

ANALYSIS OF ESSENTIAL MINERALS IN RESIDUES OF *MANGIFERA. INDICA* L. GROWN IN SELECTED DIVISIONS OF MBEERE SOUTH, EMBU COUNTY, KENYA

By

Michael Kariuki Njiru (BED Sc.)
Reg. No: I56/CE/14204/09

A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Applied Analytical Chemistry in the School of Pure and Applied Sciences of Kenyatta University

May, 2014

DECLARATION

I hereby declare that this is my original work and has not been presented for the award of a degree or any award in any other university.

Michael Kariuki Njiru
Chemistry Department

Signature.....Date.....

This thesis has been submitted with our approval as supervisors:

Dr. Ruth Wanjau
Department of Chemistry
Kenyatta University

Signature.....Date.....

Dr. Mildred Nawiri
Department of Chemistry
Kenyatta University

Signature.....Date.....

DEDICATION

This work is dedicated to: My Children Sharon and Shekinah, My beloved Wife Regina, My Brother and Sisters, My Mother Sarah Njiru and also to the loving memory of My late Father Njiru Nyaga.

ACKNOWLEDGEMENTS

First and foremost I offer my deepest heart-felt thanks and glory to Almighty God, who is the source of my strength and inspiration. I also acknowledge Kenyatta University administration for admitting me to undertake this course. I am very grateful to my supervisors, Dr. Ruth Wanjau and Dr. Mildred Nawiri for their consistent supervision, crucial remarks, valuable suggestions and unreserved cooperation from writing of proposal to the preparation of this thesis.

I also greatly acknowledge the staff from chemistry department Kenyatta University Dennis Ogoro and Eunice Oduol for their technical assistance. In addition, I am thankful to Geology and Mine laboratory workers (Nairobi), Mr. Joram Wambua and Mr. Josiah Chumo for their assistance during my sample analysis using AAS and AES instruments in their laboratory.

My deepest heart-felt gratitude goes to my caring wife, Regina for her encouragement, love and patience. I would like also to express my thanks to my mother Sarah for her moral support as I undertook my studies. I am grateful to my friends Vincent Odhiambo, Irene Muturi, Joseph Odundo, Syvonne Okore, Esther Nthiga, Zippora Moraa, Marianna Nzivo, John Mwangi and Mwangi Njeri whose discussions and friendship were valuable academically, spiritually and socially during the study.

TABLE OF CONTENTS

TITTLE.....	.....
DECLARATION.....	i
DEDICATION.....	iii
ACKNOWLEDGEMENTS.....	iv
TABLE OF CONTENTS.....	v
LIST OF TABLES.....	x
LIST OF FIGURES.....	xi
ABBREVIATIONS AND ACRONYMS.....	xii
ABSTRACT.....	ix
CHAPTER ONE:INTRODUCTION.....	1
1.1 Background information.....	1
1.2 Problem Statement and Justification.....	5
1.3 Hypothesis.....	5
1.4 Objectives.....	5
1.4.1 General objective.....	5
1.4.2 Specific objectives.....	6
1.5 Significance of the study.....	6
1.6 Scope and limitations	7
CHAPTER TWO: LITERATURE REVIEW.....	8
2.1 Mbeere South.....	8
2.2 Mango varieties and maturity.....	8
2.3 Mango nutritive content.....	10

2.4 Role of essential minerals from mango residues.....	11
2.5 Uses of mango residues in different parts of the world.....	20
2.6 Methods of analysis.....	21
2.7 The Atomic absorption spectroscopy (AAS).....	22
2.7.1 Components of AAS.....	22
2.7.2 Working principle of the AAS.....	23
2.8. Atomic emission spectroscopy (AES) principle.....	25
CHAPTER THREE: MATERIALS AND METHODS.....	27
3.1 Study Area.....	27
3.2 Experimental research design.....	27
3.3 Sampling.....	27
3.4 Sample pre-treatment.....	28
3.5 Chemicals, reagents and solvents.....	29
3.6 Cleaning of apparatus.....	29
3.7 Sample digestion for spectroscopic measurements.....	29
3.8 Preparations of standard solutions for AAS and AES.....	30
3.9 Recovery test.....	32
3.10 Reproducibility.....	33
3.11 Operating parameters for AAS and AES.....	33
3.12 Calculation of concentrations of minerals in the samples.....	34
3.13 Data analysis.....	35
CHAPTER FOUR: RESULTS AND DISCUSSIONS.....	36
4.1 Introduction.....	36

4.2 Method validation.....	36
4.2.1 Regression analysis.....	36
4.2.2 Recovery test.....	38
4.2.3: Reproducibility.....	38
4.3.0: Levels of essential minerals in seeds from varieties of mangoes.....	39
4.3.1 Sodium (Na) in mango seeds.....	41
4.3.2 Potassium (K) in mango seeds.....	42
4.3.3 Magnesium (Mg) in mango seeds.....	44
4.3.4 Calcium (Ca) in mango seeds.....	45
4.3.5 Zinc (Zn) in mango seeds.....	46
4.3.6 Copper (Cu) in mango seeds.....	47
4.3.7 Iron (Fe) in mango seeds.....	48
4.3.8 Manganese (Mn) in mango seeds.....	49
4.4.0 Levels of essential minerals in endocarps from varieties of mangoes.....	51
4.4.1 Sodium (Na) in mango endocarps.....	53
4.4.2 Potassium (K) in mango endocarps.....	54
4.4.3 Magnesium (Mg) in mango endocarps.....	55
4.4.4 Calcium (Ca) in mango endocarps.....	56
4.4.5 Zinc (Zn) in mango endocarps.....	57
4.4.6 Copper (Cu) in mango endocarps.....	58
4.4.7 Iron (Fe) in mango endocarps.....	59
4.4.8 Manganese (Mn) in mango endocarps.....	60
4.5.0 Levels of essential minerals in peels from varieties of mangoes.....	61

4.5.1 Sodium (Na) in mango peels.....	63
4.5.2 Potassium (K) in mango peels.....	64
4.5.3 Magnesium (Mg) in mango peels.....	65
4.5.4 Calcium (Ca) in mango peels.....	66
4.5.5 Zinc (Zn) in mango peels.....	67
4.5.6 Copper (Cu) in mango peels.....	68
4.5.7 Iron (Fe) in mango peels.....	69
4.5.8 Manganese (Mn) in mango peels.....	70
4.5.9 Variations of minerals in mango residues.....	71
CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS.....	74
5.1 Conclusions.....	74
5.2 Recommendations from this study.....	75
5.3 Recommendation for further work.....	76
REFERENCES.....	77
APPENDICES.....	83
Appendix 1: Sodium calibration curve.....	83
Appendix 2: Potassium calibration curve.....	83
Appendix 3: Magnesium calibration curve.....	84
Appendix 4: Zinc calibration curve.....	84
Appendix 5: Copper calibration curve.....	85
Appendix 6: Iron calibration curve.....	85
Appendix 7: Manganese calibration curve.....	86
Appendix 8: Study area-Mbeere South.....	87

Appendix 9: Varieties of mango species analyzed in this study.....88

Appendix 10: Parts of mango fruit.....89

LIST OF TABLES

Table 3.1:	Concentration of the standards and minerals before and after spiking	.....33
Table 3.2:	The Atomic Absorption Spectroscopy (AAS) and Atomic Emission Spectroscopy (AES) operating conditions	.....34
Table 4.1:	The AAS and AES regression results of minerals analyzed	.....37
Table 4.2:	Percentage recovery of the minerals	.....38
Table 4.3:	Reproducibility test for the minerals measured	.....39
Table 4.4:	Mean levels of essential minerals (mg/100g) in the seeds of varieties of mangoes from Gachoka and Kiritiri divisions	.....40
Table 4.5:	Mean levels of essential minerals (mg/100g) in the endocarps of varieties of mangoes from Gachoka and Kiritiri divisions	.....52
Table 4.6:	Mean levels of essential minerals (mg/100g) in the peels of varieties of mangoes from Gachoka and Kiritiri divisions	.....62
Table 4.7:	Comparison of minerals (mg/100g) in mango residues from Gachoka and Kiritiri divisions	.....72

LIST OF FIGURES

Figure 2.1: Schematic representation of atomic absorption spectroscopy (AAS).....	23
Figure 4.1: Calibration curve for calcium standard solution using AAS.....	37

ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectroscopy
AES	Atomic Emission Spectroscopy
ATP	Adenosine Tri phosphate
ANOVA	Analysis of Variance
CV	Coefficient of Variation
DM	Dry Matter
DNA	Deoxyribonucleic Acid
FNB	Food and Nutrition Board
NRC	National Research Council, USA
RDA	Recommended Daily Allowance
RNA	Ribonucleic Acid
USDA	United States Development Agency

ABSTRACT

The mesocarp (edible part) of *Mangifera indica* L. (mango) is known for its contribution towards addressing nutritional challenges that face most of the developing countries. Based on the Recommended Daily Allowance (RDA) recommended levels by National Research Council (NRC) USA, mangoes would provide sufficient amounts of essential minerals, sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), Zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn). However, as a result of consuming mangoes, over 150,000 tonnes of the residues (non edible parts) namely the epicarp (peels), endocarp (shell) and the seed kernels that account for 40-50 % of the fruit are dumped thus posing a concern on environmental pollution. A knowledge gap on the potential nutritional contribution and benefits of these residues in the arm of reducing environmental pollution is therefore called for. The Mbeere south in Embu county Kenya, grows varieties of mangoes some of which are ngowe, apple and van dyke. Residues of these varieties of mangoes grown in Mbeere were investigated to assess their food value particularly with regard to mineral content (Na, K, Mg, Ca, Zn, Cu, Fe, Mn). Mangoes were sampled twice randomly during the harvest period and the minerals measured using Atomic Absorption and Emission Spectrometry. Data analysis by one-way ANOVA was done using SPSS 18 for windows. The range of concentration (mg/100g) of essential minerals from lowest to the highest levels were as follows: In seeds; 0.48 ± 0.05 (Cu, in apple) - 1492.05 ± 43.75 (Ca, in ngowe): In endocarp; 0.38 ± 0.02 (Cu, in ngowe) - 1689.5 ± 9.15 (Ca, in van dyke): In peels; 0.38 ± 0.03 (Cu, in ngowe) - 1482 ± 2.05 (Ca, in apple). In most cases, there were no significant differences ($p < 0.05$) in the levels of essential minerals both, between the residues and mango varieties. The seeds and peels residues as well as the ngowe and van dyke mango varieties recorded significantly higher levels of most minerals. Similarly, the levels of essential minerals decreased in the order $Ca > K > Mg > Na > Fe > Mn > Zn > Cu$. With regard to the RDA recommended levels of minerals, these findings indicate that mango residues are a rich source of essential minerals. This potential can be explored for other benefits such as for use in animal feeds/supplements than to cause the present hazard of environmental pollution. It's a way of waste management.

CHAPTER ONE: INTRODUCTION

1.1 Background information

Mangifera indica L. belong to the genus *Mangifera*. of the family *Anacardiaceae*. Notable plants in this family include cashew (genus *anacardium*), ivy, sumac, smoke tree and manila. Mangoes account for approximately half of all tropical fruits produced worldwide. The Food and Agriculture Organization of the United Nations estimated worldwide production at nearly 35,000,000 tonnes in 2009 (FAO, 2011).

In Kenya, mangoes grow best from 0-1500 m above sea level but can grow in higher elevations. The area under mango production in Kenya was estimated at 28,794 Ha with an output of 448,631 metric tonnes (MOA, 2007). Main areas of mango production are the Eastern, Central, Nyanza and Coastal regions (Griesbach, 2003). In Eastern, only one crop of mango is produced per year while in Coast, there are two harvesting seasons. In Eastern two districts, Embu and Mbeere are known for high level of mango production (Gathambiri *et al.*, 2006). Two types of mangoes are grown in Kenya, the local and the exotic or improved varieties. The local varieties include ngowe, dodo, boribo and batawi while the exotic varieties include apple, kent, keit, tommy atkins, van dyke, haden, sensation, sabre, sabine, paffin, maya, kenston and hesine (Griesbach, 2003).

The mango fruit is a large fleshy drupe, highly variable in size, shape, colour and taste and weighing up to 1 kg in some cultivars. Green when unripe, the fruit turns orange-reddish as it ripens after 5 to 6 months. Some of maturity indices for mango are; number of days after full bloom, flesh colour, fruit size, skin colour, fruit shape (fullness of

shoulders) and soluble solids content (Slaughter, 2009). The fruit consists of thick epicarp/exocarp (peel) which represents 7-24 % of the whole fruit weight, a resinous edible mesocarp (flesh), a woody endocarp (pit) and seed. Mango fruit contains amino acids, carbohydrates, fatty acids, minerals, organic acids, proteins and vitamins (Berardini *et al.*, 2005).

Mbeere south is located in the arid and semi-arid land (ASAL) of Embu county and is divided into Kiritiri, Gachoka, Makima and Mwea administrative divisions. In Mbeere, over 75 % of the local mangoes varieties produced are ngowe, dodo, batawi and boribo and have dominated mango production although improved varieties of kent, tommy atkins, apple, van dyke and sensation were introduced in Mbeere (Msabeni *et al.*, 2010). Mango is successfully grown on a wide range of soils. In Mbeere, soil profiles are classified as huplic acrisols and luvic arenosols of which nutrient depletions vary according to soil texture, leaching, volatilization and erosion (Bosch *et al.*, 1998). Iron content varies greatly, while low zinc and copper was observed in Mbeere soils (Karyotis *et al.*, 2005).

Okonko *et al.* (2009), defined waste or otherwise residue as any material which has not yet been fully utilized, the left over's from production and consumption. During the processing of ripe mango, peels and seeds are produced as waste which is approximately 40-50 % of the total fruit weight (Sruamsiri and Silman, 2009). It is estimated that mango processing yields between 150,000 and 400,000 tonnes of wastes worldwide, which may cause environmental problems in the vicinity of the plants (Heuzé *et al.*, 2012). The use

of mango wastes in livestock feeding is a way of reducing environmental concerns (Jedele *et al.*, 2003; El-Kholy *et al.*, 2008).

Studies have used mango peels to snails, sheep and broilers with the results that promote their use (Omole *et al.*, 2004; Diarra and Usman, 2008; Sanon and Kanwe, 2011). Mango peels and seeds have also been evaluated for digestible nutrients ensiled with rice straw and leucaena leaves, with the *in vitro* digestibility results showing that mango by-products are good cattle feeds (Sruamsiri and Silman, 2009).

A number of minerals are essential for normal growth and reproduction in animals. The macro minerals including calcium, phosphorus, sodium, chlorine, potassium, magnesium and sulphur play important role in the maintenance of acid-base balance, osmotic pressure, membrane electric potential and nervous transmission (NRC, 2001). Trace minerals including cobalt, copper, iodine, iron, manganese, molybdenum, selenium, zinc, chromium and fluorine serve as components of metalloenzymes, enzyme cofactors and hormones of the endocrine systems (NRC, 2001). The mango mesocarp has been quantified for minerals in (mg/100g) ranging as follows: Mg 9.0, Mn 0.027, Ca 10.0, Cu 0.11, Zn 0.04 and Fe 0.13 (USDA, 2001). The recommended levels of macro and micro minerals vary for the different minerals in human beings and animals. In view of mango residues being inedible some of the mineral requirements in animals or men that have been documented include: Na 1200-1500 mg in men (DRI, 2012), K 0.5-0.8 % ruminants and 4500-4700 mg for men (Bredon and Dugmore, 2005; DRI, 2012), Mg 0.10-0.20 % in cattle and 200-400 mg for men (WHO/FAO, 1998; NRC, 2000; DRI, 2012), Zn 50 mg/kg

in goats and 8.0-11.0 mg in men (WHO/FAO, 1998; Meschy, 2010; DRI, 2012), Cu 4.0-8.0 mg/kg in non ruminants and 2.0-20.0 mg/kg in ruminants (Underwood and Suttle, 1999), Fe 50.0-100.0 mg/100g in growing, laying and lactating animals and 8.0-18.0 for men (WHO/FAO, 1998; NRC, 2005; DRI, 2012), Mn 40-50 mg/kg in goats and 1.9-2.3 mg in men (Meschy, 2010; DRI, 2012), Ca (0.5-1.0 %) in cattle, 3.5 % in poultry and 1000-1300 mg in men (WHO/FAO, 1998; NRC, 2005; DRI, 2012).

Sodium is a major extracellular cation and plays an active part in regulating the neutrality of blood serum. Considerable amounts of sodium appear in the muscles and it is associated with their contraction (Bredon and Dugmore, 2005). Potassium is a major intracellular cation and is involved in the osmotic regulation of tissue fluids and in acid-base balance. Magnesium is a constituent of bones, teeth and enzyme cofactor (Murray *et al.*, 2000). Zinc is a component of many metalloenzymes such as copper-zinc superoxide dismutase, carbonic anhydrase, alcohol phosphatase and RNA polymerase (NRC, 2001). Copper is a component of enzymes such as cytochrome oxidase, Lysyl oxidase, ceruloplasmin tyrosinase and superoxide dismutase (NRC, 2001). Iron primarily functions as component of heme found in haemoglobin and myoglobin (NRC, 2001). Manganese deficiency cause impaired growth, skeletal abnormalities and depressed reproduction (NRC, 2001). Calcium is essential for the formation of skeletal tissues, transmission of nervous tissues impulses, excitation of skeletal and cardiac muscle tissue contraction, blood clotting and as a component of milk (NRC, 2001^a).

1.2 Problem Statement and Justification

It is estimated that both local and exotic mango processing yields between 150,000 and 400,000 tones of residues worldwide from juice producing industries and domestic consumption. These residues consists of mango epicarp (peels), endocarp (seed cover) and seed which in total accounts for about 40-50 % of the total fruit weight. These mango residues are often discarded or dumped in open areas where they decompose adding to environmental pollution (Jedele *et al.*, 2003; El-Kholy *et al.*, 2008). Some studies have proposed the potential nutrient benefit of the residues but the essential mineral profile of these is still unknown. It is therefore important to draw the nutrient profile to support the value of mango residues and further completely exploit the residues for further product development. This subsequently contributes to waste management as well as reduce environmental pollution.

1.3 Hypothesis

The mango residues have significant levels of essential minerals

1.4 Objectives

1.4.1 General objective

To quantify the levels of selected macro and micro minerals in residues of local and exotic mango varieties grown in Mbeere south, Embu county, Kenya.

1.4.2 Specific objectives

- i) To quantify the levels of macro (Na, K, Mg, Ca) and micro minerals (Zn, Cu, Fe, Mn) in the seeds of ngowe, apple and van dyke mango varieties from Gachoka and Kiritiri divisions, Mbeere south, Embu county, Kenya.
- ii) To quantify the levels of macro (Na, K, Mg, Ca) and micro minerals (Zn, Cu, Fe, Mn) in the endocarps of ngowe, apple and van dyke mango varieties from Gachoka and Kiritiri divisions, Mbeere south, Embu county, Kenya.
- iii) To quantify the levels of macro (Na, K, Mg, Ca), and micro minerals (Zn, Cu, Fe, Mn) in the epicarps of ngowe, apple and van dyke mango varieties from Gachoka and Kiritiri divisions, Mbeere south, Embu county, Kenya.

1.5 Significance of the study

The results from this study are important as they draw profile of the levels of minerals in mango residues. This profile is a key for further research geared towards formulations of animal feeds or mineral supplement and will have basis of which residues are valuable for different feeds. The food nutritionists and animal feed manufacturers can use this information in incorporating mango residues as ingredients during food or feed formulation to boost the levels of essential minerals. In the long run, it will contribute to waste management.

1.6 Scope and limitations

Mangoes are grown in many counties all over Kenya, however, only one local variety (ngowe) and two exotic varieties (apple and van dyke), the most common mangoes grown in Gachoka and Kiritiri divisions Mbeere south were considered. This study analyzed the levels of Na, K, Mg, Ca Zn, Cu, Fe and Mn in mango residues. The levels in soils were not considered.

CHAPTER TWO: LITERATURE REVIEW

2.1 Mbeere South

In Kenya the main areas of mango production are the Eastern, Central, Nyanza and Coast (Griesbach, 2003). In Eastern, Embu and Mbeere are known for high level of mango production with mango yield in Mbeere being estimated at 20 tons/ha (Gathambiri *et al.*, 2006, Msabeni, 2010). Mbeere south is located in the arid and semi-arid lands (ASALs) of Embu county. It's divided into four administrative divisions: Gachoka, Makima, Kiritiri and Mwea. The region falls away from Mount Kenya along a northwest-to-southeast gradient. It experiences a bimodal pattern of rainfall with the long rains between april and june and the short rains from october to december. The district can be subdivided into several agro-ecological zones based on altitude, rainfall and soil characteristics. In Mbeere, the soils are well drained, shallow to deep, yellowish brown, loamy sand to sandy loam, luvic arenosols. They are strongly acid to slightly acid and low in organic C, total N and extractable P (Muya, 2003). Specifically in Kiritiri, the soils are well drained, shallow to deep root yellowish brown while at Gachoka the soils are loamy sandy luvic arenosols. The agro-ecological zones are directly linked with the major enterprises in the district, which include cotton and mangoes in the higher altitude, higher rainfall areas, and tobacco and livestock in the drier, lower altitude areas (Msabeni, 2010).

2.2 Mango varieties and maturity

Mango is successfully grown on a wide range of soils. The trees do well in sandy soils, loam, black cotton and even murram soils at other elevations (Griesbach, 2003). The

mango fruit is a large, fleshy drupe, containing an edible mesocarp of varying thickness. Fruit color is genotype dependant and range from green, greenish-yellow, yellow and red bluish. The exocarp is thick and glandular. The mesocarp can be fibrous or fiber-free with flavor ranging from turpentine to sweet. The endocarp is woody, thick and fibrous (Slaughter, 2009). The picture showing different parts of a mango is shown in Appendix 10.

The apple mango fruits are medium to large, nearly round in shape and have a rich yellow or orange to red colour when ripe. Average length measures 9.7 cm by 11 cm in width, and the weight is 280-580 g (mean: 397 g). The skin is smooth and thin, and the juicy yellow flesh is of excellent flavour and of melting texture virtually free from fibre. This is not a polyembryonic cultivar and trees propagated by seed are very heterogeneous in fruit shape, colour and quality (Griesbach, 2003).

Ngowe is the most easily recognized of the local mango fruits. It is large, oblong and slender with a very prominent hook-like beak at the apex. From pale green, the fruit develops to a most attractive yellow to orange colour when ripe. The deep yellow flesh is of excellent quality, virtually free from fibre, melting and carries no turpentine taste. The average fruit length measures 14 cm with a width of 9.5 cm and a weight range of 425—600 g (mean: 523 g). The seeds are polyembryonic which means progeny develops more or less true-to-type (Griesbach, 2003).

The van dyke is an ovate, small to medium-sized fruit (average weight 280 g) is very attractive showing a bright yellow ground colour with a heavy crimson blush and prominent beak. The average fruit dimensions are: 10.5 cm length by 7.9 cm width. The skin is thick, though easily separating and covered with numerous white/yellow lenticels. The flesh is quite firm, melting and juicy with little fibre, orange-yellow, rich, spicy and sweet with a strong pleasant aroma. It is of good to excellent quality. The seed is mono-embryonic and covered by a medium-sized woody stone (7.1 % of fruit weight). The trees are medium-sized with a large open canopy and are regular producers but yield only moderately (Griesbach, 2003). The photographs of ngowe, apple and van dyke mango varieties are shown in Appendix 9.

Maturity of mangoes depends on cultivars and environmental conditions thus it takes 90 to 160 days after flowering for maturity to be attained. The fruits are generally picked when they begin to change colour. A destructive maturity test that can be applied even before the external colour break starts is to examine the colour of the flesh around the seed. When this begins to change from green-white to yellow or orange, it indicates that the fruit is beginning to ripen and may therefore be picked. Also the greater the swelling of the shoulders above the stalk attachment, the riper the fruit is likely to be (Griesbach, 2003; Slaughter, 2009).

2.3 Mango nutritive content

Mango fruit contains essential vitamins (A, B6, C and E) and dietary minerals (K, Cu, Mg, Ca, Zn and Fe) and 17 amino acids. As well, mango peel and pulp contain other

phytonutrients, such as the pigment antioxidants carotenoids and polyphenols and omega-3 and -6 polyunsaturated fatty acids. Antioxidants of the peel and pulp include carotenoids, such as the pro-vitamin A compound, β -carotene, lutein and α -carotene (USDA, 2001; Gouado *et al.*, 2007). Up to 25 different carotenoids have been isolated from mango pulp, the densest content for which was β -carotene accounting for the yellow orange pigmentation of most mango species (Chen *et al.*, 2004). Contained within the peel and pulp are rich contents of polysaccharides as fiber sources, especially starch and pectins (Lagher *et al.*, 2002). Peels and leaves also have significant content of polyphenols, including xanthenes, mangiferin and gallic acid (Barreto *et al.*, 2008).

2.4 Role of essential minerals from mango residues

Heart function and nerve impulse conduction and transmission are dependent on proper balance of sodium and potassium (NRC, 2001). Sodium (Na) is an essential nutrient, the cation mainly responsible for regulating extracellular fluid volume and plasma volume (Institute of Medicine, 2004). It is also important in ionic and osmotic balance, muscle contractions, nerve impulse transmission, glucose and amino acid transport and it further strengthens cells and endoskeleton (Ekanayake and Nair, 1998; NRC, 2001). Sodium requirement for immature leghorn type layer chicken was set at 0.15 % while its requirements for sheep was set at 0.7-1.0 g/kg DM and cattle 0.8-1.2 g/kg DM (NRC, 1994; Freer, 2007).

The levels of Na in *Maldah*, *Anwar ritual*, *Chounsa* and *Dusehri* mango varieties in seeds from Pakistan were found to be 0.0925 g%, 0.1375 g%, 0.1125 g% and 0.0575 g%

respectively (Shad *et al.*, 2001). Shad *et al.* (2001) explained these variations to be due to change in soil composition, climatic conditions and varietal differences in parent trees and the study helped to assess the food value of mango seed kernels particularly with regard to mineral contents. In Ghana, Na level in wild mango *Irvingia gabonensis* was 74.71 ± 1.23 ppm in mesocarp (pulp), 81.39 ± 1.22 ppm in endocarp (seed coat) and 43.83 ± 1.06 ppm in seed (Ayivor *et al.*, 2011). These results showed that, all the parts of the wild mango are rich source of important minerals that have a very positive effect on human health. The levels reported in other studies were cashew nut 12.0 mg/100g, Syrian sumac fruit 101.04 ± 0.15 mg/ kg, Chinese sumac fruit 871.00 ± 0.42 mg/kg and Congo mango seed flour 2.70 ± 0.02 mg/100g (Kossah *et al.*, 2009; Nzikou *et al.*, 2010; USDA 2011). The results showed that both Syrian and Chinese sumac fruits could be used in human diets to supply the required minerals (Kossah *et al.*, 2009).

Potassium is the principal cation in intracellular fluid and functions in acid-base balance, regulation of osmotic pressure, conduction of nerve impulse, muscle contraction particularly the cardiac muscle, cell membrane function and Na^+/K^+ -ATPase (Soetan *et al.*, 2010). Severe potassium deficiency is characterized by hypokalemia—a serum potassium concentration of less than 3.5 mmol /L. The adverse consequences of hypokalemia include cardiac arrhythmias, muscle weakness and glucose intolerance (FNB, 2005). The potassium requirement for immature leghorn type layer chicken was set at 0.25 % while the requirements for sheep and cattle were 5 g/kg DM (NRC, 1994; Freer, 2007).

The levels of K in *Maldah*, *Anwar ritual*, *Chounsa* and *Dusehri* mango varieties in seeds from Pakistan were 1.49 g%, 1.63 g%, 1.14 g% and 1.42 g% respectively (Shad *et al.*, 2001). The variations in the mineral levels may be due to physical and chemical nature of the soil in the production sites, the ability to take up metals by the plants, deposition of metals in the environment, use of untreated water, the nature of the fruit, exposed surface area and the anthropogenic activities like use of heavy metal-based pesticides (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010). The Congo mango seed flour contained 158.0 ± 0.12 mg/100g while the Ghana K level in wild mango *Irvingia gabonensis* was 0.303 ± 0.01 % in mesocarp (pulp), 1.331 ± 0.022 % endocarp (seed coat) and seed 0.723 ± 0.042 % (Nzikou *et al.*, 2010; Ayivor *et al.*, 2011). The results from Ghana showed that all the parts of the wild mango are rich source of important minerals that have a very positive effect on human health. The levels reported in other members of *Anacardiaceae* family include cashew nut 660.0 mg/100g, Syrian sumac fruit 7441.25 ± 0.07 mg/kg and Chinese sumac fruit 5576.00 ± 0.68 mg/kg (USDA, 2011; Kossah *et al.*, 2009). The results showed that both Syrian and Chinese sumac fruits could be used in human diets to supply the required minerals (Kossah *et al.*, 2009).

The magnesium (Mg) ions play a role in manipulating important biological polyphosphate compounds like Adenosine Triphosphate (ATP), Deoxyribonucleic Acid (DNA) and Ribonucleic Acid (RNA) and in the metabolism of fat and protein (Housecraft and Sherpe, 2008). It is also a constituent of bones, teeth and enzyme cofactor (Murray *et al.*, 2000). Deficiency of Mg in poultry leads to slow growth, lethargy, loss of appetite and spasms (Prabakaran, 2003). Magnesium deficient calves fed

with milk only for a long period develop skin lesions, nervous muscular irritability and eventually, convulsions leading to death while older animals develop grass tetany. Magnesium requirement for sheep is 0.9-1.2 g/kg DM and cattle are 1.3-2.2 g/kg DM while the requirement for poultry is 60 mg/kg DM (NRC, 1994; Kelly, 2007). The Recommended Dietary Allowance (RDA) of Mg for adult men and women are 320-420 mg/day (FNB, 2001).

Different proportions of magnesium has been reported in cashew nut 292.0 mg/100g, Syrian sumac fruit 605.74 ± 0.51 mg/kg, Chinese sumac fruit 871.00 ± 0.42 mg/kg and Congo mango seed flour 22.34 ± 0.01 mg/100g (Kossah *et al.*, 2009; Nzikou *et al.*, 2010; USDA, 2011). Mango fruit pulp contains 9 mg/100g of Mg while Nigeria mango seed contains 94.8 mg/100g (USDA, 2001; Fowomola, 2010). In Ghana, Mg level in wild mango *Irvingia gabonensis* was 0.014 ± 0.004 % in mesocarp (pulp), 0.012 ± 0.006 % in endocarp (seed coat) and 0.048 ± 0.008 % in seed (Ayivor *et al.*, 2011). The results from Ghana show that all the parts of the wild mango are rich source of many important minerals that have a very positive effect on human health (Ayivor *et al.*, 2011).

Calcium functions as a constituent of bones and teeth, regulation of nerve and muscle function (Soetan *et al.*, 2010). It is also involved in blood coagulation, enzyme activation, membrane permeability, muscle contraction, normal transmission of nerve impulses and in neuromuscular excitability (Soetan *et al.*, 2010). Calcium deficiency in poultry leads to poor growth, soft bones, thin shell or shell-less eggs and poor egg production (Prabakaran, 2003). Dietary deficiency of Ca in cattle leads to rickets, slow growth, poor

bone development, easily fractured bones and reduced milk yield. The recommended daily allowance for Ca in cattle is 2.0-11.0 g/kg DM and that for sheep is 1.4-7.0 g/kg DM (Kelly, 2007). In poultry Ca requirement is 0.8-1.0 %kg DM for broilers and 0.8-0.90 % kg DM for layers (NRC, 1994). The RDA for Ca in men of 1000 mg/day has been set (FNB, 2010). Tolerable upper intake levels of calcium of 2500 mg/day have been recommended (Michael *et al.*, 2005).

Different proportions of Ca reported in *Maldah, Anwar ritual, Chounsa and Dusehri* mango seeds from Pakistan were 0.107 g%, 0.4925 g%, 0.5675 g% and 1.1125 g% respectively. The variations in the mineral levels may be due to physical and chemical nature of the soil in the production sites, the ability to take up metals by the plants, deposition of metals in the environment, use of untreated water, the nature of the fruit, exposed surface area and the anthropogenic activities like use of heavy metal-based pesticides (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010). Mango fruit pulp contains 10 mg/100g Ca while the Nigeria mango seed contains 111.3 mg/100g (USDA, 2001; Fowomola, 2010). Both studies concluded that mango seed is a nutritional promising seed. The findings reported in other studies include cashew nut 37.0 mg/100g, Syrian sumac fruit 3155.53 ± 0.41 mg/kg, Chinese sumac fruit 3898.00 ± 0.5 mg/kg and Congo mango seed flour 10.21 ± 0.05 mg/100g (Kossah *et al.*, 2009; Nzikou *et al.*, 2010; USDA, 2011).

Zinc is essential in fat absorption, growth, good health, structural stability of the molecules and membranes (Suttle, 2010). It is also a component of metallo enzyme such

as carbonic anhydrase, alkaline phosphatase and phospholipase (Suttle, 2010). Zinc deprivation is characterized by inappetence, cessation of growth, anorexia, abnormalities of skin and appendages, skeletal disorders and reproductive disorders (Suttle, 2010). Zinc deficiency in poultry leads to poor growth and shortening of leg bones (Prabakaran, 2003). Its deficiency in male cause atrophy in seminiferous tubules and inefficient testicular development, leading to reduced testicular size, lack of libido and can adversely affect spermatogenesis (Satish, 2003). The recommended dietary allowance for zinc in cattle and sheep is 9-20 mg/kg DM (Kelly, 2007). In poultry Zn requirements is 40.0 mg/kg of feed in broilers and 35.0 mg/kg in layers (NRC, 1994). The RDA for adults is 8 mg/day for women and 11 mg/day for men. The median intake from food in the United States was approximately 9 mg/day for women and 14 mg/day for men (FNB, 2001).

The level of Zn in *Maldah*, *Anwar ritual*, *Chounsa* and *Dusehri* mango varieties seeds reported in Pakistan were as follows 6.15 mg/100g, 10.20 mg/100g, 6.15 mg/100g and 3.45 mg/100g respectively (Shad *et al.*, 2001). The variations in the mineral levels may be due to physical and chemical nature of the soil in the production sites, the ability to take up metals by the plants, deposition of metals in the environment, use of untreated water, the nature of the fruit, exposed surface area and the anthropogenic activities like use of metal-based pesticides (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010). Mango fruit pulp and mango seeds in Nigeria contained 0.04 mg/100g and 1.10 mg/100g of Zn respectively (USDA, 2001; Fowomola, 2010). Fowomola (2010) concluded that, mango seed is a nutritional promising seed. Levels

reported in other studies were as follows: cashew nut 5.78 mg/100g, Syrian sumac fruit 55.74±0.38 mg/100g and Chinese sumac fruits 17.20±0.38 mg/100g (Kossah *et al.*, 2009; USDA, 2011). The results showed that both Syrian and Chinese sumac fruits could be used in human diets to supply the required minerals (Kossah *et al.*, 2009). In Ghana, Zn level in wild mango *Irvingia gabonensis* was 6.72±0.62 ppm in mesocarp (pulp), 63.54±5.99 ppm in endocarp (seed coat) and 57.86±5.50 ppm in seed (Ayivor *et al.*, 2011). The results showed that all the parts of the wild mango are rich source of important minerals that have a very positive effect on human health (Ayivor *et al.*, 2011).

Copper is required by the body for the production of red blood cells, as it is essential for absorption and transport of iron necessary for hemoglobin synthesis (Tuormaa, 2000). In poultry, Cu requirement is 80 mg/kg for broilers and 40 mg/kg for layers (NRC, 1994). Copper deficiency in poultry leads to anemia, impaired body response and lowered activity (Prabakaran, 2003). Normal body requirement of copper for growing, finishing cattle and lactating cattle is 10 mg/kg (NRC, 2000). The median intake of copper from food in the United States is approximately 1.0 to 1.6 mg/day for adult men and women (FNB, 2001).

The level of copper in *Maldah*, *Anwar ritual*, *Chounsa* and *Dusehri* mango varieties in seeds from Pakistan were as follows 0.10 mg/100g, 0.65 mg/100g, 0.05 mg/100g and 0.30 mg/100g respectively (Shad *et al.*, 2001). The study helped to assess the food value of mango seed kernels particularly with regard to mineral contents (Shad *et al.*, 2001). In Ghana, Cu level in wild mango *Irvingia gabonensis* was 44.12±3.97 ppm in mesocarp

(pulp), 11.93 ± 0.55 ppm in endocarp (seed coat) and 57.22 ± 4.20 ppm in seed (Ayivor *et al.*, 2011). Mango fruit pulp contains 0.11 mg/100g of Cu while Nigeria mango seed contains 0.1 mg/100g (USDA, 2001; Fowomola, 2010). According to Fowomola (2010), mango seed is a nutritional promising seed. Levels reported in other members of *Anacardiaceae* family include cashew nut 2.195 mg/100g, Syrian sumac fruit 42.68 ± 0.45 mg/100g and Chinese sumac fruits 9.56 ± 0.19 mg/100g (Kossah *et al.*, 2009; USDA, 2011).

Iron is an essential minerals required as a component of myoglobin and hemoglobin responsible for transporting oxygen and carbon dioxide (Cancado and Chiatone, 2009). Iron also participates in a variety of biochemical functions including electron transport in mitochondria, catecholamine metabolism and DNA synthesis. Early signs of iron deficiency include anemia and low blood haemoglobin (Cancado and Chiatone, 2009).

The suggested dietary allowances for Fe in cattle are 40 mg/kg (Freer, 2007). In poultry, Fe daily allowance is 80.0 mg/kg in broilers and 60.0 mg/kg in layers (NRC, 1994). The RDA for all age groups of men and postmenopausal women is 8 mg/day; the RDA for premenopausal women is 18 mg/day (FNB, 2001). The median dietary intake of iron is approximately 16 to 18 mg/day for men and 12 mg/day for women (FNB, 2001). The levels of Fe in *Maldah*, *Anwar ritual*, *Chounsa* and *Dusehri* mango seeds from Pakistan were 0.25mg/100g, 0.40mg/100mg, 0.20 mg/100g and 1.55 mg/100g respectively (Shad *et al.*, 2001). Mango fruit pulp contains 0.13 mg/100g of Fe while the Nigeria mango seed contains 11.9 mg/100g (USDA, 2001; Fowomola, 2010). According to Fowomola

(2010), this information would serve as a guide for the possible utilization of mango seed by animal feed manufacturers as an alternative source of food ingredient. The levels reported in other studies include, cashew nut 6.68 mg/100g, Syrian sumac fruit 174.15 ± 0.18 mg/kg and Chinese sumac fruit 180.00 ± 0.67 mg/kg (USDA, 2011; Kossah *et al.*, 2009). The results showed that both Syrian and Chinese sumac fruits could be used in human diets to supply the required minerals (Kossah *et al.*, 2009). In Ghana, Fe level in wild mango *Irvingia gabonensis* was 64.58 ± 5.23 ppm in mesocarp (pulp), 1730.8 ± 180.83 ppm in endocarp (seed coat) and 193.74 ± 17.82 ppm in seed (Ayivor *et al.*, 2011).

Manganese is important in the breakdown of carbohydrates, synthesis of nitric acid and metabolism of glucose and glycogen (Cozzolino, 2005). Manganese acts as enzyme cofactors in enzymes such as transferases, hydrolases and isomerases (Cozzolino, 2005). Its deficiency in poultry leads to staggering gait and enlarged joints (Prabakaran, 2003). In cows, Mn deficiency leads to irregular estrous cycle, cystic ovary, increase in embryonic mortality and reduced conception rate. The suggested daily allowance for Mn in cattle and sheep is 20-25 mg/kg DM while that for poultry is 60 mg/kg for broilers and 30 mg/kg for layers (NRC, 1994; Kelly, 2007). The Adequate Intake for adult men and women is 2.3 and 1.8 mg/day respectively (FNB, 2001).

Manganese is present in mango seeds and also in cashew nuts in different proportions. The concentrations of Mn reported in seeds of four different mango varieties grown in Pakistan were as follows: *Maldah* 0.75 mg/100g, *Anwar retual* 1.00 mg/100g, *Chounsa*

0.09 mg/100g and *Dusehri* 0.70mg/100g (Shad *et al.*, 2001). The mango fruit pulp contains 0.027 mg/100g of Mn while the Nigeria mango seeds contain 0.04 mg/100g (USDA, 2001; Fowomola, 2010). In Ghana, Mn level in wild mango *Irvingia gabonensis* was 81.29 ± 0.16 ppm in mesocarp (pulp), 136.71 ± 0.080 ppm in endocarp (seed coat) and 70.97 ± 0.63 ppm in seed (Ayivor *et al.*, 2011). The results showed that all the parts of the wild mango are rich source of many important minerals that have a very positive effect on human health (Ayivor *et al.*, 2011). The levels reported in other members of *Anacardiaceae* family were: cashew nut 1.655mg/100g, Syrian sumac fruit 10.57 ± 0.39 mg/kg and Chinese sumac fruits 11.60 ± 0.35 mg/kg (Kossah *et al.*, 2009; USDA, 2011).

2.5 Uses of mango residues in different parts of the world

In West Africa, fresh mango peels have been fed successfully to snails with no adverse effects but gave lower performance than papaya peels (Omole *et al.*, 2004). In Burkina Faso, experiment with sheep concluded that mango peels from dried mango processing units are useful feed for animal with regard to its nutritive value and intake characteristics by sheep. However, mango seed kernels showed low palatability probably due to the tannin content. It could however be incorporated in a diet in limited amount with the peels and a protein source (Sanon and Kanwe, 2011). In Nigeria, it was concluded that 20 % of the maize can be replaced with boiled mango kernel meal in the diet of broilers without adverse effects on both growth and blood parameters (Diarra and Usman, 2008) Approximately 0.4 to 0.6 million tons of mango peels is generated annually in India (Anonymous, 2004). This waste is either used as cattle feed or dumped in open areas, where it adds to environmental pollution (Anonymous, 2004). In India again, treated (de-

oiled, soaked or boiled) mango seed kernel has been successfully used to replace maize in levels up to 15-20 % in poultry diets (Ravindran and Blair, 1991).

In Thai, a study was conducted in beef cattle to determine the nutritive value of mango by-products (peels and seeds) and to evaluate the digestible nutrients of ensiled mango by-products with rice straw and leucaena leaves. The digestibility of nutrients of ensiled mango peel with rice straw increases with increasing admixture of leucaena leaves. In vitro digestibility showed that all forms of mango peel by-products can be used as cattle feed (Sruamsiri and Silman, 2009).

2.6 Methods of analysis

The methods of analysis include Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) (Davidowski *et al.*, 2010), Atomic Absorption Spectroscopy (AAS) (Gian *et al.*, 2009), Atomic Emission Spectroscopy (AES) (Miller *et al.*, 2010), Energy Dispersive X-ray Fluorescence (EDXRF) (Beckhoff *et al.*, 2006) and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) (Pavel *et al.*, 2005). The AAS were used for analysis of Cu, Zn, Mg, Fe, Ca and Mn while AES was used in the analysis of alkali minerals (K and Na). Both methods were preferred because of their sensitivity, availability and selectivity.

2.7 The Atomic absorption spectroscopy (AAS)

2.7.1 Components of AAS

An atomic absorption spectrophotometer consists basically of light source, atomizer, monochromator, detector and the read out device. The light source emits the sharp line spectrum of the metals to be determined. The source of radiation is the hollow cathode lamp which consists of a tungsten anode and a cylindrical cathode sealed in a glass tube that is filled with neon or argon at a pressure of 1-5 torr. It gives specific radiation for each element to be analyzed. The atomizers are of two types, the flame electro thermal atomizers. They produce atomic vapor of the sample to be analyzed. Monochromators are filters, prisms or gratings that disperse or separate radiation so that the selected wavelength corresponding to a particular energy of the samples is transmitted. A detector (usually the photomultiplier tube or phototube or photodiode array detectors) senses the selected wavelength of light from the monochromators. The electrical signal produced is amplified by the amplifier. A read out system which includes both chart recorders and digital display records the atomic spectra and absorbance values respectively (Okalebo *et al.*, 2002). The schematic representation of Atomic absorption spectroscopy is shown in figure 2.1.

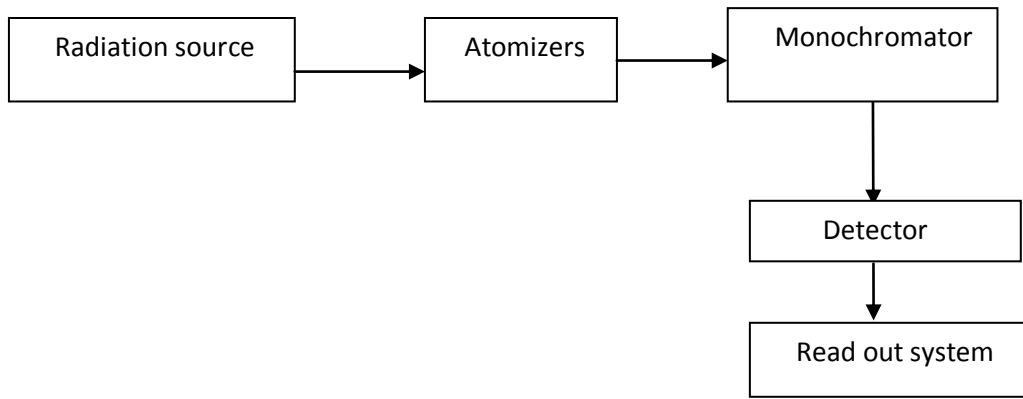


Figure 2.1: Schematic representation of atomic absorption spectroscopy (AAS)

Source: (Skoog and Leary, 1992; Okalebo *et al.*, 2002).

2.7.2 Working principle of the AAS

To determine the concentration of a certain metal ion in a sample, the following steps occur within an atomic absorption spectrometer: A hollow cathode lamp, with the cathode made of the metal to be tested for, emits light of a certain frequency. The light produced by the lamp is passed through the sample to be tested vaporized in a flame. The degree of light absorption is proportional to the concentration of the metal in the sample. The intensity of the light that passes through the flame is measured by a photomultiplier tube. By comparing the intensity with that produced from a control sample containing none of the metal ions being tested for, the degree of absorption, or absorbance, can be determined. The absorbance is then compared to that of a series of diluted standard solutions in order to determine the concentration. This involves the use of a calibration graph.

The standard solutions should produce a straight-line graph. The absorbance recorded for the sample being tested can be matched with a concentration using the graph. Absorption of light is associated with transition process from the steady state to another for instance

the case of a steady state O and J where $E_o < E_j$, the o-j transitions results in the absorption of light with the frequency given in Equation 1

$$\nu_{oj} = \frac{E_j - E_o}{h} \dots\dots\dots \text{Eq. 1}$$

Where

h =plank's constant

ν =Frequency

E_o =Energy at ground state

E_j =Energy at excited state

O-J=Transition stimulated by absorption of external radiation

The number of atoms in the excited state relative to the number in the ground state is

given by Maxwell-Boltzmann law given by the Equation2

$$\frac{N_1}{N_0} = \frac{g_1}{g_0} \exp\left(\frac{E_0 - E_1}{KT}\right) \dots\dots\dots \text{Eq 2}$$

Where:-

N_1 =Number of atoms in the excited state

N_0 =Number of atoms in the ground state

g_1 and g_0 =statistical weight of excited and ground state respectively

k =Boltzmann's constant

T =Absolute temperature

E_o =Energy of ground state

E_1 =Energy of the excited state

The relative fraction of atoms in the excited state is dependent on temperature whereas intensity is independent of temperature. Sample solution is aspirated through nebulizer into the air acetylene flame (Taylor *et al.*, 2006). An electrically heated graphite furnace is used when high sensitivity is required. The sample solution gets dispersed into mist of droplets and then gets evaporated into dry salt.

The dry salt goes into vapor then dissociate into atoms that absorb resonance radiation from external source. The unabsorbed radiation is allowed to pass through the monochromator which isolates the existing spectral lines. The isolated analyte line falls on the detector and the output of which is amplified and recorded. The parameter measured is absorbance (A) and related to concentration by the Equation 3.

$$A = \log I_0/I = \epsilon cl \dots \dots \dots \text{Eq 3}$$

Where:-

- A=Absorbance
- I_0 =Incidence radiation
- I=Attenuated radiation
- ϵ =Molar absorptivity ($\text{Lmol}^{-1}\text{cm}^{-1}$)
- c=Concentration (mol dm^{-3})
- l=Path length (cm)

Since the relationship between absorbance (A) and concentration(C) is linear over a wide range of concentration (Beer's law), standards are used to obtain a calibration curve from which concentration of analyte is established through interpolation method.

2.8. Atomic emission spectroscopy (AES) principle

Atomic emission spectroscopy (AES) is a method of chemical analysis that uses the intensity of light emitted from a flame, plasma, arc, or spark at a particular wavelength to determine the quantity of an element in a sample. The wavelength of the atomic spectral line gives the identity of the element while the intensity of the emitted light is proportional to the number of atoms of the element.

The atomic emission is used mainly in the analysis of alkali metals, particularly in biological tissues and fluids. Atomic emission spectroscopy can be more sensitive than atomic absorption spectroscopy. This is true for element whose resonance lines are associated with low energy values (typically with wavelengths greater than 400nm). Thus, sodium (589.0nm), lithium (670.8nm) and potassium (404.7nm) show great sensitivity with atomic emission spectroscopy (Medham *et al.*, 1999).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Area

Mbeere south is found in Embu County, Kenya. The region has four divisions, namely, Mwea, Gachoka, Makima and Kiritiri. The Kiritiri and Gachoka divisions are found in higher altitude regions and are well known for mango productions while the remaining Makima and Mwea divisions are on lower altitude zones and are known for maize and green grams production. In Kiritiri the soils are well drained, shallow to deep, yellowish brown, while at Gachoka the soils are loamy sandy luvisc arenosols. Geographically, Mbeere district lies between latitude $0^{\circ} 20'$ and $0^{\circ} 50'$ south and longitude $37^{\circ} 16'$ and $37^{\circ} 56'$ east (Kinuthia *et al.*, 2009) shown in Appendix 8.

3.2 Experimental research design

Mango fruit is a large fleshy drupe containing an edible mesocarp of varying thickness and is widely grown in Kenya. To quantify the levels of Na, K, Mg, Ca, Zn, Cu, Fe and Mn in mango residues, mature mangoes were sampled twice, flesh yellow in colour from Kiritiri and Gachoka divisions Mbeere south. The residues parts epicarp, endocarp and seeds were separated from the mesocarps (edible parts). The residues were then chopped to small pieces, oven dried, ground to powder, wet digested in a mixture of HNO_3 and H_2SO_4 acids and finally analyzed using AAS and AES instruments.

3.3 Sampling

Purposive non probability strategy was used to select the sampling sites. The sampling sites selected were Gachoka and Kiritiri divisions (shown in Appendix 8), the main

criterion for selection of sampling sites was the availability of the three mango varieties. Ripe mango fruits, five months old after flowering and flesh yellow in colour, were sampled from Kiritiri and Gachoka divisions in Mbeere south. Sampling was done from six farms randomly selected in each division approximately 5 km radius apart. Each farm was divided into six sections from within which one mango of each variety was sampled making a total of 18 mangoes per farm for three varieties and 108 mangoes in each division. The mangoes of each variety in every division were homogenized to get the representative sample. The same procedure was repeated during the second sampling done a month later. The samples were packed into labeled bags and transported to Kenyatta university chemistry laboratory.

3.4 Sample pre-treatment

In the laboratory, the mango samples were washed and rinsed with distilled water and the peels, endocarp and seeds separated from the pulp before being chopped into small pieces. The residue parts (peels, endocarps and seeds) were placed on labeled aluminum foil, oven dried at 105°C and reweighed repeatedly until constant masses were obtained (moisture content < 10 %). The dry samples were ground in a blender to reduce them to smaller particle size. The ground sample powders of each variety for two sampling times in the two divisions were thoroughly homogenized using a blender to get a representative sample for each division. They were then stored at room temperature in well labeled plastic bags awaiting digestion and spectroscopic measurements.

3.5 Chemicals, reagents and solvents

All chemicals, reagents and solvents used were analytical grade concentrated nitric acid, sulfuric acid, hydrogen peroxide and hydrochloric acid. They were sourced from Thomas Baker Chemicals Ltd Mumbai India whereas sodium, potassium, magnesium, calcium, zinc, copper, iron and manganese metals were purchased from Fluka Chemie GmbH Chemical Company, inc.USA.

3.6 Cleaning of apparatus

All the glassware were soaked in 10 % analytical grade nitric acid overnight, thoroughly washed with detergent, rinsed with double distilled de-ionized water and dried in an oven at 105°C.

3.7 Sample digestion for spectroscopic measurements

A 0.5 g of ground sample was weighed accurately using electronic balance model AAA (Adam Co limited). The 9 ml mixture of HNO₃ and H₂SO₄ ratio 2:1 were added to the sample in the Kjeldahl flask, and then gently heated on a hot mantle until the dense brown fumes began to appear before hydrogen peroxide was added drop wise to clear the brown fumes. Digestion continued until the solution was clear and white fumes observed. The digested sample was cooled and filtered using What man No. 42 filter paper into 100 ml clean dry volumetric flask and then diluted to the mark with distilled de-ionized water. They were then transferred into separate well labeled plastic bottles and stored in a deep freezer at -20° C awaiting measurements by AAS and AES instruments.

3.8 Preparations of standard solutions for AAS and AES

Stock solutions were prepared from analytical grade granulated metals of high purity (99.9 %). Each metal was first dried at 105° C, cooled in desiccators prior to weighing and transferred into 250 ml volumetric flasks.

Sodium stock solution was prepared by dissolving 2.542 g of dried NaCl in distilled de-ionized water and diluted to one litre give 1000 µg/ml Na. The Calibration curve was prepared from standard solution containing 0.1, 0.2, 0.5, 0.6 and 1.0 ppm sodium ions made by serial dilution of stock solution as shown in Appendix 1.

Stock solution for potassium 1000 µg/ml was prepared by dissolving 1.9070 g of dried potassium chloride in about 100 ml of distilled water and making the volume to one litre. The calibration curve was prepared from 1.5, 1.0, 1.5, 2.0 and 2.5 ppm of standard solutions containing potassium ions as shown in Appendix 2.

Magnesium stock solution 1000 µg/ml was prepared by dissolving 1.000 g of magnesium in 1:4 nitric acid and was then diluted to one litre with distilled water. The calibration curve was prepared from 5.0, 8.0, 10.0, 15.0 and 20.0 ppm standard solutions containing Mg ions made by serial dilution of stock solution as shown in Appendix 3.

Calcium stock solution was prepared by dissolving 2.497 g of dried calcium carbonate in a minimum volume of 1:4 nitric acid and then diluted to one litre to give 1000 µg/ml of Ca. The calibration curve was prepared from 1.0, 2.0, 2.5, 3.0 and 4.0 ppm standard

solutions containing calcium ions made by serial dilution of stock solution as shown in Figure 2.

Zinc stock was prepared by dissolving 1.000 g of Zn metal in 40 ml HCl (1:1) and diluting it to the mark using distilled de-ionized water to give 1000 $\mu\text{g/ml}$. The calibration curve was prepared from 0.4, 0.8, 1.0, 1.4 and 1.6 ppm standard solutions containing Zinc ions as shown in Appendix 4.

To prepare Cu stock solution, 1.000 g of pure copper was dissolved in a minimum volume of 1:1 HNO_3 acid and diluted to 1 litre of acid to give 1000 $\mu\text{g/ml}$ of Cu. The calibration curve was made from 2.0, 5.0, 6.0, 8.0 and 10.0 ppm standard solutions of copper ions as shown in Appendix 5.

To prepare iron stock solution, 1.000 g of pure iron was dissolved in 20 ml 1:1 HCl acid and diluted to 1 litre of acid to give 1000 $\mu\text{g/ml}$ of Fe. The calibration curve was prepared from 2.0, 2.5, 5.0, 7.5 and 10.0 ppm standard solutions containing iron ions made by serial dilution of stock solution as shown in Appendix 6.

Manganese stock solution was prepared by dissolving 1.000 g of Mn in a minimum volume of 1:1 nitric acid and diluting it one litre to give 1000 $\mu\text{g/ml}$. The calibration curve was prepared from 0.5, 1.0, 2.0, 3.0 and 4.0 ppm standard solutions containing Manganese ions as shown in Appendix 7.

During serial dilution of stock solutions, the final acid concentration was maintained at about 1 % to keep the metal in free ionic state. The stock solutions were stored in plastic bottles and labeled appropriately. Working standards were freshly prepared from stock solutions each time an analysis was carried out, using serial dilution Equation 4

$$C_1V_1 = C_2V_2 \dots\dots\dots \text{Eq 4.}$$

Where:

C_1 - original concentration

V_1 -original volume

C_2 - new concentration

V_2 - new volume

3.9 Recovery test

The accuracy of AAS and AES were investigated by repeatedly spiking samples with known amount of standards and calculating the percentage recoveries using the Equation

5

$$R\% = \left(\frac{a-b}{c} \right) 100 \dots\dots\dots \text{Eq 5}$$

Where:

R-% recovery;

a- Concentration of the sample after spiking,

b- Concentration of sample before spiking

c- Concentration of standard used for spiking.

The concentration of spiked, unspiked and the standards added are shown in table 3.1

Table 3.1: Concentration of the standards and minerals before and after spiking

Minerals	Concentration of unspiked sample Mean±SE (µg/ml)	Concentration of standard added to the sample (µg/ml)	Concentration of spiked sample (Mean±SE) (µg/ml)
Na	1.30±0.01	20	20.90±0.02
K	1.60±0.03	20	21.00±0.01
Mg	0.5±0.04	20	20.09±0.01
Ca	0.1±0.01	10	10.21±0.06
Zn	5.00±0.02	100	104.70±0.01
Cu	4.00±0.01	100	102.10±0.04
Fe	2.5±0.01	50	50.90±0.03
Mn	2.4±0.04	50	51.02±0.01

From table 3.1, the recovered amount after digestion of the spiked samples was used to calculate % recovery according to (Al Weher, 2008). A mean recovery of the matrix was evaluated at 95 % confidence level (Borosova *et al.*, 2002). The recovery results are as shown in table 4.2 in chapter 4.

3.10 Reproducibility

Reproducibility was checked by running five replicate measurements for a given sample and the results are indicated in table 4.3 in chapter 4.

3.11 Operating parameters for AAS and AES

Analysis of Na and K was done by AES while Mg, Ca, Zn, Cu, Fe and Mn analysis was done in replicates using computerized Varian Spectrophotometer model AA-10. The standards, blank and samples were aspirated in replicates under same conditions. For better precision, standards were measured before and after the sample solutions. The blank was measured between standards and samples to ensure stability of the base line.

The operating conditions of the AAS and AES run with air/acetylene flame are given in table 3.2.

Table 3.2: The Atomic Absorption Spectroscopy (AAS) and Atomic Emission Spectroscopy (AES) operating conditions

Instrument	Element	Wavelength (nm)	Slit width (nm)	Oxidant flow rate (l/min)	Sensitivity (ppm)	Detection limit (ppm)	Lamp current (mA)	Optimum working range
AES	Na	589.0	0.1	1.5	0.003	0.0001	5.0	0.2-2.0
AES	K	766.5	1.0	1.5	0.01	0.003	5.0	0.4-2.0
AAS	Mg	285.2	0.1	4.5	0.0003	0.09	2.0	5.0-20.0
AAS	Ca	422.7	0.5	4.5	0.08	0.01	3.0	1.0-4.0
AAS	Zn	213.9	1.0	1.5	0.01	0.01	2.0	0.4-1.6
AAS	Cu	324.7	0.5	1.5	0.03	0.04	2.0	2.0-8.0
AAS	Fe	248.3	0.2	1.5	0.35	0.40	2.30	2.5-4.0
AAS	Mn	279.5	0.7	1.5	0.25	0.20	2.0	1.0-4.0

3.12 Calculation of concentrations of minerals in the samples

The concentration of essential minerals in the samples was worked out from the obtained AAS and AES analytical results (read out) using the Equation 6

$$\text{Actual concentration} \left(\frac{\mu\text{g}}{\text{mg}} \right) = \frac{\text{Concentration} (\mu\text{g/ml}) \times \text{Volume digested (ml)}}{\text{Weight of dried sample taken (g)}} \dots\dots\dots \text{Eq 6}$$

In cases of dilution, the actual weight was obtained by multiplying the read out results with the dilution factor. The means of the replicate measurements were then calculated from the actual concentration obtained. The concentrations of Na, K, Mg, Ca, Zn, Cu, Fe and Mn in the samples were worked out by calculating their means and standard deviation values.

3.13 Data analysis

Mean values obtained for Na, K, Mg, Ca, Zn, Cu, Fe and Mn studied in the three parts of mango residues and the three varieties of mango samples were compared by One-Way ANOVA at 95 % level using SPSS 18 for windows assuming that there was a significant difference among them when the statistical comparison gives $p < 0.05$. Whenever a significance difference exists, the means were compared at $p = 0.05$ significance level which accounts for errors since a sample was used to represent a population (Sawyer and Beebe, 2007).

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

The levels of sodium, potassium, magnesium, calcium, zinc, copper, iron and manganese from the peel, endocarp and seeds of van dyke, ngowe and apple mango varieties was determined by AAS and AES. The results are presented and discussed in this chapter.

4.2 Method validation

The method validation of the various instruments that were used was done using regression analysis, recovery tests and reproducibility.

4.2.1 Regression analysis

The absorbance/emission values of different sets of standards were used to plot calibration curves. The calibration curve for standard solutions of Ca was used using AAS as shown in figure 4.1. The calibration curves for sodium-AES, potassium-AES, magnesium-AAS, zinc-AAS, copper-AAS, iron-AAS and manganese-AAS are shown in Appendix 1 to 7.

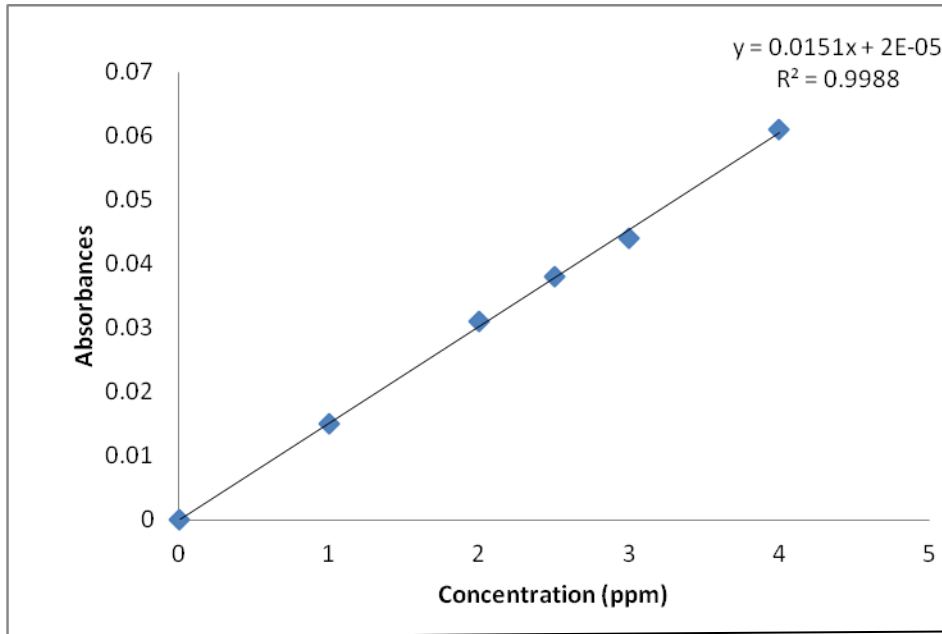


Figure 4.1: Calibration curve for calcium standard solution using AAS

From figure 4.1, the sensitivity of the analysis method was taken as the slope of the calibration curves. The regression results of minerals by AAS and AES instruments are summarized in table 4.1

Table 4.1: The AAS and AES regression results of minerals analyzed

Instruments	Minerals	r^2	Regression equation
AES	Na	0.9998	$y=0.0876x-0.0002$
AES	K	0.9984	$y=0.06x+0.0013$
AAS	Mg	0.9996	$y=0.0299x+0.0034$
AAS	Ca	0.9988	$y=0.0151x+2E-05$
AAS	Zn	0.9976	$y=0.1485x+0.0023$
AAS	Cu	0.9987	$y=0.0386x+0.003$
AAS	Fe	0.9999	$y=0.3683x-0.0024$
AAS	Mn	0.9996	$y=0.0906x+0.0016$

r– Correlation coefficient

In table 4.1, the values of correlation coefficient and the regression equation indicate that a linear relationship exists between the instrumental response and the concentration of the

standards used. These values agree with the range of values reported for a good calibration curve (best line of fit) (Mendham *et al.*, 1999).

4.2.2: Recovery test

The recovery test results are indicated in table 4.2.

Table 4.2: Percentage recovery of the minerals

Minerals.	% Recovery
Na	98.0
K	97.0
Mg	97.95
Ca	101.1
Zn	99.70
Cu	99.70
Fe	96.80
Mn	97.24

From table 4.2, the percentage recovery lies within the range 96.80%-101.10 % which is within the acceptable range of 80 % to 120 % expected for all the minerals indicating good accuracy for the analysis procedure (Duan *et al.*, 2003).

4.2.3: Reproducibility

The mean, standard deviation and the coefficient of variations were tabulated and recorded in table 4.3

Table 4.3: Reproducibility test for the minerals measured

Minerals	Mean \pm Sd	CV (%)
Na	1968.66 \pm 45.71	2.32
K	9722.29 \pm 253.41	2.61
Mg	1539.43 \pm 34.18	2.22
Ca	14919.70 \pm 508.23	3.41
Zn	5.58 \pm 0.14	2.51
Cu	8.44 \pm 0.27	3.20
Fe	61.78 \pm 2.23	3.61
Mn	13.06 \pm 0.316	2.42

From table 4.3 the reproducibility test for all the minerals measured was between 2.22% - 3.41 %. This range of values fall between 2 % – 5 % range recommended for a good analytical instrument used (Mendham *et al.*, 1999).

4.3 Levels of essential minerals in seeds from varieties of mangoes

The consolidated mean values of essential minerals in seeds for three mango varieties sampled from six farms, in two sampling times, obtained from Kiritiri and Gachoka divisions are shown in Table 4.4.

Table 4.4: Mean levels of essential minerals (mg/100g) in the seeds of varieties of mangoes from Gachoka and Kiritiri divisions

Division	Mango varieties n=3	Na	K	Mg	Ca	Zn	Cu	Fe	Mn
Gachoka	Ngowe	258.05±1.65 ^b	1105.90±3.30 ^b	329.95±26.35 ^b	1492.05±43.75 ^b	0.92±0.12	1.46±0.01 ^b	2.85±1.15	5.05±0.25 ^b
	Apple	188.05±6.65 ^a	832.55±26.65 ^a	204.75±18.85 ^a	781.15±103.75 ^a	0.62±0.02	1.26±0.00 ^a	6.48±3.12	1.40±0.50 ^a
	V/ dyke	237.20±15.80 ^b	1034.25±46.65 ^b	245.85±5.05 ^{ab}	882.40±142.50 ^a	1.02±0.12	1.26±0.00 ^a	3.66±0.01	3.00±0.90 ^{ab}
	p-value	<0.05	<0.05	<0.05	<0.05	>0.05	<0.05	>0.05	>0.05
Kiritiri	Ngowe	160.70±4.30 ^a	866.10±1.90 ^b	261.90±4.80	978.30±5.00	0.90±0.03	0.72±0.02 ^b	16.35±0.02 ^a	1.13±0.03 ^a
	Apple	189.85±0.15 ^b	645.45±0.45 ^a	233.60±7.60	974.95±0.05	0.87±0.07	0.48±0.05 ^a	33.32±0.02 ^c	1.53±0.03 ^b
	V/ dyke	236.75±5.05 ^c	970.10±5.90 ^c	259.10±4.20	976.70±0.70	0.70±0.03	0.65±0.02 ^b	30.56±0.56 ^b	2.15±0.02 ^c
	p-value	<0.05	<0.05	>0.05	>0.05	>0.05	<0.05	<0.05	<0.05

Mean followed by the same small letter(s) within the same column are not significantly different within the same division (SNK, $\alpha=0.05$)

From the results presented in table 4.4, the seeds of ngowe, apple and van dyke mango varieties sampled from the two divisions, Gachoka and Kiritiri, were found to contain the essential minerals Na, K, Mg, Ca, Zn, Cu, Fe and Mn. Further, the levels of the minerals were found to differ significantly between some varieties ($p < 0.05$) as discussed in the following sub-sections.

4.3.1 Sodium (Na) in mango seeds

The mean levels of sodium from seeds in mango residues sampled from Gachoka division as indicated by table 4.4 ranged from 188.05 ± 6.65 mg/100g to 258.05 ± 1.65 mg/100g in the apple and ngowe respectively. However, in Kiritiri the van dyke mango seeds had the highest concentration of Na 236.75 ± 5.05 mg/100g while ngowe mango were also found to have the lowest levels 160.70 ± 4.30 mg/100g. These levels were found to differ significantly between the seeds of mango varieties obtained from both divisions. In both divisions the levels of Na in ngowe seed differed significantly while in apple and van dyke there was no significant difference.

The levels of Na in seeds of the mango varieties were found to be below the RDA for men 1,200-1500 mg/day, but slightly above that for cattle 0.8-1.2 g/kg DM, sheep 0.7-1.0 g/kg DM and chicken 0.15 % (Freer, 2007). While man does not consume mango seeds, the levels as found in the seeds of the mango varieties can potentially be useful as animal feed (DRI, 2012; Freer, 2007; NRC, 2001). Sodium is needed in either macro or major quantities where it acts as an electrolyte for ionic and osmotic balance, to strengthen cells and the endoskeleton, and further it is important in, nerve impulse transmission, glucose

and amino acid transport as well as for muscle contractions (Ekanayake and Nair, 1998; NRC, 2001).

Mango seeds have been evaluated for their elemental composition and Na has been reported in the mango seeds from various regions of the world including Pakistan, Congo and Ghana (Shad *et al.*, 2001; Nzikou *et al.*, 2010; Ayivor *et al.*, 2011). In comparison, the mango seeds in this study had Na levels higher than those found by some researchers (Shad *et al.*, 2001; Nzikou *et al.*, 2010). Shad *et al.* (2001) found seeds of mango from Pakistan to contain 0.0925 g%-0.1375 g% and concluded that mango seed kernels are helpful in terms of food value particularly with regard to mineral content. In Congo, flour from mango seeds were found to contain 2.70 ± 0.02 mg/100g Na leading to a conclusion that mango seed kernel have ash content of 3.2 % (with the presence of the following minerals Ca, K, Na, Mg and P) (Nzikou.,2010). It can be explained however, that the differences in the levels of Na in the mangoes from this study and those of other studies could be attributed to physical and chemical nature of the soil and the ability to take up minerals by the plants (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010).

4.3.2 Potassium (K) in mango seeds

From table 4.4, the mean concentration of K from Gachoka seeds ranged from 832.55 ± 26.65 - 1105 ± 3.30 mg/100g in apple and ngowe mango varieties respectively. The concentration of K in Kiritiri mango seeds ranged from 645.45 ± 0.45 mg/100g in apple to 970.10 ± 5.90 mg/100g in van dyke. These levels differed significantly between mango

varieties obtained from both divisions $p < 0.05$. In both regions, the levels in ngowe differed significantly while in apple and van dyke there was no significant difference. It can further be explained that the differences in the levels of K in the mangoes from this study could be attributed to differences in soil composition (Shad *et al.*, 2001).

The mean concentration of K compares well with RDA for ruminants of 0.5 % and 0.8 % (Bredon and Dugmore, 2005). Nevertheless, the recommended dietary intake for K in men 4500-4700 mg is far much above this range (DRI, 2012). From the results, mango seeds from Gachoka and Kiritiri may be a good source of K for ruminants feed but a poor source of human diet. Potassium is the principal cation in intracellular fluid and functions in acid-base balance (Soetan *et al.*, 2010).

Mango seeds and other members of *Anacardiaceae* family have been evaluated for their elemental composition and their K level has been reported from various regions of the world including Pakistan, Congo, Syria and Ghana (Shad *et al.*, 2001; Kossah *et al.*, 2009; Nzikou *et al.*, 2010; Ayivor *et al.*, 2011). Potassium concentrations from Gachoka and Kiritiri mango seeds are below the findings reported in Pakistan mango seeds 1.14 g%-1.63 g% but above the values reported in Congo mango seeds flour 158.0 ± 0.12 mg/100g (Shad *et al.*, 2001; Nzikou *et al.*, 2010). However, the concentrations compares favourably with the levels reported in Syrian sumac fruit 7441.25 ± 0.07 mg/kg and Ghana's wild mango *Irvingia gabonensis* seed 0.723 ± 0.042 % (Kossah *et al.*, 2009; Ayivor *et al.*, 2011). The results from Ghana concluded that all parts of wild mango

Irvingia gabonensis seed have important minerals that have positive effect on human health (Ayivor *et al.*, 2011).

4.3.3 Magnesium (Mg) in mango seeds

As indicated in table 4.4, the mean concentrations of Mg from Gachoka ranged from 204.75 ± 18.85 - 329.95 ± 26.35 mg/100g in apple and ngowe seeds respectively. At Kiritiri, magnesium concentration ranged from 233.60 ± 7.60 - 261.90 ± 4.80 mg/100g in apple and ngowe seeds respectively. There was no significant difference in the levels of Mg in the seeds of the three mango varieties from Kiritiri while in Gachoka there was a significant difference. It can be explained however, that the differences in the levels of Mg in the mangoes from this study may be due to physical and chemical nature of the soil in the production sites and the ability to take up metals by the plants (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010).

The Mg levels were above the RDA for sheep 0.9-1.2 g/kg DM and cattle 1.3-2.2 g/kg but within the range required for human beings 320-420 mg/day (FNB, 2001; Kelly 2007). From the above results, mango seeds from Gachoka may be a good source of Mg for cattle, sheep and human beings though man does not consume mango seeds. Magnesium play a role in manipulating important biological polyphosphate compounds like ATP, DNA and RNA (House craft and Sherpe, 2008).

Mango seeds and other members of the *Anacardiaceae* family have been evaluated for their elemental composition and their Mg level have been reported in various regions of

the world including Nigeria and Congo. In comparison, concentrations of Mg exhibited by mango seeds from Gachoka and Kiritiri were higher than those reported in mango seeds from Ghana's wild mango *Irvingia gabonensis* seed 0.048 ± 0.008 %, Nigeria mango seeds 94.8 mg/100g and Congo mango seed flour 22.34 ± 0.01 g/100g (Fowomola, 2010; Nzikou *et al.*, 2010; Ayivor *et al.*, 2011). However, the values of Mg obtained in cashew nut 292.0 mg/100g, a member of *Anacardiaceae* family, fall within this range (USDA, 2011).

4.3.4 Calcium (Ca) in mango seeds

In table 4.4, the concentration of Ca in Gachoka mango seed ranged from 781.15 ± 103.7 - 1492.05 ± 43.75 mg/100g in apple and ngowe respectively. There was a significant difference in the Ca concentrations of the seeds of the three mango varieties from Gachoka $p < 0.05$. At Kiritiri, calcium concentration ranged from 974.95 ± 0.05 - 978.30 ± 5.00 mg/100g in apple and ngowe seeds respectively where the levels did not differ significantly.

The concentration of Ca in mango seeds from Gachoka were above the RDA for poultry 0.8-1.0 %kg DM in broilers and 0.8-0.90 %kg DM for layers (NRC, 1994). The dietary allowance for men of 1000 mg/day falls within this range (FNB, 2010). Therefore, mango seed can be a good source of Ca for both men and poultry though man does not consume mango seeds. In a study in Nigeria, boiled mango seed kernel meal replaced 20 % of the maize in the broilers diet without adverse effects on growth and blood parameters (Diarra

and Usman, 2008). Calcium is essential for the formation of skeletal tissues and transmission of nervous tissues impulses (NRC, 2001).

The Ca findings falls within the levels reported in Pakistan mango seeds 0.107 g % - 1.1125 g % leading to a conclusion that mango seeds are helpful in terms of food values particularly with regard to mineral content (Shad *et al.*, 2001). The levels reported in Congo mango seed flour 10.21 mg/100g and mango seeds in Nigeria 111.3 mg/kg are significantly below this range (Nzikou *et al.*, 2010; Fowomola, 2010). In a study in Nigeria, Fowomola (2010) concluded that, mango seed is a nutritional promising seed. It can be explained further that, the differences in the levels of Ca in the mangoes residues from this study and those of other studies could be attributed to differences in soil composition, climatic conditions and varietal differences in parent trees (Shad *et al.*, 2001).

4.3.5 Zinc (Zn) in mango seeds

From table 4.4, the Zn level from Gachoka seeds ranged from 0.62 ± 0.02 mg/100g in apple to 1.02 ± 0.12 mg/100g in van dyke while its concentration in mango seeds from Gachoka ranged from 0.70 ± 0.03 - 0.90 ± 0.03 mg/100g in van dyke and ngowe seeds respectively. There was no significant difference in the levels of Zn between the three varieties in both divisions since $p > 0.05$. The low zinc levels in mango seeds could be due to low levels in Mbeere soils (Karyotis, 2005).

The RDA for Zn in broilers 40.0 mg/kg, layers 35.0 mg/kg, adult men 11.0 mg/day and women 8.0 mg/day are above this range (NRC, 1994; FNB, 2001). This implies that mango seeds from Kiritiri may be a poor source of Zn for men and poultry. Zinc is essential in fat absorption, growth, good health, structural stability of the molecules and membranes (Suttle, 2010).

Mango seeds have been evaluated for their Zn elemental composition and their level has been reported from various regions of the world including Pakistan, Ghana and Nigeria (Shad *et al.*, 2001; Ayivor *et al.*, 2011; Fowomola, 2010). The concentrations of Zn in Gachoka and Kiritiri divisions were below the levels reported in Pakistan mango seeds 3.45 mg/100g-10.20 mg/100g and Ghana's wild mango *Irvingia gabonensis* seed 193.74±17.82 ppm (Shad *et al.*, 2001; Ayivor *et al.*, 2011). The values however compares well with the levels obtained in Nigeria mango seeds 1.10 mg/100g (Fowomola, 2010).

4.3.6 Copper (Cu) in mango seeds

As indicated from table 4.4, ngowe seeds from Gachoka recorded the highest concentration of Cu 1.46±0.01 mg/100g with both apple and van dyke recording similar concentrations of 1.26±0.00 mg/100g. Further, the Cu concentration of mango seeds from Kiritiri ranged from 0.48±0.05 to 0.72±0.02 mg/100g in apple and ngowe mango varieties respectively. There was a significant difference in copper levels in the three varieties from both divisions. The variations in the copper mineral levels may be due to deposition of heavy metals in the environment and the anthropogenic activities like use of heavy metal (Cu) based pesticides (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et*

al., 2009; Saeed *et al.*, 2010). The levels of Cu were above the concentrations obtained in Pakistan mango seeds 0.05-0.65 mg/100g and mango fruit pulp 0.11 mg/100g (Shad *et al.*, 2001; USDA, 2001).

The concentration of Cu were above the RDA for ruminants 2.0-20.0 mg/kg, non-ruminants 4.0-8.0 mg/kg but RDA for men was within the range 1.0-1.6 mg/day (Underwood and Suttle, 1999; FNB, 2001). This suggests that mango seeds from Gachoka and Kiritiri may be a good source of Cu for ruminants, non-ruminants and men. Copper is a component of enzymes such as cytochrome oxidase, lysyl oxidase, ceruloplasmin tyrosinase and superoxide dismutase (NRC, 2001).

4.3.7 Iron (Fe) in mango seeds

From table 4.4, the mean concentrations of Fe in mango seeds from Gachoka ranged from 2.85 ± 1.15 - 6.48 ± 3.12 mg/100g in ngowe and apple varieties respectively. There is no significant difference in the concentrations of Fe in the three varieties from Gachoka $p < 0.05$. Further, the Fe concentration of mango seeds from Kiritiri range in ngowe and apple were 16.35 ± 0.02 - 33.32 ± 0.02 mg/100g respectively, where they differed significantly from that of Gachoka. This could support a research study done by Karyotis *et al.*, 2005 who observed that Fe content in Mbeere soils varied greatly.

The concentration of Fe was within the range required for growing, laying and lactating animals 50.0-100.0 mg/kg (NRC, 2005). The dietary intake of iron in human beings of 8.0-18.0 mg/day is also within this range (DRI, 2012). Therefore, mango seeds may be a

better source of Fe for man, growing, laying and lactating animals. In India treated (de-oiled, soaked or boiled) mango seed kernel has been successfully used to replace maize in levels up to 15-20 % in poultry diets (Ravindran and Blair, 1991). Iron participates in a variety of biochemical functions including electron transport in mitochondria, catecholamine metabolism and DNA synthesis (Cancado and Chiatone, 2009).

Mango seeds have been evaluated for their Fe elemental composition and their level has been reported from various regions of the world including Pakistan, Ghana and Nigeria (Shad *et al.*, 2001; Fowomola, 2010; Ayivor *et al.*, 2011). The concentrations in Gachoka and Kiritiri were above the levels reported in Pakistan mango seeds 0.20-1.55 mg/100g, but within the concentrations reported in Nigeria mango seeds 11.90 mg/100g and Ghana's wild mango *Irvingia gabonensis* seed 57.86 ± 5.50 ppm (Shad *et al.*, 2001; Fowomola, 2010; Ayivor *et al.*, 2011). According to Ayivor *et al.* (2011), all the parts of wild mango are rich source of important minerals that have a positive effect on human health.

4.3.8 Manganese (Mn) in mango seeds

As per table 4.4, the Mn mean concentration in Gachoka mango seed residue ranged from 1.40 ± 0.50 - 5.05 ± 0.25 mg/100g in apple and ngowe seeds respectively. Similarly at Kiritiri, Mn concentration range was 1.13 ± 0.03 - 2.15 ± 0.02 mg/100g for ngowe and van dyke respectively. Manganese concentrations did not differ significantly at Gachoka, but, at Kiritiri it differed significantly between the seeds of the three varieties.

The RDA for Mn in cattle and sheep 20-25 mg/kg and adult human beings 2.3-1.8 mg/day falls within this range (FNB, 2001; Kelly, 2007). From the above, it can be concluded that Gachoka and Kiritiri mango seeds can be a better source of Mn for cattle, sheep and human beings. Manganese is important in the breakdown of carbohydrates, synthesis of nitric acid and metabolism of glucose and glycogen (Cozzolino, 2005).

The Mn concentrations in table 4.4 above were within the levels of reported in cashew nut 1.655 mg/100g, Syrian sumac fruit 10.57 ± 0.39 mg/kg and Chinese sumac fruit 11.60 ± 0.35 mg/kg (Kossah *et al.*, 2009; USDA, 2011). However, Mn concentrations in Gachoka and Kiritiri mango seeds were above the levels reported in Pakistan mango seeds 0.09-1.00 mg/100g and mango fruit pulp 0.027 mg/100g (Shad *et al.*, 2001; USDA, 2001). According to Kossah (2009), both Syrian and Chinese sumac fruits could be used in human diets to supply required mineral minerals. The variations in the Mn mineral levels in Mbeere and other parts of the world may be due to physical and chemical nature of the soil in the production sites, the ability to take up metals by the plants, deposition of metals in the environment, use of untreated water, the nature of the fruit, exposed surface area and the anthropogenic activities like use of heavy metal-based pesticides (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010).

4.4 Levels of essential minerals in endocarps from varieties of mangoes

The consolidated mean values of eight essential minerals in endocarps for three mango varieties sampled from six farms, in two sampling times, obtained from Kiritiri and Gachoka divisions are shown in table 4.5.

Table 4.5: Mean levels of essential minerals (mg /100g) in the endocarps of varieties of mangoes from Gachoka and Kiritiri divisions

Division	Mango varieties (n=3)	Na	K	Mg	Ca	Zn	Cu	Fe	Mn
Gachoka	Ngowe	189.70±5.00	1163.10±203.90	268.45±11.55 ^c	1323.60±73.80	1.57±0.20	1.38±0.02	23.23±1.77 ^a	3.35±1.45
	Apple	203.85±29.15	860.90±21.70	127.80±0.60 ^a	814.15±89.15	1.58±0.05	1.38±0.08	31.58±2.52 ^{ab}	2.12±0.05
	V/dyke	155.55±19.15	761.75±75.85	176.95±3.05 ^b	917.85±119.55	2.18±0.08	1.42±0.05	41.60±4.10 ^b	2.86±0.00
	p-value	>0.05	>0.05	<0.05	>0.05	>0.05	>0.05	<0.05	>0.05
Kiritiri	Ngowe	149.00±1.00 ^a	785.70±2.30 ^b	273.50±0.50 ^c	1413.70±6.30 ^b	1.98±0.02 ^c	0.75±0.02 ^b	9.70±0.23 ^b	2.93±0.03 ^c
	Apple	188.50±0.50 ^c	458.30±0.70 ^a	160.35±6.65 ^a	887.90±1.20 ^a	1.22±0.02 ^b	1.25±0.02 ^c	6.33±0.03 ^a	1.65±0.02 ^b
	V/dyke	174.85±0.15 ^b	456.60±1.00 ^a	238.00±4.00 ^b	1689.15±9.15 ^c	1.07±0.00 ^a	0.52±0.02 ^a	13.65±0.12 ^c	1.52±0.02 ^a
	p-value	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Mean followed by the same small letter(s) within the same column are not significantly different within the same division (SNK, $\alpha=0.05$)

From the results presented in table 4.5, the endocarps of ngowe, apple and van dyke mango varieties sampled from the two divisions, Gachoka and Kiritiri, were found to contain the essential minerals Na, K, Mg, Ca, Zn, Cu, Fe and Mn. Further, the levels of the minerals were found to differ significantly in all the varieties from Kiritiri and some varieties from Gachoka ($p < 0.05$). The results of each mineral in the endocarps are discussed in the following sub-sections.

4.4.1 Sodium (Na) in mango endocarps

In table 4.5, the mean concentration of Na from Gachoka endocarp ranged from 155.55 ± 19.15 - 203.85 ± 29.15 mg/100g in van dyke and apple mango varieties respectively. In Gachoka, the levels did not differ significantly. Similarly, the concentrations of Na from Kiritiri ranged from 149.00 ± 1.00 mg/100g to 188.50 ± 0.50 mg/100g in ngowe and apple endocarp where they significantly differed.

The Na concentrations were found to be above the recommended dietary allowance for cattle 0.8-1.2 g/kg DM, sheep 0.7-1.0 g/kg DM and poultry 0.15 % (Freer, 2007; NRC, 1994). They were however below the recommended dietary intake for men 1,200 mg-1,500 mg (DRI, 2012). From the results, mango endocarp from Gachoka and Kiritiri may be a good source of Na for cattle feed but a poor source of human diet.

The findings in Gachoka and Kiritiri endocarp were above the levels reported in Pakistan mango seeds 0.0575 g%-0.1375 g%, Congo mango seed flour 2.70 ± 0.02 mg/100g and Ghana's wild mango *Irvingia gabonensis* endocarp (seed coat) 81.39 ± 1.22 ppm (Shad *et*

al., 2001; Nzikou *et al.*, 2009; Ayivor *et al.*, 2011). The differences in the levels of Na in the mangoes from this study and those of other studies could be attributed to differences in soil composition, climatic conditions and varietal differences in parent trees (Shad *et al.*, 2001).

4.4.2 Potassium (K) in mango endocarps

As indicated in table 4.5, the mean concentrations of K from Gachoka ranged from 761.75 ± 75.85 mg/100g- 1163.10 ± 203.90 mg/100g in van dyke and ngowe endocarp respectively. In Gachoka, the levels did not differ significantly. Likewise the concentration of K in Kiritiri mango endocarp ranged from 456.60 ± 1.00 mg/100g in van dyke to 785.70 ± 2.30 mg/100g in ngowe. There was a significant difference in the levels of K in the three mango varieties $p < 0.05$.

These concentrations were below RDA for men 4500-4700 mg/day, but within the RDA for ruminant's 0.5 %-0.8 % DM (DRI, 2012; Bredon and Dugmore, 2005). From table 4.5, mango endocarp from Gachoka may be a good source of K for ruminants but a poor source of K for man. Potassium is involved in regulation of osmotic pressure, conduction of nerve impulse, muscle contraction particularly the cardiac muscle and cell membrane function (Soetan *et al.*, 2010).

The potassium concentrations from Gachoka and Kiritiri mango endocarp were within the findings reported in Pakistan mango seeds 1.14 g%-1.63 g% and Syrian sumac fruit 7441.25 ± 0.07 mg/kg but above the values reported in Congo mango seeds flour

158.0±0.12 mg/100g (Shad *et al.*, 2001; Kossah *et al.*, 2009; Nzikou *et al.*, 2010). In comparison, the findings reported in Ghana's wild mango *Irvingia gabonensis* endocarp (seed coat) 1.331±0.022 % fall slightly above this range (Ayivor *et al.*, 2011). The variations in the mineral levels may be due to physical and chemical nature of the soil in the production sites and the ability to take up metals by the plants (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010).

4.4.3 Magnesium (Mg) in mango endocarps

As per table 4.5, in endocarp of mangoes sampled from Gachoka division, the mean levels of Mg ranged from 127.80±0.60 to 268.45±11.55 mg/100g in apple and ngowe varieties respectively. However, in Kiritiri, the mean concentrations of Mg ranged from 160.35±6.65-273.50±0.05 mg/100g in apple and ngowe endocarps respectively. These levels were found to differ significantly between the three mango varieties obtained from both divisions $p < 0.05$. The differences in the levels of Mg in the mango endocarps in this study may be due to variations in the physical and chemical nature of the soil and the ability to take up metals by the plants (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010).

The concentrations of Mg exhibited by mango endocarps from Kiritiri was noted to be higher than those reported in mango seeds from Nigeria 94.8 mg/100g, Ghana's wild mango *Irvingia gabonensis* endocarp 0.012±0.006 % and Congo mango seed flour 22.34±0.01 g/100g (Fowomola, 2010; Ayivor *et al.*, 2011; Nzikou *et al.*, 2010).

In comparison to RDA, the Mg levels were above the range required for growing and finishing cattle 0.10 % but below the recommended dietary intake for men 200-400 mg/day (NRC, 2000; DRI, 2012). Therefore, mango endocarp from Gachoka and Kiritiri may be a better source of Mg for growing and finishing cattle but a poor source of Mg for human beings though man does not consume mango endocarp. Magnesium plays an important role in metabolism of fat and protein (Housecraft and Sherpe, 2008).

4.4.4 Calcium (Ca) in mango endocarps

From table 4.5, Calcium concentration of mango endocarp from Gachoka ranged from 814.15 ± 89.15 - 1323.60 ± 73.80 mg/100g in apple and ngowe mango varieties respectively. There was no significant difference in the concentration of Ca in the three varieties $p > 0.05$. Further, the concentration of Ca in Kiritiri mango endocarp ranged from 887.90 ± 1.20 - 1689.15 ± 9.15 mg/100g in apple and van dyke varieties respectively. There was a significant difference in the Ca concentrations of three mango varieties $p < 0.05$.

The RDA for broilers 0.8 %-1.0 %kg DM, layers 0.8-0.90 %kg DM, cattle 2.0-11.0 g/kg DM, sheep 1.4-7.0 g/kg DM and men 1000 mg/day fall within this range (NRC, 1994; Kelly, 2007; FNB, 2010). This shows that mango endocarp from Gachoka and Kiritiri may be a rich source of Ca for poultry, cattle, sheep and men. Calcium is involved in muscle contraction, normal transmission of nerve impulses and in neuromuscular excitability (Soetan *et al.*, 2010).

The Ca values reported in Pakistan mango seeds 0.1075 g%-1.1125 g% lies within the range of results in table 4.5 (Shad *et al.*, 2001). However, the levels obtained in Congo mango seed flour 10.21 ± 0.05 mg/100g and cashew nut 37.0 mg/100g were far much below these findings (Nzikou, *et al.*, 2010; USDA, 2011). It can be explained however, that the differences in the levels of Ca in the mangoes from this study and those of other studies was attributed to differences in climatic conditions (Shad *et al.*, 2001).

4.4.5 Zinc (Zn) in mango endocarps

In the results presented from table 4.5, the mean concentrations of Zn sampled from Gachoka ranged from 1.57 ± 0.20 to 2.18 ± 0.08 mg/100g in ngowe and van dyke endocarp respectively. The levels do not differ significantly between the three varieties sampled from Gachoka. Similarly, the Zn level from Kiritiri endocarps ranged from 1.07 ± 0.00 mg/100g in van dyke to 1.98 ± 0.02 mg/100g in ngowe. There was a significant difference in the three varieties since $p < 0.05$. Though variations was noted between varieties from both regions, the mineral concentrations in ngowe and apple did not differ significantly while in van dyke a significant difference was noted. The differences in the levels of Zn in the mangoes endocarp from this study may be attributed to physical and chemical nature of the soil in the production sites and the ability to take up metals by the plants (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010).

The Zn levels were above the RDA for goats 5.0 mg/kg DM but below the recommended dietary intake for men 8.0-11.0 mg (Meschy, 2010; DRI, 2012). From the above results, mango endocarp from Gachoka may be a good source of Zn for goats but a poor source

for human beings. Deficiency of Zn in poultry leads to slow growth, lethargy, loss of appetite and spasms (Prabakaran, 2003).

The concentrations of Zn exhibited by mango endocarp from Gachoka were lower than those reported in mango seeds from Pakistan 3.45-10.20 mg/100g and Ghana's wild mango *Irvingia gabonensis* endocarp (seed coat) 63.54±5.99 ppm, but compares fairly well with the levels reported in Nigeria mango seeds 1.10 mg/100g (Shad *et al.*, 2001; Fowomola, 2010; Ayivor *et al.*, 2011).

4.4.6 Copper (Cu) in mango endocarps

From table 4.5, the van dyke mango endocarp from Gachoka recorded the highest concentration of Cu 1.42±0.05 mg/100g while ngowe recorded the lowest concentrations of 1.38±0.02 mg/100g. There was no significant difference in the concentrations of Cu between the three varieties from Gachoka. Van dyke endocarps from Kiritiri recorded the lowest concentration of Cu 0.52±0.02 mg/100g while apple endocarp recorded the highest concentrations of 1.25±0.02 mg/100g. There was a significant difference in copper levels of the endocarps between the three mango varieties from Kiritiri. In both regions, the Cu levels in ngowe and van dyke apple differ significantly while that for van dyke no significant difference was noted. This difference could be as a result of use of more heavy metal (Cu)-based pesticides in Gachoka than at Kiritiri (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010).

The Cu requirements for different animals are as follows, non-ruminants 4.0-8.0 mg/kg, ruminants 2.0-20.0 mg/kg and adult men and women 1.0-1.6 mg/day (Suttle and Underwood, 1999; FNB, 2001). These levels lies within the above range thus suggesting that mango endocarp from Gachoka and Kiritiri may be a rich source of Cu for men, ruminants and non-ruminants.

The levels of Cu were slightly above the concentrations obtained in Nigeria mango seeds 0.1 mg/100g and mango fruit pulp 0.11 mg/100g (USDA, 2001; Fowomola, 2010). However, the concentrations obtained in Pakistan mango seeds of 0.05-0.65 mg/100g and Ghanas wild mango *Irvingia gabonensis* endocarp (seed coat) of 11.93 ± 0.55 ppm falls within the above range (Shad *et al.*, 2001; Ayivor *et al.*, 2011).

4.4.7 Iron (Fe) in mango endocarps

From table 4.5, the mean concentrations of Fe from Gachoka ranged from 23.23 ± 1.77 mg/100g- 41.60 ± 4.10 mg/100g in ngowe and van dyke endocarp respectively. However, concentrations of Fe in mango endocarp sampled from Kiritiri ranged from 6.33 ± 0.03 to 13.65 ± 0.12 mg/100g in apple and van dyke varieties respectively. There was a significant difference in the concentrations of Fe between the varieties sampled from both divisions. These great variations could support a research study done by Karyotis *et al.* (2005) who observed that Fe content in Mbeere soils varied greatly.

The concentration of Fe is within the range required for growing, laying and lactating animals 50.0-100.0 mg/kg and human beings 8.0-18.0 mg/day (WHO/FAO, 1998; NRC, 2005; DRI, 2012). From the above results, mango endocarp from Gachoka and Kiritiri may be a good source of Fe for both human beings and animals. Iron participates in a variety of biochemical functions and its deficiency leads to anemia and low blood haemoglobin (Cancado and Chiatone, 2009).

Iron concentrations from Gachoka and Kiritiri were above the findings reported in Pakistan mango seeds 0.20-1.55 mg/100g and mango fruit pulp 0.13 mg/100g but within the levels reported in Nigeria mango seeds 11.9 mg/100g (Shad *et al.*, 2001; USDA, 2001; Fowomola, 2010). However, the findings reported in Ghana's wild mango *Irvingia gabonensis* endocarp (seed coat) of 1730.8 ± 180.83 ppm is far much above the range obtained in Gachoka and Kiritiri divisions (Ayivor *et al.*, 2011). The variations in the mineral levels may be due to physical and chemical nature of the soil in the production sites, the ability to take up metals by the plants, deposition of metals in the environment, use of untreated water, the nature of the fruit, exposed surface area (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010).

4.4.8 Manganese (Mn) in mango endocarps

In the results presented in table 4.5, the mean concentrations of Mn from Gachoka endocarp ranged from 2.12 ± 0.05 - 3.35 ± 1.45 mg /100g in apple and ngowe mango varieties respectively. The levels of Mn in Gachoka did not differ between the three

mango varieties. Further, the Mn mean concentration in Kiritiri mango endocarps ranged from 1.52 ± 0.02 mg/100g in van dyke to 2.93 ± 0.03 mg/100g in ngowe. There was a significant difference in the mean levels of Mn in the endocarp of three mango varieties from Kiritiri $p > 0.05$.

The Mn concentrations were found to be within the recommended dietary allowance for cattle and sheep 20.0-25.0 mg/kg DM and 30 mg/kg layers (NRC, 1994; Kelly, 2007). From the results, mango endocarp from Gachoka may be a good source of Mn for cattle, sheep and poultry (layers). Manganese is important in the metabolism of glucose and glycogen (Cozzolino, 2005).

The Mn values in Gachoka and Kiritiri were above the levels reported in Pakistan mango seeds 0.09-1.00 mg/100g, Nigeria mango seeds 0.04 mg/100g and mango fruit pulp 0.027 mg/100g (Shad *et al.*, 2001; USDA, 2001; Fowomola, 2010). However, the levels of Mn reported in Ghana's wild mango *Irvingia gabonensis* endocarp (seed coat) of 136.71 ± 0.080 ppm is far much above the range obtained in Gachoka and Kiritiri divisions (Ayivor *et al.*, 2011).

4.5 Levels of essential minerals in peels from varieties of mangoes

The consolidated mean values of eight essential minerals in peels for three mango varieties sampled from six farms, in two sampling times, obtained from Kiritiri and Gachoka divisions are shown in table 4.6

Table 4.6: Mean levels of essential minerals (mg /100g) in the peels of varieties of mangoes from Gachoka and Kiritiri divisions.

Divisions	Mango varieties n=3	Na	K	Mg	Ca	Zn	Cu	Fe	Mn
Gachoka	Ngowe	209.70±3.30	1093.40±44.20	310.00±10.40	1203.65±38.75 ^a	1.40±0.33	1.03±0.17	9.35±3.25	1.65±0.52 ^a
	Apple	214.70±15.00	1100.45±121.25	250.60±34.30	1482.05±2.05 ^b	0.75±0.12	0.87±0.03	15.37±4.13	4.30±0.30 ^b
	Van dyke	194.00±14.00	868.00±104.60	198.40±27.30	1476.40±1.00 ^b	0.55±0.05	0.70±0.03	7.27±0.47	4.29±0.01 ^b
	p-value	>0.05	>0.05	>0.05	<0.05	>0.05	>0.05	>0.05	<0.05
Kiritiri	Ngowe	192.00±6.00 ^a	935.90±0.10 ^c	280.00±6.00 ^c	845.80±0.90 ^a	3.08±0.02 ^c	0.38±0.02 ^a	11.15±0.02 ^b	4.85±0.12 ^b
	Apple	291.55±0.45 ^c	777.60±1.60 ^b	242.60±0.60 ^b	1081.60±8.30 ^c	1.12±0.02 ^a	1.50±0.17 ^b	4.95±0.02 ^a	3.65±0.02 ^a
	Van dyke	216.45±0.45 ^b	669.10±0.10 ^a	183.60±3.60 ^a	910.45±0.35 ^b	1.90±0.03 ^b	0.42±0.02 ^a	23.55±0.22 ^c	4.60±0.07 ^b
	p-value	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Mean followed by the same small letter(s) within the same column are not significantly different within the same division (SNK $\alpha=0.05$)

From the results presented in table 4.6, the peels of ngowe, apple and van dyke mango varieties sampled from the two divisions, Gachoka and Kiritiri, were found to contain the essential minerals Na, K, Mg, Ca, Zn, Cu, Fe and Mn. Further, the levels of the minerals were found to differ significantly in all the varieties from Kiritiri and some varieties from Gachoka ($p < 0.05$). The results of each mineral in the peels are discussed in the following sub-sections.

4.5.1 Sodium (Na) in mango peels

In the results presented from table 4.6, the apple mango peels from Gachoka recorded the highest concentration of Na 214.70 ± 15.00 mg/100g while van dyke recorded the lowest concentrations of 194.00 ± 14.00 mg/100g. There was no significant difference in Na levels in the three varieties $p > 0.05$. The mean concentration of Na from Kiritiri peels ranged from 192.00 ± 6.00 - 291.55 ± 0.45 mg/100g in ngowe and apple mango varieties respectively. There was a significant difference in the mean levels of Na in peels of the three mango varieties $p < 0.05$.

The concentrations of Na was above the RDA for cattle 0.8-1.2 g/kg DM, sheep 0.7-1.0 g/kg DM and chicken 0.15 % (Freer, 2007). The requirements for human beings of 1,200-1500 mg/day are above this range (DRI, 2012). This suggests that mango peels from Gachoka and Kiritiri may be a poor source of Na for men but a good source of Na for cattle, sheep and poultry. In Thai, in vitro digestibility showed that all forms of mango peel by-products can be used as cattle feed (Sruamsiri and Silman, 2009).

The findings of Na in Kiritiri and Gachoka peels were above the levels reported in Pakistan mango seeds 0.0575 g%-0.1375 g% and Congo mango seed flour 2.70 ± 0.02 mg/100g (Shad *et al.*, 2001; Nzikou *et al.*, 2009).

4.5.2 Potassium (K) in mango peels

From table 4.6, the concentration of K in Gachoka mango peels ranged from 868.00 ± 104.60 mg/100g in van dyke to 1100.45 ± 121.25 mg/100g in apple. There was no significant difference in the levels of K in the peels of the three mango varieties $p > 0.05$. Similarly, the mean concentrations of K from Kiritiri mango peels ranged from 669.10 ± 0.10 - 935.90 ± 0.10 mg/100g in van dyke and ngowe residues respectively.

These concentrations were below RDA for men 4500-4700 mg/day, but within the RDA for ruminant's 0.5 %-0.8 % DM (Bredon and Dugmore, 2005; DRI, 2012). From the above results, mango peels from Kiritiri may be a good source of K for ruminants but a poor source of K for man. Severe K deficiency causes hypokalemia (serum K concentration of less than 3.5 mmol /L). Adverse consequences of hypokalemia include cardiac arrhythmias, muscle weakness and glucose intolerance (FNB, 2005).

The potassium concentrations for Gachoka mango peels were slightly below the findings reported in Pakistan mango seeds 1.14 g%-1.63 g% but far much above the values reported in Congo mango seeds flour 158.0 ± 0.12 mg/100g (Shad *et al.*, 2001; Nzikou *et al.*, 2010). It can be explained however, that the differences in the levels of K in the mangoes from this study and those of other studies could be attributed to the ability to

take up metals by the plants and deposition of metals in the environment (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010).

4.5.3 Magnesium (Mg) in mango peels

As indicated from table 4.6, in Gachoka, Mg concentration ranged from 198.40 ± 27.30 - 310.00 ± 10.40 mg/100g in van dyke and ngowe peels respectively. There was no significant difference in the levels of Mg in the three mango varieties $p > 0.05$. Furthermore, the mean concentrations of Mg in mango peels from Kiritiri ranged from 183.60 ± 3.60 - 280.00 ± 6.00 mg/100g in apple and ngowe varieties respectively. There was a significant difference in the levels of Mg in the peels of ngowe, apple and van dyke mango varieties $p < 0.05$.

The concentration of Mg were above the range required for growing and finishing cattle 0.1 % but compares fairly well with the recommended dietary intake for men 200-400 mg/day (NRC, 2000; DRI, 2012). Therefore, mango endocarp may be a better source of Mg for growing, cattle and human beings. In West Africa, fresh mango peels have been fed successfully to snails with no adverse effects but gave lower performance than papaya peels (Omole *et al.*, 2004). Magnesium is a constituent of bones, teeth and is an enzyme cofactor (Murray *et al.*, 2000).

The concentration of magnesium found in mango fruit pulp 9 mg/100g, Nigeria mango seed 94.8 mg/100g and Congo mango seed flour 22.34 ± 0.01 mg/100g are far much below

the above range while the levels reported in cashew nut 292.0 mg/100g falls within this range (USDA, 2001; Fowomola, 2010; Nzikou *et al.*, 2010; USDA, 2011).

4.5.4 Calcium (Ca) in mango peels

In the results from table 4.6, the calcium concentration from Gachoka ranged from 1203.65±38.75-1482.05-2.05 mg/100g in ngowe and apple peels respectively. Similarly, the concentration of Ca in Kiritiri mango peels ranged from 845.80±0.90-1081.60±8.30 mg/100g in ngowe and apple varieties respectively. Generally, a significant difference in the Ca concentrations was noted between the three mango varieties from both regions $p < 0.05$.

The RDA for broilers 0.8-1.0 % kg DM, layers 0.8-0.90 % kg DM, cattle 2.0-11.0 g/kg, sheep 1.4-7.0 g/kg DM and men 1,000 mg/day fall within this range (NRC, 1994; Kelly, 2007; FNB, 2010). It can therefore be concluded that mango peels are a very rich source of Ca for cattle, sheep and men. Calcium functions as a constituent of bones and teeth, regulation of nerve and muscle function (Soetan *et al.*, 2010).

The Ca findings in Gachoka and Kiritiri were within the levels reported in Pakistan mango seeds 0.107 g%-1.1125 g% (Shad *et al.*, 2001). The levels reported in Congo mango seed flour 10.21 mg/100g and mango seeds in Nigeria 111.3 mg/kg are significantly below this range (Nzikou *et al.*, 2010; Fowomola, 2010).

4.5.5 Zinc (Zn) in mango peels

The results in table 4.6, depicts that the Zn concentration in mango residues ranged from 0.55 ± 0.05 - 1.40 ± 0.33 mg/100g in van dyke and ngowe peels respectively. There was no significant difference in the levels of Zn in the three varieties $p>0.05$. Similarly, the mean concentrations of Zn from Kiritiri ranged from 1.12 ± 0.02 - 3.08 ± 0.02 mg/100g in apple and ngowe peels respectively. These levels differed significantly in the peels of three mango varieties $p<0.05$. In both regions, the levels of Zn in ngowe and apple peels did not differ significantly while that for van dyke differed significantly. These variations in the mineral levels may be due to physical and chemical nature of the soil (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010). The low Zn levels in Gachoka and Kiritiri could be attributed to low Zn levels in soils as reported by Karyotis *et al.* (2005).

The RDA for Zn in broilers 40.0 mg/kg, layers 35.0 mg/kg, adult men 11.0 mg/day and women 8.0 mg/day are above this range (NRC, 1994; FNB, 2001). This implies that mango peels from Gachoka may be a poor source of Zn for men and poultry. Zinc deprivation is characterized by inappetence, cessation of growth, anorexia, abnormalities of skin and appendages, skeletal disorders and reproductive disorders (Suttle, 2010).

The concentrations of Zn exhibited by mango peels from Kiritiri was lower than those reported in mango seeds from Pakistan 3.45-10.20 mg/100g but its levels compares fairly

well with the levels reported in Nigeria mango seeds 1.10 mg/100g (Shad *et al.*, 2001; Fowomola, 2010).

4.5.6 Copper (Cu) in mango peels

From table .4.6, the Cu concentration of mango peels from Gachoka ranged from 0.70 ± 0.03 - 1.03 ± 0.17 mg/100g in van dyke and ngowe mango varieties respectively. There was no significant difference in the concentration of Cu in the three varieties since $p > 0.05$. Further, Apple mango peels from Kiritiri recorded the highest concentration of Cu 1.50 ± 0.17 mg/100g while ngowe recorded the lowest concentrations of 0.38 ± 0.02 mg/100g. There was a significant difference in the concentrations of Cu levels in the three varieties $p < 0.05$.

The non-ruminants require copper level of between 4.0-8.0 mg/kg while ruminants require 2.0-20.0 mg/kg which is within the range (Suttle and underwood, 1999). Likewise, adult men and women require 1.0-1.6 mg/day which is in agreement with the above range (FNB, 2001). This suggests that mango peels from Kiritiri and Gachoka may be a rich source of Cu for men, ruminants and non-ruminants. The low copper level in mango peels could be due to low Cu level in Mbeere soils (Karyotis *et al.*, 2005).

The Cu levels were within the concentrations obtained in Pakistan mango seeds 0.05-0.65 mg/100g, but slightly above the levels reported in Nigeria mango seeds 0.1 mg/100g and mango fruit pulp 0.11 mg/100g (Shad *et al.*, 2001; USDA, 2001; Fowomola, 2010). The levels reported in cashew nut 2.195 mg/100g are slightly above this range (USDA, 2001).

It can be explained however, that the differences in the levels of Cu in the mangoes from this study and those of other studies was attributed to exposed fruit surface area and the anthropogenic activities like use of heavy metal (Cu)-based pesticides (Zurera *et al.*, 1989; Sharma *et al.*, 2006; Sharma *et al.*, 2009; Saeed *et al.*, 2010).

4.5.7 Iron (Fe) in mango peels

From table 4.6, the iron concentration of mango peels from Gachoka range in van dyke and apple were 7.27 ± 0.47 - 15.37 ± 4.13 mg/100g respectively. There was no significant difference in the levels of iron in the three varieties $p > 0.05$. The mean concentrations of Fe from Kiritiri ranged from 4.95 ± 0.02 - 23.55 ± 0.22 mg/100g in apple and van dyke peels respectively where they differed significantly. The significant difference in the concentrations of Fe between the mango varieties sampled from both divisions could be supported by a research study done by Karyotis *et al.* (2005) who observed that Fe content in Mbeere soils varied greatly.

The RDA in broilers 80 mg/kg, 60.0 mg/kg in layers and men/women 8.0 mg/day are below this range (NRC, 1994; FNB, 2001). This implies that mango peels from Gachoka may be a very rich source of Fe for men and poultry. Calcium is involved in blood coagulation, enzyme activation and membrane permeability (Soetan *et al.*, 2010).

Iron concentrations from Kiritiri were above the findings reported in Pakistan mango seeds 0.20-1.55 mg/100g and mango fruit pulp 0.13 mg/100g (Shad *et al.*, 2001; USDA,

2001). However, the levels reported in Nigeria mango seeds 11.9 mg/100g falls within this range (Fowomola, 2010).

4.5.8 Manganese (Mn) in mango peels

In the results from table 4.6, the Gachoka Mn concentration in peels range was 1.65 ± 0.52 - 4.30 ± 0.30 mg/100g for ngowe and apple peels respectively. Likewise, the Mn mean concentration in Kiritiri mango peels ranged from 3.65 ± 0.02 mg/100g in apple to 4.85 ± 0.12 mg/100g in ngowe. There was a significant difference in the concentration of Mn in the three varieties in both regions $p < 0.05$.

The recommended dietary intake for Mn in goats 40.0-50.0 mg/kg and men 1.90-2.30 mg/day are within the range (Meschy, 2010; DRI, 2012). This implies that mango peel may be a good source of Mn for men and goats. Manganese deficiency cause impaired growth, skeletal abnormalities and depressed reproduction (NRC, 2001).

The Mn concentrations in Gachoka and Kiritiri mango peels were slightly above the levels reported in Pakistan mango seeds 0.09-1.00 mg/100g and mango fruit pulp 0.027 mg/100g (Shad *et al.*, 2001; USDA, 2001). However, the concentrations were within the levels of Mn reported in cashew nut 1.655 mg/100g, Syrian sumac fruit 10.57 ± 0.39 mg/kg and Chinese sumac fruit 11.60 ± 0.35 mg/kg (Kossah *et al.*, 2009; USDA, 2011).

4.5.9 Variations of minerals in mango residues

Table 4.7 shows a comparison of the essential minerals in the peels, endocarps and seeds of the ngowe, apple and van dyke mango varieties.

Table 4.7: Comparison of minerals (mg /100g) in mango residues from Gachoka and Kiritiri divisions

Element	Mango varieties	Region	Peel (n=3)	Endocarp (n=3)	Seed (n=3)	p-value
Na	Ngowe	Kiritiri	192.00±6.00 ^b	149.00±1.00 ^a	160.70±4.30 ^a	<0.05
		Gachoka	209.70±3.30 ^b	189.70±5.00 ^a	258.05±1.65 ^c	<0.05
	Apple	Kiritiri	291.55±0.45 ^b	188.50±0.50 ^a	189.85±0.15 ^a	<0.05
		Gachoka	214.70±15.00	203.85±29.15	188.05±6.65	>0.05
	Van dyke	Kiritiri	216.45±0.45 ^b	174.85±0.15 ^a	236.75±5.05 ^c	<0.05
		Gachoka	194.00±14.00	155.55±19.15	237.20±15.80	>0.05
K	Ngowe	Kiritiri	935.90±0.10 ^c	785.70±2.30 ^a	866.10±1.90 ^b	<0.05
		Gachoka	1093.40±44.20	1163.10±203.90	1105.90±3.30	>0.05
	Apple	Kiritiri	777.60±1.60 ^c	458.30±0.70 ^a	645.45±0.45 ^b	<0.05
		Gachoka	1100.45±121.25	860.90±21.70	832.55±26.65	>0.05
	Van dyke	Kiritiri	669.10±0.10 ^b	456.60±1.00 ^a	970.10±5.90 ^c	<0.05
		Gachoka	868.00±104.60	761.75±75.8	1,034.25±46.65	>0.05
Mg	Ngowe	Kiritiri	280.00±6.00	273.50±0.50	261.90±4.80	>0.05
		Gachoka	310.00±10.40	268.45±11.55	329.95±26.5	>0.05
	Apple	Kiritiri	242.60±0.60 ^b	160.35±6.65 ^a	233.60±7.60 ^a	<0.05
		Gachoka	250.60±34.30	127.80±0.60	204.75±18.85	>0.05
	Van dyke	Kiritiri	183.60±3.60 ^a	238.00±4.00 ^b	259.10±4.20 ^c	<0.05
		Gachoka	198.40±27.30	176.95±3.05	245.85±5.05	>0.05
Ca	Ngowe	Kiritiri	845.80±0.90 ^a	1413.70±0.0 ^c	978.30±5.00 ^b	<0.05
		Gachoka	1203.65±38.75	1323.60±73.80	1492.05±43.75	>0.05
	Apple	Kiritiri	1081.60±8.30 ^c	887.90±1.20 ^a	974.95±0.05 ^b	<0.05
		Gachoka	1482.05±2.05 ^b	814.15±89.15 ^a	781.15±103.75 ^a	<0.05
	Van dyke	Kiritiri	910.45±0.35 ^a	1689.15±9.15 ^c	976.70±0.70 ^b	<0.05
		Gachoka	1476.40±1.00	917.85±119.55	882.40±142.50	>0.05
Zn	Ngowe	Kiritiri	3.08±0.02 ^c	1.98±0.02 ^b	0.90±0.03 ^a	<0.05
		Gachoka	1.40±0.33	1.57±0.20	0.92±0.12	>0.05
	Apple	Kiritiri	1.12±0.02 ^b	1.22±0.02 ^b	0.87±0.07 ^a	<0.05
		Gachoka	0.75±0.12 ^a	1.58±0.05 ^b	0.62±0.02 ^a	<0.05
	Van dyke	Kiritiri	1.90±0.03 ^c	1.07±0.00 ^b	0.70±0.03 ^a	<0.05
		Gachoka	0.55±0.05 ^a	2.18±0.08 ^c	1.02±0.12 ^b	<0.05
Cu	Ngowe	Kiritiri	0.38±0.02 ^a	0.75±0.02 ^b	0.72±0.02 ^b	<0.05
		Gachoka	1.03±0.17	1.38±0.02	1.46±0.01	>0.05
	Apple	Kiritiri	1.50±0.17 ^b	1.25±0.02 ^b	0.48±0.05 ^a	<0.05
		Gachoka	0.87±0.03 ^a	1.38±0.08 ^b	1.26±0.00 ^b	<0.05
	Van dyke	Kiritiri	0.42±0.02 ^a	0.52±0.02 ^b	0.65±0.02 ^c	<0.05
		Gachoka	0.70±0.03 ^a	1.42±0.05 ^b	1.26±0.00 ^b	<0.05
Fe	Ngowe	Kiritiri	11.15±0.02 ^b	9.70±0.23 ^a	16.35±0.02 ^c	<0.05
		Gachoka	9.35±3.25 ^a	23.23±1.77 ^b	2.85±1.15 ^a	<0.05
	Apple	Kiritiri	4.95±0.02 ^a	6.33±0.03 ^b	33.32±0.02 ^c	<0.05
		Gachoka	15.37±4.13 ^a	31.58±2.52 ^b	6.48±3.12 ^a	<0.05
	Van dyke	Kiritiri	23.55±0.22 ^b	13.65±0.12 ^a	30.56±0.56 ^c	<0.05
		Gachoka	7.27±0.47 ^a	41.60±4.10 ^b	3.66±0.01 ^a	<0.05
Mn	Ngowe	Kiritiri	4.85±0.12 ^c	2.93±0.03 ^b	1.13±0.03 ^a	<0.05
		Gachoka	1.65±0.52	3.35±1.45	5.05±0.25	>0.05
	Apple	Kiritiri	3.65±0.02 ^c	1.65±0.02 ^b	1.53±0.03 ^a	<0.05
		Gachoka	4.30±0.30 ^b	2.12±0.05 ^a	1.40±0.50 ^a	<0.05
	Van dyke	Kiritiri	4.60±0.07 ^c	1.52±0.02 ^a	2.15±0.02 ^b	<0.05

Mean levels with the same small letters within the same row are not significantly different while the one without differ significantly (SNK, $\alpha=0.05$).

From table 4.7, all the three parts were found to contain essential minerals Na, K, Mg, Ca, Zn, Cu, Fe and Mn. The results indicate that there were significant differences ($p < 0.05$) in the levels of most minerals between the residues. Notably, the general trend was that the seeds had the highest average levels while the endocarp had the lowest. This would be expected as also reported by Ayivor *et al.* (2011) in the study carried out in Ghana wild mango in which the levels of minerals in the pulp, endocarp and seed differed in their concentrations.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the objectives and the results of this study which was to determine the levels of Na, K, Mg, Ca, Zn, Cu, Fe and Mn in residues of three mango varieties from Kiritiri and Gachoka divisions, the following conclusions can be drawn.

- i) The minerals K, Na, Mg, Ca, Zn, Cu, Fe and Mn were available in mango residues in levels that are potentially useful for health benefit.
- ii) The levels of essential minerals in decreasing order were as follows $Ca > K > Mg > Na > Fe > Mn > Zn > Cu$
- iv) Sodium levels were significantly higher in apple with respect to peel and endocarp but seed of van dyke had significantly high sodium levels.
- v) Potassium levels were significantly higher in ngowe peels and endocarps but van dyke had significantly higher K in seeds.
- vi) Magnesium levels were significantly higher in ngowe seeds, peels and endocarps.
- vii) Zinc levels were significantly higher in ngowe peels and endocarps but for van dyke it was significantly higher in endocarps.
- viii) Copper levels were significantly higher in apple peels and seeds but for van dyke it was higher in endocarps.
- ix) Iron levels were significantly higher in van dyke seeds, peels and endocarps.
- x) Manganese levels were significantly higher in van dyke seeds and peels and high in ngowe endocarps

- xi) Calcium levels were significantly higher in apple peels, van dyke endocarps and ngowe seeds.
- xii) There were variations in levels of minerals in residues with a general trend seed>peel> endocarp
- xiii) Variations of essential minerals in mango varieties were noted but generally ngowe and van dyke recorded significantly higher levels of most minerals than apple.

5.2 Recommendations from this study

- i) The residues analyzed in this study contain substantial levels of essential minerals with respect to the RDA in cattle and poultry and therefore can be explored for use in preparation of animal feeds and mineral supplements.
- ii) The seeds had significantly higher level of most minerals among the three residues analyzed and therefore they can be explored for use as animal feeds to supply essential minerals sufficiently.
- iii) Ngowe and Van dyke residues recorded the highest concentrations and therefore they can be used to supply with the eight minerals analyzed in this study adequately.

5.3 Recommendations for further work

- i) Other fruits like pineapples, bananas, avocados and paw paws residues in Kenya should to be analyzed for essential macro and micro minerals.
- ii) The levels of proteins, vitamins and carbohydrates in mango fruit residues need to be investigated as they play important role in the body of animals.
- iii) The varieties of mangoes grown and consumed in other parts of Kenya need to be analyzed for the same minerals as in this study.
- iv) The Bio availability of minerals in mango residues in animal's body need to be investigated.

REFERENCES

- Al Weher, M. (2008). Levels of heavy metal Cd, Cu and Zn in three fish species collected from Northern Jordan Valley. *Jordan Journal of Biological Sciences* **1**:41-46.
- Anonymous, (2004). By-product and waste utilization (value addition of mango processing waste). *Journal of Food Digestion* **27**: 14-17.
- Ayivor, J.E., Debrah, S.K., Nuviadenu, C. and Forson, A. (2011). Evaluation of elemental contents of wild mango (*Irvingia gabonensis*) fruit in Ghana. *Advanced Journal of Food Science and Technology* **3**: 381-384.
- Barreto, J.C., Trevisan, M.T. and Hull W.E. (2008). Characterization and quantitation of polyphenolic compounds in bark, kernel, leaves, and peel of mango *Mangifera. indica L.* *Journal of Agriculture and Food Chemistry* **56**: 5599-5610.
- Beckhoff, B., Langhoff, N., Langgiefer, B., Wedell, R. and Wolff, H. (2006). Hand book of practical X-ray fluorescence analysis. Springer Verlag, Berlin Heidelberg. Pp 301-303.
- Berardini, N., Knodler, M., Schieber, A. and Carle, R. (2005). Utilization of mango peels as a source of pectin and polyphenolics. *Innovative Food Science & Emerging Technologies* **6**: 442-452.
- Borosova, D., Mocak, J., Beinrohr, E. and Miskovic, P. (2002). Validation and quality assurance of arsenic determination in urine by GFAAS after toluene extraction. *Polish Journal of Environmental Studies* **11**: 617-623.
- Bosch, H., Gitari, J.N., Ogara, V.N., Maobe, S. and Vlaming, J. (1998). Monitoring nutrient flows and economic performance in African farming systems (NUTMON) 111: Monitoring nutrient flows and balances in three districts in Kenya. *Agricultural Ecosystems Environment* **71**: 63-80.
- Bredon, R.M. and Dugmore, T.J. (2005). Mineral & vitamin nutrition of dairy cattle Cedara agricultural development institute.
- Cancado, R.D. and Chiatton, C.S. (2009). Aspectos atuais do metabolismo do ferro. *Revista Brasileira de medicina*. Available at: <http://www.cibersaude.com.br/revista.Asp?fase=roo3> and id material=1684.
- Chen, J.P., Tai, C.Y. and Chen, B.H. (2004). Improved liquid chromatographic method for determination of carotenoids in Taiwanese mango (*Mangifera. indica L.*). *Journal of Analytical Chromatography*. **1054**: 261-268.
- Christian, G. D. (2004). Analytical chemistry. 6th Edition. John Willy & Sons Pte. Ltd, Asia. Pp 111-112.

- Cozzolino, S.M.F. (2005). Biodisponibilidade de Nutrientes Barueri: Ed Manole; 459.
- Davidowski, L., Grosser, Z. and Sarojam, P. (2010). The analysis of baby foods and juices for metals to protect a sensitive population. *Ecoanalytix Review* Pp 1-6.
- Diarra, S.S. and Usman, B.A. (2008). Growth performance and some blood variables of broiler chickens fed raw or boiled mango kernel meal. *International Journal of Poultry Science* 7: 315-318.
- Dietary Reference Intake (DRI). (2012). Recommended Dietary Allowance and Adequate Intake (RDA / RDI) for Adults, Children, Pregnancy & Nursing - Adequate Intake (AI) - Tolerable Upper Intake Levels. National Academies, Washington, DC.
- Duan, T., Kang, J., Chen, H. and Zeng, X. (2003). Determination of ultra concentration of elements in high purity tellurium by inductively coupled plasma spectrometry after iron (III) hydroxide co precipitation. *Journal of Spectrochemica Acta Part B* **58**: 1679-1685.
- Ekanayake, E.R. and Nair, B.M. (1998). Proximate composition, mineral and amino acid content of mature *Canavalia gladiata* seeds. *Food Chemistry* **66**:115-119.
- El-Kholy, K.F., Solta, M.E., Abd El-Rahman, S.A.E., El-Saidy, D.M. and Foda, D. S. (2008). Use of some agro-industrial by products in Nile Tilapia fish diets. The 8th International Symposium on Tilapia in Aquaculture.
- Food and Agriculture organization (FAO). (2011). <http://faostat.fao.org/default.aspx>.
- Food and Nutrition Board (FNB). (2001). Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc Pp 1-773.
- Food and Nutrition Board (FNB). (2005). Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate.Pp 186-268.
- Food and Nutrition Board (FNB). (2010). Dietary Reference Intakes for Calcium and Vitamin D. Committee to Review Dietary Reference Intakes for Vitamin D and Calcium. National Academy Press, Washington, DC. Pp 1-700.
- Fowomola, M.A. (2010). Some nutrients and antinutrients contents of mango, *Manginifera indica* seeds. *African Journal of Food Science* **4**: 472-476.
- Freer, M. (2007): Nutrient requirement of domesticated ruminants. Pp 1-530.

- Gathambiri, C.W., Gitonga, J.G., Kamau, M., Njuguna, J.K., Kiiru, S.N., Muchui, M.N., Gatambia, E.K. and Muchira, D.K. (2006). Assessment of potential and limitation of postharvest value addition of mango fruits in Eastern province: A case study in Mbeere and Embu districts.
- Gian, C., Zaheer, D., Christian, D., Angela, M., Eva, M., Hanna, M., Margot, E. and Jennifer, W. (2009). Analysis of toxic heavy metals in selected infant formula milk commercially available in Philippines by AAS. *Food Chemistry Journal* **67**: 40-50.
- Gouado, I., Schweigert, F.J., Ejoh, R.A., Tchouanguep, M.F. and Camp, J.V. (2007). Systemic levels of carotenoids from mangoes and papaya consumed in three forms (juice, fresh and dry slice). *European Journal of Clinical Nutrition* **61**: 1180–1188.
- Griesbach, J. (2003). Mango growing in Kenya. World agro forestry centre (ICRAF), Nairobi Kenya. Pp 111.
- Heuzé, V., Tran, G., Bastianelli, D., Archimède, H. and Lebas, F. (2012). Mango *Mangifera indica* fruit and by-products. Feedipedia.org. A programme by INRA, CIRAD, AFZ and FAO. <http://www.feedipedia.org/node/516>.
- Housecroft, C.E. and Sharpe, A.G. (2008). Inorganic Chemistry 3rd Edition Prentice Hall Pp. 305–306.
- Institute of Medicine. (2004). The Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. National Academies Press, Washington, D.C.
- Jedele, S., Hau, A. M. and Von Oppen, M. (2003). An analysis of the world market for mangos and its importance for developing countries. Conference on International Agricultural Research for Development. University of Hohenheim, Germany Pp 1-11.
- Karyotis, T., Davis, D., Christos, N., Louis, G. and Fred, M. (2005). Nutrients, trace elements and net N mineralization in acidic Kenyan soils. *Soil Science and Plant Nutrition*. **61**: 645-648.
- Kelly, J. (2007). Reference nutrient requirements of domesticated ruminants. Csiro Publishing Amazon Comp. Pp 1-270.
- Kinuthia, Z., Warui, D. and Karanja, F. (2009). Mapping and characterising water points in Mbeti south location, Mbeere district. Institute of Economic Affairs (IEA). Research Paper Series No. 21 Pp 1-15.
- Kossah, R., Nsabimana, C., Zhao, J., Chen, H., Tian, F., Zhang H. and Chen, W. (2009). Comparative Study on the Chemical Composition of Syrian Sumac (*Rhus coriaria* L.) and Chinese Sumac (*Rhus typhina* L.) fruits. *Pakistan Journal of Nutrition* **8**: 1570-1574.

- Lagher, F., Reicher, F. and Ganter, J.L. (2002). Structural and rheological properties of polysaccharides from mango (*Mangifera indica* L.) pulp. *International Journal of Biological Macromolecules* **31**: 9-17.
- Medham, R.C., Renny, J.O. and Barnes, K. (1999). Vogel's text book of quantitative chemical analysis 6th Edition Prentice Hall, UK.
- Meschy F. (2010). Recent progress in assessment of mineral requirement of goats. *Livestock Production Science Journal* **64**: 9-14.
- Michael, J.G., Hester, H.V. and Frans, J.K. (2005). Introduction to human nutrition. Blackwell science limited. Pp 117-224.
- Miller, P.F., Vandome, F.A. and McBrewster, J. (2010). Atomic Emission Spectroscopy. Pp 1-104.
- Ministry of Agriculture Kenya. (MOA). (2007). Annual report.
- Msabeni, A., Muchai, D., Masinde, G., Matoke, S. and Gathaara, V. (2010). Sweetening the mango: Strengthening the value chain. *Working Document Series* **136**: 1-74.
- Murray, R.K., Granner, D.K., Mayes, P.A. and Rodwell, V.W. (2000). Harpers Biochemistry, 25th Edition, McGraw-Hill, Health profession Division, USA.
- Muya, E.M. (2003). Soil characterization of Kibichoi, Gachoka and Ngaita research sites. Site evaluation report no. P109. Kenya Soil Survey, Kenya Agricultural research Institute, Nairobi Kenya.
- National Research Council (NRC). (1994). Nutrient requirements of poultry .The 9th Revised Edition, National academy press, Washington DC. Pp 1-157.
- National Research Council (NRC). (2000). Nutrient requirements of beef cattle.The 7th Revised Edition, National academy press, Washington DC. Pp 54-74.
- National Research Council (NRC). (2001). Nutrient requirements of beef cattle. The 7th Revised Edition, National academy press, Washington DC. Pp. 1-234.
- National Research Council (NRC). (2001^a). Nutrient requirements of dairy cattle. The 7th Revised Edition, National academy press, Washington DC. Pp. 1-381.
- National Research Council (NRC). (2005). Mineral tolerance of animals. The Second Revised Edition, National academy press, Washington DC. Pp 1-469.

Nzikou, J.M., Kimbonguila, A., Matos, L., Loumouamou, B., Pambou-Tobi, N.P.G., Ndangui, C.B., Abena, A. A., Silou, T., Scher, J. and Desobry, S. (2010). Extraction and Characteristics of Seed Kernel Oil from Mango (*Mangifera indica*). *Journal of Environmental and Earth Sciences* **2**: 31-35.

Okalebo, J.R., Gathua, K.W. and Woomer, P.L. (2002). Laboratory methods of soils and plant analysis. A working manual, 2nd Edition, Sacred Africa, Nairobi Pp 29-68.

Okonko, I. O., Adeola, I., Aloysius, F.E., Damilola, O. and Adewale, O.A. (2009). Utilization of food wastes for sustainable development. *Electronic Journal of Environmental, Agriculture and Food Chemisry*. **8**: 263-286.

Omole, J.A., Ayodeji, O.I. and Raji, M.A. (2004). "The potential of peels of mango, plantain, cocoyam and pawpaw as diets for growing snails (*Archachatina marginata*)". *Livestock Research for Rural Development* **16**: 102-130.

Pavel, Y., Richard, J.S., Morrison, X., Douglas, G. and Chadwick, M. (2005). *Spectrochemical acta part B: Journal of Atomic Spectroscopy* **60**: 986-992.

Prabakaran, R. (2003). Good practices in planning and management of integrated commercial poultry production in South Asia. Pp 1-100.

Ravindran, V. and Blair, R. (1991). Feed resources for poultry production in Asia and pacific region. Energy sources. *World Poultry Science Journal* **47**: 213-231.

Saeed, A., Safina, N., Tuseef, S.M., Seema, M., Muhammad, N. and Anwaar, A. (2010). Physico-chemical attributes and heavy metal content of mangoes (*Mangifera Indica* L.) cultivated in different regions of Pakistan. *Pakistan Journal of Botany* **42**: 2691-2702.

Sanon, H.O. and Kanwe, B.A. (2011). Valorisation of mango peels and seed kernels in animal feeding. Nutritive value and voluntary feed intake by sheep Pp 1-20.

Satish, K. (2003). "Management of infertility due to mineral deficiency in dairy animals". In proceedings of ICAR summer school on" Advance diagnostic techniques and therapeutic approaches to metabolic and deficiency diseases.

Sawyer, W. and Beebe, A. (2007). Chemistry experiment for instrumental methods. Wiley, New York. Pp 43-51.

Shad, M.A., Rehman, A. and Daud, K. (2001). Minerals contents of mango seeds kernels. *Journal of Biological Sciences* **1**: 195-197.

Sharma, R.K., Agrawal, M. and Marshall, F.M. (2006). Heavy metals contamination in vegetables grown in waste water irrigated areas of Varanasi, India. *Bulletin of Environmental Contamination and Toxicology* **77**: 311-318.

Sharma, R.K., Agrawal M. and Marshall, F.M. (2009). Heavy metals in vegetables collected from production and market sites of a tropical urban area of India. *Food and Chemical Toxicology* **47**: 583-591.

Skoog, D.A. and Leary, J. (1992). Principles of instrumental analysis. The 4th edition. Saunders publications, Fort Worth. Pp 162-163.

Slaughter, D.C. (2009). Nondestructive Maturity Assessment Methods for Mango: A Review of Literature and Identification of Future Research Needs. Biological and Agricultural Engineering University of California, Davis Pp 1-18.

Soetan, K.O., Olaiya, C.O. and Oyewole, O.E. (2010). Importance of mineral elements for humans, domestic animals and plants. *African Journal of Food Science* **4**: 200-222.

Sruamsiri, S. and Silman, P. (2009). Nutritive value and nutrient digestibility of ensilaged mango by products. *Maejo International Journal of Science and Technology* **3**: 371-378.

Suttle, N.F. (2010). Mineral nutrition of livestock, 4th Edition, MPG Books Group UK, Pp 426-458.

Taylor, A., Branch, S., Day, M., Patriciarca, M. and White, M. (2006). Atomic spectrometry. *Journal of Analytical Atomic Spectrometry*; **21**: 114-121.

Tuormaa, T.E. (2000). Chromium, Selenium, copper and other trace minerals in health and reproduction. *Journal of Orthomolecular Medicine* **15**: 145-157.

Underwood, E.J. and Suttle, N.F. (1999). The mineral nutrition of livestock, 3rd Edition, New York: CAB publishers.

United States Department of Agriculture. (USDA). (2001). Mango fruit national nutrient database for standard reference.

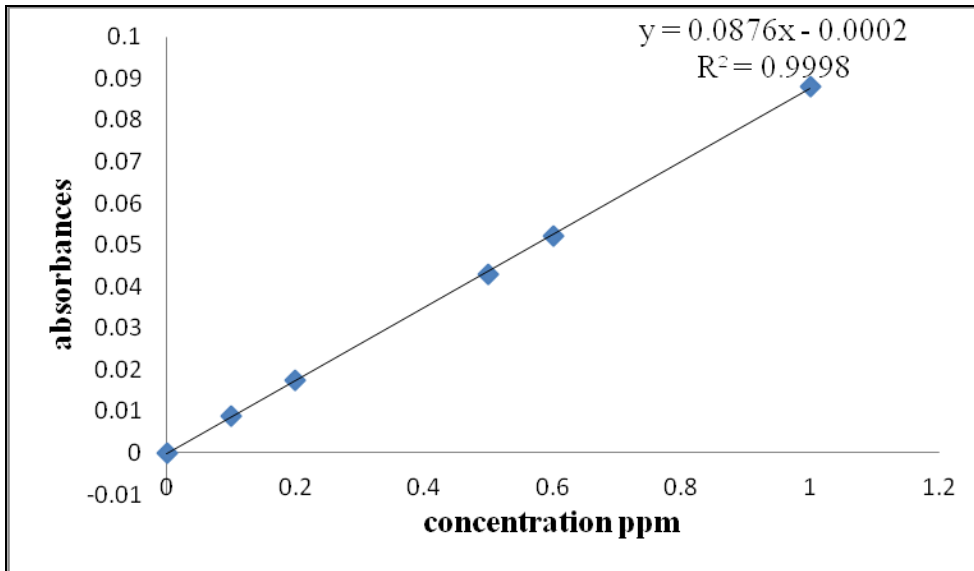
United States Department of Agriculture. (USDA). (2011). Mango fruit national nutrient database for standard reference.

World Health organization/Food Agricultural Organization (WHO/FAO). (1998). Expert consultation on human vitamin and mineral requirements, Bangkok, Thailand.

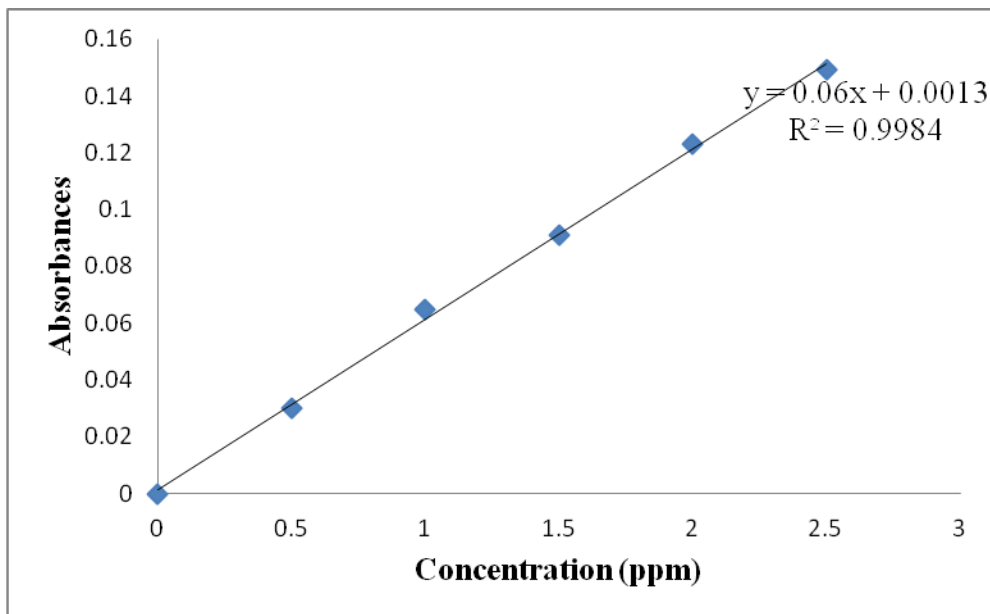
Zurera, G., Moreno, R., Salmeron, J. and Pozo, R. (1989). Heavy metal uptake from greenhouse border soils for edible vegetables. *Journal of the Science Food and Agriculture* **49**: 307-314.

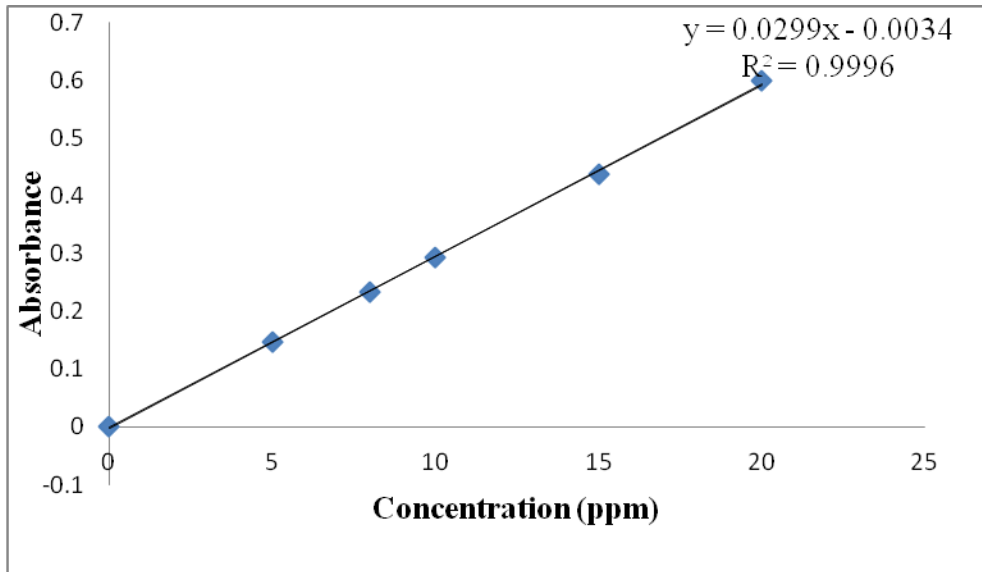
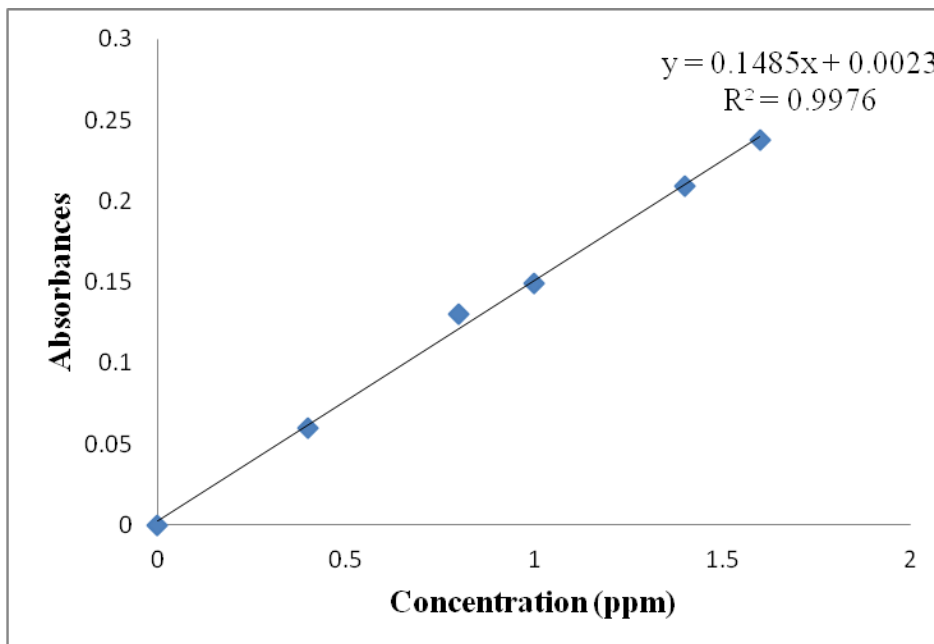
APPENDICES

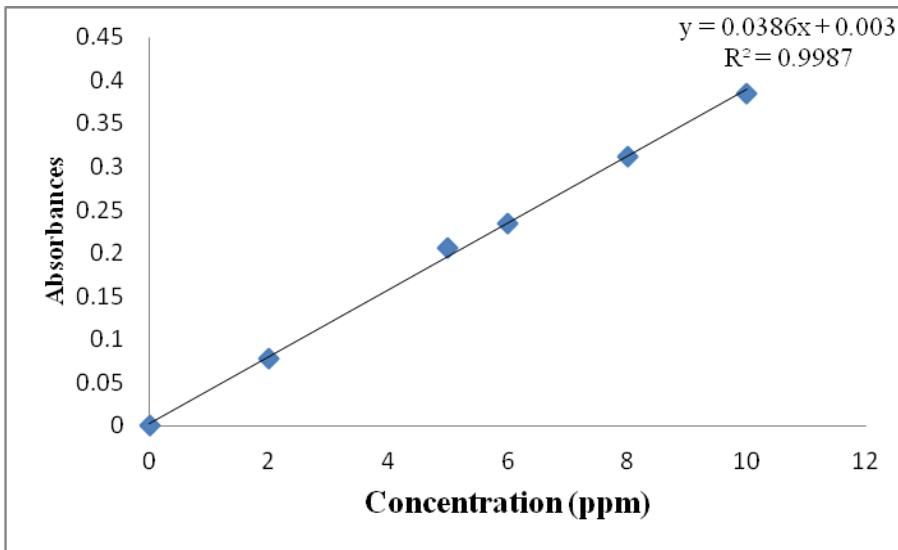
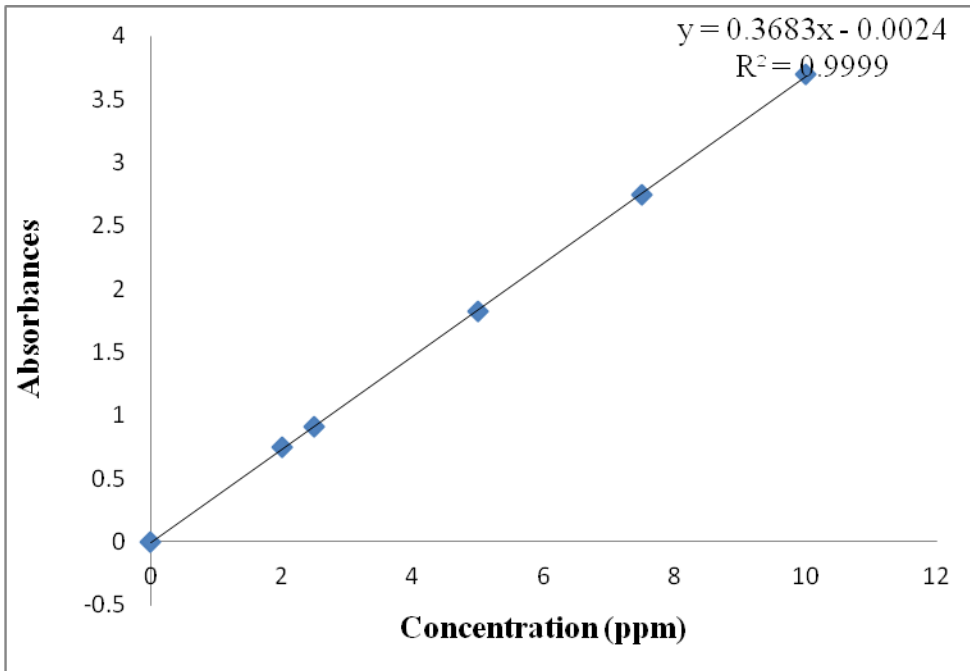
Appendix 1: Sodium calibration curve

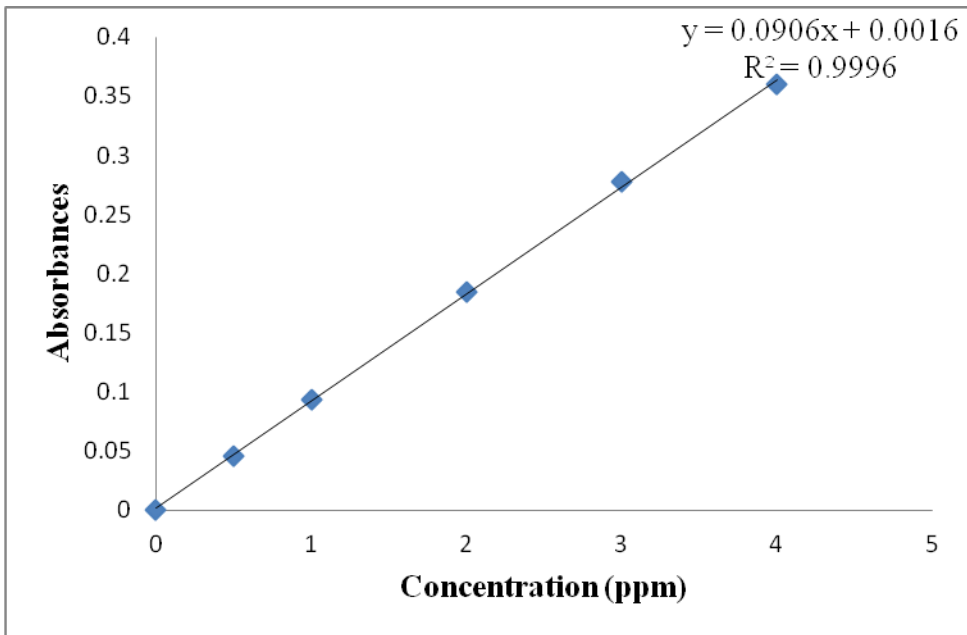


Appendix 2: Potassium calibration curve

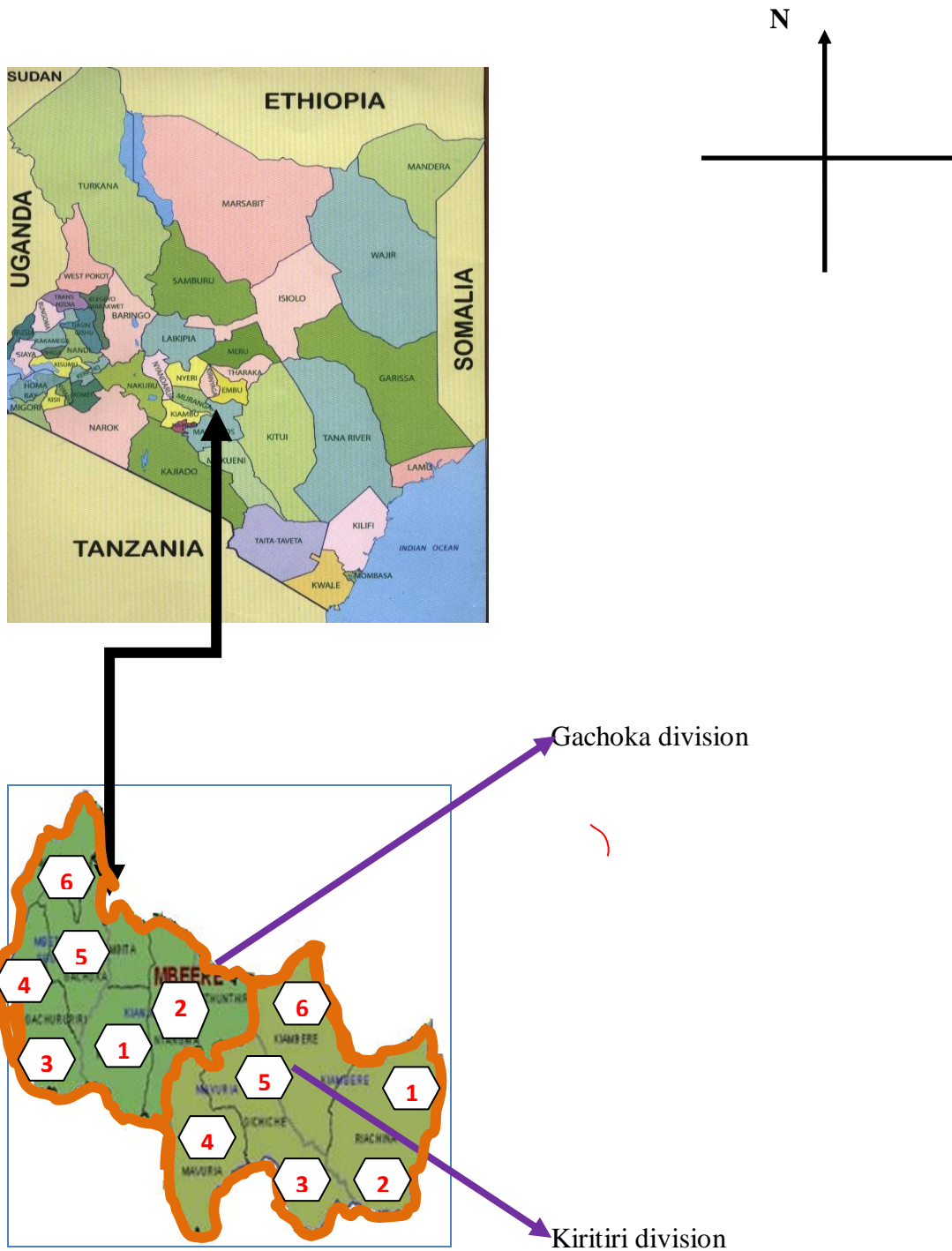


Appendix 3: Magnesium calibration curve**Appendix 4: Zinc calibration curve**

Appendix 5: Copper calibration curve**Appendix 6: Iron calibration curve**

Appendix 7: Manganese calibration curve

Appendix 8: Study area-Mbeere South



Source: (Kinuthia *et al.*, 2009)

Appendix 9: Varieties of mango species analyzed in this study

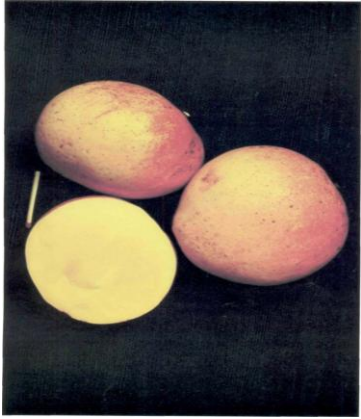


Plate 2.1: Apple



Plate 2.2: Van dyke

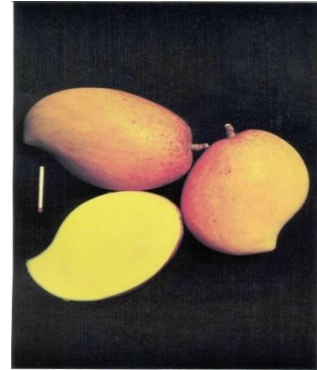
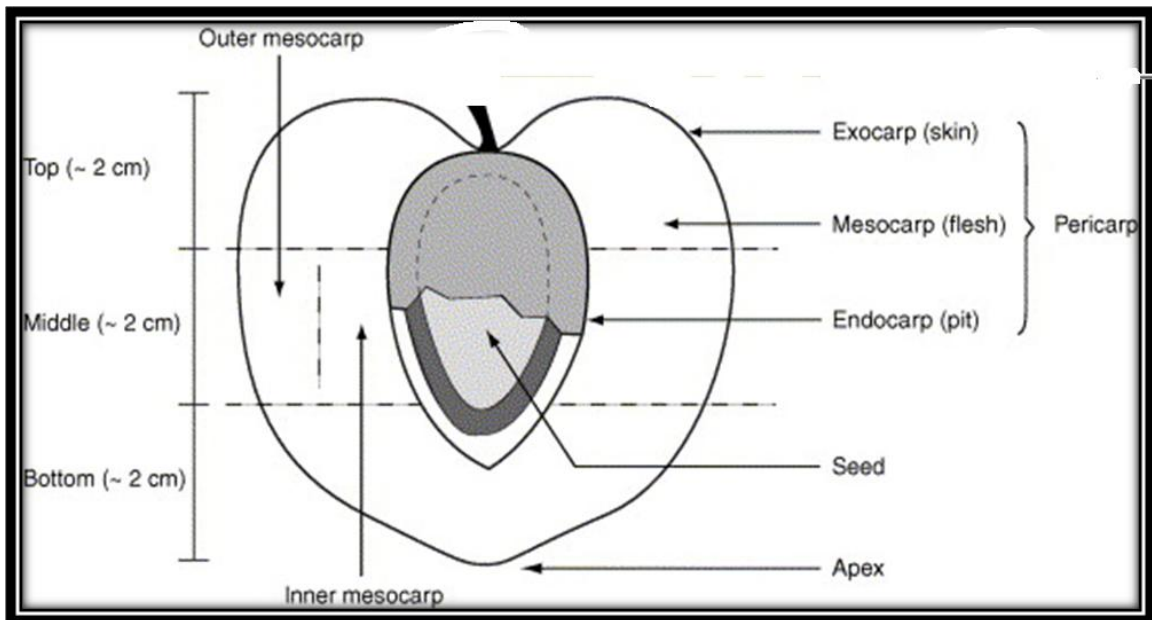


Plate 2.3: Ngowe

Source: (Griesbach, 2003)

Appendix 10: Parts of mango fruit

Source: (Griesbach, 2003)