chicken consumption (mg/Kg bw/day)"))
Overall Cadmium contamination distribution (mg/kg)	Input (levels)	RiskExpon (0.030612, RiskShift (0.00017006), Risk Name ("Overall Cadmium contamination distribution (mg/kg)"))
Cd distribution in eggs(mg/kg)	Input (levels)	RiskPearson5(2.0092,0.060056, RiskShift (0.010224), RiskName ("CD distribution in eggs(mg/kg)"))
Cadmium levels distribution in muscles (mg/kg)	Input (levels)	RiskExpon (0.025888, RiskShift (0.00064719), RiskName ("CD levels distribution in muscles (mg/kg)"))
Cadmium distribution in liver (mg/kg)	Input (levels)	RiskInvgauss (0.047524,0.016068, RiskShift (0.0040491), RiskName ("CD distribution in liver (mg/kg)"))
Cadmium levels distribution in gizzards (mg/kg)	Input Extent	RiskExpon (0.040525, RiskShift (-0.0010131), RiskName ("CD levels distribution in gizzards (mg/kg)"))
Cadmium intake from gizzards (mg/Kg bw/day)	Output	Risk Output () + B1*B6
Cadmium intake from eggs (mg/Kg bw/day)	Output	Risk Output () + B1*B3
Cadmium intake from liver (mg/Kg bw/day)	Output	Risk Output () + B1*B5
Cadmium intake from muscles (mg/Kg bw/day)	Output	Risk Output () + B1*B4
Cadmium overall intake (mg/Kg bw/day)	Output	Risk Output () + B1*B2

Table 5.4 Formulae used in quantitative risk assessment simulation model for mercury analysis in each of the crowded tables decrease font and use 1.5 spacing for all

Unit	Function	Distribution
Chicken consumption (mg/Kg bw/day)	Input Extent	RiskInvgauss(0.0023045,0.0010667,RiskShift(0.0000612686),RiskName("Chicken consumption (mg/Kg bw/day)"))
Overall Mercury contamination distribution (mg/kg)	Input (levels)	RiskExpon(0.025993,RiskShift(0.00018566),RiskName("Overall lead contamination distribution (mg/kg)"))
Mercury distribution in eggs(mg/kg)	Input (levels)	RiskUniform(-0.0016579,0.033158,RiskName("Hg distribution in eggs(mg/kg)"))
Mercury levels distribution in gizzards (mg/kg)	Input (levels)	RiskExpon(0.024663,RiskShift(-0.00061656),RiskName("Hg levels distribution in gizzards (mg/kg)"))
Mercury levels distribution in muscles (mg/kg)	Input (levels)	RiskExpon(0.027387,RiskShift(-0.00068469),RiskName("Hg levels distribution in muscles (mg/kg)"))
Mercury distribution in liver (mg/kg)	Input (levels)	RiskInvgauss(0.047524,0.016068,RiskShift(-0.0040491),RiskName("Hg distribution in liver (mg/kg)"))
Mercury intake from eggs (mg/Kg bw/day)	Output	RiskOutput () + B1*B3
Mercury intake from gizzards (mg/Kg bw/day)	Output	RiskOutput () + B1*B4
Mercury intake from liver (mg/Kg bw/day)	Output	RiskOutput () + B1*B6
Mercury intake from muscles (mg/Kg bw/day)	Output	RiskOutput () + B1*B5
Mercury overall intake (mg/Kg bw/day)	Output	RiskOutput () + B1*B2

5.4 Results

5.4.1 Results for distribution fitting and simulation for copper intake through free range chicken products in Embakasi area.

Copper overall distribution (Table 5.5) in all sampled chicken products were defined by laplace distribution with a mean of 0.518 mg/kg while copper in eggs had an extreme value distribution with a mean of 0.038 mg/kg. Copper distribution in liver was defined by log logistic value distribution with a mean of 0.78 mg/kg while copper in muscles had a normal distribution with copper in gizzard exhibiting a logistic distribution model with a mean of 0.48 mg/kg. The distribution for consumption of chicken with respect to copper was invgaus, with an average of 0.002 mg/kgbw/day.

Overall copper intake averaged 0.001 mg/kgbw/day with copper intake through eggs at 0.00 mg/kgbw/day. Copper intake through the liver was highest at 0.002 mg/kgbw/day, gizzards and muscle had equal intake levels of 0.001 mg/kgbw/day while eggs have the least intake of nil. The study findings on copper intake in eggs indicate lower intake levels compared to findings by Ahmed (2017) of 0.053 mg/kgbw/day. The study finding therefore indicate liver copper levels are high which is indicative of liver function in detoxification of toxic substances thus higher levels.

Table 5.5 Distribution fitting and simulation for copper intake through consumption of free range chicken products in Embakasi area.

	Mean output	**90% CI**	
		Min	**Max**
Chicken consumption (mg/Kg bw/day)	0.002	0.000	+∞
Chicken muscle consumption(mg/Kgbw/day)	0.0016	0.000	+∞
Chicken gizzard consumption(mg/Kgbw/day)	0.00008	0.000	+∞
Chicken liver consumption(mg/Kgbw/day)	0.0000	0.000	+∞
Chicken eggs consumption(mg/Kgbw/day)	0.0000	0.000	+∞
Overall Copper contamination distribution (mg/kg)	0.518	-∞	+∞
Copper distribution in eggs(mg/kg)	0.038	-∞	+∞
Copper distribution in liver (mg/kg)	0.780	0.209	+∞
Copper levels distribution in muscles (mg/kg)	0.523	-∞	+∞
Copper levels distribution in gizzards (mg/kg)	0.485	-∞	+∞
Copper intake from eggs (mg/Kg bw/day)	0.000	-∞	+∞
Copper intake from gizzards (mg/Kg bw/day)	0.001	-∞	+∞
Copper intake from liver (mg/Kgbw/day)	0.002	0.000	+∞
Copper intake from muscles (mg/Kg bw/day)	0.001	-∞	+∞
Copper overall intake (mg/Kg bw/day)	0.001	0.000	+∞

CI- CI-confidence interval, Bw-body weight

5.4.2 Distribution fitting and simulation for cadmium intake through consumption of free range chicken

The overall distribution for cadmium in free range chicken was defined by exponential distribution (Table 5.6) with a mean of 0.03 mg/kg for the respective chicken parts and products. Cadmium in eggs was defined by Pearson distribution with a mean of 0.049 mg/kg, chicken muscles and gizzards had distributions defined by exponential distribution with means of 0.025 mg/kg and 0.04 mg/kg respectively. Cadmium distribution in liver was defined by Invgauss with a mean of 0.04 mg/kg. For consumption of chicken with respect to cadmium, the distribution was invgaus with an average of 0.0024 mg/kgbw/day.

Overall cadmium intake upon consumption of chicken products was noted averaging 0.00007 mg/kgbw/day equivalent to 0.0021 mg/kgbw/month if one is to consume chicken every day for a month. Cadmium intake through consumption of gizzard and eggs is 0.00011 mg/kgbw/day, muscle is 0.00006 mg/kgbw/day while intake through consumption of liver is 0.00009 mg/kgbw/day.

There is no risk in consumption of poultry parts in the study area (infinity maximum levels) in as far as contamination with respect to cadmium is concerned with WHO maximum set of PTMI of 0.025 mg/kgbw/month. According to Lazarus *et al.* (2014), Studies in Croatia indicate high level of cadmium in offal organs of game meat with liver having 74% higher levels compared to the provisional tolerable weekly intake and would be a significant contributor to cadmium in humans if consumed on monthly basis especially for sensitive groups such as children and pregnant mothers.

Table 5.6: Distribution fitting and simulation for cadmium intake through consumption of free range chicken.

	Mean output	90% CI	
		Min	Max
Chicken consumption (mg/Kg bw/day)	0.002370	0.00006	+∞
Chicken muscle consumption(mg/Kgbw/day)	0.001896	0.0000048	+∞
Chicken gizzard consumption(mg/Kgbw/day)	0.000095	0.00000	+∞
Chicken liver consumption(mg/Kgbw/day)	0.000047	0.00000	+∞
Chicken eggs consumption(mg/Kgbw/day)	0.00019	0.00000	+∞
Overall Cadmium contamination distribution (mg/kg)	0.03044	-0.00017	+∞
Cadmium distribution in eggs(mg/kg)	0.04928	-0.01022	+∞
Cadmium levels distribution in muscles (mg/kg)	0.02524	-0.00060	+∞
Cadmium distribution in liver (mg/kg)	0.04347	-0.00405	+∞
Cadmium levels distribution in gizzards (mg/kg)	0.03951	-0.00101	+∞
Cadmium intake from gizzards (mg/Kg bw/day)	0.00011	0.00000	+∞
Cadmium intake from eggs (mg/Kg bw/day)	0.00011	-0.00002	+∞
Cadmium intake from liver (mg/Kg bw/day)	0.00009	-0.00001	+∞
Cadmium intake from muscles (mg/Kg bw/day)	0.00006	0.00000	+∞
Cadmium overall intake (mg/Kg bw/day)	0.00007	0.00000	+∞

CI- CI-confidence interval, Bw-body weight

5.4.3 Distribution fitting and simulation for mercury intake through consumption of free range chicken

Mercury in chicken parts and products under consideration (Table 5.7) had an overall distribution described by exponential distribution., Similarly mercury in chicken muscle and chicken gizzard were described by exponential distributions with mean values of 0.0258 mg/kg, 0.0267 mg/kg and 0.024 mg/kg for the overall, muscles and gizzards respectively. The distribution of mercury in liver followed the invgauss distribution model. Consumption of chicken with respect to mercury had invgauss distribution with an overall distribution of 0.0258 mg/kgbw/day with intake levels of 0.0001 mg/kgbw/day for liver, muscle and gizzards while eggs had nil intake levels upon consumption.

Mercury overall intake through consumption of poultry parts and products from study area was found to be 0.0001 mg/kgbw/day. With respect to body parts, gizzard mercury intake levels were 0.0001 mg/kgbw/day, liver, muscle and eggs 0.0001 mg/kgbw/day with infinity consumption therefore no risk in the intake of either poultry parts or product from area under study. Studies in Croatia on mercury intake through consumption of offal of wild boar game meat noted levels of 0.0534 mg/kgbw/day which were significantly higher compared to findings of this study, with high levels attributed to non-restriction of feeding ways of wild game (Lazarus *et al.,* 2014). Arnich *et al.* (2012) reported levels of 0.0078 kg/kgbw/day of mercury at 95 percentiles in poultry and game meat which are higher compared to the study findings.

Table 5.7 Distribution fitting and simulation for mercury intake through consumption of free range chicken

	Mean output	Min 90% CI	Max 90% CI
Chicken consumption (mg/Kgbw/day)	0.0024	0.0001	+∞
Chicken muscle consumption(mg/Kgbw/day)	0.00204	0.0000	+∞
Chicken gizzard consumption(mg/Kgbw/day)	0.00096	+∞	+∞
Chicken liver consumption(mg/Kgbw/day)	0.00048	0.0000	+∞
Chicken eggs consumption(mg/Kgbw/day)	0.00072	+∞	+∞
Overall mercury contamination distribution (mg/kg)	0.0258	-0.0002	+∞
Mercury distribution in eggs(mg/kg)	0.0158	-0.0017	0.0332
Mercury levels distribution in gizzards (mg/kg)	0.0240	-0.0006	+∞
Mercury levels distribution in muscles (mg/kg)	0.0267	-0.0007	+∞
Mercury intake from eggs (mg/Kg bw/day)	0.0000	0.0000	0.0001
Mercury intake from gizzards (mg/Kg bw/day)	0.0001	0.0000	+∞
Mercury intake from liver (mg/Kg bw/day)	0.0001	0.0000	+∞
Mercury intake from liver (mg/Kg bw/day)	0.0001	0.0000	+∞
Mercury intake from muscles (mg/Kg bw/day)	0.0001	0.0000	+∞
Mercury overall intake (mg/Kg bw/day)	0.0001	0.0000	+∞

CI- CI-confidence interval, Bw-body weight

5.4.4 Distribution fitting and simulation for lead intake through consumption of free range chicken

Lead overall distribution and best fit simulation followed (Table 5.8) a Laplace distribution model with a mean of 0.2197 mg/kg. Lead levels in muscle were defined by a triangular distribution with a mean of 0.2689 mg/kg, while lead levels in gizzards followed log logistic distribution with a mean of 0.2040 mg/kg. The lead levels in liver were defined by laplace distribution already described averaging 0.2825 mg/kg while lead in eggs was characterized by extreme value distribution averaging 0.038 mg/kg. With respect to intake levels, lead levels overall averaged 0.0005 mg/kgbw/day, individual body parts under study had lead mean intake levels of 0.0006 mg/kgbw/day for liver, 0.0004 mg/kgbw/day for gizzard, 0.0001 mg/kgbw/day for eggs and 0.0006 mg/kgbw/day for muscles. However, in general initial provisional tolerable maximum intake levels of lead initially set at 0.025 mg/kgbw/week was removed by WHO indicating there is no safe levels with consumption of lead contaminated products. Thus, from this study product in the study area are risky in as far a lead contamination is concerned.

Similarities in studies can be drawn from infant milk lead levels analysis in EU by Mania *et al.* (2015), infants being sensitive population on contamination require lower levels of contaminants. Infant meal from fish had average 0.00009 mg/kgbw/day for a 6-month old infant to 0.00053 mg/kgbw/day for a 1year old child.

Table 5.8 Distribution fitting and simulation for lead intake through consumption of free range chicken

	Mean output	90% CI	
		Min	Max
Chicken overall consumption (mg/Kg bw/day)	0.0024	0.0001	+∞
Chicken muscle consumption(mg/Kgbw/day)	0.00204	0.0001	+∞
Chicken gizzard consumption(mg/Kgbw/day)	0.00096	0.0000	+∞
Chicken liver consumption(mg/Kgbw/day)	0.00048	0.0000	+∞
Chicken eggs consumption(mg/Kgbw/day)	0.00072	-∞	+∞
Overall lead contamination distribution (mg/kg)	0.2197	-0.0035	+∞
Lead distribution in eggs(mg/kg)	0.0380	-∞	+∞
Lead distribution in liver (mg/kg)	0.2825	-∞	+∞
Lead levels distribution in muscles (mg/kg)	0.2689	-0.0287	0.4853
Lead levels distribution in gizzards (mg/kg)	0.2040	-0.0974	+∞
Lead intake from eggs (mg/Kg bw/day)	0.0001	-∞	+∞
Lead intake from liver (mg/Kg bw/day)	0.0006	-∞	+∞
Lead intake from muscles (mg/Kg bw/day)	0.0006	-0.0001	0.0011
Lead intake from gizzards (mg/Kg bw/day)	0.0004	-0.0002	+∞
Lead overall intake (mg/Kg bw/day)	0.0005	0.0000	+∞

CI- CI-confidence interval, Bw-body weight

5.4.5 Estimated margins of dietary exposure to heavy metals among free range chicken consumers in Embakasi Kenya

The levels of exposure of various heavy metals (Table 5.9) compared to other studies and set levels by Codex show that the average mean dietary exposure for lead is at 0.0011 mg/kgbw/day at 95 percentiles. EFSA has set a 0.5 µg/kgbw/day for neuro developmental effects for children and pregnant mothers, JECFA (2011) withdrew the initial PTMW set levels of 0.025 mg/kgbw/week indicating there are no safe levels of exposure to lead, this study finds lead exposure above CAC (2011) levels indicating that consumption of free range chicken is likely to expose consumers to risks associated with lead poisoning. Other studies by Ahmed (2017) on eggs reported a dietary exposure of 0.615 mg/kgbw/day which is way above the CAC set levels and findings in this study.

Cadmium exposure levels were 0.0002 mg/kgbw/day at 95 % percentile against recommended levels by WHO of 0.00025 mg/kgbw/month which were lower than studies by Ahmed (2017) of 0.012 mg/kgbw/day and above those reported by Azzam *et al.* (2011) of no detectable amounts indicative of safe free-range product from study area.

For copper, the studies indicated exposure levels of 0.002 mg/kgbw/day at 95 percentiles where found to be well below the recommended levels by Codex alimentarius Committee (2005) of 0.5 mg/kgbw/day which could indicate macronutrient deficiency in feeding practices of free-range poultry producers.

Mercury exposure levels were found to be 0.0002 mg/kgbw/day at 95 percentiles which are well within set limits by JECFA (2011) of 0.004 mg/kgbw/day in products other than fish and oyster products. (Table 5.9) indicative of safe nature of free-range products from study area against mercury contamination.

Margins of exposure of an average person based on the WHO recommended (WHO 2014) human body weight were calculated by multiplying dietary exposure by the recommended average weight of a normal human (65kg), the results of MOE of each metal are shown in Table 5.9.

MOE in free range chicken for lead contamination were recorded at 0.072 mg/kgbw/day, copper at 0.156 mg/kgbw/day, cadmium 0.013 mg/kgbw/day and mercury 0.033 mg/kgbw/day the study findings showered consistencies with studies by Nasreddine (2006) who observed higher levels of lead in total dietary exposure in China (0.08 mg/kgbw/day, Japan (0.084 mg/kgbw/day) and Egypt (0.242 mg/kgbw/day while lower levels of lead MOE were observed in UK (0.024 mg/kgbw/day) and France (0.018 mg/kgbw/day).

Cadmium MOE levels as a result of intake through free range chicken were lower than those observed by Nasreddine (2006) for China (0.021 mg/kgbw/day), Japan (0.032 mg/kgbw/day and Egypt (0.0197 mg/kgbw/day) but higher than those observed in UK (0.012 mg/kgbw/day) and France (0.0027 mg/kgbw/day.

Mercury margin of exposure were observed to be higher than those reported by Nasreddine (2006) for UK (0.004 mg/kgbw/day while lower than those observed in Egypt (0.076 mg/kgbw/day.

Table 5.9: Estimated margins of dietary exposure to heavy metals through consumption of free range chicken

	Lead		Copper		Cadmium		Mercury	
	Mean	**P 95**	**Mean**	**P 95**	**Mean**	**P 95**	**Mean**	**P 95**
Dietary Exposure (mg/kg bw/day)	0.0005	0.0011	0.0013	0.002	0.00007	0.0002	0.0001	0.0002
MOE (65 Kg person) mg/person/day	0.033	0.072	0.085	0.156	0.005	0.013	0.007	0.033

Heavy metal exposure levels differed if levels in body part is to be considered (Table 5.10), lead levels of exposure were higher in liver at 0.0010 mg/kgbw/day at 95 percentiles (0.007 mg/kgbw/week) while lowest in muscle at 0.0009 mg/kgbw/day (0.0063 mg/kgbw/week). These findings were similar to work done by Lazarus *et al.* (2014) for game meat roe deer muscle where lead was 0.176 mg/kgbw/day at 95 percentiles higher than the study findings. Cadmium exposure levels differed in body parts with highest levels occurring in liver at 0.0004 mg/kgbw/day and lowest in muscle of 0.0002 mg/kgbw/day at 95 percentiles, levels obtained were lower to JECFA (2011) limits set at 25 µg/kgbw/month while comparable study (Mania *et al.*,2015). Cadmium levels in infant formulae indicated dietary intake of 2.5-47 % of the provisional tolerable monthly intake established by JECFA (2011).

Copper exposure levels showed a higher level of 0.0034 mg/kgbw/day in liver at 95 percentile and low of 0.0001 mg/kgbw/day at 95 percentiles in eggs. Mercury levels of exposure have no significant difference in amounts in gizzards, muscle and liver at 0.0002 mg/kgbw/day and lowest in eggs at 0.0001 mg/kgbw/day sample mercury levels being within JECFA, for inorganic mercury the provisional tolerable weekly intake is set at 4 µg/kgbw/week thus indicate free range chicken are safe in as far as inorganic mercury contamination exposure is concerned. Similar findings were reported by Lazarus *et al.* (2014) that mercury levels in muscles of 0.004 mg/kgbw/day exposures at 95^{th} percentile for rare consumers of red deer game meat while frequent consumers' exposure at 95^{th} percentile of 0.05 mg/kgbw/day levels that are considered safe by EFSA requirements. There is higher accumulation of heavy metals in liver compared to other body parts this informs the metabolic functions of liver in living organisms of detoxification.

Table 5.10 Estimated margins of dietary exposure to heavy metals from consumption of free range chicken products

Body parts		Lead		Copper		Cadmium		Mercury	
		Mean	**P 95**	**Mean**	**P 95**	**Mean**	**P 95**	**Mean**	**P 95**
Muscles	Dietary Exposure (mg/kg bw/day)	0.0006	0.0009	0.0012	0.0018	0.0001	0.0002	0.0001	0.0002
	MOE (65Kg person) mg/person/day	0.039	0.0585	0.078	0.117	0.0065	0.013	0.0065	0.013
Liver	Dietary Exposure (mg/kg bw/day)	0.0005	0.0010	0.0017	0.0034	0.0001	0.0004	0.0001	0.0002
	MOE (65Kg person) mg/person/day	0.0325	0.065	0.1105	0.221	0.0065	0.026	0.0065	0.013
Gizzards	Dietary Exposure (mg/kg bw/day)	0.0004	0.0011	0.001	0.002	0.0001	0.0003	0.0001	0.0002
	MOE (65Kg person) mg/person/day	0.026	0.0715	0.065	0.13	0.0065	0.0195	0.0065	0.013
Eggs	Dietary Exposure (mg/kg bw/day)	0.0001	0.0011	0.0001	0.0001	0.0001	0.0003	0.0	0.0001
	MOE (65Kg person) mg/person/day	0.0065	0.0715	0.0065	0.0065	0.0065	0.0195	0	0.0065

5.4.6 Characterization of the risk of consuming free range chicken

Exposure to high amounts of heavy metals has been shown to have adverse effect on human health with lead known to induce retardation in neurobehavioral development (WHO 1986) observed in children of mothers having been exposed to lead. Cadmium on the other hand is known to bio accumulate in body organs with ability to impair reabsorption functions leading to increased urinary excretion with lower molecular weight (WHO 1986b).

Copper is an essential micronutrient but excessive about may lead to Wilson disease and Menke's disease that involve peculiar hair and increased levels of mental retardation in addition death may occur before 3 years to patients due to neurological impairment (Goyer,1996). Primarily exposure to mercury is in the form of methyl mercury. Mercury exist on earth surface ranging from 0.02 mg/kg to 0.15 mg/kg. Mercury affects peripheral and central nerves system of fetus as a result of neurotoxicity (WHO 1986b). Accordingly, JECFA 2011 has set provisional tolerable weekly intake for cadmium at 0.025 mg/kgbw/month, copper provisional maximum tolerable daily intake of 0.5 mg/kgbw/day, while mercury is set at permissible tolerable maximum intake of 0.004 mg/kgbw/day.

Mercury dietary exposure was found to be 0.002 mg/kgbw/day at 95 percentiles below JECFA 2005 recommend similarly for cadmium, and copper recorded 0.002 mg/kgbw/day at 95 percentiles all below JECFA recommended level. There is no inherent risk of exposure in consumption of free-range product that can be associated with mercury, copper and cadmium. However, for lead the study observed levels of 0.0011 mg/kgbw/day dietary exposure and 0.072 mg/kgbw/day for margin of exposure for persons of 65 kg at 95percentile. JECFA (2011) has no set levels of lead exposure following review and repeal of initial provisional tolerable weekly intake set limit of 0.025 mg/kgbw/week set in 1986.

Therefore, the current study shows low risk associated with consumption of free-range products even though consumers may be exposed to lead through consumption of chicken parts at some marginal levels comparably to levels reported by Ahmed *et al*. (2017).

5.4.7 Conclusion

Intake and exposure margins for various heavy metals except for lead were found to be within the WHO (2013) recommended limits of 0.04 µg/kgbw/day for mercury in foods other than fish and sea foods, 0.5 µg/kgbw/day for copper (EFSA 2012) and 25 µg/kgbw/month for cadmium. Levels of lead were above set limits of EFSA (2011) provisional maximum tolerable daily intake limit of 0.5 µg/kgbw/day. Lead provisional tolerable daily intake levels was withdrawn by JECFA citing insufficient data thus indicating there are no safe levels of lead exposure to humans. In comparison to EU requirement lead permissible daily maximum intake remain lower (0.5 µg/kgbw/day) than study findings as such indicating marginal risk of over consumption of free range chicken.

The levels of heavy metals may range from zero to infinity since the amount of heavy metals in chicken part and chicken products will be a reflection of level of contamination in the environment. Therefore, the higher the levels of HM in the environment the higher the amount of the same in chicken and chicken products.

CHAPTER SIX

GENERAL CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

Free range chicken consumption in Embakasi and Nairobi county has a popularity of (78.1 %) compared to exotic broiler chicken (15.7 %). Consumption level of (87%) frequency within a month of free range chicken indicate high consumption of free range chicken within the study area.

There is presence of heavy metal contamination in free range chicken parts with lead levels in organs averaging (0.25± 0.01 mg/kg) higher than maximum permissible levels of 0.1 mg/kg by WHO/FAO 2013 and Kenya Standard 1398-2017 for dressed chicken. Cadmium, mercury and copper levels were found to be below permissible maximum levels of 0.05 mg/kg, 0.03 mg/kg (WHO, 2012) and 1ppm (FSANZ,2011)

Environmental analysis of soil, water, feed and vegetation reveled presence of heavy metals with soils in all the sample collection sites indicating high levels of lead while cadmium, mercury and copper levels were moderate. From the sample analysis it is evident that environment contribute weakly to presence of harmful contaminants in free range chicken products.

Lead dietary exposure through free range chicken products was found to be 0.0011 mg/kgbw/day at 95 percentiles which is above JECFA levels of nil levels while EFSA levels are set at 0.5 µg/kgbw/day for neurodevelopment effects. Cadmium, mercury and copper marginal exposure levels at 95 percentiles were found to be within WHO/EFSA permissible levels.

6.2 Recommendations

High exposure of lead through free range chicken consumption is a pointer that government agencies, local authorities and the population need to be educated more on appropriate modes of free range chicken production, marketing and transportation.

Cadmium levels are marginally close to WHO permissible consumption levels through food therefore it would be ideal for MOH, Kenya Bureau of Standards and Ministry of Agriculture to work on strategies to reduce exposure of free range chicken products towards contamination.

Ministry of Health and Kenya Bureau of Standards need to ensure effectiveness of set standards and codes especially create awareness to the wider public including informal settlements of requirements of the KS-1398-2017 dressed chicken code.

Efforts should be made by government agencies to control pollution as a result of e-wastes, municipal waste treatment, effluent which is a likely source of the detected levels of mercury, lead and cadmium through contaminated air dispersal, water effluent and waste. Reallocation of road side market shades to safer location with appropriate infrastructure and technical services for chicken markets away from fossil fuel emission should be considered.

This study recommends that further research should be conducted to determine levels of heavy metals in more environmental samples of soil, water, vegetation, air and feeds in areas under free range chicken production since the used sample size in this study were for the purpose of indication. Among the study limitation were limitation of research funds for analysis thus would not analyses wide samples to conclusively relate presence of heavy metals in free range chicken to a particular source.

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APPENDICES

Appendix i: Consumption questionnaire

Survey on consumption of free-range poultry products in Embakasi area Nairobi, Kenya

The aim of this study is to measure the current dietary consumption pattern of free-range poultry products so as to form a basis for future monitoring and evaluation of the poultry industry in Kenya. Your honest responses will be used to inform research team of the current situation and will therefore be treated with utmost confidentiality; and will not be used for purposes other than research only.

Your cooperation and participation are highly appreciated.

Thank you for accepting to take part in this study.

Enumerator's name………………………………….. Start time……………………. End time……………………………….

Background information

1; General Information

Classifying information

Date of interview

Location of interview

Name of the outlet/building

GPS coordinates of residence

Date checked

Date of Data entry

2: Respondent and general household information

2.1. Name of respondent

2.2. Respondent gender

2.3 Educational Level

2.4. Age

2.5. Estimated body weight(kg)

2.6. Estimated height

2.7. Marital status

2.8. Main occupation

3.0 Consumer Study

3.1. Do you consume free range poultry products?

3.2. If not why?

3.3 What is your favorite part of a poultry plate?

3.4 If yes on 3.1 how often do you consume poultry products? Once Daily ( ), Twice daily( ), Once per week (), Twice weekly ( ) thrice a week ( ) other …………………………………

3.5 What unit pack or amount do you purchase at any given time you buy poultry? Less than 0.25 kg () 0.5kg ( ) 0.75kg ( ) or whole ( ) state the price Ksh…………………..

3.6 Do you consume all chicken you buy alone? Yes…………...No…………..

3.7 If no how much of the chicken you buy do you eat? Who else consumes the chicken.....................?

3.8 Where do you usually purchase your chicken? Kiosk ( ) Supermarket ( ) streets ( )

3.9 Why do you buy from your preferred outlet? Quality ( ) Affordability ( ) After sales services ( )

4.0 What complaint, if any, have you ever raised on the chicken you buy? List typical: A=?;B=?..

1. A
2. B
3. C
4. D

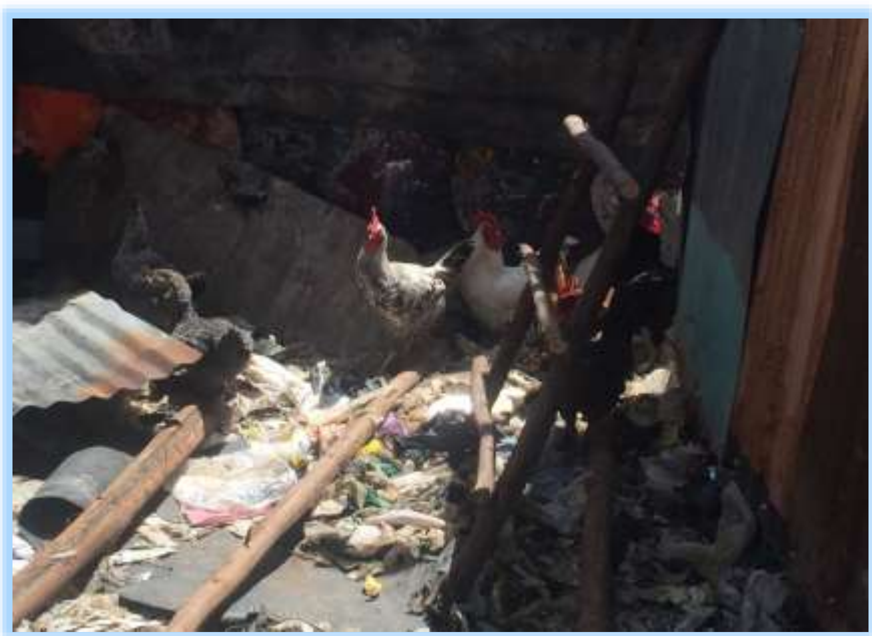
Any comments on free range poultry you would wish to share?

Thank you.

Appendix ii: Free range chicken rearing

Controlled feeding of free range chicken in back yard of home stead in Embakasi area

Free range chicken rearing at Dandora dumpsite for markets wider Nairobi county



Appendix iii: Transportation and slaughter of free range chicken

Transportation of free range chicken to markets along Jogoo road via long distance public transport vehicles

Appendix iv Free range chicken slaughter make shift within street-road market at Mtindwa stage and Dandora area

Appendix v: Sample collection and storage

Chicken parts segregated prepared ready for transportation to the lab at Kabete campus for lab analysis

Muscle Drumstick	Chicken Gizzards	Chicken liver