EFFECT OF CULTURAL PRACTICES AND POST-HARVEST HANDLINGS ON NUTRIENTS, ANTI-NUTRIENTS AND TOXIC SUBSTANCES IN SELECTED NIGERIAN LEAFY VEGETABLES

BY

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A thesis submitted to the Postgraduate School of the Federal University of Technology, Minna, in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Biochemistry

MAY, 2010

DEDICATION

This thesis is dedicated to:

the evergreen memory of my late brother, Alhaji Anthony Musa who in the course of this programme travelled home where he met an unfortunate incidence that led to his sudden death which left me in pains and agony; and my son Ojoniko Collins Musa whose arrival rekindled my hope and strength for attainment of this success.

CERTIFICATION

This thesis titled: *Effect of cultural practices and post-harvest handlings on nutrients, antinutrients and toxic substances in selected Nigerian leafy vegetables* by: MUSA, Amanabo (Ph.D/SSSSE/2001/061) meets the regulations governing the award of the degree of Doctor of Philosophy (Ph.D) of the Federal University of Technology, Minna and is approved for its contribution to scientific knowledge and literary presentation.

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I hereby declare that this thesis entitled "*Effect of cultural practices and post-harvest handlings on nutrients, antinutrients and toxic substances in selected Nigerian leafy vegetables*" has been written by me and it is a record of my research work. This work has not been presented for any other higher degree programme. All citations are indicated and sources of information are duly acknowledged by means of references.

Amv

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ACKNOWLEDGEMENTS

I am most grateful to God Almighty for granting me life and strength to complete this research work. My profound gratitude goes to my co-supervisors, Professor J.A.Oladiran, Professor (Mrs) H.O. Akanya and Professor M.I.S. Ezenwa for their encouragement, support and adequate supervisory role played towards the success of this programme. May God Almighty reward them accordingly (Amen).

Words are grossly inadequate to express my heartfelt gratitude to my major supervisor, Dr. E.O. Ogbadoyi who gave me a conducive working environment and provided me some reagents used for this work. He gave me unreserved supervisory role from the beginning to the end of this progromme. He was indeed a motivator and a pillar of the success of this work.

The role played by Dr. E. Evans and Dr. H.A. Makun towards the success of this work is highly acknowledged. My appreciation goes to other lecturers and non-teaching staff of the Department for their assistance towards the success of this work among them are late Professor J.A. Abalaka, Professor T.A. Gbodi, Mr. S. Mailafiya, Mall. A.N. Saidu, Mall. A.Y. Kabir, Dr. H.Adeyemi, Miss K. Tosin, Alhaji .A. Oyewo, Mall. D. Dauda and Mall.S Shaibu.

My appreciation also goes to the present Head of Department of Biochemistry, Dr.A.A.Jigam, for his various advices and words of encouragement. The suggestions and advices from Professor U.J.J. Ijah, Dr. S.O. Oyeleke of Microbiology Department as well as Dr. A. Iyaka, and Mr. Bala of Chemistry Department of this institution are also acknowledged.

Baba, Mohammed Umar, Ameachi Eze, Akowe Ikani, Felix Amaje, Mohammed Itodo, Mohammed Etubi, Ismaila Umar, Saidu.Mallam, J. B. Azaki, M.S. Gwam. Dr. Peter Shaba, Etsu Mohammed, M.S.Ako, Dr. Mathew Kodan, Dr. A.F. Lawal, Tanko Yusuf, Masu-d Izom, Haruna Ibrahim, ASP. Yakubu Ojoh, Engr. George Enemadukwu, Alhaji Sule and Tijani Idakwo, Ngozi Ossai, Rakiya Habila, Dafe Habila, Beatrice Ila, Biola Tijani, Dorcas just to mention a few.

I owe the entire Management of College of Agriculture, Mokwa, especially the present Provost, Dr. M. T. Nagya and former ones (Dr. E. K. Tsado and Mr. S. N. Kolo) for granting me study leave.

I quite appreciate the understanding of my family (my wife, Mrs Hassana Musa, Collins, Sonia and Jennifer) for their support and prayer to the success of this programme.

The foundation laid by my late father, Musa Odiba and my mother, Mrs ALadi Odiba on my education is highly appreciated without which I may not be able to attain this level of education. The moral supports from my uncles, ASP. Ibrahim Idakwo and Dr. Isaac.I. Achoba) is highly acknowledged.

Last but not the least, I acknowledge the wonderful support from all my brothers and sisters who are too numerous to mention for their contributions towards the completion of this work. May God Almighty bless them all (Amen).

ABSTRACT

Studies were conducted to determine the effect of post-harvest handlings and cultural practices on antinutrient (soluble and total oxalates), toxic substances (cyanide and nitrate) and some micronutrients which include vitamin C, β-carotene (provitamin A) and mineral elements (Fe, Mg, Cu, Zn, Ca Na and K) in some Nigerian leafy vegetables, namely *Amaranthus cruentus, Hibiscus sabdariffa, Corchorus olitorius, Telfairia occidentalis* and *Vernonia amygdalina*. The postharvest handling includes processing methods and storage conditions. The processing methods adopted were boiling (vegetables were boiled in distilled water for 5 and 10 minutes) and sun drying, while the storage conditions involved freezing of vegetables in a freezer for a period of four weeks. Samples used to determine effect of post-harvest handlings were obtained from three different markets in Minna town, Niger state, Nigeria. The cultural practices investigated were soil nitrogen levels, leaf position or leaf age, vegetative and reproductive phases. Results obtained showed that the oxalate, cyanide and nitrate contents in some of the fresh vegetables analysed are high enough to induce toxicity in man. All the processing methods adopted significantly ($p < 0.05$) reduced the antinutrients and toxic substances in all the vegetable samples except that the reduction in cyanide and total oxalate in *Corchorus olitorius* and nitrate in *Vernonia amygdalina* caused by sun drying were not significant ($p > 0.05$). Boiling reduced these toxic substances significantly ($p < 0.05$) more than sun drying did. The antinutrients and toxic substances decreased with boiling time. The processing methods also reduced vitamin C content significantly ($p < 0.05$) in all the vegetables. Boiling method retained more of the vitamin compared to sun drying method. β-carotene levels increased in the boiled vegetables, while its content was reduced in sundried vegetables. However, boiling exceeding 5 minutes led to significant ($p < 0.05$) reduction in β-carotene levels in the vegetables studied. Mineral elements (Fe, Cu, Mg, Na and K) decreased with boiling in all the leafy vegetables analysed, whereas sun drying had no significant effect on the mineral contents. Freezing reduced the levels of all the antinutrients studied in all the vegetables. The reduction was generally significant within the first week of freezing after which the decreasing effect was not significant up to four weeks of storage. β-carotene and vitamin C generally decreased significantly ($p < 0.05$) with freezing time, however, the decrease in the vitamin was significant within the first week and thereafter showed no significant decrease. Application of nitrogen fertilizer significantly ($p < 0.05$) elevated cyanide, nitrate and β-carotene contents whereas levels of vitamin C, soluble and total oxalates decreased with the applied nitrogen fertilizer in some of the studied vegetables. Results also showed that the levels of Fe, Zn and Cu in *Telfairia occidentalis* and Mg in *Vernonia amygdalina* were increased with the applied nitrogen fertilizer. The concentrations of cyanide and nitrate were generally higher in older leaves than younger ones except that cyanide was higher in younger leaves of *Telfairia occidentalis* at fruiting, nitrate was higher in younger leaves of *Telfairia occidentalis* and *Vernonia amygdalina*. The soluble and total oxalate content in the vegetables increased with leaf age except in *Corchorus olitorius* at market maturity where the oxalate level was highest in the middle leaves than in the other leaf regions. Vitamin C content was concentrated more in the middle leaf region compared to basal and upper leaf positions in the vegetables except in *Telfairia occidentalis* at market maturity, where the vitamin was highest in the upper leave than the two leaf positions. β-carotene content was highest in the middle and upper leaves in *Amaranthus cruentus,* and *Telfairia occidentalis* respectively. In *Hibiscus sabdariffa* and *Corchorus olitorius* the provitamin was highest in the middle and upper leaves at market maturity and fruiting respectively. Similarly the level of β-carotene content in *Vernonia amygdalina* was highest in upper and middle leaves at market

maturity and fruiting respectively. Levels of Fe, Ca and Mg were generally highest in the older compared to younger leaves, while the K content was highest in the younger leaves than the older ones. The antinutrients and toxic substances were significantly increased during fruiting except that the nitrate content decreased in *Amaranthus cruentus, Corchorus olitorius* and *Telfairia occidentalis*. β-carotene content decreased significantly in *Amaranthus cruentus* and *Telfairia occidentalis* and increased in *Corchorus olitorius* and *Vernonial amygalina* during fruiting. Fruiting reduced vitamin C content in *Corchorus olitorius* and increased the vitamin content in *Amaranthus cruentus* and *Vernonia amygdalina* while fruiting had no significant effect on vitamin C content in *Hibiscus sabdariffa* and *Telfairia occidentalis*. There was generally a strong positive significant ($p < 0.01$) correlation between oxalates, nitrate and cyanide with Mg, Na, Zn, Ca, K and Fe.

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LIST OF ABBREVIATIONS

FAO – Food and Agricultural Organisation.

FDALR – Federal Department of Agriculture and Land Resources.

CEC – Cation Exchange Capacity.

USDA – United State Department of Agriculture.

WHO – World Health Organisation.

JECFA – Joint FAO/WHO Expert Committee on Food Additives.

ADI – Accepted Daily Intake.

EU – European Commission.

SCF – Scientific Committee on Food.

IITA – International Institute of Tropical Agriculture.

CHAPTER ONE

INTRODUCTION

The world today is faced with an acute need to provide adequate food for its entire people. Increasing awareness about quality of food in relation to health is significantly influencing our modern agricultural and food industries (Fasuyi and Aletor, 2005). This is because the health of an individual is dependent to a large extent on the quality of food intake (Weerakkody, 2006). Food stuff may be broadly classified as vegetables, cereals, nuts, oil seeds, milks, milk products and meat, with vegetable forming 90% of the world food product (Dasai, 1988). In the tropics, vegetables are strictly confined to plants with edible leaves or stems (Oke and Ojofeitimi, 1987). Nigerian families select vegetables as an integral part of their daily meal. These vegetables are cheap and easy to cook. They can be cooked together with staple food, with the addition of condiments or they can be eaten raw (Ejoh *et al.*, 2005; Oboh, 2005; Fasuyi, 2006; Antia *et al.*, 2006).

The quality of these vegetables though difficult to define can be discussed in terms of four basic characteristics of food (orgnoleptic properties), namely: colour or eye appeal, texture or feel, odour or flavour and nutritive value. Like other food stuffs, vegetables provide essential nutrients for energy, growth and good health (Sealy *et al.,* 1990; Fasuyi, 2006; Anjana *et al.*, 2007).

Vegetables are also known to contain various toxic substances, and anti-nutrients which reduce their nutritive value (Watzl and Leitzmann, 1995; Macrae *et al.,* 1997; Oboh, 2005; Antia *et al.,* 2006; Weerakkody, 2006; Adeboye and Babajide, 2007; Adeniji *et al.*, 2007). Anti-nutrients or anti-nutritional factors are substances found in most foods and are poisonous or in some way limit the bioavailability of the nutrients to the body

(Aganga and Tshwenyane, 2003). They are known to inhibit or block important path ways in body metabolism (Novak and Hasselberger, 2000). The anti-nutrients and toxic substances that are common in our diets are phytates, oxalates, tannins, aflatoxin, oligosaccharides, cyanide in form of hydrogen cyanide, phenolics, trypsin, chymotrypsin and amylase inhibitors, lectin, alkaloids, non-protein amino acids, saponins and nitrates (Abakr and Ragaa, 1996; Liener, 1994; Majeb *et al.*, 2006).

The anti-nutrients occur in such small quantities that they may cause no harm. But if the diet is not varied some of these toxins can build up in the body to harmful levels. Each antinutrient has a tolerable level. The tolerable levels for cyanide in food sample are 10 – 30mg/kg body weight (IITA, 1989). The maximum tolerance dose of nitrate and nitrite is about 10-15mg and 4.0mg nitrite per Kg daily respectively. The European Commission's (EU) Scientific Committee on Food (SCF) prescribed the acceptable daily intake (ADI) of nitrate as 3.65 mg/kg body weight (Anjana *et al.*, 2007). In developed countries, the maximum level of nitrate in spinach is between 2000-3000 mg/Kg fresh product while that of lettuce is between 2,500 – 4,500 mg/Kg fresh product. The permissible levels vary from one country to another and from season to season with higher nitrate level permitted in winter-grown vegetables (Muramoto, 1999). Even though the maximum tolerance levels of oxalate in food was not clearly stated,
Oguchi *et al.*, (1996), gave the limit value of oxalate in spinach as 250mg/100g fresh weight. James (1972) reported that swine and cattle fed with amaranthus having an oxalate content as high as 120-300g/Kg dry matter were poisoned and eventually died.

The antinutrients and toxic substances that are studied in this research work are oxalate, cyanide and nitrate. Relatively large amounts of oxalates are found in some

leafy vegetables. A diet high in oxalates can cause calcium deficiency by chelating the calcium ions in the body (Aletor and Omodara, 1994). This equally results in the formation of urinary calculi leading to kidney damage, contributing to incidence of oxaluria and oxalemia conditions (Sealy *et al.*, 1990). Cyanides in the form of hydrogen cyanide are found in some vegetables and several plant species as cyanogenic glycosides. Accumulation of cyanide beyond tolerance level leads to goiter if diet is low in iodine. Other toxic effects of cyanide include inhibition of cell respiration, neurological damages and gastrointestinal disturbance (Novak and Haselberger, 2000). Richard (1991) reported that levels of HCN exceeding 200 mg/kg in forages on wet-weight basis is considered dangerous while levels in forages on dry weight basis exceeding 500 mg/kg should be considered potentially toxic. There have been several reports of methemoglobinemia following the consumption of spinach and other vegetables with high levels of nitrate, but the conversion of nitrates to nitrites during storage, rather than nitrates themselves was responsible for methemoglobinemia. Nitrites from nitrate can react with amines in human to form nitrosamines which are Cancinogenic (Whitney *et al.*, 1990; Galler, 1997; Mevissen, 1997; Muramoto, 1999; Prakasa and Puttanna, 2000; Gupta *et al.*, 2000; Safaa and Abd EL Fattah, 2007).

Attempts were made by some researchers to determine presence of toxins in leafy vegetables. Other studies attempted to reduce the presence of toxic levels of some selected leafy vegetable by means of improved agricultural practices, processing and storage. Muramoto (1999) worked on nitrate content in some leafy vegetables from organic and conventional farms in California and reported that conventional spinach nitrate levels exceed the maximum levels specified by European Commission Regulation

much more than organic spinach. He equally stated that spinach nitrate levels are affected by the rate and type of nitrogen fertilizers applied, and also by soil nitrification activity, soil texture and harvest time. Abakr and Ragaa (1996) examined the reduction of nitrate and oxalate levels in some selected leafy vegetables and the interplay of manipulating soil nutrient supply, different blanching media and preservation methods followed by cooking. Ogbadoyi *et al., (*2006) also studied the effect of processing and preservation methods on oxalate levels of some Nigerian leafy vegetables. The study revealed that freezing and controlled boiling of vegetables and then throwing away the water used for boiling before using the vegetables in meals will considerable reduce the oxalate content. Most of these work have undermined what actually happens to nutrients in the vegetables (especially minerals and vitamins) while attempting to reduce some of these toxins. In some of these works, effect of leaves positions on these vegetables as its affect the bioaccumulation of these toxins and nutrients were overlooked. Moreover, these researches were mostly conducted in other countries with different environmental conditions and on different vegetable species. Therefore, the results obtained may not be directly extrapolated to our species of vegetables. This research work attempts to study the effect of soil fertility, leaf position and post harvest handling on nutrient contents and toxic substances in some of our indigenous leafy vegetables.

Against this background, the following five widely used vegetables have been selected for this study. These are fluted pumpkin (*Telfairia occidentalis*), amaranthus (*Amaranthus cruentus*), roselle (*Hibiscus sabdariffa*), bitter leaf (*Vernonia amygdalina*) and jute mallow (*Corchorus olitorius*).

1.1 Justification

Vegetables assume importance in man's diet especially the lower income earners who are unable to afford animal proteins. These groups of people depend on vegetables (that include legumes) for their nutrients requirement (Robinson, 1990). Also with growing consciousness that a diet primarily of animal origin could pose some risk to health, the consumption of vegetables has increased considerably (Macrae *et al*, 1997; George, 1999). Though vegetables are rich in nutrients, they also contain other substances which cause serious nutritional problems. Some of these compounds include Oxalates, nitrates, alkaloids, cyanides. Oxalate is known to chelate mineral elements (Ca^{2+}, Fe^{2+}, Na^{+}, K^{+} etc.) in the body making them unavailable. Oxalate in combination with calcium leads to the formation of insoluble calcium oxalates which are precipitated and deposited in the kidney to form kidney stone (Prien, 1991). Also, high level of nitrates in vegetables when ingested can be converted to nitrite which when combined with haemoglobin forms metheamoglobin, which is incapable of carrying oxygen in the body. This condition is known as metheamoglobinemia or blue-baby disease. Incidence of metheamoglobinaemia earlier believed to have been confined to infants only, has been reported in all age groups with high nitrate ingestion, with infants and adults above 45 years age, being most susceptible to nitrate toxicity (Gupta *et al.*, 2000). Equally high level of nitrate in the body resulting from its high levels in foods and water is known to cause cancer (Macrae, *et al.*, 1997; Takebe and Yoneyame, 1997; Oguchi *et al.*, 1996). Cyanide known to be present in plants, including leafy vegetables, is a potent poison which exert its ultimate lethal effect of histotoxic anoxia by binding to the active site of cytochrome oxidase,

thereby stopping aerobic cell metabolism (Ames *et al.*, 1981, Ellenhorn and Barcelonx, 1988).

From the foregoing, high levels of these toxins in our leafy vegetables affect health negatively. There is also economic loss arising from the cost of treating people affected by diseases caused by these toxins. The net effect is the retardation of individual and national development. The outcome of this research is expected to guide both producers and consumers of leafy vegetables in their bid to reduce the incidence of diseases and health problems associated with these substances. This will go a long way in improving the general well being of the people and increased productivity.

1.2 Objectives

The main objective of this research work is to reduce the level of anti-nutrients and toxic substances (oxalates, cyanides and nitrates) in some selected Nigerian leafy vegetables to the barest minimum through cultural practices and post harvest treatments without compromising their nutritive values.

In order to achieve this objective, the research is designed to determine the effect of the following on the accumulation of cyanide, oxalate, nitrate, vitamins (vitamin C and β-carotene) and minerals (Fe, Mg, Zn, Cu, Ca, Na and K) in the selected leafy vegetables.

(i). Soil fertility (nitrogen fertilizer level)

(ii). Age of leaf on the plants

(iii). Vegetative/reproductive phase of plant

(iv). Processing method and

(v). Storage conditions

CHAPTER TWO

LITERATURE REVIEW

2.1 Leafy Vegetables

Vegetables offer the cheapest means of providing adequate supplies of vitamins, minerals and fibre for the people who live in the tropics (Alfred and Patric 1985; Wills *et al.*, 1986; Kimura and Itokawa, 1990; Takebe *et al.*, 1995; Oguchi *et al.*, 1996; Grazyna and Waldemar, 1999; Kmiecik and Lisiewska, 1999; Aliyu and Morufu, 2006; Adeboye and Babajide, 2007). The leaves of green vegetable plants manufacture carbohydrate by a natural process called photosynthesis. The starches and sugar produced are not stored in the leaves but translocated to other parts of the plant for use or to be stored. Therefore, the leaves have low energy value and can be included in large quantity in sliming diets (George, 1999). Vegetables contain actively growing tissues and those which are dark green e.g. fluted pumpkin, water leaf etc, have high content of chlorophyll and are probably the most nutritious. The dark green leaves of vegetables are rich in β-carotene (precursor of vitamin A). They are also important sources of vitamin B complex, folic acid and minerals such as calcium and iron (Oyenuga and Fatuga, 1975; Herbert, 1987; Robinson 1990; Oguchi *et al.*, 1996; Macrae *et al.*, 1997; Grazyna and Waldemar, 1999; Shahnaz *et al.*, 2003; Aliyu and Morufu, 2006; Weerakkody, 2006; Adeboye and Babajide, 2007). Spinach is particularly a rich source of iron (Fe). Leech (1983) stated that the absorption of iron is assisted by vitamin C, thus it is essential to prepare vegetables in a manner that will retain the maximum amount of vitamin C, because vitamin C is often lost before consumption through oxidation and leaching during preparation. Little carotene, portion of water soluble vitamins and appreciable quantities

of Fe, Mg, Ca and P may be lost if the cooking water of vegetables is discarded (Macrae *et al.,* 1997).

Studies have indicated that some neglected amaranthus species have high lysine contents (Schippers, 2000). Analysis of leaves and seed has shown that the seed of *Amaranthus edulis* are rich in protein with a high lysine and methionine content. But the concentration of these compounds is higher in tropical vegetables than those of temperate region (Schippers, 2000). The chemical compositions of leafy vegetables has been reported to be influenced by soil types, season of the years, differences in temperature, length of day, light intensity and other micro factors (Harris, 1975; Samson, 1977; Watanabe *et al.*, 1994; Takebe *et al.*, 1995, Grevsen and Kaack, 1996; Oguchi *et al.*, 1996; Takebe and Yoneyama, 1997; Grazyna and Waldemar, 1999; Bolanle *et al.,* 2004; Singh, 2005; Aliyu and Morufu, 2006; Adeboye and Babajide, 2007).

2.1.1 Amaranthus (*Amaranthus cruentus*)

Amaranthus (commonly called: "Alayyaho" in Hausa and "Tete" in Yoruba) is a widely distributed genus of short-lived herbs, occurring mostly in temperate and tropical regions. There are about 60 species of Amaranthus and several of them are cultivated as leafy vegetables, cereals or ornamental plants (Schippers, 2000; He, 2002; Dhellot *et al.*, 2006).

Amaranthus cruentus is an herbaceous annual leafy vegetable that can be produced for fresh market in 4 - 6 weeks after planting. It can be produced all the year round depending on the availability of water. This plant requires loamy to sandy loam soil for good yield and does well in soils with high organic matter content (Grubben, 1986). In

Nigeria, amaranthus leaves combined with condiments are used to prepare sauce (Oke, 1983; Mepha *et al.*, 2007; Akubugwo *et al.*, 2007).

Amaranthus cruentus has a high nutritional value because of the high levels of vitamins including β-carotene (precussor of vitamin A), vitamin B6, vitamin C, riboflavin, and folate, as well as dietary minerals including calcium, iron, magnesium, phosphorus, potassium, zinc, copper, and manganese (Makus, 1984; Makus and Davis, 1984; Igbokwe *et al.*, 1988; Sussan and Anne, 1988; Stallknecht and Schaeffer, 1993). This vegetable is also rich in lysine, an essential amino acid that is lacking in diets based on cereals and tubers (Schipper, 2000). However the moderately high content of oxalic acid in the leaves of this vegetable inhibits the absorption of calcium, and also means that they should be avoided or eaten in moderation by people with kidney disorders, gout, or rheumatoid arthritis. Amaranthus under certain conditions have high nitrate content exceeding tolerable limit (Macrae *et al.*, 1997).The vegetable is also known to contain some appreciable level of anthocyanin.

2.1.2 Roselle (*Hibiscus sabdariffa)*

Roselle (*Hibiscus sabdariffa*) popularly called "Yakuwa" in Hausa belongs to the family of Malvaceace and is a popular vegetable in Indonesia, India, West Africa and many tropical regions (Tindal, 1986; Babatunde, 2003). The vegetable is widely grown in the North-Eastern and middle belt regions of Nigeria (Akanya *et al*, 1997). This plant has been found to thrive on a wide range of soil conditions. It can perform satisfactorily on relatively infertile soils but for economic purposes, a soil well supplied with organic materials and essential nutrients is important in the productions (Tindal, 1986, Adanlawo

and Ajibade, 2006). It can tolerate relatively high temperature throughout the growing and fruiting periods. The plant requires an optimum rainfall of approximately 45 - 50cm distributed over a 90 - 120 day growing period (Tindal, 1986). In Nigeria, two botanical varieties were recognised, the red variety in which the calyx is used for the preparation of "sobo" drink and the green variety which calyx and leaves are used in stew and sauces (Duke, 1985; Syndenham, 1985; Adanlawo and Ajibade, 2006; Ojokoh, 2006). The leaves and calyx of the green variety are very rich in vitamin C and riboflavin with some major mineral elements (Babalola, 2000). Roselle has been shown to contain phytic acid, tannin and glucoside such as delphinidin-3-monoglucosides and delphinidin which are toxic to animal and human tissue at high concentration (Morton, 1987; Ojokoh *et al.*, 2002). Tannins form complexes with protein (Goldstein and Swain, 1963). Phytic acid chelates minerals and form complexes with proteins, and thereby affects their nutritive value (Evans and Bandemer, 1967). Cyanogenic glucosides also found in this plant are inhibitors of cytochrome oxidase enzyme (Aletor, 1993)

2.1.3 Jute Mallow (*Corchorus olitorius*)

The genus *Corchorus* consists of 50 - 60 species, of which about 30 are found in Africa. *Corchorus* is mainly known for its fibre product, jute and for its leafy vegetables (Schippers, 2000). Several species of *Corchorus* are used as vegetable, of which *Corchorus olitorius* is most frequently cultivated.

Corchorus olitorius called jews mallow or jute mallow in English, ayoyo in Hausa and ewedu in Yoruba is popular as vegetable in both dry or semi-arid regions and in the humid areas of Africa. The plant grows well in light (sandy), medium (loamy) and heavy

(clay) soils. This vegetable does well in acid, neutral and basic (alkaline) soils (Facciola, 1990). *Corchorus olitorius* is widely consumed as a health vegetable in Japan, because it contains abundant carotenoids, vitamins B_1, B_2, C and E, and minerals. On the other hand, accidental death of cattle has occurred when the cattle were fed vegetation containing seeds, because the seeds contain cardiac glycoside 5 (Shinobu *et al.*, 2000).

The dark-green leaves of *Corchorus olitorius* have varying proportion of Ca, Fe, β-carotene, vitamin C, fibre and protein required for health. It was noticed that many of the useful micronutrients are lost in cooking process, especially when the water is thrown away. Thus it is best to boil the sauce for as short a time as possible (Adebanjo and Shopeju, 1993; Schipper, 2000).

2.1.4 Fluted Pumpkin (*Telfairia occidentalis*)

Fluted pumpkin (*Telfairia occidentalis*) (called "ugwu" by Igbos) is a creeping vegetative shrub that spread low across the ground with large lobed leave, and long twisting tendrils (Syndenham, 1985; Horsfall and Spiff, 2005; Christian, 2006; Ojiako and Igwe, 2008). Nkang *et al.* (2003) reported that this vegetable is of commercial importance grown across the low land humid tropic in West Africa (Nigeria, Ghana and Sierra Leone being the major producers). Fluted pumpkin prefers a loose, friable ample humus and shaded position. Nitrogen is essential for adequate vegetation and should ideally be given in the form of manure (Schippers, 2000). The leaves and seeds are widely eaten as they are good sources of minerals (potassium, magnesium, sodium, phosphorus and iron), vitamins, fibres, fats (Schipper, 2000; Nkang *et al*, 2003; Christian, 2006). Harvesting of fluted pumpkin takes place 120 - 150 days after planting. Horsefall

and Spiff, (2005) reported the presence of antinutritional factors (oxalate and phylate) in the leaves and seeds of this vegetable.

2.1.5 Bitter Leaf (*Vernonia amygdalina*)

Vernonia amygdalina locally called "shuwaka" in Hausa, "olugbu" in Igbo and "Ewuro: in Yoruba is a shrub of up to 5m high, with abovate to oblanceolate leaves with the widest part below the middle. It is a perennial crop and some bushes are known to have been in continuous production for up to 7 years. This species is frequently found in gardens (Schippers, 2000) and commonly found in Nigeria, Cameroon, Gabon and Congo. *Vernonia amygdalina* is generally raised by stem cutting are planting at an angle of 45^0 to obtain faster sprouting (Schippers, 2000). It is one of the leafy vegetables that can be used in an attempt to alleviate the problem of micronutrient malnutrition, prominent in tropical Africa (Ejoh et *al.*, 2005). This leafy vegetable is relatively inexpensive, easily and quickly cooked and rich in several nutrients especially β-cartotene and vitamin C, which are essential for human health. The vegetable also provides some minerals such as iron, phosphorus, calcium, potassium (Oshodi, 1992).

Bitter leaf is known to contain some secondary metabolites such as dhurrin which is a cyanogenic glycoside (Oke, 1966; Anderson, 1985). Bitterness in *Vernonia amygdalina* is partly caused by saponins, which can be poisonous to human and other animals (Schippers, 2000).

2.2 Nutrient Composition of Vegetables

Vegetables are considered as protective foods supplying carbohydrate, protein (especially legumes) minerals, vitamins and crude fibre, which are essential ingredients of a balanced diet (Oyenuga and Fatuga, 1975; Robinson, 1990; Shahnaz *et al.*, 2003; 'Weerakkody, 2006). In addition to their nutritional role, they increase attractiveness and palatability of a diet by providing sensory appeal through their variety of colours and flavours.

Vegetables in general, except for a few are not considered to be the primary sources of carbohydrate, protein and fat (Antia *et al*, 2006; Aliyu and Morufu, 2006). However some of them with storage roots and tubers are rich in carbohydrate, particularly starch, in amount comparable to the cereal crops. The leguminous vegetables supply as much as 14% protein, dry seed supplying even more. The lipid content of most vegetables is less than 0.1 %. Most leafy vegetables and root crops are rich in minerals. Carrot and leafy vegetables are also high in carotene (provitamin A) and vitamin C (Macrae *et al.*, 1997; Weerakkody, 2006).

The nutrient content of a vegetable is dependent on several factors. The environment, in which the crop is grown, such as temperature, light, moisture, nutrients and physical and chemical properties of the soil, plays an important role (Takebe and Yoneyama, 1997; Grazyna and Waldemar, 1999; Bolanle *et al.*, 2004; Singh, 2005; Weerakkody, 2006). The amount of nutrient can also vary depending on variety, cultural practices, and stages of maturity, post harvest handling and storage conditions. Once vegetable is harvested, its composition starts changing as a result of physiological and biochemical activities which are natural processes. In addition, methods of cooking

influence the nutrient content of vegetables in particular; leaching losses and oxidative changes are considered as deteriorative processes (Schippers, 2000; Aliyu and Morufu, 2006). The major nutrients in vegetables are briefly described below.

2.2.1 Vitamins

Vitamins are a class of nutrients that are essentially required by the body for its various biochemical and physiological processes. The human body does not synthesis vitamins therefore, must obtain them from the diets (Achinewhu, 1983; Robinson, 1990; Shahnaz *et al.*, 2003; Khalid *et al.*, 2004; Oboh, 2005). Vitamins are subdivided into fat soluble and water soluble vitamins. Fat soluble vitamins are those that are soluble in fat solvents. They are vitamins A, D, E and K. Water soluble vitamins are those which are soluble in water and include vitamin C and vitamin B series that are usually termed vitamin B complex (Olaofe, 1992; George, 1999; Khalid *et al.*, 2004).

2.2.1.1. Vitamin A

Vitamin A is found in the coloured vegetables (such as carrots, tomatoes, greens,etc) in the form of provitamin, known as beta carotene (β-carotene), that our body transforms into vitamin A or retinal, according to the body's needs (Oslson *et al*, 2000). Since the intestinal absorption of carotenes is not as easy as vitamin A which comes from animals, it is calculated that we need six times more vegetable β-carotene than animal retinal (George, 1999).

Vitamin A is known to perform the following functions:

(i) Formation of the visual pigments in the retina, the lack of vitamin A impedes seeing in poor light (night blindness) (Simon *et al.*, 1996).

(ii) Forming and maintaining the cells which cover the skin, eyes, mouth and internal organs. Where there is lack of vitamin A, the skin, and especially the membrane, which covers the eye, are weakened and dry up. When this deficit happens, serious blindness is a result (George, 1999; Mclaren and Frigg, 2001; Akubugwo *et al.*, 2007).

(iii) Vitamin A reduces the risks of the formation of cancerous tumors in the organs of our body, due to its strong antioxidant action (Oduro *et al.*, 2008)

The recommended dietary allowances for vitamin A (retinol) in human being is as follows: 300 μg for 1 – 3 years, 400 μg for 4 – 8 years, 600 μg for 9 – 13 years, 900 μg for 14 – 18 years (men), 900 μg for above 19 years (men), 700 μg for 14 – 18 years (women), 700 μg for above 19 years (women), 750 μg for 14 – 18 years (pregnancy), 770 μg for above 19 years (pregnancy), 1,200 μg for 14 – 18 years (lactation), 1,300 μg for above 19 years (lactation) (Akanya, 2004). Ejoh *et al*, (2005) reported that various food processing methods reduced the level of total carotenoid in different species of bitter leaf. Report by USDA (1998) indicated that whereas only about 1 % of β-carotene present in the raw carrots is available for absorption, the value increased to about 19%. The report concluded that moderate cooking increases the availability of β-carotene in vegetables, as it helps in breaking down the cell walls of the cells of vegetable. Repeated cooking at high temperatures however, destroys some of the provitamin in vegetables.

2.2.1.2 Vitamin C

Vitamin C (Ascorbic acid) is a water-soluble antioxidant (Khalid *et al.*, 2004). It is a vegetation vitamin per excellence. No one whose diet is based on vegetables will lack Vitamin C. The vitamin is found in citrus fruits, green peppers, red peppers, tomatoes, strawberries, broccoli, Brussels sprouts, turnip, amaranthus and other leafy vegetables (George, 1999; Khalid *et al.*, 2004).

It is very sensitive to heat and light, so when foods are cooked or fried, a good portion is lost. The same happens to canned products (George, 1999). This is one of the reasons advanced for daily use of fresh and raw foods as fruits and salads.

According to George (1999), the recommended daily allowance of vitamin C is as follows: 40-45mg for Children, 60 mg for adult males and females, 70 mg for pregnant females 70 mg and 95 mg for lactating mothers. He added that in the case of infection, wounds or surgery, the daily requirement increases considerably, and it is well to increase daily allowance by the use of fruit juices, vegetables or pharmaceutical supplements.

Vitamin C activates the functions of all the cells. It is a powerful antioxidant and strengthening the immune system to fight against infection. It impedes the biochemical processes of cellular aging (and possibly, also cancer), which are mostly of an oxidative type (Halliwell and Glutteridge, 1990; Latham, 1997; Oduro *et al.*, 2008; Ojiako and Igwe., 2008). It favours the absorption of Fe in the intestines, contributes to the formation of defences against infections, neutralizes blood toxins, intervenes in the healing of wounds and performs many physiologically important functions (Kronhausen *et al.*, 1989; Akubugwo *et al.*, 2007; Ojiako and Igwe., 2008).

Apart from post-harvest handling which affects vitamin C level in vegetables, soils and other environmental conditions are known to affect the value of this vitamin (Dolyle, 2006). Ejoh *et al.* (2005) reported that different species of bitter leaf are good sources of vitamin A and C. However, processing methods (squeeze-washing, boiling and drying) generally lead to significant losses of these vitamins. Losses were more prominent in drying method of processing. They added that long time freezing significantly reduces the content of both vitamins and recommend that short time freezing of this leafy vegetable is required to retain reasonable amount of these vitamins. This finding is in agreement with the report of Olaofe, (1992). Chweya (1993), found that *Gynandropsis gynandra* plants respond to fertilizer (inorganic or organic) application, and that fertilizer application increased crude protein and nitrate contents; decreased β-carotene, ascorbic acid and iron, and had no effect on phenolic compounds and calcium and sodium content of the leaves. β-carotene, crude protein, nitrates and phenolic leaf contents were significantly increased while ascorbic acid, crude fibre and oxalate leaf contents were significantly reduced by nitrogen application in this leafy vegetable. The author reported further that leaf ascorbic acid content significantly increased with plant age while β-carotene increased and then decreased with plant age. Virginia (2001) also observed that nitrogen from any kind of fertilizer affects the amounts of vitamin C and nitrates as well as the quantity and quality of protein produced by plants. Study revealed that higher amount of nitrogen fertilizer increased protein production and reduced carbohydrate production. Because vitamin C is made from carbohydrates, the synthesis of vitamin C was reduced also. Moreover, the increased protein that was produced in response to high nitrogen levels contained lower amounts of certain essential amino acid

such as lysine and consequently had a lower quality in terms of human and animal nutrition. Mozafar (1993) also found that if the nitrogen in soil is more than the amount needed by the plant for protein production, the excess is accumulated as nitrates and stored predominantly in the leaves of the plant.

2.2.2 Minerals

About twenty minerals are known that form a part of our bodies; they constitute 5% of the body weight, that is, about 3.5 kilos for a 70 kilo adult. Minerals are constantly being replenished within our bodies. Around 30 grams of minerals are eliminated each day through urine, faeces, perspiration, and other secretions, and these must necessarily be replaced through food (Tietz *et al.*, 1994).

The most important sources of minerals are plant foods in their natural state, especially those originating from organic farming. Therefore, flesh diets and those based on refined products tend to be deficient in minerals (George, 1999). In most African and other developing countries, mineral deficiency especially that of iron is still a public health issue probably due to the over dependence on plant food sources, which contain more than enough minerals to meet the daily requirement of man but have a low bioavailability for physiological purposes (Adewusi and Folade, 1996; Adewusi *et al.*, 1999). The low bioavailability of minerals from plant foods has been attributed to the presence of antinutritional factor such as tannin, phytate and oxalic acid (Awoyinka *et al.*, 1995; Santamaria *et al.*, 1999) while some amino acids, ascorbic acid and other organic acids have been reported to enhance mineral bioavailability (Reinhold *et al.*, 1981).

Mineral, like other nutrient contents of vegetables are variable and are easily affected by many factors such as plant maturity, variety, age and size as well as physiological changes, weather condition, soil fertility and seasonal variation (Aliyu and Morufu, 2006).

Minerals form an integral part of functionally important organic compounds such as iron (Fe) in haemoglobin or zinc (Zn) in insulin (Delvin, 1997). They are essential for the normal functioning of muscles, heart, nerves and in the maintenance of body fluid composition among others (White *et al*., 1973; Prohp *et al*., 2006). Mineral deficiencies have manifested in forms of different disease conditions as goitre, rickets and one form of metabolic dysfunction (Prohp *et al*., 2006). Like other nutrients, losses of minerals in vegetable during post harvest treatment have been reported. Oboh, (2005) showed that various conventional food-processing techniques (like blanching and soaking) in Nigeria cause a significant decrease in the entire mineral analysed in *Cnidoscolus acontifolus*. In the same way, Shahnaz *et al.* (2003) reported that significant losses of some minerals (Ca, Mg, P and K) in peeled and cooked bitter guard, *Colocasia* and tomato. Abakr and Ragga (1996) also reported the same trend of mineral losses during blanching, canning and cooking in spinach leaves. Though this finding indicated losses of minerals during freezing of spinach leaves, it is not very significant.

Some cultural practices are known to affect the level of some minerals in vegetables. Chweya, (1993) reported that fertilizer (organic and inorganic) application decrease iron content and has no effect on calcium and sodium contents of the leaves of *Gynandropsis gynadra*. The same author reported increase in iron and calcium contents in the leaves of *Solanum nigrum* as the plant aged. Vijaya and Raman (2004), who

studied the mineral contents of common leafy vegetables consumed in India at different stages of maturity, also found that as plant got older, iron and magnesium contents increased whereas zinc and copper contents decreased in both *Amaranthus* and *Hibiscus* species.

Apart from organic coenzymes such as NAD^+ and FAD, some minerals (trace metal ions) play a major significant role in the activity of some proteins (notably enzymes) and other biochemical roles in the biological systems (Schrimshaw 1991; Ezeonu *et al.*, 2002; Obiajunwa *et al.*, 2005). The role of some minerals in the biological systems is discussed below.

Iron (Fe) may be regarded as the most important trace metal (element) because of its role being exclusively confined to the process of cellular respiration. Iron porphyrin (heme) groups are essential component of haemoglobin, myoglobin, cytochromes and the enzymes catalase and peroxidase (Obiajunwa *et al.*, 2005; Akubugwo *et al.*, 2007). The non-heme iron is almost entirely bound to proteins. These include storage forms (Feritin in liver, spleen, bone marrow and hemosiderin in liver) and transport form (transferrin in plasma). The non-heme iron also includes iron-containing flavo-proteins e.g. NADH dehydrogenase and succinate dehydrogenase, and iron sulphur-protein of respiratory chain. Iron plays a central role in metabolic processes involving oxygen transport and storage as well as oxidative metabolism and cellular growth. The fact that iron readily serves as electron donor or acceptor, accounts both for its critical metabolic role and its potential toxicity. Iron containing compounds function as carriers for oxygen and electrons and as catalyst for oxidation and hydroxylation reactions. Iron requirement depends on age and physiological condition. The suggested recommended daily intake is

as follows; 10-15mg for Infants, 15mg for 1-3 years, 10 mg for 4-10 years, 18mg for 11-18 years (males), 10mg for above 19 years (male), 18 mg for 11-50 years (females), 10 mg for above 50 years (female) (Tietz *et al.*, 1994).

Zinc is essential for the normal growth, reproduction, and life expectancy of animals, and has a beneficial effect on the processes of tissue repair, taste acuity; it enhances appetite and wound healing (Hambidge *et al.*, 1987). The metabolic functions of Zn are largely based on its presence as an essential component of many metallo-enzymes involved in virtually all aspects of metabolism. Zinc is an integral component of nearly 300 enzymes in different species of all phyla (Vallee and Auld, 1990; Obiajunwa *et al.*, 2005). Important Zinc containing metallo-enzymes in humans include carbonic anhydrase, alkaline phosphatase, RNA and DNA polymerase, thyminekinase, carboxypeptidase and alcohol dehydrogenase. Zinc plays a major role in protein synthesis and has an important function in gene expression: The involvement in gene expression involves both a structural and enzymatic role (Wintrobe and Lee, 1974; Berg, 1990). The element is also invoved in normal function of immune system (Akubugwo *et al.*, 2007). The recommended daily allowance of zinc is 10 – 15 mg/day (Tietz *et al.*, 1994).

Calcium is the most abundant mineral in the body, whose salts form the substances that hardens the skeleton and teeth (Oduro *et al.*, 2008; Akubugwo *et al.*, 2007). The body of an adult contains between 1 and 1.5 Kg of calcium, about 99% found in bones and teeth, and a small part in the blood stream and the, rest of the body. In addition to being a part of the skeleton, calcium intervenes in the transmission of nerve impulses, especially in the heart, thus maintaining the cardiac rhythm (Wintrobe and Lee, 1974). It is needed to maintain a normal coagulation of the blood. The recommended

daily allowance of calcium is as follow: children, 880mg; youth age 11-24 years, 1,200 mg; male adults, 800 mg; female adult, 800mg; pregnant female, 1,200 mg; lactating female, 1,200 mg (George, 1999).

Calcium is found in plant foods, especially in nuts and legumes. A diet based on fruits, cereals, and vegetables provides more than enough calcium needed by the body, with notable advantages over the meat diet. Among animal foods, only milk and its derivatives have important amounts of calcium, but it is very rare in meat and fish. It is well to know that oxalic acid contained in some foods may slow down the absorption of calcium, as this combination forms insoluble salts (calcium oxalate).

The body of an adult contains between 20 and 25 g of magnesium. It is part of the bone structure together with calcium and phosphorus, although in a much smaller proportion. Magnesium is an essential component of chlorophyll (Akubugwo *et al.*, 2007), just as iron is to the blood haemoglobin. The mineral has been discovered to play decisive roles in many physiological functions (Baltiflora *et al*, 1968; Olumuyiwa *et al*, 2003). The recommended daily allowance of magnesium is 80-170 mg for children, 400mg for males (15-18 years), 350 mg for aldult males, 300mg for female (15-18 years), 280 mg for aldult females, 320 mg for pregnant women and 355mg for lactating women. It frequently happens that ordinary diet provides insufficient quantities of this important mineral (George, 1999). Magnesium activates more than 300 enzymes in the body. It acts as an essential cofactor for enzymes concerned with cell respiration, glycolysis, and transmembrane transport of other cations such as Ca and K. Notably, the activity of Na-K-A TPase depends on magnesium. Magnesium can affect enzyme activity by binding the active sites of the enzyme (Pyruvate kinase, enolase), causing conformational changes

during the catalytic process (Na-K-ATpase) and promoting aggregation of multienzyme complexes (Ryan, 1991; Tietz *et al.*, 1994).

Copper may be present in biological systems in both + 1 and +2 valence states. Thus, the major functions of copper metalloproteins involve oxidation-reduction reactions. Most known copper-containing enzymes bind and react directly with molecular oxygen. Copper is an integral component of many metalloenzymes, including ceruloplasmin, cytochrome oxidase, superoxide dimutase, ascorbate oxidase, dopamine-β-hydroxylase, lysyl oxidase, and tyrosinase (Wayne and Dale, 1989; Tietz *et al.*, 1994).

The copper content of food is variable and depends on the copper content of soil in the area from which the food is obtained and on the copper loss or contamination throughout processing. Liver, oyster, nuts, cocoa, cherries, mushrooms, whole grain cereal, crustanceaus, shellfish, as well as milk and dairy products are sources of copper (Pennington and Calloway, 1974; Wayne and Dale, 1989). The estimated adequate and safe daily dietary intake of copper for adult is in the range of 1.5 - 3.0mg /day (Tietz *et al.*, 1994). Copper plays an important role in iron metabolism. Copper deficiency impairs iron absorption and resulting in anaemia. Ceruloplasmin, the major copper-containing protein in plasma, has a ferroxidase activity that oxidizes ferrous iron to ferric state prior to its binding by plasma transferring (Tietz *et al.*, 1994).

Sodium is the major cation of extra cellular fluid, because it represents about 90% of the 154 mmol of inorganic cations per litre of plasma. It plays a central role in maintaining the normal distribution of water and the osmotic pressure in the extra cellular fluid compartment (Teiz *et al.*, 1994; AIiyu and Morufu, 2006). The normal daily diet contains 8 - 15g (130 - 260 mmol) of sodium chloride, which is nearly completely

absorbed from the gastrointestinal tract. Since the body requirement is only 1 - 2 mmol/day, the excess is excreted by the kidneys, which are therefore, the ultimate regulator of the amount of Na in the body (Tietz *et al.*, 1994). Sources of sodium in our diet are vegetables, olives, bacon, sauerkrant, processed cheese, fruits and table salt (Wayne and Dale, 1989). Sodium is also required for nerve transmission, acid-base balance and maintenance of fluid balance in the body (Wayne and Dale, 1989; Aliyu and Morufu, 2006).

Potassium has chemical properties which are similar in many respects to those of sodium and like sodium; it occurs in foods as positively charged ions. Potassium is present in most ordinary diets in adequate amounts and any potassium which is consumed in excess of body's need is readily excreted by the kidneys. The mineral plays an important part in maintaining the constancy of the body's internal environment. It however behaves differently from Na in that whereas sodium (as salt) is found in the most part of the extracellular fluids (as can be recognised by the saltiness of blood, sweat and tears) potassium occurs mainly within the cells themselves. Under normal circumstances the body regulates its potassium uptake to suit its needs, but since most of the element is held within the body's cells, it is not at all easy to assess whether the current diet is supplying adequate potassium. Most ordinary western diet provide ample potassium so that it is rarely necessary for a nutritionist to pay any particular attention to the exact amount provided by the different foods consumed (Tietz *et al.*, 1994).

2.2.3. Dietary Fibres

Dietary fibres correspond to the vegetable wall residues that are resistant to enzymatic hydrolysis in the small intestine. They are oligosaccharides, polysaccharides and their (hydrophilic) derivatives which cannot be digested by human digestive enzymes to absorbable components in the upper alimentary track (Thebaudin, *et al*, 1997). Dietary fibres are consumed from vegetables, fruits and cereals, but are also added in purified form to food preparations. Different types of dietary fibres have different structures and chemical compositions, and correspondingly are of varying nutritional and technological interests.

There are two categories of dietary fibres, viz: soluble and insoluble. Insoluble dietary fibres do not dissolve in water and pass through digestive system largely unchanged. It is estimated that about 65-75% of dietary fibres in our diet is insoluble dietary fibre. Insoluble dietary fibre may be found in bran (outer covering of com, oats, rice, and wheat), whole grains of cereals (corn, barley, wheat, and oats), edible skin of fruits and vegetables. Insoluble dietary fibre accelerates intestinal transist, increases faecal weight, slows starch hydrolysis and delays glucose absorption. This leads to softer, larger faeces. It also results in an increased frequency of defecation. As the faeces move through the intestine, they scour intestinal walls and remove waste matter.

Soluble dietary fibres dissolve in water and are degraded by bacteria in the colon. The soluble fibre forms a gel-like consistency in water and is found in food like beans, com, oats, barley, peas, brussels sprouts, lentils, carrots, okro, carbage, spinach, banana, apples, amaranth, black berries, citrus fruits, etc. Soluble fibre also increases stool volume and stool water content. It is believed that soluble fibre does this in a different

manner than done by insoluble fibre. Soluble dietary fibre forms a gel in the intestine which regulates the flow of a waste material through the digestive tract. Soluble dietary fibre slows stomach emptying time (Olson *et al.*, 1996).

Generally, dietary fibres act as authentic broom in the intestines, absorbing toxins and removing harmful substances (George, 1999). Dietary fibres are recognised to reduce the risk of colon cancer, reduced the risk of appendicitis, prevent intestinal parasites, reduce risk of diverticulosis, help digestive disorders, maintain regularity of stool, prevent constipation, assist in diabetic sugar control, lower cholesterol and beneficial in weight loss (Choudhury, 1990 and Thebaudin *et al.*, 1997). Besides these nutrients, unfortunately leafy vegetables contain significant levels of antinutrients and toxic substances that have negative effects on health.

2.3 Antinutrients and Toxic Substances in Vegetables

Apart from nutritive components of vegetables, some vegetables contain harmful chemicals such as trypsin inhibitors, phytate, oxalate, nitrate, alkaloids, tannins which pose serious nutritional/ health problems (Oboh, 2005; Antia *et al.*, 2006; Weerakkody, 2006; Adeniji *et al.*, 2007) .In addition, chemicals such as glucosides induce toxicity by producing cyanide in form of hydrocyanic acid (Kaushalya *et al.*, 1988; Macrae *et al.*, 1997). The composition of antinutritional or toxic compound in our leafy vegetables sometimes makes them inferior (Weerakkody, 2006). These non-nutrient constituents of vegetable called antinutrients or antinutritional factors are of great concern in the modern nutritional studies, because if present above the tolerable level in our food, they cause a serious danger to our health (Osagie, 1998; Proph *et al.*, 2006). Moran *et al.* (1968) and

Fagbemi *et al.* (2005) showed that our traditional processing techniques could effectively reduce the antinutritional factors in legume and oil seeds. They showed that heat used in the commercial processing of seed products improves protein quality by destroying certain antinutritional factors. Sprouting or germination has been reported to improve vitamins and protein quality of some cereals and legumes with reduction in antinutritional factors (Kyler and McCready, 1975). Thus modern nutritional studies are concerned in trying to reduce the level of these antinutrients and toxic substances in our food to the barest minimum.

2.3.1 Oxalate (Oxalic Acid)

Oxalic acid is a dicarboxylic acid which consist of two carbonyl groups covalently joined together (HOOC-COOH). Traces of this acid are found in most fruits and vegetables such as asparagus, spinach, lettuce, amaranth, apple and others, mainly in the form of calcium oxalate (Akindahunsi and Salawu, 2005). It is synthesised in leaves from metabolites of both photosynthetic and non-photosynthetic origin (Singh, 2005). Nakata (2003) and John (2005) however reported that the synthesis of oxalic acid is probably via ascorbic acid. The formation of oxalic acid in *Chenopodium amaranthicolor* is positively influenced with greater absorption of cations while absorption of anions greatly reduced the oxalic acid content in this plant (Singh, 2005). Several studies have reported correlation between oxalate accumulation and calcium concentration in plants (Gilbert *et al.*, 1951).

Waldemar *et al.* (2005) found that total oxalate level in different usable parts of dill (*Anethum graveolene*) increases with increase in plant height. However, Shigeru *et al*

(2003), reported that the oxalate concentration in *Setaria sphacelata* was high enough to induce poisoning and that the oxalate decreased progressively according to the growth.

In studying the factors affecting oxalate content of tropical grass (*Setaria sphacelata*), Jone and Ford (1972), discovered that fertilization with urea increased oxalate and cation concentration and that the relation between oxalate and cation concentration was linear in an experiment conducted in autum. When the same experiment was conducted over autum and spring, there was a trend of increasing oxalate concentration with urea rate and a decline with age of the plant material. However in autum regrowths, urea reduced the oxalate in young regrowth (to two weeks) but in older regrowth, urea increased oxalate to a peak of 6.0 percent in dry matter. Jone and Ford (1972) also found that potassium at a high rate increased oxalate concentration in this plant especially if applied as potassium chloride (KCl). The ranking of the plant parts for oxalate was leaf blades > leaf sheaths > stems. No oxalate was detected in seeds. Urea increased the oxalate content of leaf sheaths and particularly of stem, but had less effect on the content in leaf blades. They concluded that the high excess cation concentration in *Setaria sphacelata* is probably the reason for the high level of oxalate encountered with this grass.

Sugiyama and Okutani (1996) reported that oxalates take part in the changes of nitrogen compounds occurring in the plant. Abakr and Ragaa (1996) reported that oxalate and nitrate contents in plant can be reduced by manipulating of the soil nutrient supply and by adopting various methods of food processing and cooking method without compromising the nutritive value of the plant. Antia *et al.* (2006) reported that proper cooking before consumption of sweet potatoes leaves or leafy vegetables significantly

reduces the total oxalate content of the leaves. Ogbadoyi *et al.* (2006) found that freezing and controlled boiling of vegetables and then throwing away the water used for boiling before using the vegetables in meals will considerably reduce the oxalate content. Oxalates are regarded as undesirable constituents of the diet (Oztekin *et al.*, 2002; Waldemar *et al.*, 2005) reducing the assimilation of calcium and favouring the formation of renal calculi (Faboya, 1990; Sealy *et al,*. 1990; Aletor and Omodara, 1994; Mandel, 1996; Takebe and Yoneyama, 1997; Nakata, 2003). Oxalates occurring in the form of potassium and sodium salts are classed as water-soluble, while the calcium, magnesium and zinc salts are insoluble (Faboya, 1990). The limit values of oxalate content in spinach are within 250mg/100g fresh weight (Oguchi *et al,*. 1996, Yamanak *et al.*, 1983).

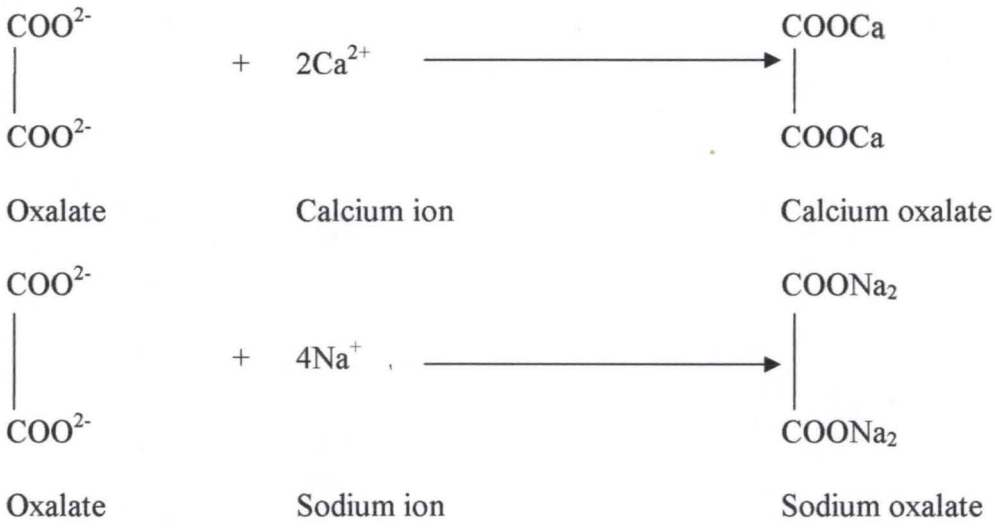


Fig 2.1: Chelation of oxalate with minerals

Once the oxalate has been absorbed into the blood stream, it chelates with some minerals (Fig. 2.1) and may have a number of effects;

(i) It may produce acute hypocalcaemia leading to death. Oxalate may upset calcium metabolism sufficient to interfere with milk production and bone growth in lactating and pregnant animals.

(ii) The most common effect of oxalate is damage to kidney owing to blockage of tubules by crystals of calcium oxalate ((Aletor and Omodara, 1994; Osagie, 1998; Mandel, 1996; Nakata, 2003; Shigeru *et al.*, 2003: Proph *et al.*, 2006). Approximately two-third of human Kidney stones is composed of Calcium oxalate (Prien, 1991).

(iii) Oxalic acid and its soluble sodium and potassium salts are poisonous if present in significant amount (Clarke and Clarke, 1975; Shigeru *et al.*, 2003; Antia *et al.*, 2006). Oxalate has been known to complex with Fe which forms stable but soluble complexes with oxalate (Hodgkinson and ZareMbski, 1968; Aletor and Omodara, 1994; Sandberg *et al.*, 1996; Okon and Akpanyung, 2005) which might be available for absorption. Some studies have shown that oxalate depressed iron (Fe) absorption. For instance, spinach which is higher in Fe content than many other leafy vegetable has often been considered a poor source of dietary Fe (Moore *et al.*, 1987).

In considering poisonous substances in leafy vegetables, Oke (1996) reported high level of oxalate in leaves of *Talinum, Celosia, Corchorus* and *Amaranthus* species. Sadik (1971) reported 14.33% oxalate in dry *Amaranthus hybridus*. Oxalic acid has been reported to be present in roselle as potassium salt which is some time called salt of roselle and this imparts a sour taste to the vegetable (Hall 1991). Cabbage contains on fresh weight basis 0.11% of oxalate as reported by Kitchen *et al.* (1964). Andrew and Visare

(1989) found oxalate to be present in 13 out of 20 vegetables to be more than 0.1% on a fresh weight basis. Munro and Basir (1969) working in Nigeria analysed 30 fruits and vegetables for their calcium and oxalate contents. They found that the oxalate content of these crops on a dry weight basis ranged from traces to 19.7%.

Apart from oxalate effect in complexing calcium and thereby making calcium unavailable for the body's usage, an excessive intake may be toxic. Several deaths have been reported from eating rhubarb leaves, but in each case, the actual cause of death was doubtful because of lack of an autopsy and sufficient test for oxalates (Snell, 1979).

However, the real hazard of rhubarb poisoning was dramatically brought to public attention in Great Britain during World War I, when in view of the shortage of cabbage; the authorities recommended that the public should be eating boiled rhubarb leaves instead. Several people among those who accepted this patriotic advice died. At least 400g of rhubarb stem would be required to contain a lethal dose of oxalate (Samson, 1977).

Roughan and Warrington (1985) reported that the young fresh leafy vegetable contain the lowest oxalate and stated that oxalate concentration in leafy vegetable increases with age, although high oxalate content have been found in some young leaves. Guthrie (1990) stated that in most vegetables containing oxalic acid, there is some amount of calcium that binds it, forming calcium oxalate and rendering the calcium useless and that only few unbound oxalate remaining binds to calcium from other food eaten at the same time.

2.3.2 Cyanide

Hydrocyanic acid (HCN) often referred to as prussic acid or as cyanide when in the ionised state (CN^-) is a colourless, odourless gas released when anything containing ionically bound or complexed CN^- is exposed to acid. Hydrocyanic acid is one of the most toxic substances, but very small quantities may be harmless. Certain bacteria, fungi, and algae can produce cyanide, and cyanide is found in a number of foods and plants. Cyanide is present in most leafy vegetables and in some plants such as cashew nut, ground nut, lima beans and cassava. Infact lima beans and cassava have been regarded as the major plants that contain high percentage of cyanide (Clevel and Soleri, 1991). Hydrocyanic acid (HCN) which is regarded as a toxic factor in cassava is released by the action of linamarase (linamarin β-D glucoside glucohydrolase) enzyme on cyanogenic glycoside, linamarin (2-(β-Dglucopyranosyloxy)-Isobutyronitrile) and related compound lotaustralin (methyllinamarin) (Ikediobi *et al*., 1987).

The bound hydrocyanic acid in the erythrocyte is in equilibrium with free hydrocyanic acid in the serum at a ration of 10: 1 (Tietz *et al*., 1994). Cyanide in serum readily crosses all biological membranes and avidly binds to heam iron (Fe^{3+}) in the cytrochrome a-a_3 complex within mitochondria (Schulz, 1984; Vesey and Wilson, 1987). When bound to cytochrome a-a_3 (Fig.2.2), CN^- is competitive inhibitor and causes uncoupling of oxidative phosphorylation (Aletor, 1993; Lehninger *et al*., 1997).

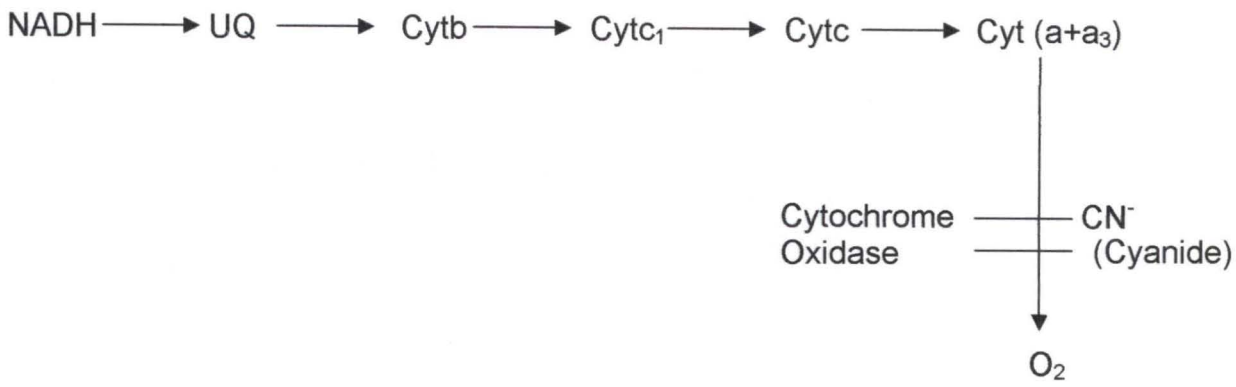


Fig.2.2: Effect of cyanide on electron transport chain

Patients exposed to toxic levels of cyanide exhibits rapid onset symptoms typical of cellular hypoxia; flushing, headache, tachypnea, dizziness, and respiratory depression, which progress rapidly to coma seizure, complete heart block, and death, if dose is sufficiently large. Symptoms are usually dose-related and correlate strongly with CN^- concentration (Ames *et al.*, 1981, Ellenhorn and Bercelonx, 1988). Treatment requires rapid identification of cyanide (CN^-) as the intoxicant followed by administration of sodium nitrite to cause formation of methemoglobin, which rapidly binds and clears cyanides, and thiosulphate (as sulphur donor) to enhance clearance via metabolism.

Cyanide is metabolised by ubiquitous enzyme rhodanese to thiocyanate (SCN^-) drawing on the body's sulphur-donor pool to convert cyanide (CN^-) to thiocyanate (SCN^-). The thiocyanate is relatively inert and is cleared by the kidney. The conversion of CN^- to SCN^- occurs slowly relative to the pharmacological action of CN^-, so measurement of SCN^- is of use on monitoring clearance but not very useful in assessing acute CN^- exposure (Tietz *et al.*, 1994).

The mechanism of cyanide metabolism is it's conversion to thiocyanate is as follows:

$$\text{Rhodanese} + 2SO_3^{2-} \longrightarrow \text{rhodanese} - S_2 + SO_3^{2-}$$

$$\text{Rhodanese - } S_2 + 2\ CN \longrightarrow \text{rhodanese} + 2\ SCN^-$$

Many species of plants contain hydrocyanic acid existing either freely or in form of a cyanogenic glycoside, an organic compound containing a sugar capable of releasing cyanide on hydrolysis. The most widely distributed of these compound are: amygdaline, which is commonly found is rosaecease (rose family), bitter almonds and is composed of (gentiobiose + benzaldehyde + HCN), prunasin (glucose + benzaldehyde + HCN), present in bird Cherry, and dhurrin (glucose + P-hydroxybenzaldehyde + HCN) which is found in millet.

An enzyme complex, emulsin, is present together with the glycosides in plant tissues and catalyses, the hydrolysis of the glycosides, first to mandelonitrile or P-hydroxymandelonitrile, and then to benzaldehyde or P-hydroxybenzaldehyde, and HCN (Fig.2.3a). These small amounts of hydrocyanic acid (HCN) which may thus occur in the diet are detoxified by the rhodanese (thiocyanate synthetase). The aldehydes are oxidized to the corresponding aromatic acids and excreted as peptide conjugate (Parke, 1974).

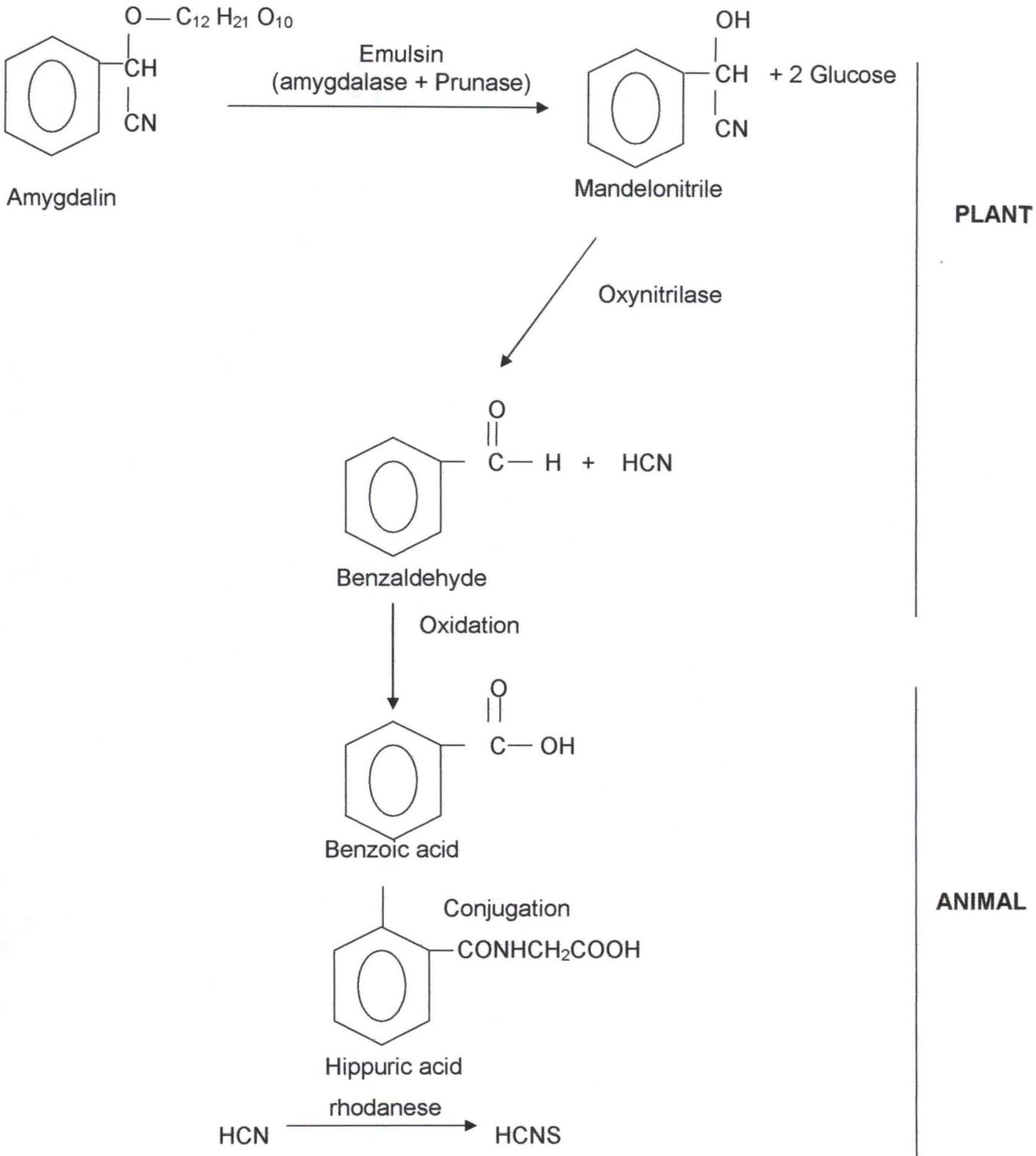
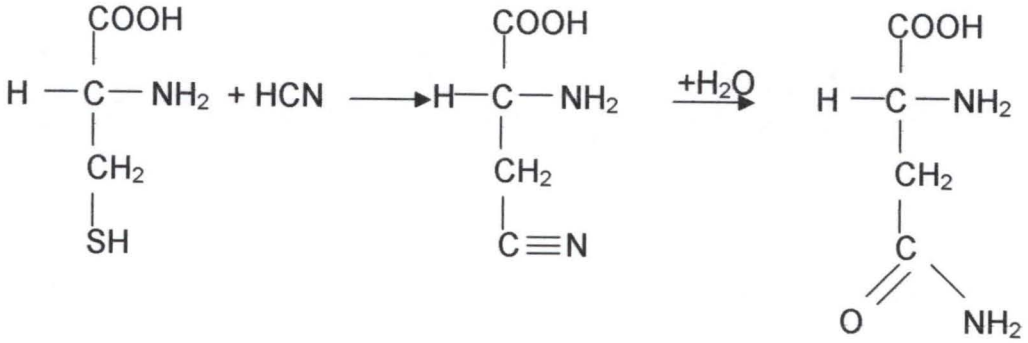


Fig. 2.3a: Hydrolysis of amygdalin

In cyanogenic plants, the conversion of HCN to asparagine could be another means of detoxification process (Fig.2.3b).



Cysteine β-cyanoalanine Asparagine

Fig. 2.3b: Conversion of HCN to asparagine in plant

The role of hydrocyanic acid has been studied extensively in plants chiefly because of the possible effect which cyanide has on man and livestock (Peter and Birger, 2002). It affects some cells such as nerve cells. It reacts with haemoglobin to form cyano-heamoglobin.

The biological functions of cyanogenic glucosides have been difficult to assess (Jones, 1998; Selmar, 1999; Jones *et al.*, 2000). Cyanogenic glucosides are constitutively produced in healthy plant tissues and belong to the class of natural products referred to as "phytoanticipins" or "allelochemicals" (Osbourn, 1996). Mechanical disruption of plant tissue containing cyanogenic glucosides results in their degradation by the sequential action of β-glucosidases and a - hydroxynitrilases (Lechtenberg and Nahrstedt, 1999; Selmar, 1999; Jones *et al.*, 2000) and release of hydrogen cyanide. The toxicity of

hydrogen cyanide renders it obvious to assume that cyanogenic glucosides repel herbivores. Thus, serving as a defence mechanism for plants that accumulate them (Jones, 1998). Cyanogenic glucosides also serve as nitrogen storage compounds (Forslund and Jonsson, 1997; Peter and Brigger, 2002).

Generally, only plants that produce more than 200mg/kg fresh weight of hydrogen cyanide are considered deleterious (Everist, 1981; Richard, 1991). Oboh (2005) reported that the cyanide level of processed Americana leaves is significantly less than the unprocessed leaves. Richard (1991) reported that plant growing in soils that are high is nitrogen and low in phosphorus and potassium tended to have high cyanide concentration. He equally stated that young rapidly growing plants are likely to contain high levels of cyanide than other plants. Thus young leaves are known to have high cyanide contents than the old leaves. Other factors known to affect cyanide accumulations are drought and plant species. It was observed that some plant species tend to accumulate high cyanide than the others because of their genetic make up. Thus Okoli *et al.* (2003), reported different levels of HCN in *Diodia scandens, Microdesmis puberula, Nuaclea popegnine, Palisota hirsuta, Ricinodendron heudelotti, Urena lobata* and *Vernonia amygdalina* to be 1.54 mg/g, 1.86 mg/g, 1.67 mg/g, 1.72 mg/g, 3.38 mg/g, 1.52 mg/g and 6.40 mg/g dry weight respectively. Drought that stressed plant increases the cyanide content of the plant (Richard, 1991; Okoli *et al.*, 2003).

Acute cyanide poisoning has been reported to result in death of patients due to oxygen starvation at cellular level (Conn, 1969). This is because HCN is an effective inhibitor of cytochrome oxidase, the last oxidase of electron transport chain in aerobic organism (Linhninger *et al.*, 1993; Aletor, 1993). The inhibition of this enzyme affects

the supply of chemical energy in form of ATP to the cell. The absence of ATP results in the metabolic breakdown of cells and consequently the whole organism is adversely affected.

Clevel and Soleri (1991) reported that the accumulation of cyanide in crucifers increased with age of plant and they advise people to eat crucifer that are young. They also pointed out that the level of HCN is reduced to the barest minimum in those properly cooked as well as in fermented cassava products.

2.3.3. Nitrates and Nitrites

Nitrates are natural components of the environment found virtually in all living things (Oladele *et al.*, 1997). They are found in air, soil, plants and animals as well as their products. Nitrate is present in all vegetables naturally and also from the use of nitrogen fertilizers. Green, leafy vegetables contain the highest concentrations of nitrate and are the major source of nitrate in the diet (Richard, 1991; Yang, 1992; Oladele *et al.*, 1997; Waclaw and Stefan, 2004; Anjana and Muhammad, 2006; Anjana *et al.*, 2007).

During the process of nitrogen cycle in nature, all nitrogen compounds in the soil are subjected gradually to nitrification by micro-organisms, the end product of which is nitrate. Nitrates are absorbed by plant roots, and they are sources of nitrogen used in synthesis of amino acid and proteins. If excess nitrates are present in the soil following the excessive use of nitrogen fertilizers, and there are unfavourable factors for synthesis of protein, such as drought, poor light (such as in winter or during cloudy spells in summer), deficiency of micro-and macro-elements, the conversion of inorganic nitrogen

to protein is inhibited and accumulation of nitrates by the plant in this soil is intensified (Richard, 1991 Oladele *et al.*, 1997, Muramoto, 1999; Anjana *et al.*, 2007).

The occurrence of nitrates and nitrites in foods and drinking water, and their effects on human health, are currently the subject of much controversy (Macrea *et al.*, 1997). Excess dietary intake of nitrates and nitrites has been reported as a cause of methaemoglobinaemia (Ziebarth, 1991; Oladele *et al.*, 1997; Gupta *et al.*, 2000). However the major concern is that the nitrogenous compounds can produce N-nitroso compound (NOC) endogenously and exogenously by reacting with amines and amides contained in foods and that the N-nitroso compound may cause human cancer (Whitney *et al.*, 1990; Macrae *et al.*, 1997; Oladele *et al.*, 1997; Waclaw and Stefan, 2004). Natural occurrences of nitrates and nitrites in foods is a consequence of nitrogen cycle, and nitrates are natural constituents of many soils and are found in most growing plants and water that may be used for foods and cooking. Animal used as sources of meat occupy a high position in the food chain (Macrea *et al.*, 1997). In general, the major source of human intake of both nitrates and nitrites, excluding consumption of high nitrate water, is food. Vegetables are the main contributors of nitrates, usually accounting for more than 75% of total amount ingested (Anjana *et al.*, 2007). The chief vegetable sources of nitrates and nitrites include cabbage, celery, lettuce potatoes; several root vegetables (carrot, radish, beets), and spinach which contain relatively high levels of nitrates but only small quantities of nitrites (Ziebarth, 1991; Waclaw and Stefan, 2004; Anjana *et al.*, 2007). Increased nitrate and nitrite levels in these vegetables usually result from the use of nitrogenous fertilizers.

Other sources include cured meats, fruits juices, milk and milk products, and breads. The amount of nitrite ingested by humans from food is very small in comparison to those of nitrates. Vegetables accumulate high levels of nitrates which perse are relatively non-toxic constituents in foods, but may be considered as a potential hazard as they are the precursor of nitrites (Lewicki *et al.*, 1994; Onyesom and Okoh, 2006). Nitrites inhibits oxygen transport by blood, leading to metheamoglobin formation, and producing a medical condition known as methaemoglobinaemia to which infants are at greater risk than adults because of the lower acidity in their stomachs. This facilitates reduction of nitrate by intestinal bacteria to nitrite which react readily with foetal haemoglobin (Sohar and Domoki, 1980; Oladele *et al.*, 1997; Safaa and Abd El Fattah, 2007).

However, incidence of methaemogblobinaemia has been recently reported to affect all age groups with high nitrate ingestion, with infants and adults above 45 years being most susceptible to nitrate toxicity (Gupta *et al.*, 2000).

Abakr and Ragaa (1996) reported that the fatal dose of nitrate for humans is about 15-70 mg nitrate and 20 mg nitrite per Kg of body weight per day; the maximum tolerance dose is about 10-15 mg nitrate and 4mg nitrite per Kg daily. WHO/FAO has stated acceptable daily intakes (ADI) for nitrate and nitrite (expressed as NO^-_3, NO^-_2) of 220mg and 8mg respectively, for a person of 60Kg body weight. However, these levels are not applicable to infant under 6 months of age, who are more susceptible to methaemoglobinaemia (Macrae *et al*, 1997). The European Commission's (EU) Scientific Committee on Food (SCF) prescribed the acceptable daily intake (ADI) of nitrate as 3.65

mg/kg body weight. This is equivalent to 219 mg/day for a 60kg person (Anjana *et al*, 2007).

Nitrates and nitrites are very readily absorbed by the body. Ingested nitrates are absorbed by passive transport from the upper small intestine in humans, and nitrites through the stomach mucosa or intestine wall by diffusion. The compounds absorbed are distributed in various tissues, but do not accumulate in them. Nitrates are not metabolised to other compounds invivo, but are converted to nitrites as a result of bacterial reduction in the gastro intestinal tract and oral cavity. The nitrites convert haemoglobin to methaemoglobin, a pigment incapable of acting as a carrier of oxygen to the tissues. Absorption is rapid and more than 50% of the oral dose is detected in human nitrate concentrations in body fluids (Serum, saliva, urine), peaking within 1-3 hours after ingestion of food and water. Approximately 60-70% of the ingested nitrate burden is excreted in the urine and only about 1 % in the faeces (Macrae *et al.*, 1997; Oladele *et al.*, 1997).

As a result of bacterial reduction of saliva nitrate in the mouth and pharynx, an average of 5% of ingested nitrate is converted to nitrite, and 25% of the absorbed nitrate is secreted in saliva.

Nitrate perse is not toxic at the levels normally present in foods. The toxic chemical form of this nitrogenous compound is nitrite (Oladele *et al.*, 1997; Anjana *et al.*, 2007). The toxicity of ingested nitrate is due to invivo reduction to nitrite (Ziebarth, 1991; Oladele *et al.*, 1997). Methaemoglobinaemia is the most prevalent and potentially the most serious complication caused by excessive nitrate and nitrite exposure. The condition is characterised by cyanosis, stupor and cerebral anoxia. Nitrite directly

oxidizes the haemoglobin ferrous iron state (Fe^{2+}) to the ferric state (Fe^{3+} which can not bind oxygen (Fig 2.4). Reduced oxygen transport produces tissue hypoxia. The net concentration of circulating methaemoglobin (Met Hb) from nitrite exposure represents nitrite oxidation of haemoglobin and met Hb reduction catalysed by erythrocytediaphorase (Metheamoglobin reductase).

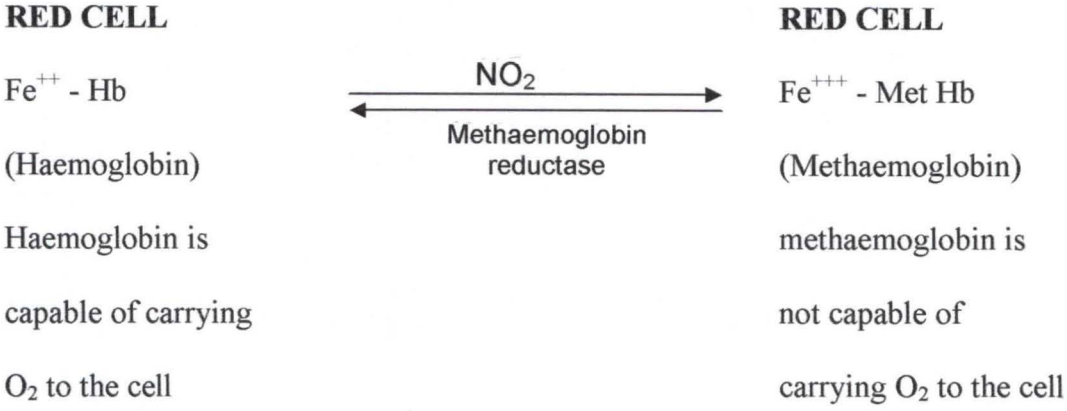


Fig. 2.4: Formation of methaemoglobin by the action of nitrate

Normally 1.2% of the body's haemoglobin is in the metheamoglobin form, but when the proportion is in excess of 10%, clinical effects are detectable (Metheamoglobinaemia). Levels of 30 - 40% lead to anoxia. It has been well documented that in some countries, water supplies containing high levels of nitrate have been responsible for cases of infantile metheamoglobinaemia and death (Macrae *et al.*, 1997).

The formation of nitroso amines following interaction of nitrous acid with secondary amines leading to the formation of alkylating agents is primarily responsible for the carcinogenic activity of nitrate (Galler, 1997; Mevissen, 1997; Waclaw and Stefan, 2004; Anjana *et al.*, 2007). The sequence of this reaction is given in Fig. 2.5 below.

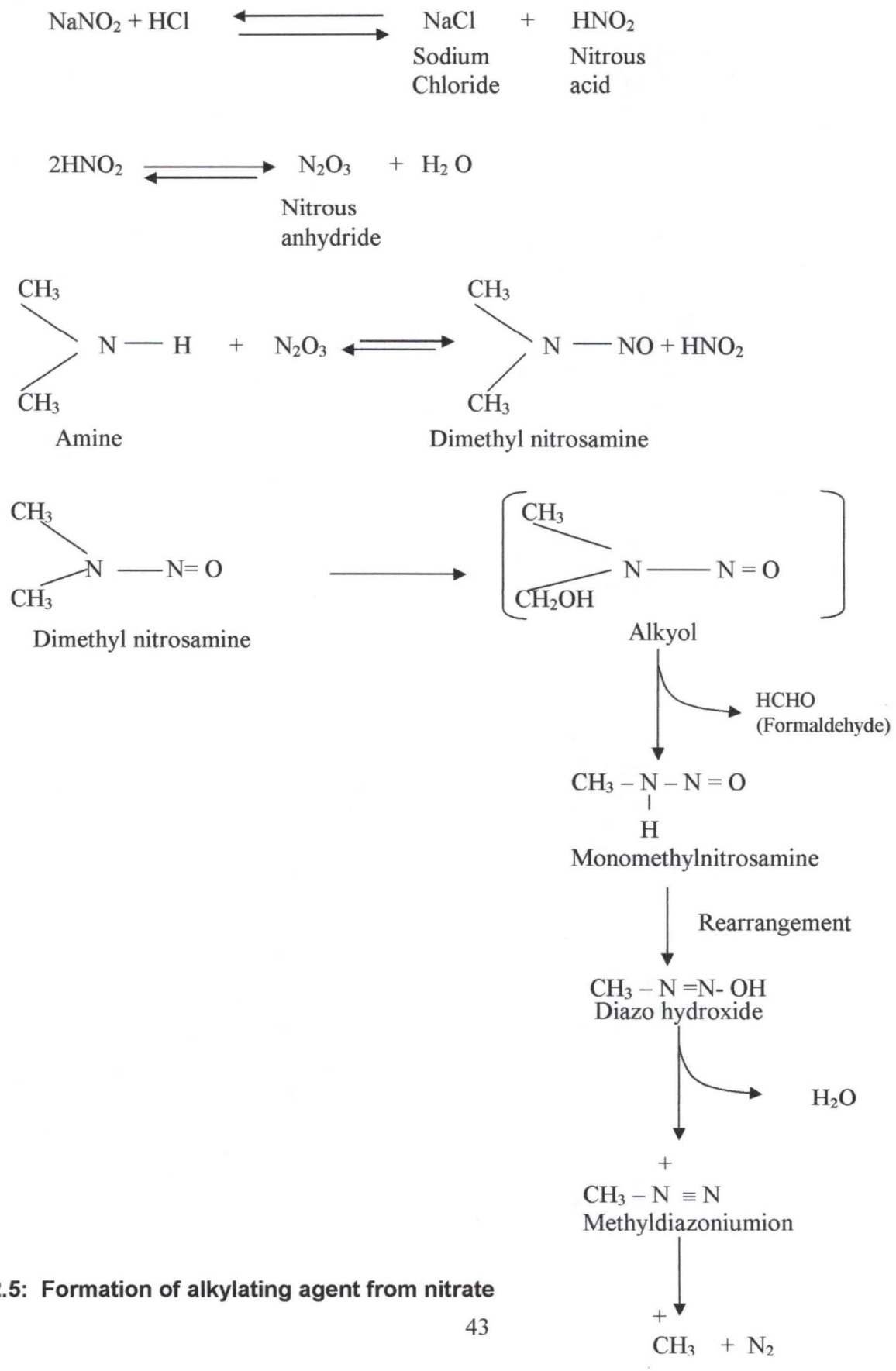


Fig.2.5: Formation of alkylating agent from nitrate

It is proposed that many of the final carcinogens formed from nitroso compounds contain a reactive and electrophilic centre with insufficient electron, capable of actively interacting with nucleophilic anions or other negatively charged molecular fragments (Miller and Miller; 1981; Pressman and Steward, 1984). Evidence has been shown that nitroso compounds are broken down in the body and converted to electrophilic products (Rubenchik, 1990). Electrophilic products formed when nitroso compounds are degraded alkylate cellular macromolecules of proteins, nucleic acids and especially the DNA. The interaction of alkylating products with nitrogenous bases of the DNA underlines the mechanism of cancer formation by nitroso compounds (Oladele *et al.*, 1997).

A number of environmental factors are known to affect the nitrate accumulation in plants (Muramoto, 1999). Accumulations of nitrate in plant are generally high in drought, low light intensity, frost or hail, low and extremely high temperature and plant disease which can damage leaf area and reduce photosynthetic activity. This is because all these factors, could lead to reduction of nitrate reductase enzyme activity. Anjana *et al.* (2007) observed a negative correlation between nitrate concentration and nitrate reductase activity in plants. Nearly all plants contain nitrate, but some species are more prone to accumulate nitrate than others. Other factors may be related to variations in the up take and distribution of nitrate or other elements needed for nitrate reductase activity, differences in generation of electron donors needed in the assimilative pathway (Cantliffer, 1972) and in photosynthetic capacity (Behr and Wiebe, 1992). Variation in nitrate content between plant species and even between cultivars of the same species has been reported (Blom-Zandstra and Eenick, 1986; Reinink and Eenink, 1988; Reinink *et al.*, 1994; Harada *et al.*, 2003).

Anjana *et al.* (2007) reported that higher nitrate concentration in six-week old plants in comparison to three-weeks old plants may be because in fully expanded leaves with low nitrate reductase activity, high nitrate contents are of limited use for nitrogen metabolism due to low nitrate mobility in the phloem and therefore get accumulated. In studying the level of nitrates in different usable parts of Dill (*Anethum graveolens*) depending on plant height, Waldemar *et al* (2005), found that the taller the plants, the smaller was the content of nitrates. Richard (1991), also reported that nitrate content is generally highest in young plant growth and decreases with maturity, with exception of some plants like Sorghum and Sudan grasses in which nitrate concentration usually remains high in mature plants and if the plants are stressed at any stage of growth they can accumulate more nitrate.

Application of excess manure or nitrogen fertilizers increase soil nitrogen levels and the subsequent uptake and accumulation by plant (Richard, 1991; Byrne *et al.*, 1999; Grazy and Weldemar, 1999; Muramoto, 1999; Waclaw and Stefan, 2004; Anjana and Muhammad, 2006; Anjana *et al.*, 2007). In addition to excess nitrogen, an imbalance of other soil nutrients can affect forage nitrate levels. Plants growing in soils deficient in phosphorus, potassium and some trace elements have high nitrate concentration (Richard, 1991).

Post harvest treatments such as blanching, boiling, cooking, drying and frozen are known to have effect in reducing the nitrate contents in vegetables (Nabrzyski and Gajewska, 1994; Poulsen *et al.*, 1995; Abakr and Ragaa, 1996; Waclaw and Stefan, 2004; Anjana and Muhammad, 2006).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 The Study Area

The pot experiment was carried out between 6th June and 18th December 2005 in the nursery of the School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Niger State of Nigeria.

Niger state has a Savana climate characterised by maritime air and rainfall is between April and October. During harmattan, dry desert winds blow between November and mid February while night temperature is very low. The geographical location of Minna is longitude 9^0 40' N and latitude 6^0 30' E. Minna lies in the Southern Guinea Savanna zone of Nigeria and has a sub-humid semi arid tropical climate with mean annual precipitation of 1200 and 1300mm. About 90% of total annual rainfull occurs between the months of June and September. Temperature rarely falls below 22°C with peaks of 40°C and 30°C in February/March and November/December, respectively. Wet season temperature average is about 29°C (Osunde and Alkassoun, 1998).

3.1.2 Soil Sampling and Analysis

The soil used in this study was collected from Minna. The soil has been classified as Inseptisol (FDARL, 1985). The bulked sample was collected during the dry season from the field which has been under fallows for about four years. The bulked soil sample was passed through 2mm sieve. Sub-sample of the soil was subjected to routine soil analysis using procedure described by Juo (1979). The soil particle sizes were analyzed

using hydrometer method; pH was determined potentiometrically in the water and 0.01M $CaCl_2$ solution in a 1: 2 soil/ liquid using a glass electrode pH meter and organic carbon by Walkey-Black method (Juo, 1979). Exchange acidity (E.A H^+ and Al^{3+}) was determined by titration method (Juo, 1979). Exchangeable Ca, Mg, K and Na were leached from the soil sample with neutral 1N NH_4OA solution. Sodium and potassium were determined by flame emission spectrophotometry while Mg and Ca were determined by E.D.T.A versenate titration method (Juo, 1979). Total nitrogen was estimated by Macrokjedal procedure and available phosphorus by Bray No 1 method (Juo, 1979).

3.1.3 Sources of the Leafy Vegetables Used

The test samples for this research work are the commonly consumed leafy vegetables in this country and they include the following: amaranthus (*Amaranthus cruentus*), roselle (*Hibiscus sabdariffa*), jute mallow (*Corchorus olitorius*), fluted pumpkin (*Telfairia occidentalis*) and bitter leaf (*Vernonia amygdalina*). In the determination of effect of processing and storage methods on the levels of some nutrients, antinutrients and toxic substances in the leaves of these vegetables, the vegetables were obtained from three markets in Minna town. These markets are Maikunkele, Bosse and Chanchaga. However, in the determination of the effect of soil fertility, age of leaves and effect of fruiting of these vegetables on bioaccumulation of the selected toxins and nutrients, the leafy vegetables were grown in pots as described below.

3.1.4 Seeds / Cuttings

The seeds of roselle (*Hibiscus sabdariffa*), fluted pumpkin (*Telfairia occidentalis)*, amaranths *(Amaranthus cruentus)*, jute mallow (*Corchorus olitorius)* and the cuttings of bitter leaf (*Vernonia amygdalina*) were obtained from Schools of Agriculture and Agricultural Technology's Farm/Nursery of Federal University of Technology, Minna.

3.2 Methods

3.2.1 Effect of Processing and Storage Methods on the Levels of Nutrients, Antinutrients and Toxic Substances in Leafy Vegetables

3.2.1.1 Drying

The leaves of the leafy vegetables were weighed, spread in clean containers and dried in the sun. The vegetables were turned occasionally in the container while in the sun until they were properly dried as indicated by caking. The dried samples were then used for the required analysis.

3.2.1.2 Boiling

150g of fresh leaves of the vegetables each were weighed out in two 1000cm^3 beakers containing 600cm^3 of distilled water. Content of one beaker was boiled for 5 minutes while the content of the second beaker was boiled for 10 minutes. The level of anti-nutrients (soluble and total oxalates), toxic substances (cyanide and nitrate) and nutrients (β-carotene, vitamin C, Fe, Mg, Cu, Na and K) in the decoctions were

determined. The levels of these compounds were also determined in leaves obtained after filtration.

3.2.1.3 Freezing

The leaves of the selected vegetables were washed with distilled water and kept in a well labelled polythene bag and stored in a freezer at the temperature of - 4°c for a period of four weeks. The levels of the nutrients, antinutrients and toxic substances were determined at weekly intervals over the four - weeks period.

3.2.2 Soil Fertility

A study of the effect of soil fertility (using different levels of nitrogen fertilizers) on nutrients, antinutrients and toxic substances was conducted as follows:

3.2.2.1 Planting, Experimental Design and Nursery Management

About ten seeds of roselle, jute mallow, amaranths and two seeds of fluted pumpkin were planted in a polythene bag filled with about 10.00kg of top soil for the first three vegetables and 20.00kg of top soil for the last one. Following emergence, the seedlings of fluted pumpkin were thinned to one plant per pot while the seedlings of the other vegetables were thinned to two plants per pot. For bitter leaf, two stem cuttings were planted per pot containing 20.00kg top soil at an angle of 45° and after sprouting, they were thinned to one plant per pot.

The factorial design was adopted to determine the effect of two levels of soil fertility, three leaf age/positions and fruiting on the different parameter stated in 3.2.1.

There were three replications of 60 pots each for each vegetable. This gave a total of 300 pots for the five selected vegetables.

The seedlings were watered twice daily (mornings and evenings) using watering can and weeded regularly. The experimental area and the surroundings were kept clean to prevent harbouring of pest. The pots were lifted from time to time to prevent the roots of the plants from growing out of the container. Insects were controlled using Sherpa plus (Saro Agro Sciences, Nigeria Ltd) four weeks after planting at the rate of 100ml per 100 litres of water.

3.2.2.2 Treatment

3.2.2.2.1 Fertilizer

The fertilizer levels for each vegetable were stated below:

Fluted pumpkin (*Telfairia occidentalis)*

F_1 (control): 0N, 30mg P_2O_5/kg soil and 22mg K_2O/kg soil

F_2: 30mgN/kg soil, 30mg P_2O_5/kg soil and 22mg K_2O/kg soil

Jute Mallow (*Corchorus olitorius)*

F_1 (control): 0N, 30mg P_2O_5/kg soil and 30mg K_2O/kg soil

F_2: 30mgN/kg soil, 30mg P_2O_5/kg soil and 30mg K_2O/kg soil

Amaranthus (*Amaranthus cruentus)*

F_1 (control): 0N, 30mg P_2O_5/kg soil and 30mg K_2O/kg soil

F_2: 37mgN/kg soil, 30mg P_2O_5/kg soil and 30mg K_2O/kg soil

Roselle (*Hibiscus sabdariffa)*

F_1 (control): 0N, 40mg P_2O_5/kg soil and 40mg K_2O/kg soil

F_2: 40mgN/kg soil, 40mg P_2O_5/kg soil and 40mg K_2O/kg soil

Bitter leaf (*Vernonia amygdalina)*

F_1 (control): 0N, 30mg P_2O_5/kg soil and 22mg K_2O/kg soil

F_2: 30mgN/kg soil, 30mg P_2O_5/kg soil and 22mg K_2O/kg soil

3.2.2.2.2 Leaf age/position on non-fruiting mother-plant

The effect of age/position of leave were determined by harvesting the leaves at three different positions on the plant (basal, middle and upper locations) on the planted vegetables after seven weeks of seedling emergence for amaranthus, jute mallow and roselle. Harvesting of the leaves of fluted pumpkin and bitter leaf was done after 12 weeks of seedling emergence and sprouting respectively.

3.2.2.2.3 Leaf age/ position on fruiting mother-plant

The level of nutrients, antinutrients and toxic substances in the leaves was determined when the vegetables in the pot had fruited. At this stage, the leaves of the planted vegetables were harvested at three different positions on the plant as stated above.

3.3 Analytical methods

3.3.1 Estimation of oxalate

Both soluble and total oxalates were determined by titrimetric method of Oke, (1966) as decribed below.

3.3.1.1 Soluble oxalate

About 2.0 grammes of samples of fresh, frozen and processed (5 and 10 minutes boiling and sundrying) leaves of the vegetables were weighed, ground and oxalate extracted with 200cm^3 of distilled water at a waterbath temperature of 100°C for 30 minutes. The resulting solution was filtered and the filtrate was diluted to 250cm^3 with distilled water. Two 50cm^3 aliquots of the extract were each treated with 6M HCl and evaporated to about 25cm^3. The 25cm^3 brown solution obtained from each aliquot were filtered and washed with hot distilled water into a conical flask and titrated with concentrated ammonia solution until the salmon pink colour of methyl red indicator changed to faint yellow. The solution obtained was heated on a hot place to 90°C and the oxalate was precipitated with 10cm^3 of 5% calcium chloride solution. The resulting solution was allowed to stand over night, filtered and the precipitates were washed with excess distilled water to remove calcium. The above precipitates were dissolved in hot 25% H_2S0_4 and diluted with distilled water to 25cm^3. The solution was later titrated with 0.1M potassium permanganate after warming to a temperature of 90°C.

3.3.1.2 Total oxalate

Exactly 2.0 grammes of the samples of fresh, frozen and processed (5 and 10 minutes boiling and sundrying) leaves of the vegetables were weighed separately and were digested (in a fume cupboard) with a mixture of 190cm^3 of distilled water and 10cm^3 of 6M HCl after grinding them in a mortar. The oxalate level was determined as described above in soluble oxalate methods.

3.3.2 Estimation of Nitrate

The nitrate content in the vegetable samples was determined by the method of Sjoberg and Alanka (1994).

3.3.2.1 Sample Preparation

Exactly 2.0 grammes of each of the vegetables were weighed, ground and transferred into 100cm^3 volumetric flask. The 75.0cm^3 of hot distilled water and 5.0cm^3 of saturated borax solution were added to precipitate the protein. The volumetric flask was warmed in boiling water bath for 15 minutes and 2.0cm^3 of $ZnSO_4$ solution was added slowly while shaking. The solution obtained was cooled to room temperature in a cool water waterbath. The resulting solution was diluted to mark with distilled water, mixed and filtered. Blank sample material was treated the same way.

3.3.2.2 Reduction of Nitrate to Nitrite

Exactly 600mg (0.6g) of zinc powder was weighed into a 50cm3 volumetric flask and spread over the bottom of the flask. Then 4.0cm^3 of cadmium sulphate ($CdSO_4$) solution was added to the zinc powder in flask to obtain homogenous mixture. The newly formed spongy metallic cadmium was allowed to stand for 10 minutes without disturbance. At the end of this time, 2.0cm^3 of 25% NH_4OH and 10cm^3 of sample solution already prepared above were added to the flask. The flask was shaken for exactly 1 minute to loosen spongy cadmium. The flask was allowed to stand for another 10 minutes and then diluted to volume with distilled water and filtered. The standard nitrate concentrations (containing 0, 50, 100, 150 and 200mg $NaNO_3$) were prepared by

adding $10cm^3$ of each standard solution to a separate volumetric flask prepared with spongy cadmium and was treated the same way as sample solution.

3.3.2.3 Nitrite Determination

Accurately $10.0cm^3$ of clear filtrate of samples, blank and standard solutions (equivalent to 0, 10, 20, 30 and 40mg of sodium nitrate) were pipetted into boiling tubes. $10cm^3$ of colour reagent consisting of equal mixture of N-(1-naphthyl) ethylenediammonium chloride reagent and sulphanilic acid solution was then added. The resulting solution was mixed for one minute and absorbance recorded at 530nm. The concentrations of nitrite in the samples were determined by comparing the absorbance of the samples with that of the standards or the concentration of nitrite in the samples in mg extrapolated from the standard curve.

Calculations:-

$$\text{mg } NaNO_3/Kg \text{ sample} = (b \times 100/M)$$

Where: b = $NaNO_3$ from standard curve (μg) and

M = weight of sample homogenate.

3.3.3 Estimation of Cyanide

Alkaline picrate method of Ikedobi *et al.* (1980) was used to determine the cyanide content in the test samples.

3.3.3.1 Preparation of Standard Curve for Cyanide Estimation

A stock solution potassium cyanide (KCN) was prepared by dissolving 4.0mg of dried KCN in 100cm^3 volumetric flask containing some quantity of distilled water and the volume was made to mark with the distilled water after dissolution. From this stock solution, a series dilution containing 0 – 2mg of KCN concentration were made in ten 15cm^3 tightly stoppered test tubes. Each tube was made up to 2.0cm^3 with distilled water. To each of the test tubes, 4.0cm^3 of alkaline picrate was added and the solutions obtained were incubated for 5 minutes in a water bath at 95°C. After cooling to room temperature, the absorbance was determined at 490nm using spectrophotometer. The values obtained were used to plot the standard curve.

3.3.3.2 Extraction

Exactly 1.0 gramme of samples of fresh, frozen and processed (5 and 10 minutes boiling and sundrying) leaves of the vegetables were weighed separately, ground and extracted thrice with 5.0cm^3 of aliquots of 0.1M sodium phosphate buffer, pH 6.8. The extracts obtained were used to determine cyanide concentration.

3.3.3.3 Assay for Cyanide

Accurately 1.0cm^3 of the vegetable extract was pipetted into 15cm^3 stoppered test tubes. This was followed by the addition of 1.0cm^3 of 0.1M NaOH solution and the solution incubated at room temperature for 30 minutes for total hydrolysis of the extracted cyanogenic glycoside (dhurrin, prunasin and amygdalin). The HCN liberated (as CN^-) after this hydrolysis, was determined by addition of alkaline picrate and the

solution incubated for another 5 minutes in water bath at 95°C. The absorbance was read after cooling to room temperature by using spectrophotometer (Spectronic 20D$^+$, Milton Roy) at wave length of 490nm.

3.3.4 Estimation of Minerals

The mineral elements were determined according to the method of Ezeonu *et al.* (2002). In this method, the leaves of the vegetables (fresh, frozen and processed form) were dried in an oven at the temperature of 110°C for 24 hours. After drying, they were ground into powder form with mortar and pestle and about 0.500g of the ground dried samples were weighed into a boiling tube and 5.0cm^3 of digestion mixture which comprised of concentrated perchloric acid and nitric acid in a ratio of 1:2 was added. The resulting mixtures were swirled and left in a fume cupboard over night. They were then digested at the temperature of 150°C on a hot plate for two hours or until frothing ceased. At the end of two hours, the samples were removed from the hot plate and cooled for 10 minute after which 3.0cm^3 of 6.0M HCl was added and the sample were further digested for another 1½ hour. The digestion flasks were removed from the hot plate and allowed to cool. The contents of each tube was made up to 50cm^3 with distilled deionised water in volumetric flask and later transferred into sample bottles. The sample were analysed for their mineral content of interest using atomic absorption spectrophotometer (Alpha 4A AAS) and flame photometer (Jenway PFP7) for Na and K only.

3.3.5 Estimation of Vitamin C (Ascorbic Acid)

The ascorbic acid content in the samples was determined by 2, 6-dichlorophenol indophenols method of Eleri and Hughes (1983).

3.3.5.1 Extraction

Exactly 2.0 grammes of samples of fresh, frozen and processed (5 and 10 minutes boiling and sundying) leaves of the vegetables were weighed separately into mortar and 15cm^3 of metaphosphoric acid/acetic acid mixture added to the vegetable in the mortar and ground with pieces of glasses. The extract obtained was decanted and filtered into 100cm^3 volumetric flask. This extraction was repeated with another 10cm^3 of metaphosporic acid/acetic acid mixtures and finally the residues were washed with distilled water. Both the second extract and washed solution were added to the first extract in the 100cm^3 volumetric flask and the volumes made up to mark with distilled water.

3.3.5.2 Assay for Vitamin C

The prepared indophenol was standardized with 5.0cm^3 of freshly prepared standard ascorbic acid.Then 5.0cm^3 of the filtered aliquots of the sample was then titrated against the standardized indophenol and the end point was reached when a faint permanent pink colour was observed. The titre value obtained was used to calculate the actual concentration of ascorbic acid present in the samples.

3.3.6 Extraction and Determination of β-Carotene

Accurately 2.0 grammes of Na_2SO_4 was added to 10.0g of vegetable leaves and ground in mortar. The ground vegetables were extracted with $100cm^3$ of hot 95% ethanol for 30 minutes in hot water bath. The extract obtained was filtered and measured. Water was added to the extract to bring the percentage of the ethanol extract to 85%. The 85% ethanol extract was cooled in a cold water bath for some minutes. After cooling, the ethanol extract was put inside separating funnel and $30cm^3$ of petroleum ether was added and the mixture shaken. The separating funnel was clamped to the retort stand for sometime to allow the solution to settle down into layers. The bottom layer containing ethanol was collected into a beaker while the top layer of the petroleum ether was stored in $250cm^3$ conical flask. The ethanol layer in the beaker were re-extracted twice with $10cm^3$ of petroleum ether. The ether layers of re-extraction was added to the original petroleum extract in the conical flask and re-extracted with $50cm^3$ of 85% ethanol in order to remove any xanthophylls which may be present. The top petroleum ether layer which contained β-carotene was collected, measured and the volume noted.

Lastly, the optical density (OD) of the final petroleum ether extract was determined at the wave length of 450nm with spectrophotometer using petroleum ether as blank.

Calculation: - The concentration of β-carotene was calculated thus:

$$A = E^{\%} \times C \times l$$

Where A = absorbance of the sample

$E^{\%}$ = extinction coefficient of β-carotene

l = path length (usually 1.0cm).

3.3.7 Statistical Analysis

Analysis of variance (ANOVA) was carried out using statistical package Minitab to determine variation between treatments (three levels of age of plant leaves, effect of processing and storage methods). The DUNCAN's Multiple Range Test (DMRT) was used for comparison of means. T-test was used to determine the effect of soil fertility using two levels of nitrogen fertilizer and effect of fruiting, while correlation coefficient was used to determine the relationship between the parameters under investigation.

CHAPTER FOUR

RESULTS

4.1 Effect of Processing Methods on Antinutrients and Toxic Substances in Vegetables

4.1.1 Cyanide Content

The results showed that the cyanide content of vegetable samples processed using different methods were in general lower than that in all fresh samples. In *Amaranthus cruentus*, the cyanide levels in fresh samples, 5 minutes decoction, 10 minutes decoction, and leaves boiled for 5 minutes, leaves boiled for 10 minutes and sun dried leaves were 88.51mg/kg, 47.01mg/kg, 55.81mg/kg, 26.88mg/kg, 21.26mg/kg and 44.36mg/kg, respectively (as shown in Figure 4.1.1). Cyanide content decreased significantly ($p < 0.05$) in all processed samples. Cyanide content in 5 and 10 minutes decoction samples were not significantly different ($p > 0.05$) from each other. There was also no significant difference between the residual cyanide in leaves boiled 5 minutes and 10 minutes. However, the amount of cyanide in the boiled leaves was significantly ($p < 0.05$) lower than levels found in the decoction samples. Sundrying of the vegetable led to a significant decrease ($p < 0.05$) in its cyanide content (about 50.11 %) compared with the fresh sample. The amount of cyanide in sundried vegetable was significantly ($p < 0.05$) higher than those found in leaves boiled for 5 and 10 minutes. The cyanide content in sundried leaves was not statistically different when compared with cyanide levels in the decoction samples (see Figure 4.1.1).

Analysis of *Hibiscus sabdariffa* showed that the processing methods adopted significantly decreased the cyanide content of the vegetable ($p < 0.05$). The cyanide profile in various processed sample of the vegetable were: fresh sample (63.96 mg/kg), 5 minutes decoction (28.42mg/kg), 10 minutes decoction (30.94mg/kg), leaves boiled for 5 minutes (18.39mg/kg), leaves boiled for 10 minutes (16.49 mg/kg) and sundried leaves (51.41mg/kg). The amount of cyanide in 5 minutes decoction was not significantly different from 10 minutes decoction ($p > 0.05$). There was also no significant difference between the amount cyanide in the leaves boiled 5 and 10 minutes. However the amount cyanide in the decoctions was significantly higher than in the boiled leaves (Figure 4.1.1). Sundrying of *Hibiscus sabdariffa* led to a significant decrease ($p < 0.05$) in its cyanide content (about 19.47 %) compare with fresh sample. The amount of cyanide in sundried leaves was significantly ($p < 0.05$) more than the cyanide found in the leaves boiled for 5 and 10 minutes, and in 5 and 10 minutes decoction samples (Figure 4.1.1).

Results obtained from analysis of *Corchorus olitorius* showed that the amount of cyanide in fresh samples were generally greater than in all the processed samples. The cyanide content in fresh sample, 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 147.77mg/kg, 71.24mg/kg, 80.63mg/kg, 40.60mg/kg, 31.89mg/kg and 128.00mg/kg respectively. Results obtained from data analysis indicated that sundrying had no significant ($p > 0.05$) effect on the cyanide content of the vegetable. However, the two boiling periods led to a significant reduction ($p < 0.05$) of cyanide content of the vegetable (figure 4.1.1). The amount of cyanide in leaves boiled 5 minutes was not significantly different from those of leaves boiled for 10 minutes. The residual cyanide in leaves boiled for 5 minutes and

10 minutes were significantly lower ($p < 0.05$) than the cyanide content in the decoction samples. The cyanogenic glycoside content in 5 and 10 minutes decoctions were also not significantly different from each other.

In *Telfairia occidentalis*, the processing methods significantly reduced the cyanide content of the vegetable ($p < 0.05$.) The cyanide levels in the various processed samples were: fresh sample (170.83mg/kg), 5 minutes decoction (36.98mg/kg), 10 minutes decoction (44.87mg/kg), leaves boiled for 5minutes (49.88mg/kg), and leaves boiled for 10 minutes (34.68mg/kg), and sundried leaves (94.74mg/kg). Apart from the sundried leaves which had significantly higher level of cyanide than the other processed samples, no significant difference was observed in the cyanide levels of the other processed samples (as shown in Figure 4.1.1).

Results obtained from analysis of *Vernonia amygdalina* showed that fresh samples had higher cyanide content than any of the processed samples. The cyanide contents in fresh sample, 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 199.11mg/kg, 51.45mg/kg, 55.06mg/kg, 62.16mg/kg, 54.44mg/kg and 107.49mg/kg respectively. The results showed that cyanide content decreased significantly ($p < 0.05$) in the processed samples. The cyanide levels in 5 minutes decoction, 10 minutes decoction, and leaves boiled for 5 and 10 minutes were not significantly different from each other (as shown Figure 4.1.1). However, sundried leaves of the vegetable had a significant ($p < 0.05$) higher amount of the cyanide than in the leaves boiled for 5 and 10minutes. The cyanide content in unprocessed fresh leaves ranged from 63.98mg/kg in *Hibiscus sabdariffa* to 199.11mg/kg in *Vernonia amygdalina* (see Figure 4.1.1)

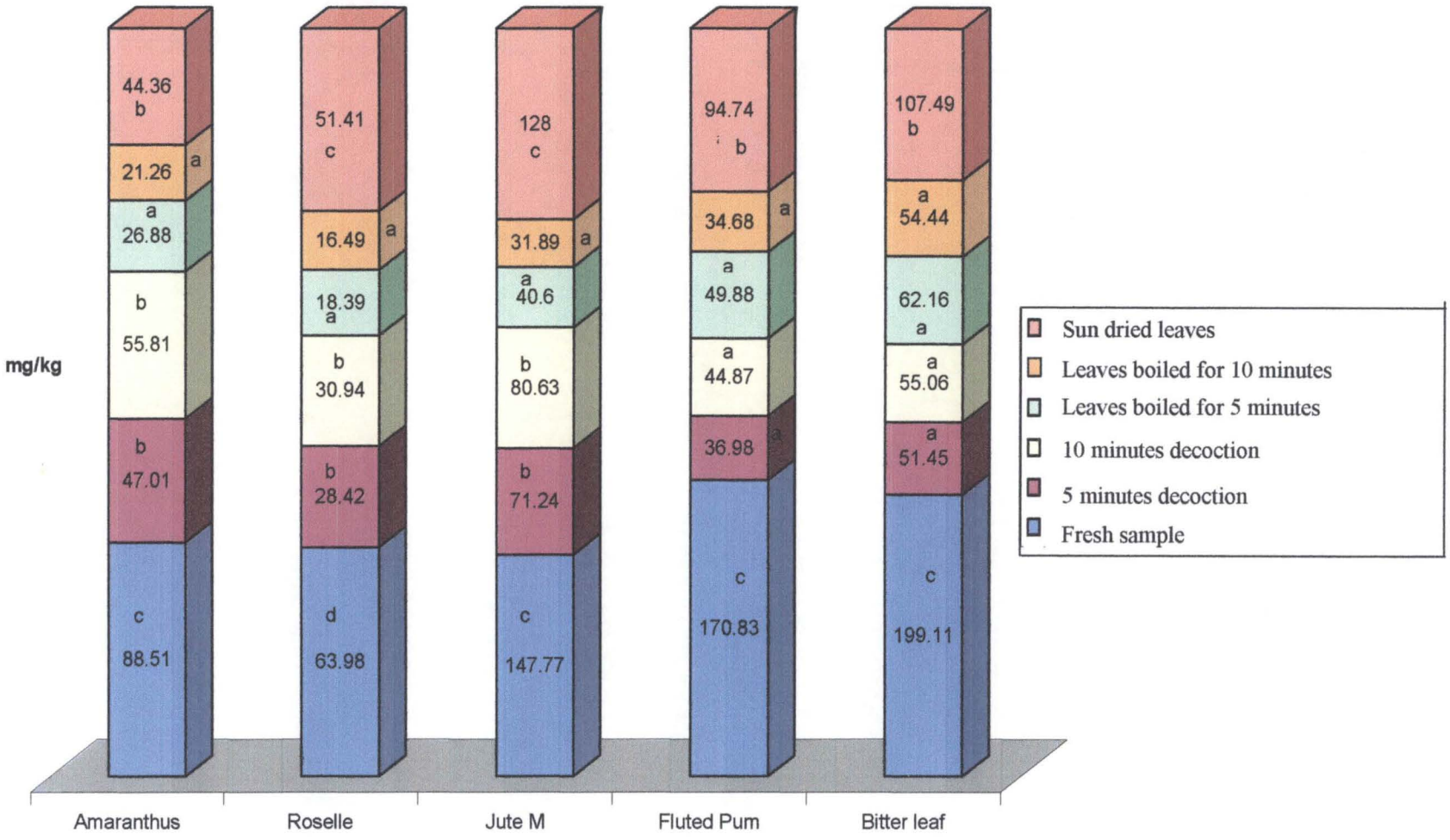


Figure 4.1.1: Effect of processing methods on cyanide content in the different vegetables studied. In each column the mean data carrying the same letter are not significantly different (P > 0.05)

4.1.2 Nitrate Content

Determination of the nitrate content of vegetable samples processed using different methods showed that the amount of nitrate in fresh sample were in general greater than that in all processed samples. The nitrate profile in the various processed samples of *Amaranthus cruentus* were; fresh sample (4335.21mg/kg); 5 minutes decoction (356.67mg/kg); 10 minutes decoction (269.67mg/kg); leaves boiled for 5 minutes (2304.63mg/kg); leaves boiled for 10 minutes (1560.24mg/kg) and sundried leaves (2009.26mg/kg). The results obtained revealed that the processing methods led to a significant ($p < 0.05$) reduction of nitrate content of the vegetable. The results also indicated that increased time of boiling significantly reduced the nitrate content of the svegetable, as there is more residual nitrate in leaves boiled for 5 minutes when compared with that boiled for 10 minutes (see Figure 4.1.2). Though more nitrates was extracted from leaves boiled for 10 minutes when compared with the leaves boiled for 5 minutes, 5 minutes decoction had more nitrate content than 10 minutes decoction. The residual nitrate found in leaves boiled for 5 and 10 minutes were not significantly ($p > 0.05$) different from nitrate content in sundried leaves.

Results obtained from analysis of *Hibiscus sabdariffa* showed that the nitrate content in fresh samples were higher than in any of the processed samples. The nitrate levels in fresh sample, 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried samples of the vegetable were 1281.50mg/kg, 93.33mg/kg, 71.05mg/kg, 509.26mg/kg, 344.45mg/kg and 647.21mg/kg respectively. The results indicated that the nitrate content decreased significantly ($p < 0.05$) in the all processed samples (Figure 4.1.2). There was no significant difference

in the residual nitrate in leaves boiled for 5 minutes, 10 minutes and sundried sample. Both samples, however, contained significant ($p < 0.05$) amount of the compound than the decoctions. Even though significant amount of nitrate was extract from boiled leaves, only small amount of the compound was found in their corresponding decoctions. The nitrate content in 5 minutes decoction was not significantly ($p > 0.05$) different from that of 10 minutes decoction.

In *Corchorus olitorius* the nitrate profile of various processed vegetable samples were as follows; fresh samples (3107.37mg/kg. 5 minutes decoction (257.25mg/kg), 10 minutes decoction (187.03mg/kg), leaves boiled for 5 minutes (433.29mg/kg), leaves boiled for 10 minutes (371.29mg/kg) and sundried leaves (1135.29mg/kg). The results showed that nitrate content decreased significantly ($p < 0.05$) in all processed samples. The nitrate content in 5 minutes decoction, 10 minutes decoction, and leaves boiled for 5 and 10 minutes were not significantly ($p > 0.05$) different from each other. Sundried leaves however, had significant ($p < 0.05$) amount of the compound than any of the processed samples (Figure 4.1.2 above).

Analysis of *Telfairia occidentalis* showed that the amount of nitrate in fresh (unprocessed) sample of the vegetable were significantly ($p < 0.05$) higher than in all processed samples of the vegetable. The nitrate levels in fresh samples, 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 2799.09mg/kg, 112.01mg/kg, 80.89mg/kg, 550.02mg/kg, 318.58mg/kg and 1397.22mg/kg, respectively. The processing methods adopted significantly ($p < 0.05$) reduced the nitrate content of the vegetable. Sundrying had the least effect since the residual nitrate in sundried leaves was significantly higher

when compared with nitrate values found in other processed samples. Only small amount of nitrate was found in decoctions compared with higher significant amount extracted from boiled leaves (see Figure 4.1.2). The residual nitrate levels in leaves boiled for 5 and 10 minutes were not significantly different from each other ($p > 0.05$). However, they had significantly higher nitrate content than the two decoctions.

Results obtained from the studies of different processing methods on nitrate content of *Vernonia amygdalina* gave the following results; fresh samples (1347.22mg/kg), 5minutes decoction(126.81mg/kg), 10 minutes decoction(110.89mg/kg), leaves boiled for 5 minutes (500.94mg/kg), leaves boiled for 10 minutes (401.89mg/kg) and sundried leaves (1107.50mg/kg. The results obtained also showed that the various processing techniques significantly ($p < 0.05$) reduced the nitrate levels of the vegetable. The nitrate content in sundried samples was significantly more ($p < 0.05$) than in any other processed samples. The residual nitrate in leaves boiled for 5 minutes was not significantly different from those leaves boiled for 10 minutes (see Figure 4.1.2). In this vegetable also only small amount of nitrate were found in the decoctions when compared with the significant amount of the compound extracted from the boiled leaves. Decoctions had the least of the parameter compared with other processed samples.

From the results obtained the increasing order of nitrate levels in vegetables are *Amaranthus cruentus* > *Corchorus olitorius* > *Tellfairia occidentalis* > *Vernonia amydalina* > *Hibiscus sabdariffa* (Figure 4.1.2 above).

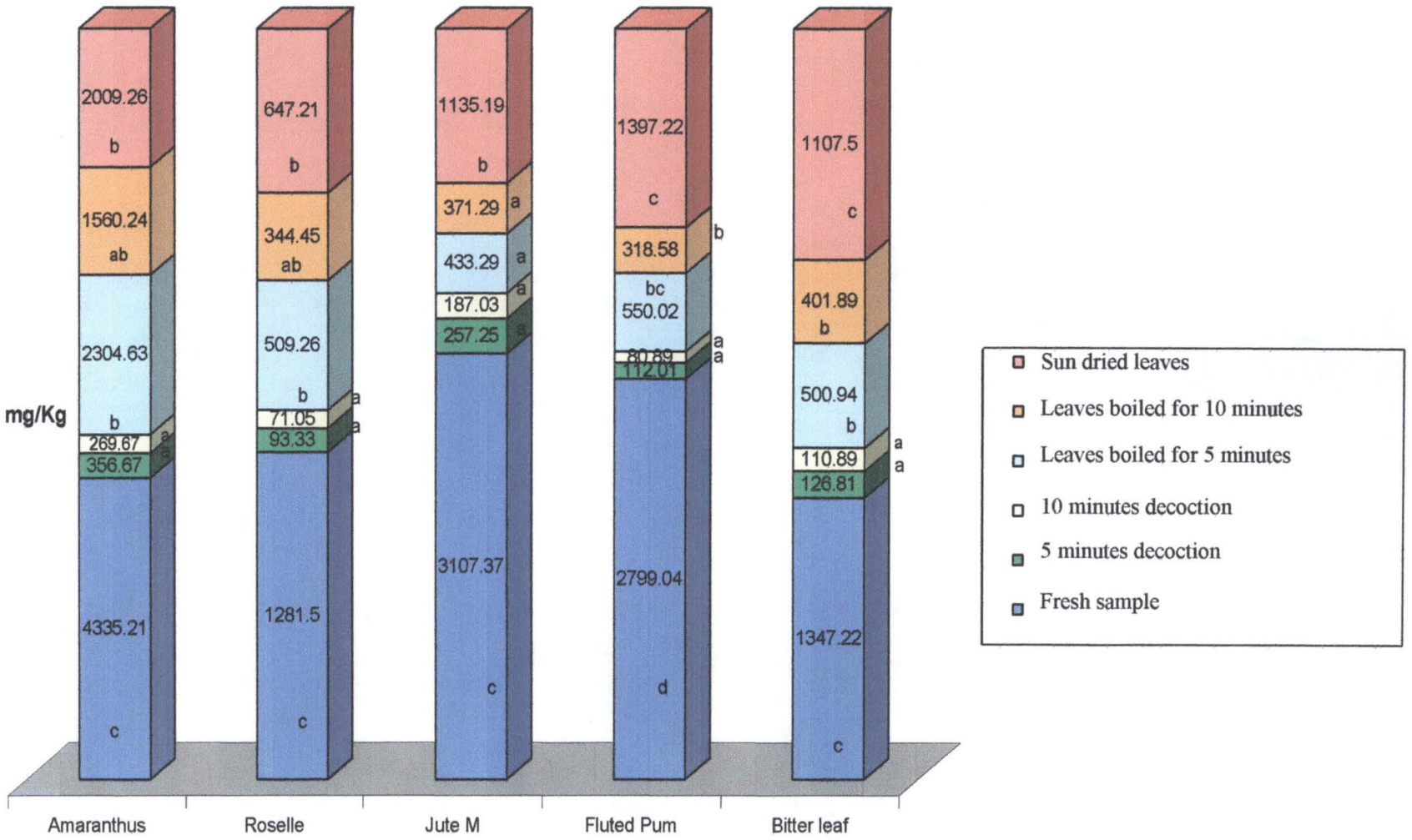


Figure 4.1.2: Effect of processing methods on nitrate content in the different vegetables studied. In each column mean data carrying the same letter are not significantly different (P > 0.05)

4.1.3 Soluble Oxalate Content

Results showed that fresh sample of the vegetables had the higher soluble oxalate content than the processed samples. In *Amaranthus cruentus* the soluble oxalate contents reduced significantly ($p < 0.05$) in the processed samples. The soluble oxalate content in fresh sample was 4.02g/kg while those of processed samples were; leaves boiled 5 minutes (2.60g/kg), leaves boiled for 10 minutes (2.03mg/kg) and sundried leaves (3.15g/kg). The residual soluble oxalate content in sundried leaves was significantly ($p < 0.05$) higher than that of leaves boiled for 10 minutes. But not significantly different from the leaves boiled for 5 minutes. The soluble oxalate content in leaves boiled for 5 minutes was also not significantly different ($p > 0.05$) from those leaves boiled for 10 minutes (Figure 4.1.3). With boiling methods of processing, soluble oxalate were not determined in the decoctions, since the oxalate extracted into boiling water is termed the total oxalate (consisting of soluble and insoluble oxalate).

From the analysis of *Hibiscus sabdariffa*, the soluble oxalate content of fresh samples, leaves boiled for 5 minutes, leaves boiled 10 minutes and sundried leaves were 1.91g/kg, 0.19g/kg, 0.11g/kg and 1.61g/kg respectively. The results revealed that sundrying had no significant ($p > 0.05$) effect on the soluble oxalate content of the vegetable. Boiling methods of processing, however led to a significant ($p < 0.05$) decreased of the antinutrient (Figure 4.1.3 above). The residual soluble oxalate content in the two separately boiled leaves was not significantly different from each other.

Studies conducted on *Corchorus olitorius* revealed that the soluble oxalate content of vegetable decreased significantly ($p < 0.05$) in all the processed samples. The amount of soluble oxalate in fresh (unprocessed) samples of vegetable was 3.49g/kg, but with sundrying, 5 and 10 minutes of boiling it decreased to 3.17g/kg, 1.92g/kg and

1.47g/kg respectively. The residual soluble oxalate in leaves boiled for 5minutes was significantly ($p < 0.05$) higher than those in leaves boiled for 10 minutes. However, these residual soluble oxalates from the two separately boiled leaves were significantly lower than in the sundried leaves (as shown in Figure 4.1.3).

The soluble oxalate content in fresh samples of *Telfairia occidentalis* was 2.855g/kg that of sundried, 5 and 10 minutes boiled leaves were 1.95g/kg, 1.24g/kg and 0.87g/kg respectively. The results indicated that fresh samples were significantly ($p < 0.05$) higher in the oxalate content than in the processed samples. The residual soluble oxalate content in the leaves boiled for 5 minutes was not significantly different from that of leaves boiled for 10 minutes. However, they were significantly ($p < 0.05$) lower than residual soluble oxalate content in sundried sample (see Figure 4.1.3).

Results from the analysis *Vernonia amygdalina* showed that the processing methods used significantly ($p < 0.05$) reduced its soluble oxalate content. The amount of oxalate in the various processed samples of the vegetable were; fresh samples (2.85g/kg), leaves boiled for 5 minutes (1.61g/kg), leaves boiled for 10 minutes (1.28g/kg) and sundried leaves (1.88g/kg). The residual soluble oxalate in sundried sample leaves boiled for 5 and 10 minutes were not significantly different ($p > 0.05$) from each other (Figure 4.1.3).

The increasing order of soluble oxalate content of the vegetables are *Amarantthus cruentus* > *Corchorus olitoius* > *Telfairia occidentalis* = Vernonia *amygdalina* > *Hibiscus sabdariffa* (Figure 4.1.3).

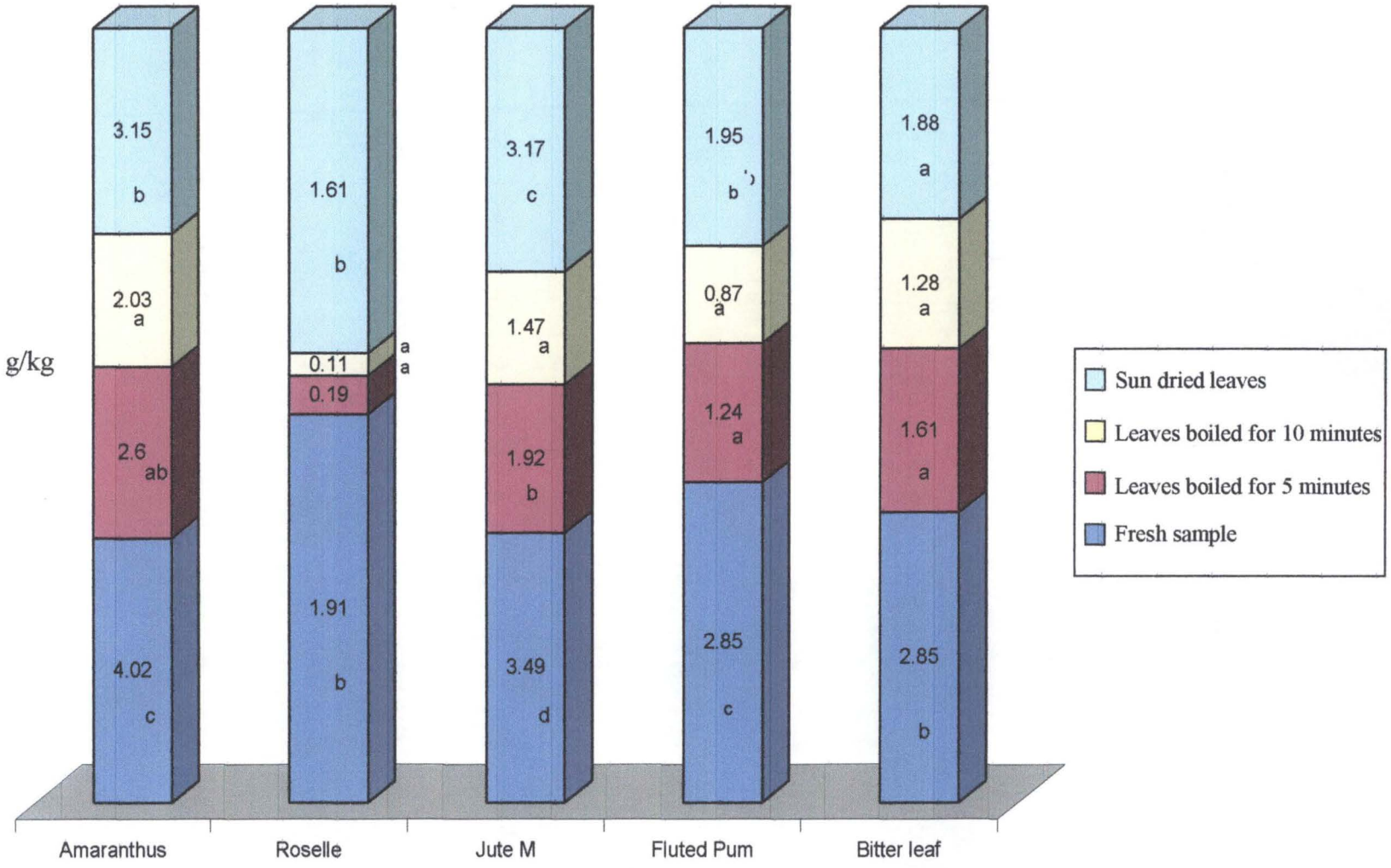


Figure 4.1.3: Effect of processing methods on soluble oxalate content in the different vegetables studied. In each column the mean data carrying the same letter are not significantly different ($P > 0.05$)

4.1.4 Total Oxalate Content

Determination of the total oxalate content of vegetable samples processed using different methods showed that the total oxalate in fresh samples were in general higher than that in all processed samples. The total oxalate content in various processed samples of *Amaranthus cruentus* were; fresh sample (7.90g/kg), 5 minutes decoction (0.87g/kg), 10 minutes decoction (1.04g/kg), leaves boiled for 5 minutes (5.89g/kg), leaves boiled for 10 minutes (5.37g/kg) and sundried leaves (6.49g/kg). The results obtained indicated that the total oxalate content of vegetable decreased significantly ($p < 0.05$) in all the processed samples (Figure 4.1.4). The total oxalate content was least in decoctions. The oxalate contents in the 5 and 10 minutes decoctions were not significantly different from each other. The oxalate content in sundried leaves was significantly ($p < 0.05$) higher than residual total oxalate in leaves boiled for 10 minutes, but it was not significantly different from the residual total oxalate content in leaves boiled for 5 minutes.

The amount of total oxalate in fresh samples of *Hibiscus sabdariffa* was 4.35g/kg while the amount in 5 minutes decoction, 10 minutes decoction, sundried leaves, leaves boiled for 5 and 10 minutes were 0.79g/kg, 0.92g/kg, 3.95g/kg, 2.36g/kg and 1.99g/kg, respectively. Results obtained revealed that boiling significantly ($p < 0.05$) reduced the total oxalate content in the vegetable. Sundrying, however, had no significant ($p > 0.05$) effect on the total oxalate content of the vegetable. The two decoctions had the least contents of the antinutrient and their oxalate content was not significantly ($p > 0.05$) different from each other. There was no significant difference between the residual total oxalate in leaves boiled for 5 minutes from that of 10 minutes boiling (as shown in Figure 4.1.4).

Studies conducted on *Corchorus olitorius* showed that sundrying had no significant ($p > 0.05$) effect on the total oxalate content of the vegetable. The two boiling methods however, significantly ($p < 0.05$) reduced total oxalate content of the vegetable. The total oxalate content of raw and processed samples of the vegetable were; fresh sample (5.85g/kg), 5 minutes decoction (0.58g/kg), 10 minutes decoction (1.07g/kg), leaves boiled for 5 minutes (3.65g/kg), leaves boiled for 10 minutes (3.00g/kg) and sundried leaves (5.48g/kg). The total oxalate in leaves boiled for 5 minutes was significantly ($p < 0.05$) higher than in the leaves boiled for 10 minutes. The two decoctions had the least content of the oxalate, but their oxalate contents were not significantly different from each other (Figure 4.1.4).

In *Telfairia occidentalis* the total oxalate content decreased significantly ($p < 0.05$) in all the processed samples. The oxalate content in the various processed samples of the vegetable were; fresh sample (4.39g/kg), 5 minutes decoction (0.48g/kg), 10 minutes decoction (0.66g/kg), leaves boiled for 5 minutes (2.59g/kg), leaves boiled for 10 minutes (2.03g/kg) and sundried leaves (2.23g/kg). Fresh samples had significant higher content ($p < 0.05$) of the antinutrient than all the processed samples of the vegetable (Figure 4.1.4). The total oxalate in leaves boiled for 5 minutes was significantly ($p < 0.05$) higher than in the leaves boiled for 10 minutes, but not significantly different from the oxalate content in sundried leaves. Even though, 10 minutes decoction contained more of the total oxalate than that of 5 minutes decoction, their oxalate contents were not significantly different from each other.

The concentration of total oxalate in fresh samples, 5 minutes decoction, 10 minutes decoction, and leaves boiled for 5 and 10 minutes; and sundried leaves of

Vernonia amygdalina were 4.76g/kg, 0.91g/kg, 1.16g/kg, 2.63g/kg, 2.14g/kg and 3.49g/kg respectively. The results obtained indicated that fresh samples had significant ($p < 0.05$) amount of total oxalate than all the processed samples. The residual total oxalate in sundried leaves was significantly higher than in the leaves boiled for 10 minutes, but not significantly different from residual total oxalate in leaves boiled for 5 minutes. Although the total oxalate in 10 minutes decoction was not significantly different from that of 5 minutes, the former appear to contain more of the oxalate (see Figure 4.1.4).

The total oxalate contents in fresh samples of different vegetables are; *Amaranthus cruentus* (7.90g/kg), *Hibiscus sabdariffa* (4.35g/kg), *Corchorus olitorius* (5.85g/kg), *Telfairia occidentalis* (4.39g/kg) and *Vernonia amygdalina* (4.76g/kg) as shown in Figure 4.1.4

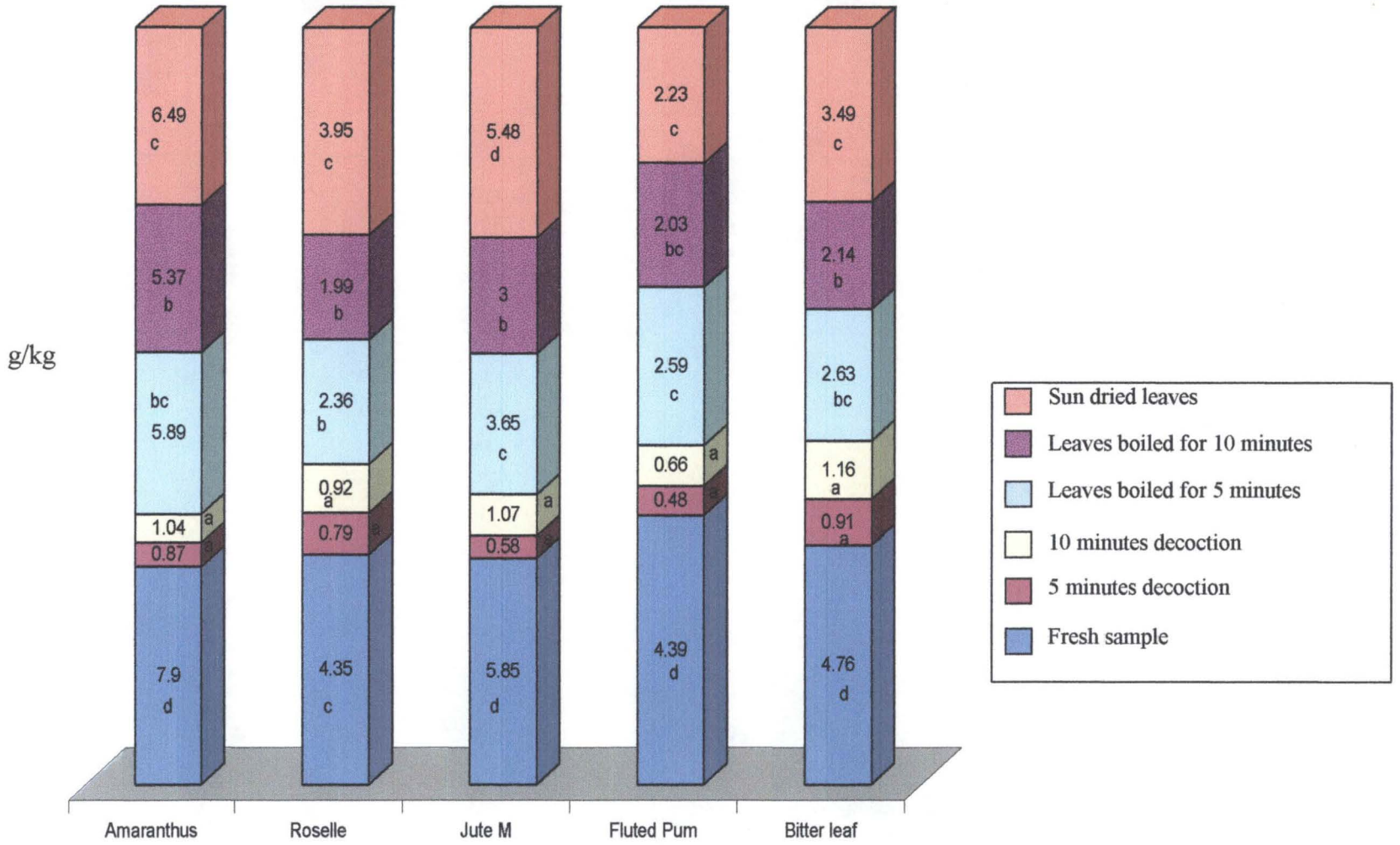


Figure 4.1.4: Effect of processing methods on total oxalate content in the different vegetables studied. In each column the mean data carrying the same letter are not significantly different (P > 0.05)

4.2 Effect of Processing Methods on Vitamins in the Vegetables

4.2.1 β-carotene Content

Analysis of the β-carotene content of vegetable samples processed using different methods showed that the amount of β-carotene in the leaves boiled for 5minutes were in general higher than in fresh and other processed samples. The β-carotene content in fresh and various processed samples of *Amanrathus cruentus* were; fresh sample (11956.80µg/100g), 5minutes decoction (12.70µg/100g), 10 minutes decoction (16.00µg/100g), leaves boiled for 5 minutes (14725.90µg/100g), leaves boiled for 10 minutes (9970.30µg/100g) and sundried leaves (8020.00µg/100g). Data analysis indicated that sundrying significantly ($p < 0.05$) reduced the β-carotene content of the vegetable. The percentage reduction of the provitamin brought by solar radiation is about 32.93%. With boiling, only leaves boiled for 10 minutes led to a significant reduction of β-carotene of vegetable. The 5 and 10 minutes decoctions were least in β-carotene content and their values were negligible (see Figure 4.2.1).

Analysis of *Hibiscus sabdariffa* showed that the amount of β-carotene in the leaves of vegetable boiled for 5 minutes were in general greater than fresh and other processed samples. The β-carotene content in fresh sample, 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 8772.00µg/100g, 42.39µg/100g, 78.00µg/100g, 9407.67µg/100g, 7213.00µg/100g and 5082.00µg/100g, respectively. The result also showed that sundrying significantly ($p < 0.05$) decreases the β-carotene content to about 42. 07% .Though the β-carotene in the leaves boiled 5 and 10 minutes were not significantly different from the levels in the fresh samples, leaves boiled for 5 minutes had higher

amount of the provitamin than the fresh samples. The amount of β-carotene in the decoction samples were negligible when compared with the amount found in the boiled leaves sample.

The amount of β-carotene in the various processed samples of *Corchorus olitorius* were; fresh sample (18432.30µg/100g), 5 minutes decoction (9.00µg/100g), 10 minutes decoction (12.80µg/100g), leaves boiled for 5 minutes (20254.76µg/100g), leaves boiled 10 minutes (17395.30µg/100g) and sundried leaves (13111.30µg/100g). Data analysis revealed that while 5 minutes boiling significantly ($p < 0.05$) increased the provitamin content of the vegetable, sundrying significantly ($p < 0.05$) decrease β-carotene content. The percentage reduction of provitamin caused by solar drying was about 28.87%. The amount of β-carotene in leaves boiled for 10 minutes was not significantly different from level in fresh sample (Figure 4.2.1). It is also pertinent to note again that negligible amount of the provitamin were found in decoctions.

Analysis of β-carotene content in the various processed samples of *Telfairia occidentalis*, gave the following results; fresh sample (18859.30µg/100g), 5 minutes decoction (19.20µg/100g), 10 minutes (38.30µg/100g), leaves boiled for 5 minutes (25249.70µg/100g), leaves boiled for 10 minutes (23455.90µg/100g) and sundried leaves (11792.00µg/100g). The results obtained showed that sundrying significantly reduced the provitamin content of the vegetable (about 36.48%). However, 5 and 10 minutes boiling significantly ($p < 0.05$) elevated the β-carotene content. The β-carotene content of the leaves boiled for 5 and 10 minutes were not significantly different. However there is a trend of decrease in the provitamin with increasing boiling time. The levels of the caroteniod in the boiled leaves were significantly ($p < 0.05$) higher than the fresh raw

samples (Figure 4.2.1). The amounts of β-carotene in the decoction samples were also negligible.

Results obtained from the determination of β-carotene content in *Vernonia amygdalina* showed that the levels of the carotenoid in fresh sample, 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 19515.33µg/100g, 32.31µg/100g, 70.18µg/100g, 23993.33µg/100g, 17689.33µg/100g, and 11666.33µg/100g respectively. Data analysis indicated that sundrying significantly ($p < 0.05$) decreased the β-carotene content of the vegetable (to about 40.22%). The β-carotene content in leaves boiled for 5 minutes was significantly ($p < 0.05$) higher than in fresh sample and in leaves boiled for 10 minutes. Even though the provitamin content in fresh sample was not significantly different from the level in the leaves boiled for 10 minutes. Negligible amount of the β-carotene were found in the decoctions (Figure 4.2.1).

The levels of β-carotene in fresh samples of the different vegetables are; *Amaranthus cruentus* (11956.80µg/100g), *Hibiscus sabdariffa* (8772.00µg/100g), *Corchorus olitorius* (18433.30µg/100g), *Telfairia occidentalis* (18859.30µg/100g) and *Vernonia amygdalina* (19515.33µg/100g). The range of the provitamin in the fresh sample of the vegetables is 8772.00µg/100g in *Hibiscus sabdariffa* to 19515.33µg/100g in *Vernonia amygdalina* (Figure 4.2.1).

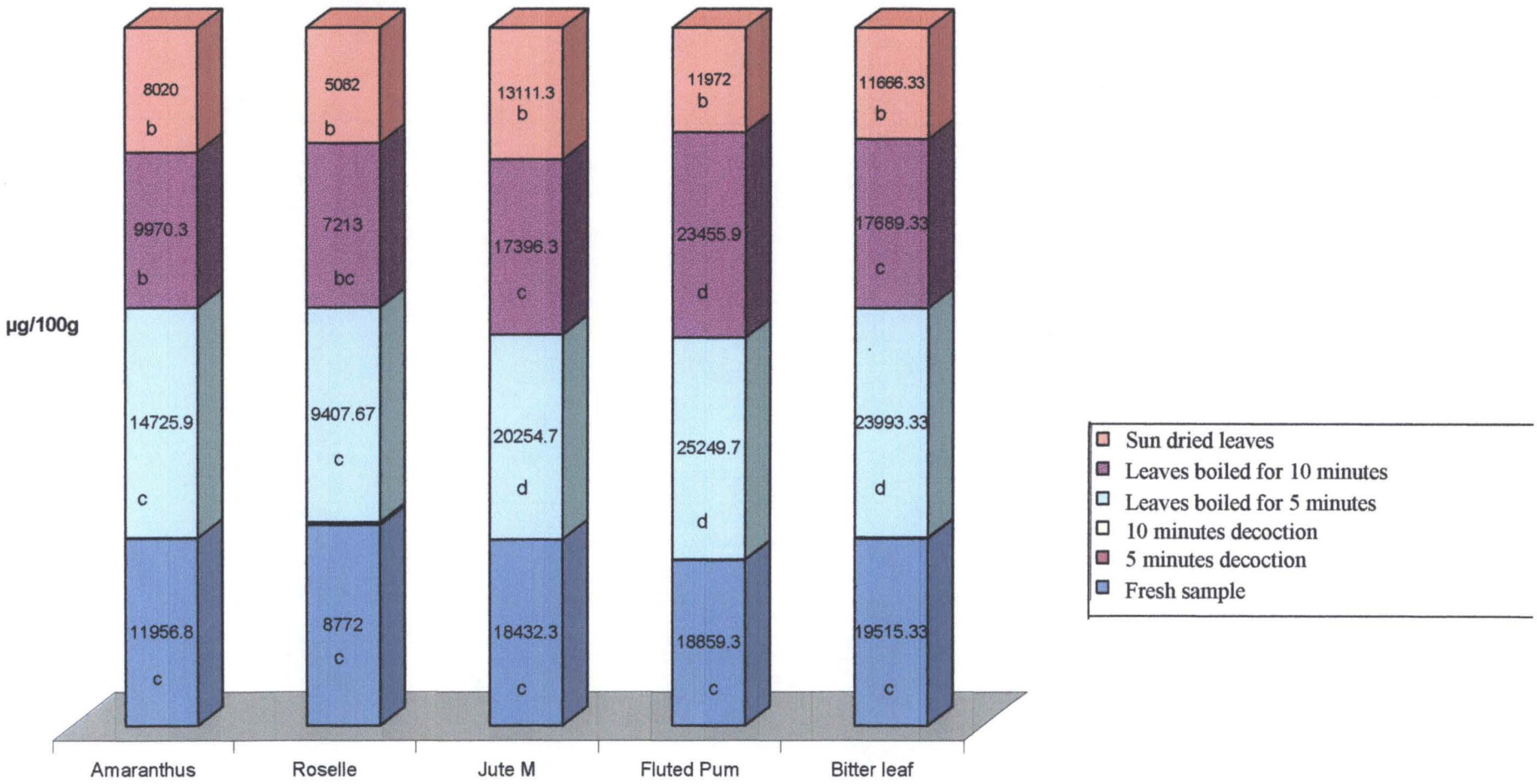


Figure 4.2.1: Effect of processing methods on β-Carotene content in the different vegetables studied. In each column the mean data carrying the same letter are not significantly different (P > 0.05)

4.2.2 Vitamins C Content

Determination of the vitamin C content of vegetable samples processed using different methods showed that the amount of vitamin C in fresh samples were significantly higher ($p < 0.05$) than that in all the processed samples. The vitamin content in different processed samples of *Amaranthus cruentus* were; fresh sample (69.35mg/100g), 5 minutes decoction (0.92mg/100g), 10 minutes decoction (1.14mg/100g), leaves boiled for 5 minutes (19.22mg/100g), leaves boiled for 10 minutes (14.40mg/100g) and sundried leaves (11.74mg/100g). The vitamin C content reduced significantly ($p < 0.05$) in all processed samples. The percentage losses of the vitamin in leaves boiled for 5 and 10 minutes were 72.30% and 79.20% respectively. Leaves boiled for 5 minutes had significant ($p < 0.05$) higher amount of vitamin C than the leaves boiled for 10 minutes. Considering high percentage lost of this important vitamin in the vegetable during boiling, only, 1.33% and 1.64% were found in 5 and 10 minutes decoctions respectively. Sundrying significantly reduced ($p < 0.05$) the vitamin content of the vegetable. This processing method resulted in a greater reduction of the vitamin (about 83.07% was recorded). Although, there was no significant difference in residual vitamin content in leaves boiled for 10 minutes from the levels in sundried leaves, the later retained less amount of vitamin (as shown in Figure 4.2.2).

Results obtained from analysis of *Hibiscus sabdariffa* clearly showed that vitamin C content significantly ($p < 0.05$) decreased in all the processed samples. The amount of vitamin C in fresh sample was 27.44mg/100g while the levels in 5 minutes decoction, 10 minutes decotion, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 0.81mg/100g, 1.30mg/100g, 14.51mg/100g, 9.67mg/100g and

9.40mg/100g, respectively. The percentage losses recorded in leaves boiled for 5 and 10 minutes were 47.51% and 64.76% respectively (see Figure 4.2.2). The 2.95% and 4.74% of vitamin found in 5 and 10 minutes decoctions were negligible compared with great losses observed in the boiled leaves. The vitamin C content in sundried leaves of vegetable was significantly ($p < 0.05$) lower than in the fresh samples. The percentage reduction recorded in sundried sample was about 65.74% for the vegetable. The residual vitamin C in sundried sample, leaves boiled for 5 and 10 minutes were not significantly different from each other.

Analysis of *Corchorus olitorius* showed that the various processing methods adopted significantly ($p < 0.05$) decreased its vitamin C content. The mount of vitamin in the processed samples of the vitamin were: fresh sample (78.90mg/100g), 5 minutes decoction (0.92mg/100g), 10 minutes decoction (1.01mg/100g), leaves boiled for 5 minutes (15.89mg/100g), leaves boiled for 10 minutes (11.60mg/100g) and sundried leaves (13.69mg/100g). The percentage losses of the vitamin in leaves boiled 5 and 10 minutes were 79.86% and 85.30% respectively. Only negligible amount of the vitamin were found in decoction samples, 1.28% and 1.16% were recorded for 5 and 10 minutes decoctions respectively. The percentage losses of the vitamin recorded in sundried sample was about 82.35%. Residual vitamin C in sundried leaves, leaves boiled for 5 and 10 minutes were not significantly different from each other (Figure 4.2.2).

The vitamin C content in *Telfairia occidentalis* decreased significantly ($p < 0.05$) in all processed samples. The amount of the vitamin in fresh sample, 5 minutes decoction, 10 minutes decoction, and leaves boiled for 5 minutes, leaves boiled for 10

minutes and sundried sample were 192.28mg/100g, 1.51mg/100g, 2.16mg/100g, 53.70mg/100g, 35.60mg/100g and 13.15mg/100g, respectively. The percentage losses of the vitamin observed in leaves boiled for 5 and 10 minutes were 72.07% and 81.49% respectively (Figure 4.2.2). Low levels of the vitamin (0.79% and 0.60%) were obtained respectively in 5 and 10 minutes decoctions. The percentage reduction of the vitamin observed in sundried sample was about 93.16%. The vitamin C content in leaves boiled for 5 minutes was not significantly different from that boiled for 10 minutes. However, the vitamin content in sundried leaves was significantly ($p < 0.05$) lower than in the leaves boiled for 5 minutes.

In *Vernonia amygdalina,* the vitamin C content in fresh leaves sample was significantly ($p < 0.05$) higher than in all processed samples. The amount of vitamin C in fresh sample was 30mg/100g and that of 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and dried leaves were 0.96mg/100g, 1.13mg/100g, 13.69mg/100g, 9.31mg/100g and 11.50mg/100g respectively. The percentage losses of the vitamin recorded in the leaves boiled for 5 and 10 minutes were 55.60% and 69.65% respectively. Negligible amount of the vitamin were also found in the decoction samples. The percentage loss of vitamin C observed during sundrying of the vegetable was 62.52%. The amount of vitamin C in sundried leaves, and leaves boiled for 5 and 10 minutes were not significantly ($p > 0.05$) different from each other (as shown in Figure 4.2.2).

The vitamin C content in fresh samples of different vegetables are; *Amaranthus cruentus* (69.35mg/100g), *Hibiscus sabdariffa* (27.44mg/100g), *Corchorus olitorius* (78.90mg/100g), *Telfairia occidentalis* (192.28mg/100g) and *Vernonia amygdalina*

(30.68mg/100g). The increasing order of the vitamin content of the vegetables are *Telfairia occidentalis* > *Corchorus olitoius* > *Amaranthus cruentus* > *Vernonia amygdalina* > *Hibiscus olitorius.* The vitamin profile indicated that *Telfairia occidentalis* had the highest value of vitamin while *Hibiscus sabdariffa* had the least.

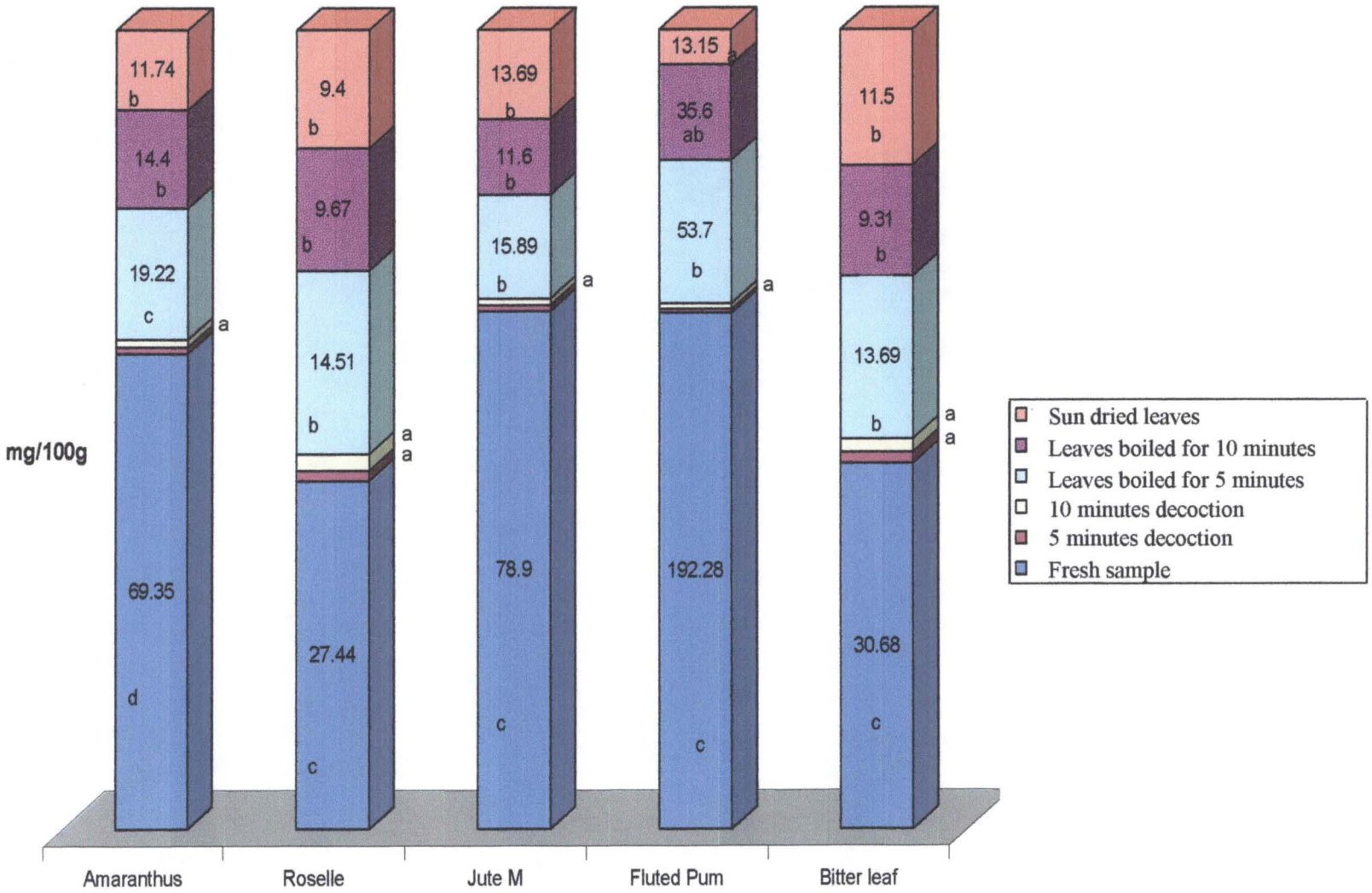


Figure 4.2.2: Effect of processing methods on Vitamin C content in the different vegetables studied. In each column the mean data carrying the same letter are not significantly different ($P > 0.05$)

4.3 Effect of Processing Methods on Mineral Elements in the Vegetables

4.3.1 Iron Content

Determination of Fe content of vegetable samples processed using different methods revealed that the amount of Fe in fresh samples were not significantly different ($p > 0.05$) from sundried samples. However, the Fe content in fresh samples was in general higher than 5 and 10 minutes boiled samples. The amount Fe in the various processed samples of *Amaranthus cruentus* were: fresh sample (19.20mg/kg), 5 minutes decoction (2.70mg/kg), 10 minutes decoction (3.53mg/kg), leaves boiled for 5 minutes (14.10mg/kg), leaves boiled for 10 minutes (10.40mg/kg) and sundried sample (18.97mg/kg). The results obtained showed that sundrying had no significant effect on the on mineral content of the vegetable. Boiling, however, significantly ($p < 0.05$) reduced the mineral content of the vegetable (as shown in Figure 4.3.1). The residual Fe in leaves boiled for 5 minutes was not significantly different from the levels in leaves boiled for 10 minutes. However, the residual Fe in leaves boiled for 10 minutes was significantly ($p < 0.05$) lower than in fresh and sundried leaves. Least amount of the mineral was found in 5 and 10 minutes decoctions. The Fe content in the 5 and 10 minutes decoctions were not significantly different from each other, even though 10 minutes decoction had numerically higher Fe content than 5 minutes decoction (see Figure 4.3.1).

Analysis of *Hibiscus sabdariffa* also revealed that sundrying had no significant ($p > 0.05$) effect on the Fe content of vegetable. The Fe content in fresh sample, 5 minutes decoction, 10 minutes decoction, and leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves of vegetable were 18.51mg/kg, 1.88mg/kg,

3.23mg/kg, 15.27mg/kg, 12.23mg/kg and 18.48mg/kg respectively. Fe contents of vegetable reduced significantly ($p < 0.05$) in leaves boiled for 5 and 10 minutes. The residual Fe in leaves boiled for 5 minutes was significantly higher when compared with leaves boiled for 10 minutes. Least amount of the mineral was found in 5 and 10 minutes decoctions (Figure 4.3.1).

The amount of Fe in the processed samples of *Corchorus olitorius* were: fresh sample (26.03mg/kg), 5 minutes decoction (6.37mg/kg), 10 minutes decoction (9.54mg/kg), leaves boiled for 5 minutes (16.63mg/kg), leaves boiled for 10 minutes (11.81mg/kg) and sundried leaves (25.98mg/kg). The results obtained showed that sundrying had no significant effect on the Fe content of the vegetable. However, 5 and 10 minutes of boiling significantly decreased ($p < 0.05$) the Fe content of *Corchorus olitorius* (Figure 4.3.1). The Fe content in the leaves boiled for 5minutes was significantly higher than in the leaves boiled for 10 boiling. The amount of the mineral in 10 minutes decoction was not significantly different from the amount in 5 minutes decoction and in leaves boiled for 10 minutes. However the later is significantly higher in the mineral content than the former.

Analysis of *Telfairia occidentalis* showed that the Fe content in fresh sample of the vegetable was 23.43mg/kg while the levels in 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 3.47mg/kg, 6.18mg/kg, 14.13mg/kg, 10.77mg/kg and 23.15mg/kg respectively. The Fe content in sundried leaves was not significantly different from the fresh unprocessed sample. The mineral content in leaves boiled for 5 and 10 minutes reduced significantly ($p < 0.05$) compared with the fresh sample, indicating that boiling

significantly reduced the Fe content of the vegetable. The Fe contents in leaves boiled for 5 minutes was significantly higher than in the leaves boiled for 10 minutes. Least amount of mineral was also observed in the decoction samples and their values were not significantly ($p > 0.05$) different from each other (as shown in Figure 4.3.1).

Results obtained from the analysis of Fe content in *Vernonia amygdalina* indicated that solar drying had no significant ($p > 0.05$) effect on the mineral content of vegetable. However, boiling of the vegetable significantly reduced the Fe content. The amount of Fe in different processed samples of *Vernonia amygdalina* were: fresh sample (23.44mg/kg), 5 minutes decoction (3.57mg/kg), 10 minutes decoction (5.59mg/kg), leaves boiled for 5 minutes (16.93mg/kg), leaves boiled for 10 minutes (10.43mg/kg) and sundried leaves (22.43mg/kg). Data analysis showed that the Fe content in the leaves boiled for 5 minutes was not significantly different ($p > 0.05$) from that in the leaves boiled 10 minutes and fresh sample. However, the amount of mineral in the fresh sample was significantly ($p < 0.05$) higher than in the leaves boiled for 10 minutes (as shown in Figure 4.3.1). The 5 and 10 minutes decoctions had the least content of the mineral and their values were not significantly different from each other.

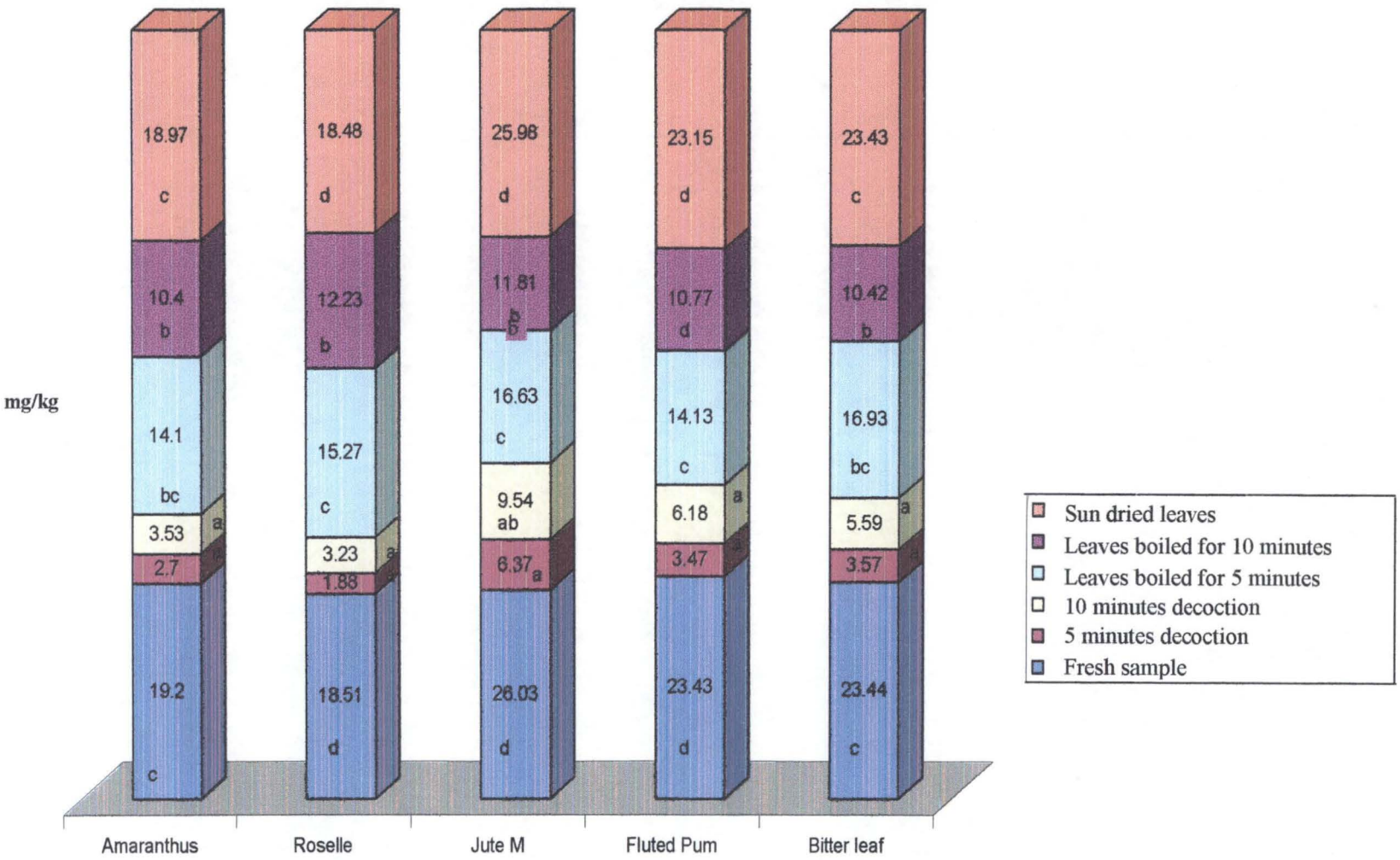


Figure 4.3.1: Effect of processing methods on iron content in the different vegetables studied. In each column the mean data carrying the same letter are not significantly different (P > 0.05)

4.3.2 Copper Content

Analysis of Cu content of the vegetable samples processed using different methods indicated that the amount of Cu in fresh samples were not significantly ($p > 0.05$) different from the level in sundried samples. However, the amount of the mineral in fresh samples was significantly ($p < 0.05$) higher than in 5 and 10 minutes boiled vegetable samples. Results obtained from analysis of Cu content in *Amaranthus cruentus* showed that the amount of the mineral in fresh sample, 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 24.24mg/kg, 1.97mg/kg, 2.2mg/kg, 15.55mg/kg, 13.83mg/kg and 24.13mg/kg respectively (Figure 4.3.2). From the results, sundrying had no significant ($p > 0.05$) effect on the Cu contents of the vegetable. However, 5 and 10 minutes boiling significantly reduced ($p < 0.05$) the mineral content of the vegetable. The amount of Cu in 5 and 10 minutes boiled leaves of *Amaranthus cruentus* were significantly ($p < 0.05$) lower than in the fresh samples. The Cu content in 5 and 10 minutes boiled leaves were not significantly different ($p > 0.05$) from each other. The 5 and 10 minutes decoction samples were least in the mineral content. Although the Cu content in the two decoction samples were not significantly different from each other, the level of mineral in 10 minutes decoction was more than in 5 minutes decoction (as shown in Figure 4.3.2).

The amount of Cu in the various processed samples of *Hibiscus sabdariffa* were as follows: fresh sample (26.67mg/kg), 5 minutes decoction (1.97mg/kg), 10 minutes decoction (2.72mg/kg), leaves boiled for 5 minutes (20.72mg/kg), leaves boiled for 10 minutes (16.70mg/kg) and sundried leaves (26.65mg/kg). The results obtained clearly showed that sundrying had no significant effect ($p > 0.05$) on the mineral content

of vegetable. However, 5 and 10 minutes boiling significantly ($p < 0.05$) reduced the Cu content of the vegetable. The residual Cu in leaves boiled for 5 minutes was significantly ($p < 0.05$) higher than in the leaves boiled for 10 minutes. The two decoction samples had the least amount of the mineral compared to other processed samples (as shown in Figure 4.3.2).

Studies conducted on Cu content of *Corchorus olitorius* showed that 5and 10 minutes boiling significantly ($p < 0.05$) reduced the Cu content of the vegetable. Sundrying, however, had no significant effect on the mineral content in *Corchorus olitorius*. The amount of Cu in fresh sample of the vegetable was 30.57mg/kg while the levels in 5 minutes decoction, 10 minutes decoction, and leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 5.10mg/kg, 7.63mg/kg, 21.41mg/kg, 13.25mg/kg and 30.40mg/kg respectively. The Cu content in the leaves boiled for 5 minutes was significantly higher than in the leaves boiled for 10 minutes. The 10 minutes decoction had more of the mineral than in the 5 minutes decoction. The mineral content in the decoction samples were significantly ($p < 0.05$) lower than in all the processed samples (see Figure 4.3.2).

Determination of Cu content in the different processed samples of *Telfairia occidentalis* revealed that sundrying had no significant ($p > 0.05$) effect on the mineral content of the vegetable. However, the two boiling periods significantly ($p < 0.05$) reduced the mineral content of the vegetable. The amount of Cu in the processed samples of the vegetable were: fresh sample (18.70mg/kg), 5 minutes decoction (3.08mg/kg), 10 minutes decoction (4.01mg/kg), leaves boiled for 5 minutes (15.17mg/kg), leaves boiled for 10 minutes (12.71mg/kg) and sundried leaves (18.54mg/kg). The level of the mineral

boiled for 10 minutes. The Cu content in the 5 and 10 minutes decoction samples were not significantly different from each other. They had the least content of the mineral than in all other processed samples (see Figure 4.3.2).

Analysis of Cu content in *Vernonia amygdalina* showed that 5 and 10 minutes of boiling significantly ($p < 0.05$) reduced its Cu content. Sundrying, however, had no significant ($p > 0.05$) effect on the mineral content of the vegetable. The Cu content in fresh samples, 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 36.70mg/kg, 4.25mg/kg, 10.16mg/kg, 18.88mg/kg, 16.52mg/kg and 36.40mg/kg respectively. The residual Cu in the leaves boiled for 5 and 10 minutes were not significantly ($p > 0.05$) different from each other. The level of the mineral in 5 and 10 minutes decoctions were not significantly different from each other, even though 10 minutes decoction had more of mineral. The 5 and 10 minutes decoctions were significantly ($p < 0.05$) lower in the mineral content than in all other processed samples (as shown in Figure 4.3.2).

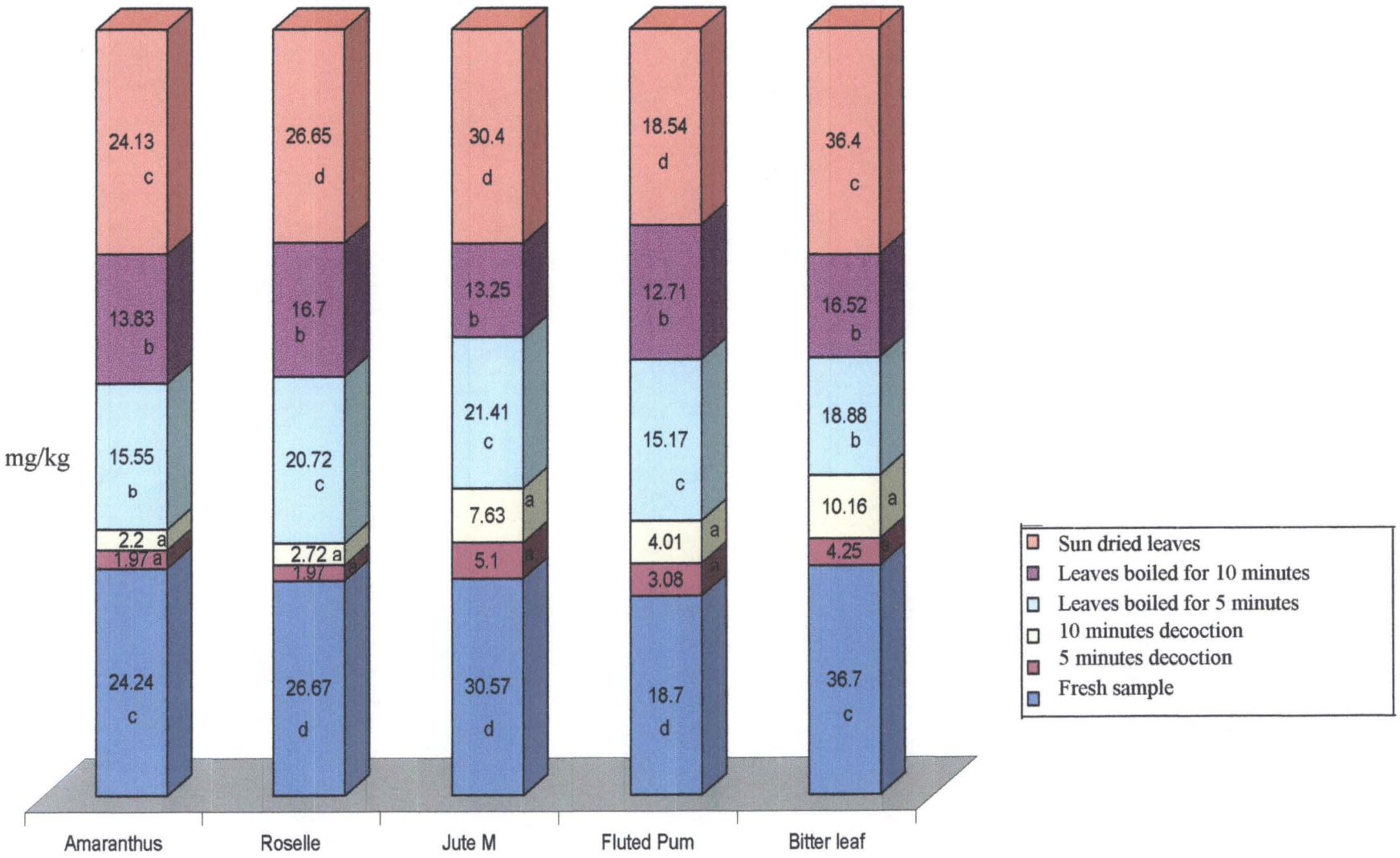


Figure 4.3.2: Effect of processing methods on copper content in the different vegetables studied. In each column the mean data carrying the same letter are not significantly different (P > 0.05)

4.3.3 Magnesium Content

Determination of Mg content of the different vegetable samples processed using different methods indicated that the amount of Mg in the fresh samples were not significantly different from sundried samples. The mineral content in the 5 and 10 minutes boiled leaves were in general lower than in fresh samples. Results obtained from the analysis of *Amaranthus cruentus* showed that the amount of Mg in the fresh sample (27.78mg/kg) was not significantly different from sundried sample (27.48mg/kg). However, 5 and 10 minutes boiling significantly ($p < 0.05$) reduced the mineral content of the vegetable leaves to 20.30mg/kg and 17.09mg/kg respectively. Residual Mg content in the leaves of *Amaranthus cruentus* boiled for 5 minutes was significantly ($p < 0.05$) higher than in the leaves boiled for 10 minutes. Decoctions were least in the mineral content. Although the amount of Mg in the 5 minutes decoction (3.93mg/kg) was not significantly ($p > 0.05$) different from that of 10 minutes decoction (4.9mg/kg), there was a trend of increased in the mineral content in the decoction samples with increasing boiling time (see Figure 4.3.3).

Analysis of *Hibiscus sabdariffa* also indicated that the Mg content in fresh sample (21.69mg/kg) of the vegetable was not significantly different ($p > 0.05$) from that of sundried sample (21.68m/kg). But with 5 and 10 minutes boiling the mineral content decreased significantly ($p < 0.05$) to 14.45mg/kg and 13.21mg/kg respectively. The Mg content in 5 and 10 minutes boiled leaves were not significant different ($p > 0.05$) from each other. The mineral content in the 5 minutes decoction (5.09mg/kg) and 10 minutes decoction (6.09mg/kg) were also not significantly different ($p > 0.05$), however, their Mg

content were significantly ($p < 0.05$) lower than in other processed samples (see Figure 4.3.3).

Results from the analysis of *Corchorius olitorius* revealed that the Mg content in fresh sample (61.79mg/kg) of the vegetable was not significantly different ($p > 0.05$) from that of sundried sample (61.09m/kg). However, 5 and 10 minutes boiling significantly decreased ($p < 0.05$) the mineral content to 39.01mg/kg and 26.27mg/kg respectively. The Mg content in 5 and 10 minutes boiled leaves were not significantly different ($p > 0.05$) from each other. The mineral content in 5 minutes decoction (9.82mg/kg) and 10 minutes decoction (16.81mg/kg) were also not significantly different ($p > 0.05$) from each other. Their Mg content was significantly ($p < 0.05$) lower than in other processed samples (as shown in Figure 4.3.3).

Analysis of Mg content in *Telfairia occidentalis* showed that 10 minutes of boiling significantly reduced ($p < 0.05$) the mineral content of the vegetable. Sundrying and 5 minutes boiling had no significant effect on the mineral content of the vegetable. The Mg content in fresh samples, 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 48.81mg/kg, 12.47mg/kg, 15.71mg/kg, 33.91mg/kg, 24.59mg/kg and 48.45mg/kg respectively. The residual Mg in the leaves boiled for 5 and 10 minutes were not significantly different from each other. The level of mineral in 5 and 10 minutes decoction were not significantly different, even though 10 minutes decoction had more of mineral content. 5 and 10 minutes decoctions were significantly lower ($p < 0.05$) in the mineral content than in all other processed samples (see Figure 4.3.2).

Results from the analysis of *Vernonia amygdalina* showed that the Mg profile of the various processed samples of the vegetable to be as follows; fresh sample (55.28mg/kg), 5 minutes decoction (7.95mg/kg), 10 minutes decoction (9.90mg/kg), leaves boiled for 5 minutes (34.76mg/kg), leaves boiled for 10 minutes (24.18mg/kg) and sundried leaves (55.24mg/kg). Results obtained indicated that 10 minutes of boiling significantly reduced ($p < 0.05$) the mineral content of the vegetable. Sundrying and 5 minutes boiling had no significant effect ($p > 0.05$) on the mineral content of the vegetable. The residual Mg in the leaves boiled for 5 and 10 minutes were not significantly different from each other. The level of mineral in 5 and 10 minutes decoctions were not significantly different from each other, even though 10 minutes decoction had more of mineral content. 5 and 10 minutes decoctions were significantly lower ($p < 0.05$) in the mineral content than in all other processed samples (Figure 4.3.2).

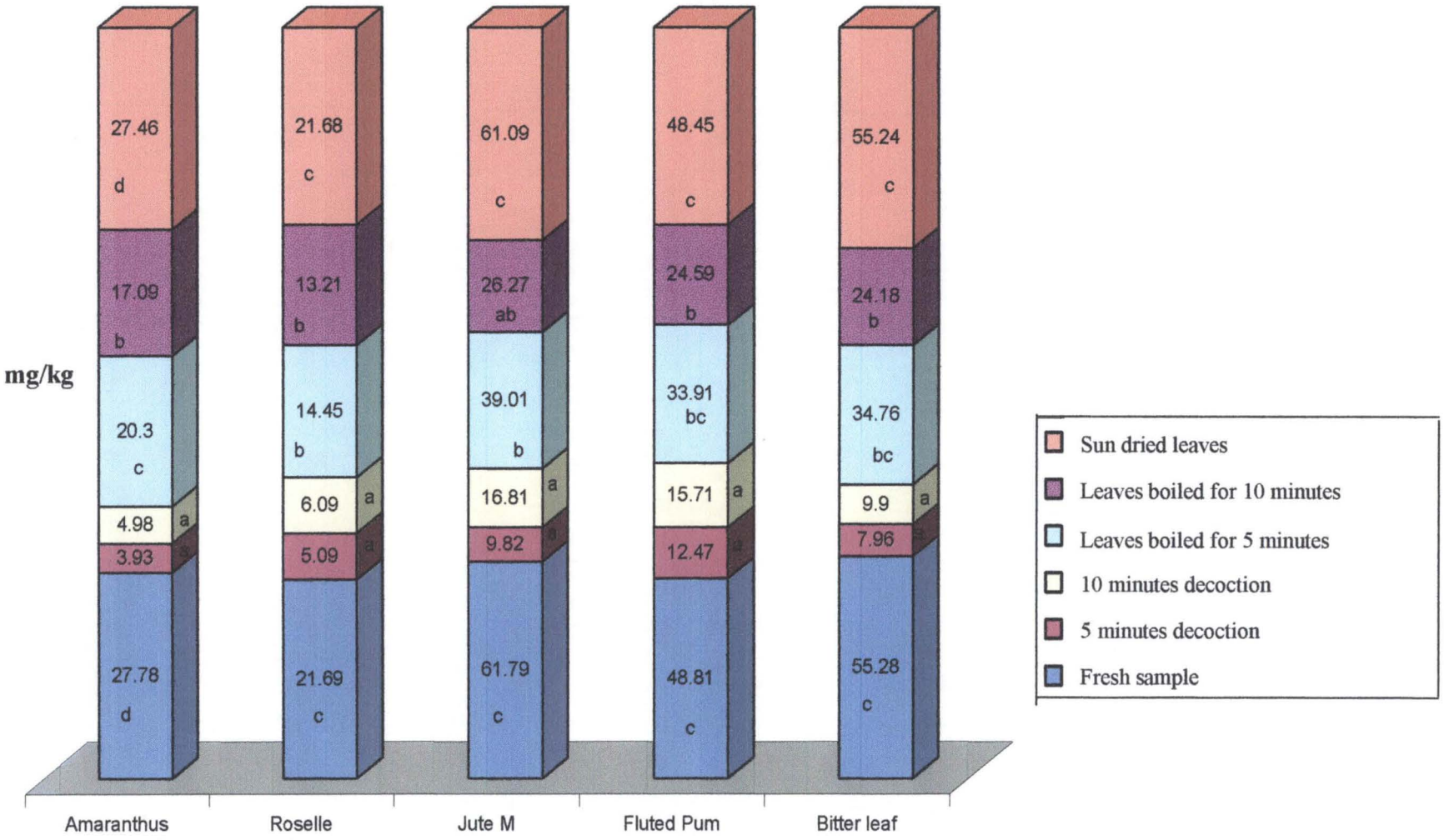


Figure 4.3.3: Effect of processing methods on magnesium content in the different vegetables studied. In each column the mean data carrying the same letter are not significantly different ($P > 0.05$)

4.3.4 Sodium Content

Analysis of Na content of the vegetable samples processed using different methods indicated that the amount of Na in fresh samples were not significantly different ($p > 0.05$) from the level in sundried samples. However, the amount of the mineral in fresh samples was in general significantly ($p < 0.05$) higher than in 5 and 10 minutes boiled vegetable samples. Results obtained from analysis of Na content in *Amaranthus cruentus* showed that the amount of the mineral in fresh sample, 5 minutes decoctoin, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 12.30mg/kg, 1.87mg/kg, 3.08mg/kg, 8.76mg/kg, 7.58mg/kg and 12.27mg/kg respectively (Figure 4.3.2). Data analysis revealed that sundrying had no significant ($p > 0.05$) effect on the Na contents of the vegetable. However, 5 and 10 minutes boiling significantly reduced ($p < 0.05$) the mineral content of the vegetable. The amount of Na in 5 and 10 minutes boiled leaves of *Amaranthus cruentus* were significantly ($p < 0.05$) lower than in the fresh samples. The Na content in 5 and 10 minutes boiled leaves were not significantly different from each other. 5 and 10 minutes decoctions were least in the mineral content. Although the Na content in the two decoctions were not significantly different from each other, 10 minutes decoction had more of the mineral than 5 minutes decoction (as shown in Figure 4.3.4).

Analysis of *Hibiscus sabdariffa* also indicated that the Na content in fresh sample (6.11mg/kg) of the vegetable was not significantly different ($p > 0.05$) from that of sundried sample (5.70m/kg). However, with 5 and 10 minutes boiling, the mineral content decreased significantly ($p < 0.05$) to 3.68mg/kg and 3.17mg/kg respectively. The Na content in 5 and 10 minutes boiled leaves were not significantly different from each

other. The Na content in 5 minutes decoction (2.11mg/kg) and 10 minutes decoctiom (2.61mg/kg) were also not significantly different from each other, but the levels of the mineral was significantly ($p < 0.05$) lower in these samples than in other processed samples (see Figure 4.3.4).

The amount of Na in the various processed samples of *Corchorus olitorius* were as follows: fresh sample (9.03mg/kg), 5 minutes decoction (1.83mg/kg), 10 minutes decoction (2.34mg/kg), leaves boiled for 5 minutes (5.85mg/kg), leaves boiled for 10 minutes (5.33mg/kg) and sundried leaves (8.66mg/kg). The results obtained clearly indicated that sundrying had no significant effect ($p > 0.05$) on the mineral content of vegetable. However 5 and 10 minutes boiling significantly reduced the Na content of the vegetable. The residual Na in leaves boiled for 5 and 10 minutes were not significantly different from each other. 5 and 10 minutes decoctions had the least amount of the mineral compared to other processed samples. The mineral content in the two decoctions were not significantly different from each other (see Figure 4.3.4).

Determination of Na content in the different processed samples of *Telfairia occidentalis* showed that sundrying had no significant effect ($p > 0.05$) on the mineral content of the vegetable. However, the two boiling periods significantly reduced the mineral content of the vegetable. The amount of Na in the processed samples of the vegetable were; fresh sample (11.48mg/kg), 5 minutes decoction (4.68mg/kg), 10 minutes decoction (5.84mg/kg), leaves boiled for 5 minutes (5.10mg/kg), leaves boiled for 10 minutes (4.43mg/kg) and sundried leaves (11.32mg/kg). Data analysis showed that the amount of Na in 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 and

10 minutes were not significantly different ($p > 0.05$) from each other. They had the least content of the mineral than in sundried samples (Figure 4.3.4).

Results from the analysis of *Vernonia amygdalina* showed that the Na profile of the various processed samples of the vegetables to be as follows; fresh sample (8.03mg/kg), 5 minutes deccoction (1.97mg/kg), 10 minutes decoction (2.18mg/kg), leaves boiled for 5 minutes (5.78mg/kg), leaves boiled for 10 minutes (4.74mg/kg) and sundried leaves (8.00mg/kg). The results indicated that 10 minutes of boiling significantly ($p < 0.05$) reduced the mineral content of the vegetable. Sundrying and 5 minutes boiling had no significant effect on the mineral content of the vegetable. The residual Na in the leaves boiled for 5 and 10 minutes were not significantly different from each other. The level of mineral in 5 and 10 minutes decoctions were not significantly different from each other, even though 10 minutes decoctiom had more of mineral content. 5 and 10 minutes decoctions were significantly ($p < 0.05$) lower in the mineral content than in all other processed samples (as shown in Figure 4.3.4).

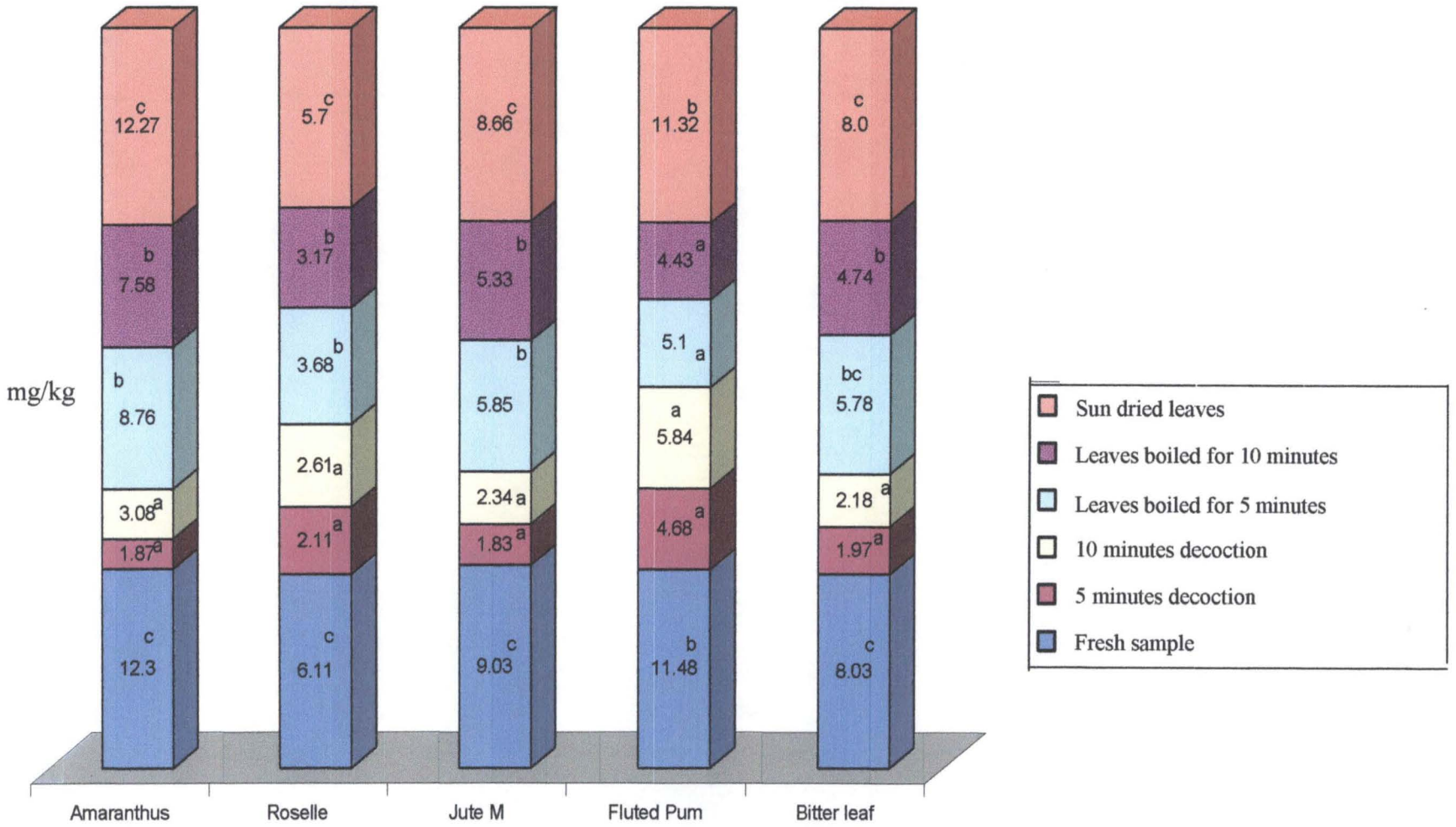


Figure 4.3.4: Effect of processing methods on sodium content in the different vegetables studied. In each column the mean data carrying the same letter are not significantly different (P > 0.05)

4.3.5 Potassium Content.

Analysis of K content of the vegetable samples processed using different methods indicated that the amount of K in fresh samples were not significantly different ($p > 0.05$) from the level in sundried samples. However, the amount of the mineral in fresh samples was significantly higher ($p < 0.05$) than in 5 and 10 minutes boiled vegetable samples. Results obtained from analysis of K content in *Amaranthus cruentus* showed the amount of the mineral in fresh sample, 5 minutes decoction, 10 minutes decoction, and leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 241mg/kg, 109.72mg/kg, 130.07mg/kg, 78.75mg/kg, 60.00mg/kg and 239.50mg/kg respectively (Figure 4.3.5). From the results, sundrying had no significant effect on the K contents of the vegetable. However, 5 and 10 minutes boiling significantly ($p < 0.05$) reduced the mineral content of the vegetable. The amount of K in leaves boiled 5 and 10 minutes were not significantly different from each other. The mineral content in the boiled leaves were significantly ($p < 0.05$) lower than in the decoctions. The K content in 5 and 10 minutes decoctions were also not significantly different from each other.

The amount of K in the various processed samples of *Hibiscus sabdariffa* were as follows: fresh sample (61.88mg/kg), 5 minutes decoction (40.61mg/kg), 10 minutes decoction (43.72mg/kg), leaves boiled for 5 minutes (19.33mg/kg), leaves boiled for 10 minutes (13.25mg/kg) and sundried leaves (55.99mg/kg). The results obtained showed that sundrying had no significant ($p < 0.05$) effect on the mineral content of vegetable. However 5 and 10 minutes boiling significantly ($p < 0.05$) reduced the K content of the vegetable. The residual K in leaves boiled for 5 and 10 minutes were not significantly different from each. The K content in these boiled leaves was significantly ($p < 0.05$)

lower than in their corresponding decoctions. The mineral content in the two decoctions were not significantly different from each other (see Figure 4.3.5).

Results from the analysis of *Corchorius olitorius* revealed that the K content in fresh sample (176.25mg/kg) of the vegetable was not significantly different ($p > 0.05$) from that of sundried sample (175.97m/kg). However, 5 and 10 minutes boiling significantly decreased ($p < 0.05$) the mineral content to 108.75mg/kg and 82.89mg/kg respectively. The K content in the leaves boiled for 5 and 10 minutes were not significantly different from each other. The mineral content in 5 minutes decoction (59.58mg/kg) and 10 minutes decoction (77.02mg/kg) were also not significantly different from each other. The K content in the decoctions and boiled leaves were not significantly different from each other, except that leaves boiled for 5 minutes was significantly ($p < 0.05$) higher in the mineral content than 5 minutes decoction (as shown in Figure 4.3.5).

Analysis of K content in *Telfairia occidentalis* showed that 5 and 10 minutes of boiling significantly reduced ($p < 0.05$) K content of the vegetable. Sundrying, however, had no significant effect on the mineral content. The K content in fresh samples, 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 minutes, leaves boiled for 10 minutes and sundried leaves were 183.92mg/kg, 61.03mg/kg, 84.26mg/kg, 118.13mg/kg, 73.15mg/kg and 182.83mg/kg respectively. The residual K in the leaves boiled for 5 minutes was significantly higher ($p < 0.05$) than in leaves boiled 10 minutes. The mineral content in 5 and 10 minutes decoction were not significantly different from each other (see Figure 4.3.5).

Determination of K content in the different processed samples of *Vernonia amygdalina* revealed that sundrying had no significant effect ($p > 0.05$) on the mineral content of the vegetable. However, 5 and 10 minutes of boiling significantly reduced ($p < 0.05$) the mineral content of the vegetable. The amount of K in the processed samples of the vegetable were; fresh sample (288.92g/kg), 5 minutes decoction (122.61mg/kg), 10 minutes decoction (142.24mg/kg), leaves boiled for 5 minutes (150.00mg/kg), leaves boiled for 10 minutes (121.73mg/kg) and sundried leaves (288.61mg/kg). Data analysis showed that the amount of K in 5 minutes decoction, 10 minutes decoction, leaves boiled for 5 and 10 minutes were not significantly different ($p > 0.05$) from each other (see Figure 4.3.5).

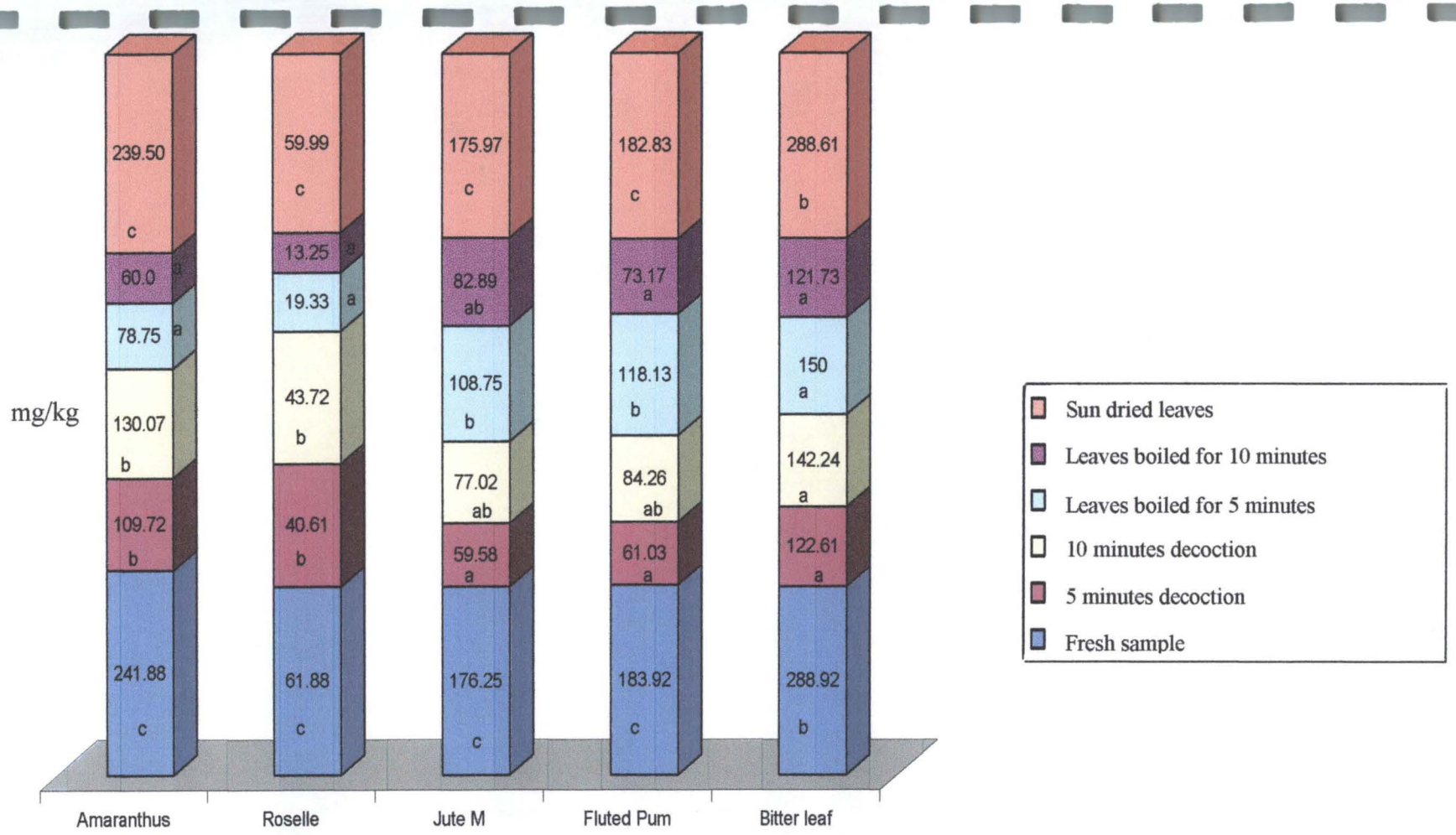


Figure 4.3.5: Effect of processing methods on potassium content in the different vegetables studied. In each column the mean data carrying the same letter are not significantly different ($P > 0.05$)

4.4 Effect of Freezing on Antinutrients and Toxic Substances in Vegetables

4.4.1 Cyanide Content

The results of the determination of cyanide concentrations in fresh and frozen samples of the different vegetables studied showed that cyanide content decreased with freezing. The cyanide concentrations in fresh samples of *Amaranthus cruentus* decreased significantly ($p < 0.05$) after a week of freezing from 88.51mg/kg to 56.59mg/kg (Figure 4.4.1 and Appendix 1). In the subsequent second, third and fourth weeks, the cyanide content also decreased insignificantly with time and the values obtained were 53.27mg/kg, 52.30mg/kg and 46.58mg/kg respectively.

Similarly cyanide levels were also found to decrease with freezing in *Hisbicus sabdariffa*. Significant ($p < 0.05$) reduction of cyanide contents from sample 63.98mg/kg in fresh sample to 50.42mg/kg was observed after two weeks of storage in the refrigerator. The decrease in the first week (54.26mg/kg) was however not significant. The mean values obtained for the third week (57.17mg/kg) and fourth week (47.01mg/kg) also indicated reduction in level which was not significantly different from those of the first and second week (Figure 4.4.1 and Appendix 2).

The decreasing effect of freezing on cyanide content was also observed in *Corchorus olitorius*. The levels determined in fresh, and those frozen for one, two, three and four weeks were 147.77 mg/kg, 67.46 mg/kg, 56.30 mg/kg, 48.74 mg/kg and 47.33mg/kg respectively. The reduction was significant ($p < 0.05$) between the fresh and frozen samples. However, the values observed in the frozen samples were insignificantly different from each other ($p > 0.05$).

Cyanide levels were also found to decrease with freezing in *Telfairia occidentalis*. Significant ($p < 0.05$) reduction of cyanide contents from 170.83mg/kg to 84.51mg/kg was observed after two weeks of storage in the refrigerator. The decrease in the first week (99.45mg/kg) was however not significant ($p > 0.05$). The mean values obtained for the third (70.66mg/kg) and fourth weeks (69.04mg/kg) also indicated reduction in level which was not significantly different from those of the first and second weeks (as shown in Figure 4.4.1 and Appendix 4).

The amount of cyanide in fresh samples of *Vernonia amygdalina* decreased significantly ($p < 0.05$) after a week of freezing from 199.11mg/kg to 69.74mg/kg. In the subsequent second, third and fourth weeks, the cyanide content also decreased insignificantly with time and the values obtained were 58.96mg/kg, 52.80mg/kg and 48.00mg/kg respectively (see Figure 4.4.1 and Appendix 5).

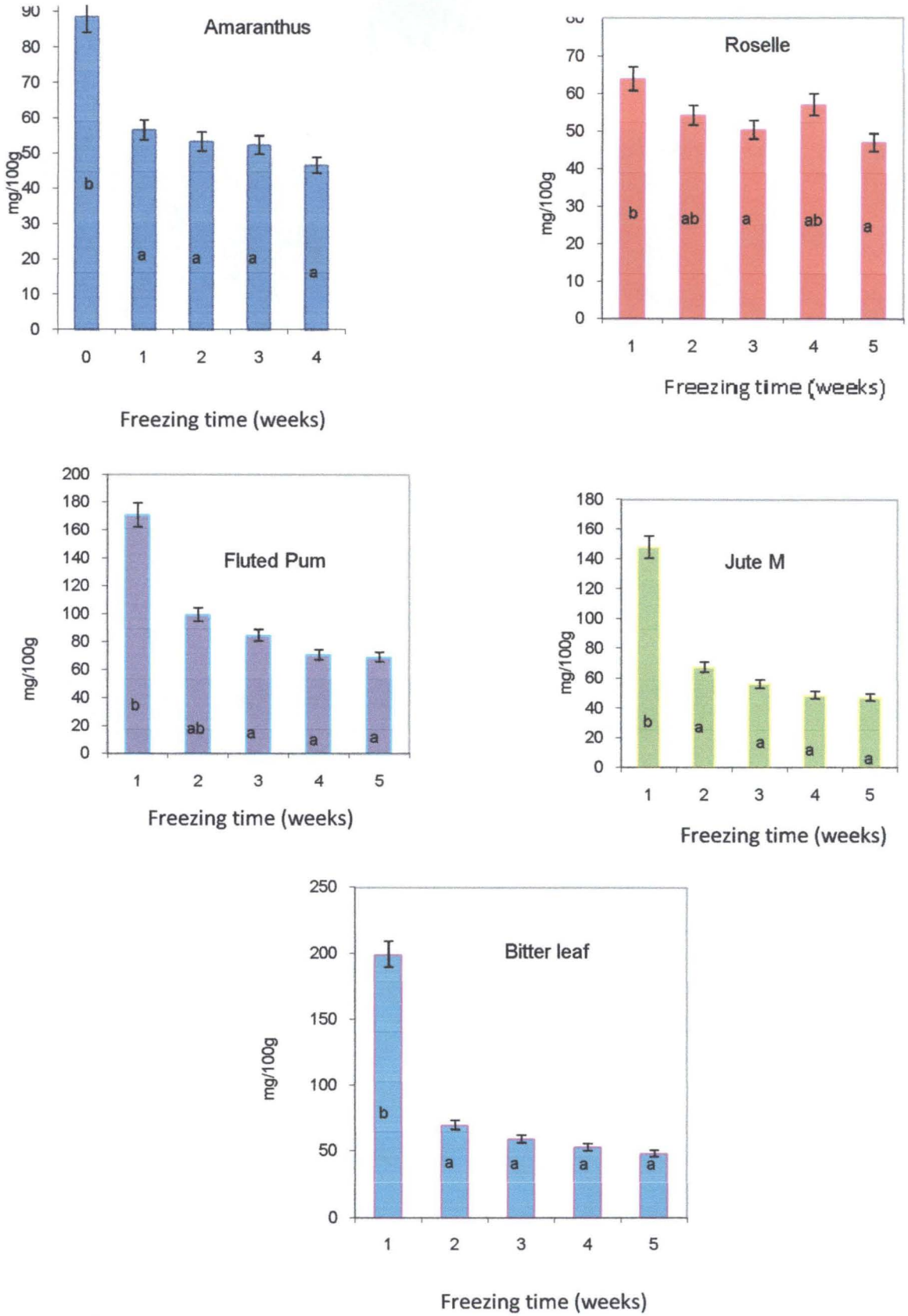


Figure 4.4.1: Effect of freezing time on cyanide content in the different fresh vegetables. In each bar chart, bars with the same letters were not significantly different from each other (P>0.05).

4.4.2 Nitrate content

Results obtained from the analysis of nitrate contents in the fresh and frozen samples of the different vegetables studied indicated that freezing generally decreased the nitrate content of the vegetables. The levels of nitrate in the fresh, and those of one, two, three and four weeks frozen samples of *Amaranthus cruentus* were 4335.22mg/kg, 4263.33mg/kg, 3288.00mg/kg, 3208.43mg/kg and 3149.31mg/kg respectively (Appendix 6). The results revealed that the decreasing effect of freezing on nitrate content in *Amaranthus cruentus* was not significant in one week of freezing. However, after two weeks of freezing the nitrate concentration decreased significantly ($p < 0.05$). The values obtained for third and fourth weeks of freezing also indicated reduction in nitrate levels which were not significantly different ($p > 0.05$) from the second weeks (as shown in Figure 4.4.2).

Similarly nitrate levels were also observed to decrease with freezing in *Hisbicus sabdariffa*. Significant ($p < 0.05$) reduction of nitrate contents from1281.50mg/kg to 800.96mg/kg was noticed after two weeks of storage in the refrigerator. The decrease in the first week (878.72mg/kg) was however not significant. The mean values obtained for the third (678.13mg/kg) and fourth weeks (661.93mg/kg) also indicated reduction in level which was not significantly different ($p > 0.05$) from those of the first and second weeks (see Figure 4.4.2 and Appendix 7).

Analysis of *Corchorus olitorius* also showed that freezing decreased nitrate content of the vegetable. The levels determined in fresh, and those frozen for one, two, three and four weeks were 3107.40 mg/kg 2438.87 mg/kg, 2224.08 mg/kg, 2140.70 mg/kg and 2035.00mg/kg respectively. The reduction was significant ($p < 0.05$) between

the fresh and frozen samples. However, the values observed in the frozen samples were insignificantly different ($p > 0.05$) from each other (as shown in Figure 4.4.2 and Appendix 8).

Nitrate levels were also found to decrease with freezing in *Telfairia occidentalis*. Significant ($p < 0.05$) reduction of nitrate contents from 2799.04mg/kg in fresh sample to 1339.83mg/kg was observed after two weeks of freezing. The decrease in the first week (1514.83mg/kg) was however not significant ($p > 0.05$). The mean values obtained for the third (1072.22mg/kg) and fourth weeks (1035.17mg/kg) also indicated reduction in level which was not significantly ($p > 0.05$) different from those of the first and second weeks (see Figure 4.4.2 and Appendix 9).

The nitrate content of *Vernonia amygdalina* also decreases with freezing time. Significant ($p < 0.05$) reduction in the nitrate concentration from 1347.22mg/kg in fresh sample to 920.57mg/kg was recorded after three weeks of storage in the freezer. The mean value obtained from the fourth weeks (842.26mg/kg) indicated reduction in nitrate content which was not significantly different from second weeks (1069.39mg/kg). The nitrate content in first week (1320.65mg/kg) was however significantly ($p < 0.05$) higher those in the third weeks and fourth weeks (as shown in Figure 4.4.2 and Appendix10).

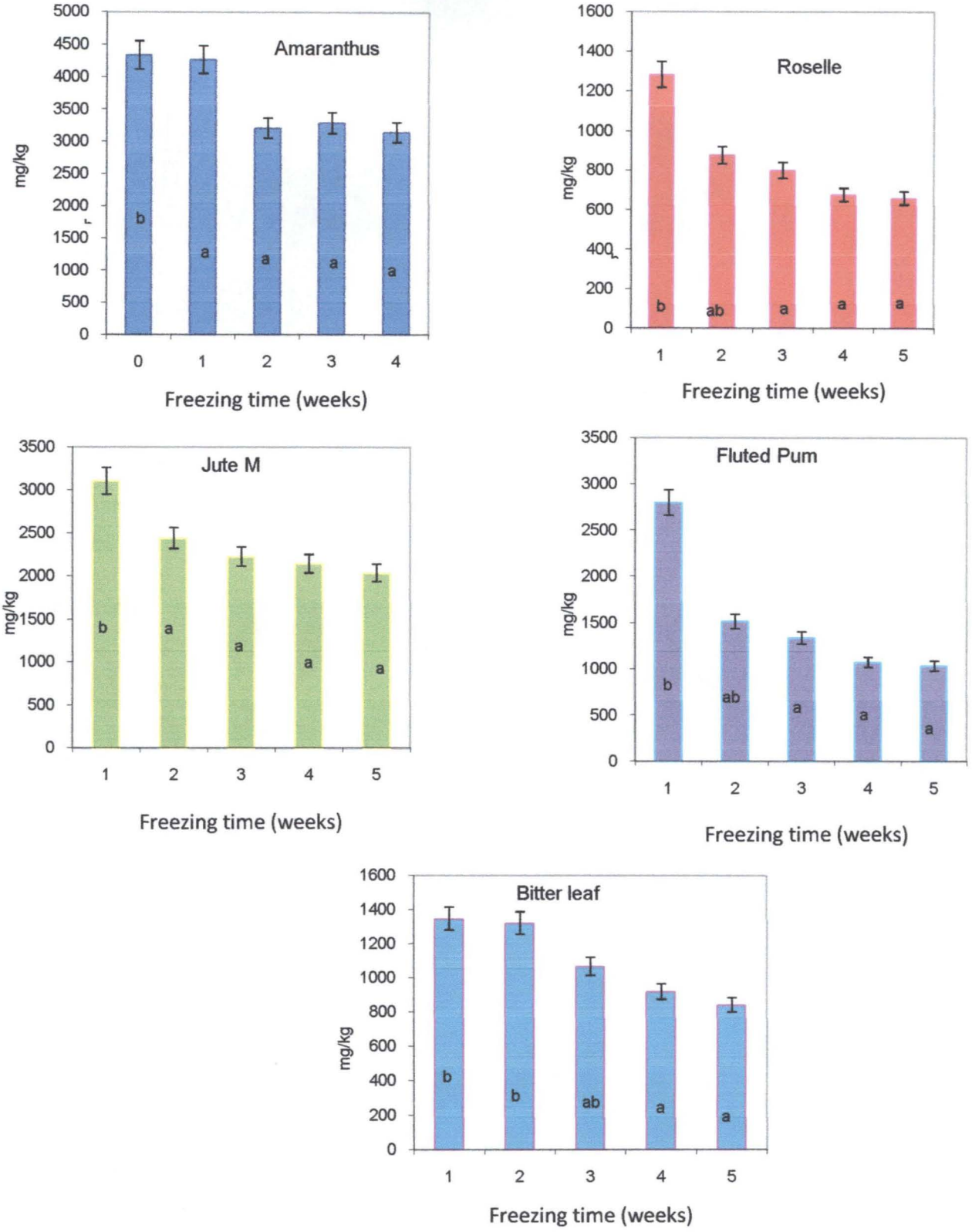


Figure 4.4.2: Effect of freezing time on nitrate content in the different fresh vegetables. In each bar chart, bars with the same letters were not significantly different from each other (P>0.05).

4.4.3 Soluble Oxalate Content.

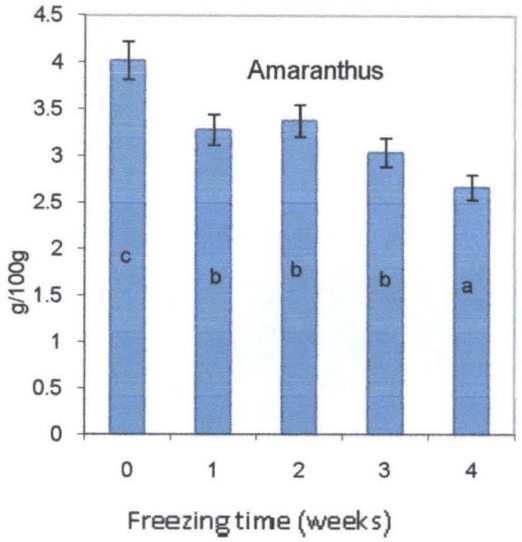
Determination of the effect of freezing on the soluble oxalate content in the different fresh vegetables studied showed that the oxalate content in leafy vegetables decline with freezing time. In *Amaranthus cruentus* the soluble oxalate levels in fresh and those of one, two, three and four weeks frozen samples were 4.02g/kg, 3.28g/kg, 3.38g/kg, 3.04g/kg and 2.67g/kg respectively. The results obtained revealed that the soluble oxalate content of the vegetable decreased significantly ($p < 0.05$) in the first week of storage and remain significantly unchanged ($p > 0.05$) for second and third weeks until the fourth weeks where a significant decreased ($p < 0.05$) was again observed (see Figure 4.4.3 and Appendix 11).

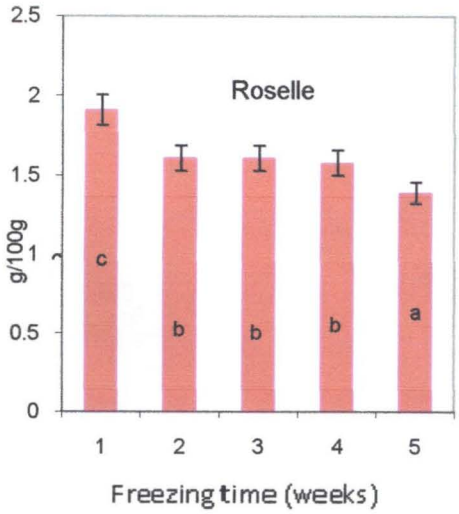
Similarly soluble oxalate levels were also found to decrease with freezing in *Hisbicus sabdariffa*. Significant reduction ($p < 0.05$) of soluble oxalate contents from 1.91g/kg to 1.61g/kg was observed after one week of storage in the refrigerator. In the subsequent second and third weeks, the soluble oxalate also decreased insignificantly with storage time and the values obtained were 1.6og/kg and 1.58g/kg respectively. The fourth weeks of freezing led to a significant reduction ($p < 0.05$) of the oxalate concentration to 1.39g/kg (Figure 4.4.3 and Appendix 12).

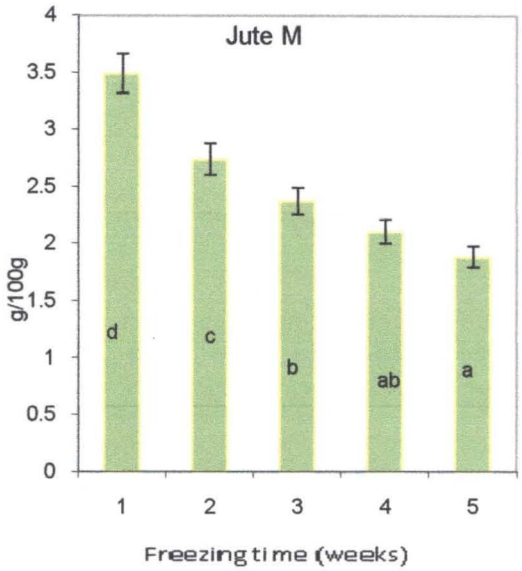
The soluble oxalate concentrations in fresh samples of *Corchorus olitorius* decreased significantly ($p < 0.05$) after one and two weeks of freezing from 3.49g/kg to 2.74g/kg and 2.37g/kg respectively. The soluble oxalate level in the third weeks (2.10g/kg) was not significantly different ($p > 0.05$) from the second and fourth weeks (1.88g/kg). However, second weeks frozen sample had significant higher ($p < 0.05$) content of the parameter than the fourth weeks (Figure 4.4.3 and Appendix 13).

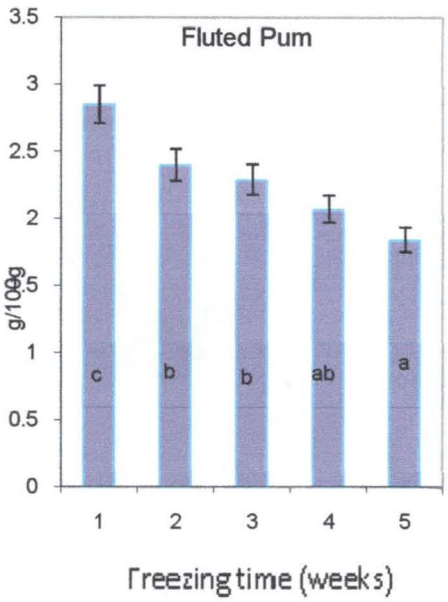
Analysis of soluble oxalate content in *Telfairia occidentalis* showed a decrease in the oxalate level with freezing time. Significant reduction ($p < 0.05$) in the parameter from 2.85g/kg in fresh sample to 2.40g/kg was recorded in one week of freezing. The mean value obtained from the second weeks (2.29g/kg), third weeks (2.07g/kg) and fourth weeks (1.84g/kg) freezing also indicated reduction in soluble oxalate content. While the reduction in third weeks was not significantly different from second and fourth weeks, however, the oxalate content in the fourth weeks of frozen sample was significantly ($p> 0.05$) lower than second weeks (as shown in Figure 4.4.3 and Appendix14).

The amount of soluble oxalate in fresh samples of *Vernonia amygdalina* decreased significantly ($p < 0.05$) after a week of freezing from 2.85g/kg to 1.76g/kg. In the subsequent second, third and fourth weeks of freezing, the oxalate content also decreased insignificantly ($p > 0.05$) with time and the values obtained were 1.62g/kg, 1.50g/kg and 1.31g/kg respectively (see Figure 4.4.3 and Appendix 15).









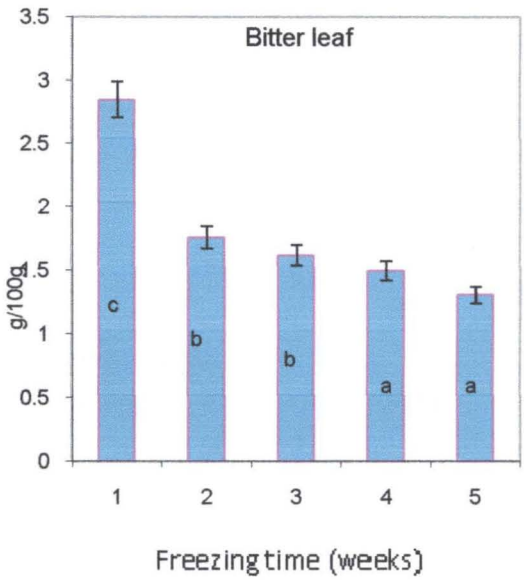


Figure 4.4.3: Effect of freezing time on soluble oxalate content in the different fresh vegetables. In each bar chart, bars with the same letters were not significantly different from each other (P>0.05).

4.4.4 Total Oxalate Content

Determination of total oxalate concentrations in fresh and frozen samples of the different vegetables studied showed that cyanide content decreases with freezing. The total oxalate concentrations in fresh samples of *Amaranthus cruentus* decreased significantly ($p < 0.05$) after a week of freezing from 7.99g/kg to 6.27g/kg. In the subsequent second, third and fourth weeks, the total oxalate content also decreased insignificantly with time and the values obtained were 6.15g/kg, 5.74g/kg and 5.02g/kg, respectively (as shown in Figure 4.4.4 and Appendix 11).

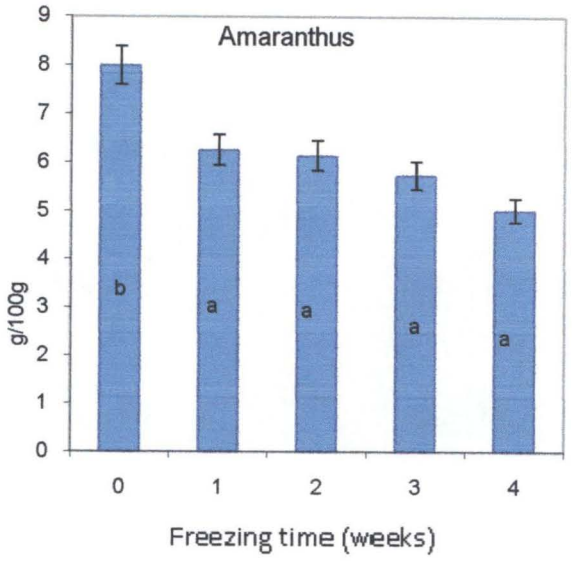
The decreasing effect of freezing on total oxate content was also observed in *Hibiscus sabdariffa.* The levels determined in fresh, and those frozen for one, two, three and four weeks were 4.35g/kg, 3.56g/kg, 3.52g/kg, 3.26g/kg and 3.22g/kg, respectively. The reduction was significant ($p < 0.05$) between the fresh and frozen samples. However, the values observed in the frozen samples were insignificantly different ($p > 0.05$) from each other.

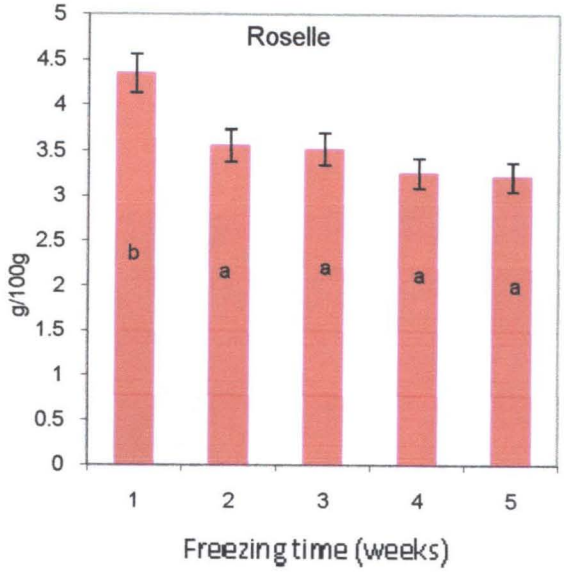
The total oxalate content in fresh samples of *Corchorus olitorius* decreased significantly ($p < 0.05$) after one and two weeks of freezing from 5.85g/kg to 4.88g/kg and 4.67g/kg respectively. The oxalate level in the third weeks (4.24g/kg) was not significantly different ($p > 0.05$) from the second and fourth weeks (4.0g/kg). However, second weeks frozen sample had significant higher ($p > 0.05$) content of the parameter than the fourth weeks (see Figure 4.4.4 and Appendix 13).

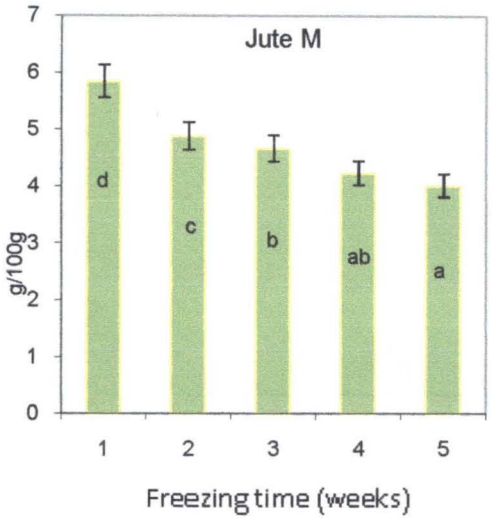
Analysis of total oxalate content in fresh samples of *Telfairia occidentalis* revealed that the oxalate level decreased significantly ($p < 0.05$) after a week of freezing from 4.39g/kg to3.12g/kg. In the subsequent second, third and fourth weeks, the oxalate

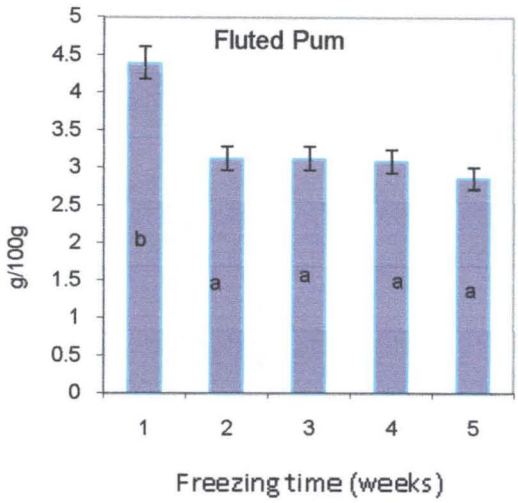
content also decreased insignificantly ($p > 0.05$) with time and the values obtained were3.12g/kg,3.08g/kg and 2.86g/kg respectively (as shown in Figure 4.4.4 and Appendix 14).

The reducing effect of freezing on total oxalate content was also recorded in *Vernonia amygdalina.* The levels observed in fresh sample, and those frozen for one, two, three and four weeks were 4.76g/kg, 3.08g/kg, 2.55g/kg, 2.26g/kg and 2.25g/kg respectively. The reduction was significant ($p > 0.05$) between the fresh and frozen samples. However, the values observed in the frozen samples were insignificantly different from each other ($p > 0.05$).









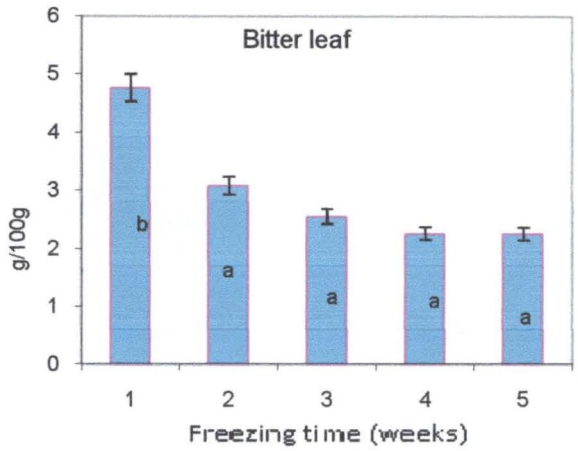


Figure 4.4.4: Effect of freezing time on total oxalate content in the different fresh vegetables. In each bar chart, bars with the same letters were not significantly different from each other (P>0.05).

4.5 Effect of Freezing on vitamins content in the vegetables

4.5.1 β-carotene Content

Determination of β-carotene content in fresh and frozen samples of the different vegetable studied revealed that freezing generally reduce the provitamin content in the all vegetables. The results obtained from the analysis of β-carotene content in *Amaranthus cruentus* showed a decrease in the level of carotenoid with freezing time. Significant reduction ($p < 0.05$) in the provitamin from 11956.80 µg/100g in fresh sample to 9557.00 µg/100g was observed in one week of freezing. The mean value obtained from the second weeks (9088.00 µg/100g), third weeks (8381.70 µg/100g) and fourth weeks (7067.30 µg/100g) of freezing also indicated reduction in β-carotene content. While the reduction in third weeks was not significantly different from second and fourth weeks, the provitamin content in the fourth weeks of freezing was significantly ($p < 0.05$) lower than second weeks (see Figure 4.5.1 and Appendix1).

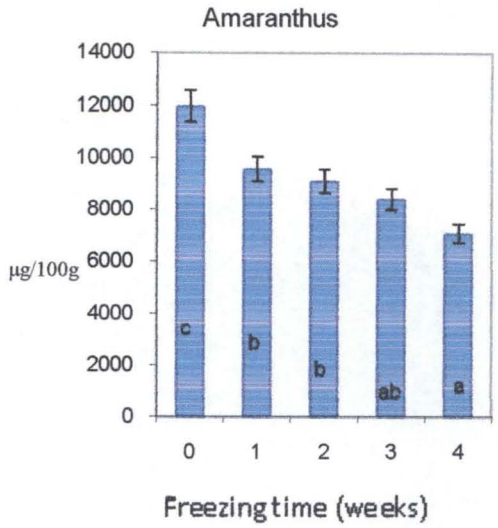
Similarly β-carotene levels were also found to decrease with freezing in *Hisbicus sabdariffa*. Significant ($p < 0.05$) decline of carotenoid contents from 8772.67 µg/100g to 4551.00 µg/100g was observed after two weeks of storage in the refrigerator. The decrease in the first week (6249.00 µg/100g) was however not significant. The level of β-carotene obtained for the third (3891.63 µg/100g) and fourth weeks (3814.67 µg/100g) indicated reduction in level of the provitamin which were not significantly different from those of the first and second weeks freezing (as shown in Figure 4.5.1 and Appendix 2).

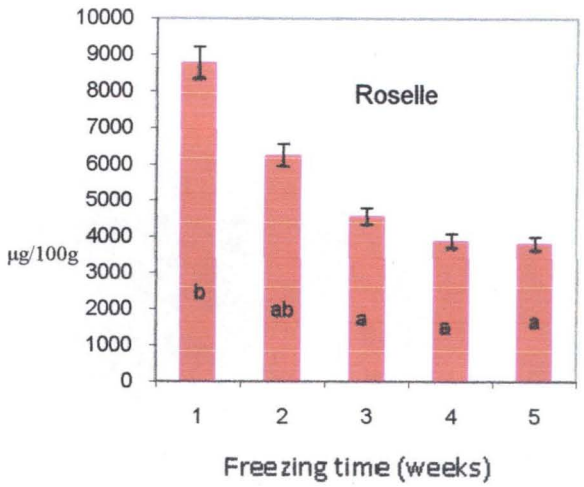
The decreasing effect of freezing on β-carotene content was also observed in *Corchorus olitorius*. The levels determined in fresh, and those frozen for one, two, three and four weeks were 18432.30 µg/100g, 16303.30 µg/100g, 15341.70 µg/100g,

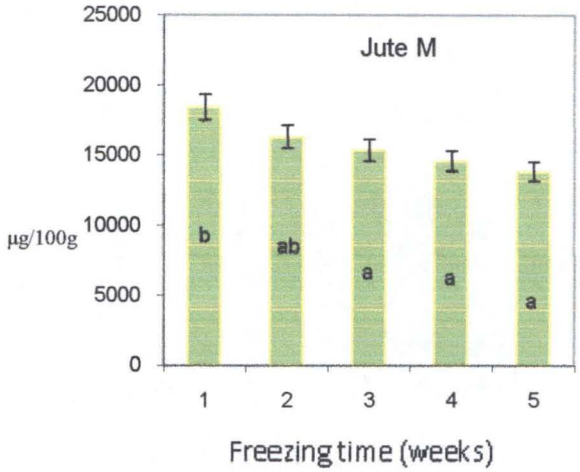
14571.70 µg/100g and 13834.70 µg/100g, respectively. The reduction in carotenoid after one week of freezing was insignificant. However, data analysis of the subsequent second, third and fourth weeks of storage in the refrigerator showed a significant ($p < 0.05$) declined of the provitamin. The observed values of the β-carotene in the frozen samples were insignificantly different from each other (as shown in Figure 4.5.1 and Appendix 3).

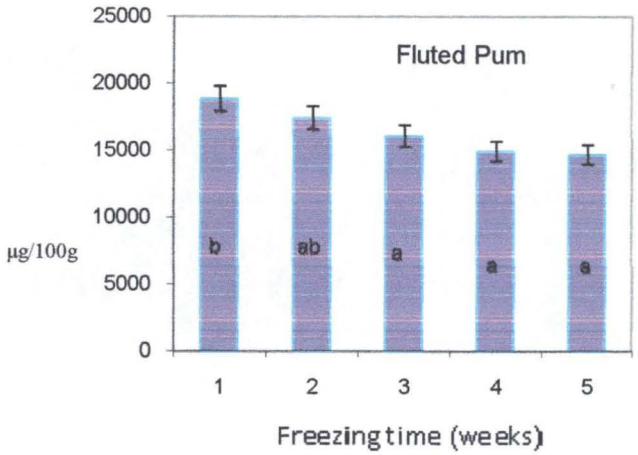
In *Telfairia occidentalis* the β-carotene contents of fresh sample (18859.00µg/100g) decreased significantly ($p < 0.05$) in the second weeks (16072.00 µg/100g) of storage in refrigerator. The decrease in the first week (17427.00 µg/100g) was however not significant. The values obtained for the third (14941.70 µg/100g) and fourth weeks (14690µg/100g) also indicated reduction in level which was not significantly different from those of the first and second weeks (as shown in Figure 4.5.1 and Appendix 4).

Similarly the provitamin contents were also found to decrease with freezing in *Vernonia amygdalina*. Significant reduction of β-carotene contents from 19515.30µg/100g to 15837.30µg/100g was observed after two weeks of freezing. The decrease in the first week (16528.30 µg/100g) was however not significant. The mean values obtained for the third weeks (14490.70µg/100g) and fourth weeks (11940.00µg/100g) also indicated reduction in level which was not significantly different from those of the first and second weeks (see Figure 4.5.1 and Appendix 5).









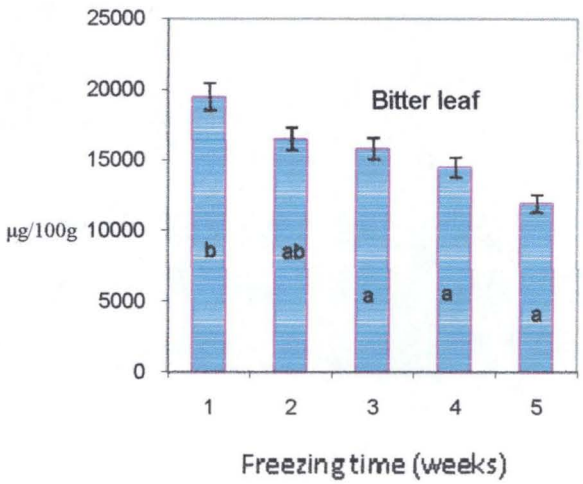


Figure 4.5.1: Effect of freezing time on β-carotene content in the different fresh vegetables. In each bar chart, bars with the same letters were not significantly different from each other (P>0.05).

4.5.2 Vitamin C Content.

The results of the determination of vitamin C concentrations in fresh and frozen samples of the different vegetables studied showed that vitamin C content decreases with freezing. The vitamin concentrations in fresh samples of *Amaranthus cruentus* decreased significantly ($p < 0.05$) after one week of freezing from 69.35mg/100g to 13.34mg/100g (Figure 4.5.2 and Appendix 1). In the second, third and fourth weeks, the vitamin C content also decreased insignificantly with time and the values obtained were 11.21mg/100g, 10.14mg/100g and 10.14mg/100g, respectively.

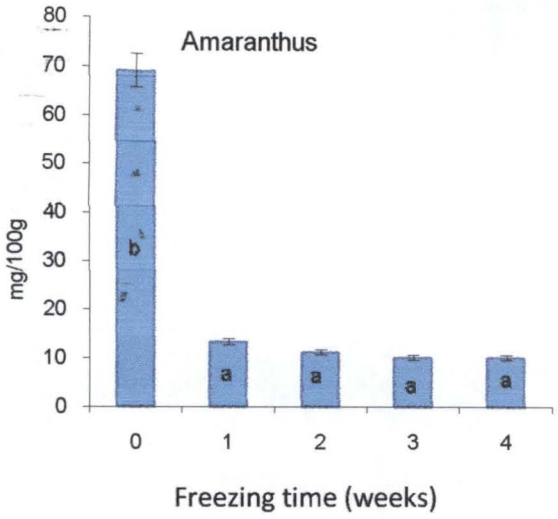
The decreasing effect of freezing on vitamin C content was also observed in *Hibiscus sabdariffa.* The levels determined in fresh, and those frozen for one, two, three and four weeks were 27.44mg/100g, 12.91 mg/100g, 11.06 mg/100g, 10.49 mg/100g and 9.46mg/100g respectively. The reduction was significant ($p < 0.05$) between the fresh and frozen samples. However, the values observed in the frozen samples were insignificantly different (as shown in Figure 4.5.2 and Appendix 2).

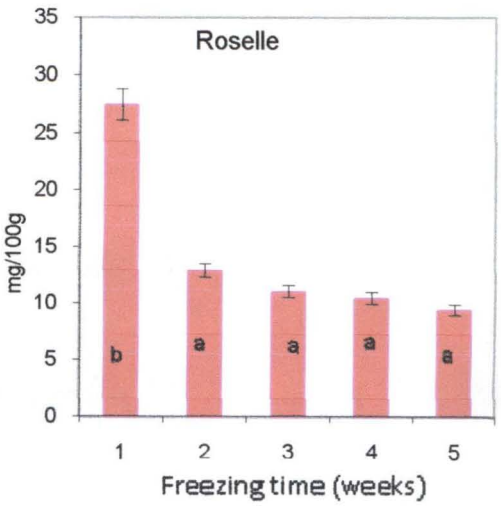
The amount of vitamin C in fresh samples of *Corchorus olitorius* decreased significantly ($p < 0.05$) after a week of freezing from 78.90mg/100g to 16.43mg/100g. In the subsequent second, third and fourth weeks, the vitamin C content also decreased insignificantly with time and the values obtained were 14.34mg/100g, 12.05mg/100g and 10.96mg/100g respectively (see Figure 4.5.2 and Appendix 3).

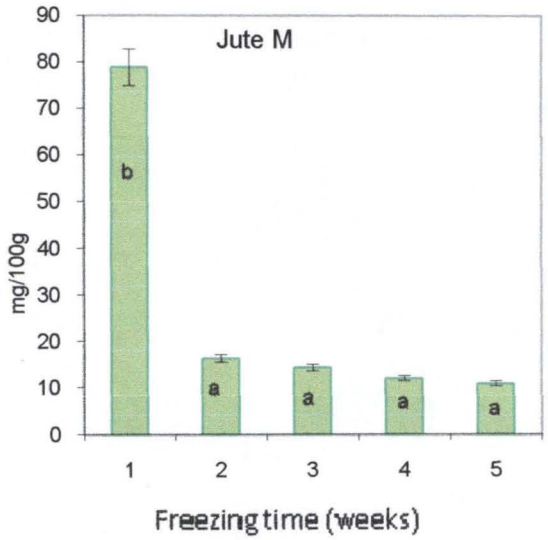
Analysis of vitamin C content in fresh samples of *Telfairia occidentalis* revealed that the vitamin level decreased significantly ($p < 0.05$) after a week of freezing from 192.28mg/100g to 19.15mg/100g. The levels recorded in the second, third and fourth weeks, indicates a decreased in vitamin content with increased in freezing period

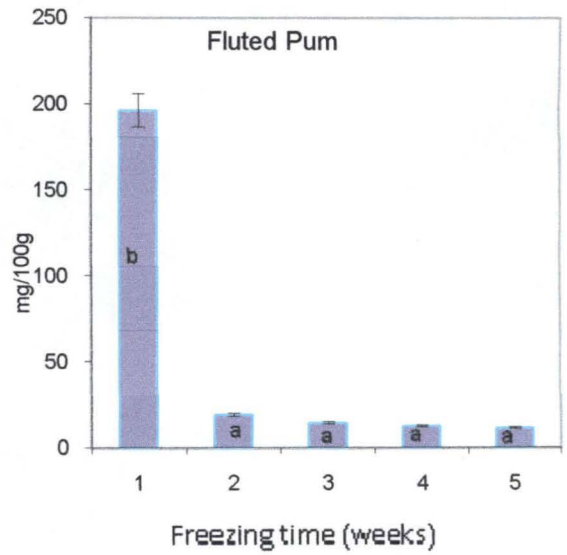
though it was insignificant ($p > 0.05$) and the values obtained were 14.24mg/100g,12.60mg/100g and 11.50mg/100g, respectively (as shown in Figure 4.5.2 and Appendix 4).

The vitamin C concentrations in fresh samples of *Vernonia amygdalina* decreased significantly ($p < 0.05$) after a week of freezing from 30.68mg/100g to 14.25mg/100g. In the subsequent second, third and fourth weeks, the vitamin content also decreased insignificantly with time and the values obtained were 10.95mg/100g, 10.95mg/100g and 9.86mg/100g, respectively (see Figure 4.5.2 and Appendix 5).









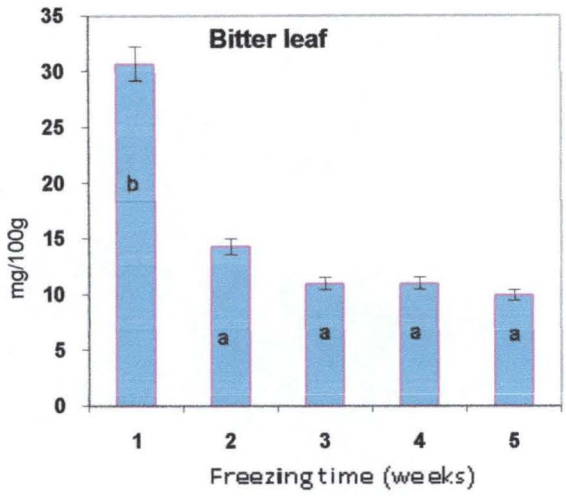


Figure 4.5.2: Effect of freezing time on vitamin C content in the different fresh vegetables. In each bar chart, bars with the same letters were not significantly different from each other (P>0.05).

4.6. Effect of Freezing on Mineral Elements content in the Vegetables

4.6.1 Iron Content

Results obtained from the analysis of Fe content in fresh and frozen samples of the different studied Nigerian leafy vegetables showed that freezing generally reduced the mineral content of the vegetables. In *Amaranthus cruentus* the Fe levels in fresh and those of one, two, three and four weeks frozen samples were 19.20mg/kg, 17.90mg/kg, 17.08mg/kg, 14.60mg/kg and 13.16mg/kg, respectively. The results obtained revealed that the Fe content of the vegetable decreased significantly ($p < 0.05$) in the first week of storage and remain insignificantly ($p > 0.05$) unchanged for second weeks until the third weeks where a significant ($p < 0.05$) decreased was again observed. The decreased in level of the mineral recorded in fourth weeks of freezing was insignificant from third weeks (as shown in Figure 4.6.1. and Appendix 16).

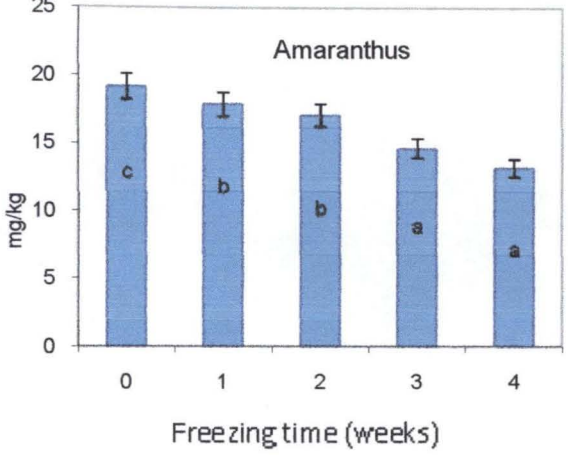
The Fe content of *Hibiscus sabdariffa* also decreases with freezing time. Significant ($p < 0.05$) reduction in the mineral concentration from 18.51mg/kg in fresh sample to 15.55mg/kg was recorded after three weeks of storage. The mean value obtained from the fourth weeks (14.45mg/kg) indicated reduction in Fe content which was not significantly different from second weeks (16.91mg/kg). The mineral content in first week (17.56mg/kg) was however, significantly ($p < 0.05$) higher than those in the third weeks and fourth weeks (see Figure 4.6.1 and Appendix 17).

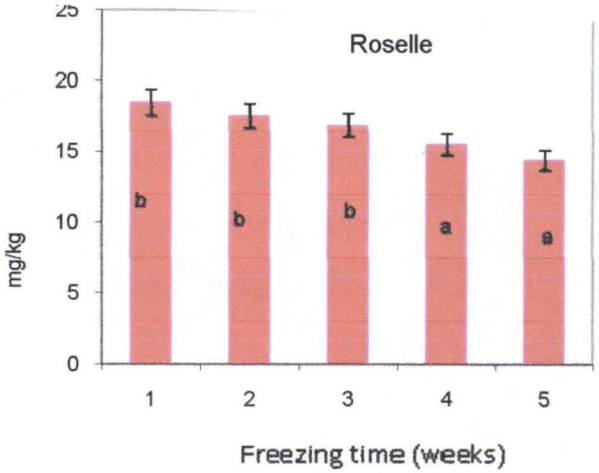
The levels of Fe in the fresh, and those of one, two, three and four weeks frozen samples of *Corchorus olitorius* were 26.03mg/kg, 25.47mg/kg, 20.64mg/kg, 19.03mg/kg and 19.03mg/kg, respectively (as shown in Appendix 18). The results revealed that the decreasing effect of freezing on Fe content in *Corchorus olitorius* was

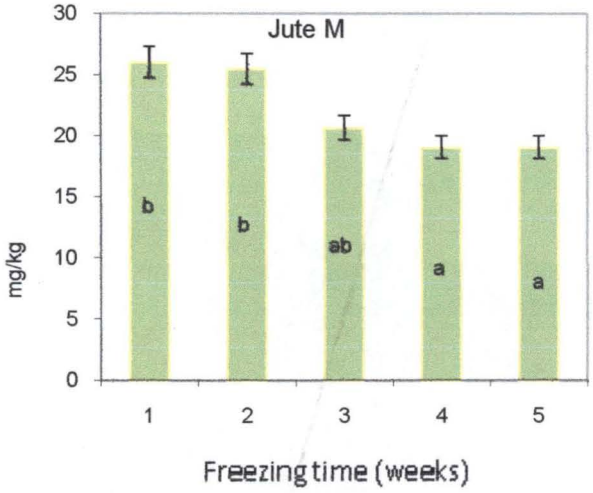
not significant in one week of freezing. However, after two weeks of freezing the mineral concentration decreased significantly ($p < 0.05$). The values obtained for third and fourth weeks of freezing also indicated reduction in nitrate levels which were not significantly different ($p > 0.05$) from the second weeks (see Figure 4.6.1).

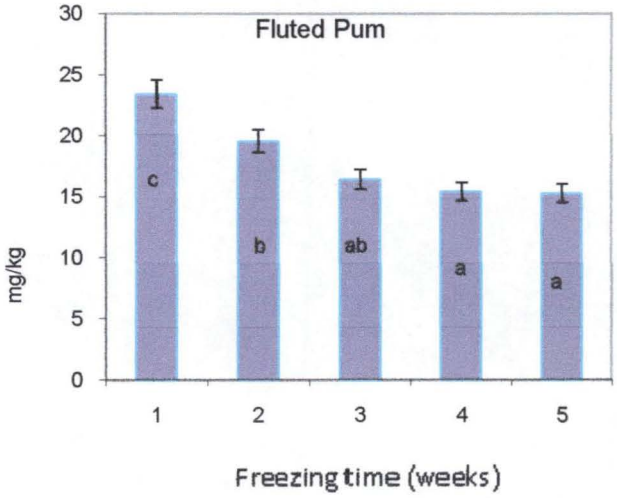
The results obtained from the analysis of Fe content in *Telfairia occidentalis* showed a decrease in the level of the mineral with freezing time. Significant reduction ($p < 0.05$) in the Fe concentration from 23.43mg/kg in fresh sample to 19.55mg/kg was observed in one week of freezing. The mean value obtained from the second weeks (19.55mg/kg), third weeks (16.41mg/kg) and fourth weeks (15.41mg/kg) of freezing also indicated reduction in mineral content. While the reduction in third weeks was not significantly different from second and fourth weeks, the Fe content in the fourth weeks of freezing was significantly ($p < 0.05$) lower than second weeks.(Figure 4.6.1 and Appendix19).

Similarly the Fe contents were also found to decrease with freezing in *Vernonia amygdalina*. Significant ($p < 0.05$) reduction of the mineral contents from 26.77mg/kg to 21.43mg/kg was observed after three weeks of freezing. The decrease in the first week (23.44mg/kg) and second weeks (23.03mg/kg) were however not significant. The mean values obtained for the fourth weeks (18.76mg/kg) also indicated reduction in level which was not significantly different from those of the first second and third weeks (as shown in Figure 4.6.1 and Appendix 20).









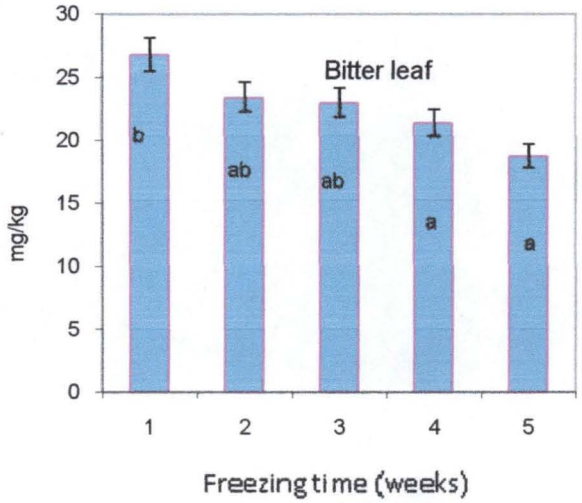


Figure 4.6.1: Effect of freezing time on iron content in the different fresh vegetables. In each bar chart, bars with the same letters were not significantly different from each other (P>0.05).

4.6.2 Copper Content

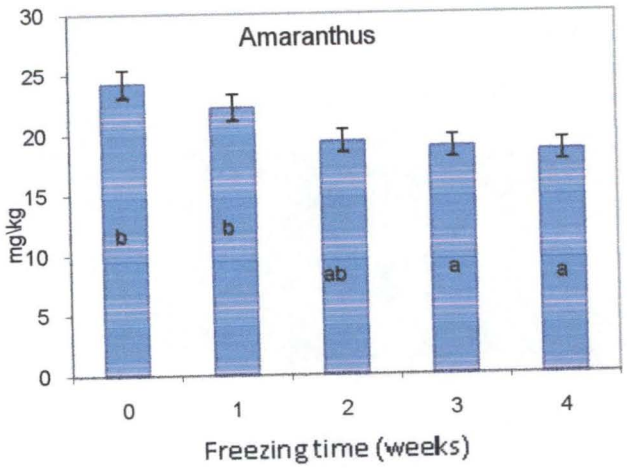
The results of the determination of Cu concentrations in fresh and frozen samples of the different vegetables studied also showed a general decreased in the mineral content with increasing freezing duration. Whereas the decrease observed with some vegetables were significant, with other vegetables the reduction in the mineral content throughout freezing period was not significant. The Cu content of *Amaranthus cruentus* also decreases with freezing time. Significant ($p < 0.05$) reduction in the mineral concentration from 24.24mg/kg in fresh sample to 18.89mg/kg was recorded after three weeks of freezinng. The mean value obtained from the fourth weeks (18.54mg/kg) indicated reduction in Cu content which was not significantly different from second weeks (16.91mg/kg). The mineral content in first week (22.22mg/kg) was however significantly higher ($p < 0.05$) than those in the third weeks and fourth weeks of freezing (see Figure 4.6.1 and Appendix 21).

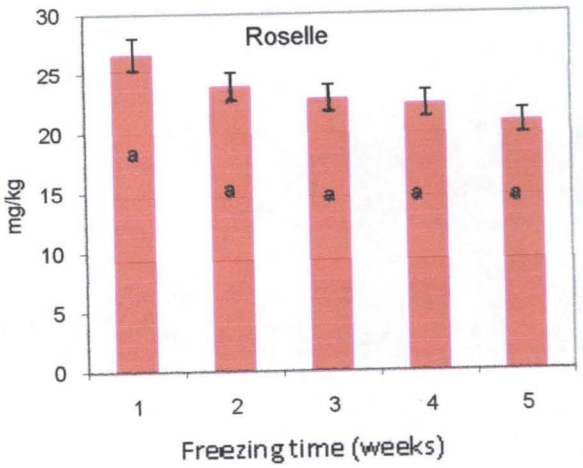
The decreasing effect of freezing on Cu content was also observed in *Hibiscus sabdariffa*. The levels determined in fresh, and those frozen for one, two, three and four weeks were 26.67mg/kg, 23.89mg/kg, 22.83mg/kg, 22.34mg/kg and 20.84mg/kg, respectively. Data analysis showed that the reduction of the mineral content in the vegetable during freezing period was not significant (Figure 4.6.2 and Appendix 22).

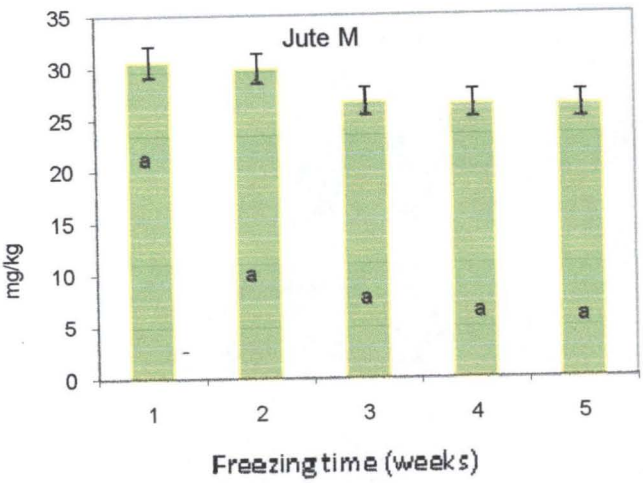
Similarly insignificant ($p > 0.05$) decreased in the Cu level in *Corchorus olitorius* and *Telfairia occidentalis* during storage in the refrigerator was recorded. The mean values obtained in fresh, and those frozen for one, two, three and four weeks in *Corchorus olitorius* were 30.56mg/kg, 28.98mg/kg, 26.64mg/kg, 26.40mg/kg and 26.26mg/kg respectively (as shown in Figure 4.6.2 and Appendix 23). While the mean

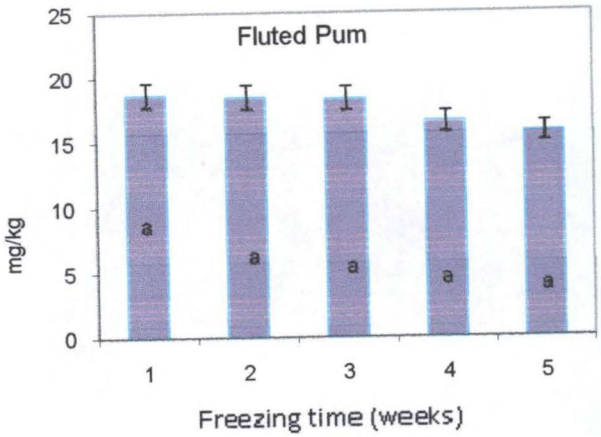
values for fresh, and those frozen one, two, three and four weeks in *Telfairia occidentalis* were 18.70mg/kg, 18.48mg/kg, 18.35mg/kg, 16.59mg/kg and 15.76mg/kg, respectively (see Figure 4.6.2 and Appendix 24).

The Cu levels were also found to decrease with freezing in *Vernonia amygdalina*. Significant ($p < 0.05$) reduction of Cu contents from 36.70mg/kg in fresh sample to 24.74mg/kg was observed after two weeks of freezing. The decrease in the first week (30.85mg/kg) was however not significant. The values obtained for the third weeks (26.63mg/kg) and fourth weeks (22.98mg/kg) also indicated reduction in level of the mineral which were not significantly different from those of the first and second weeks (as shown in Figure 4.6.2 and Appendix 25).









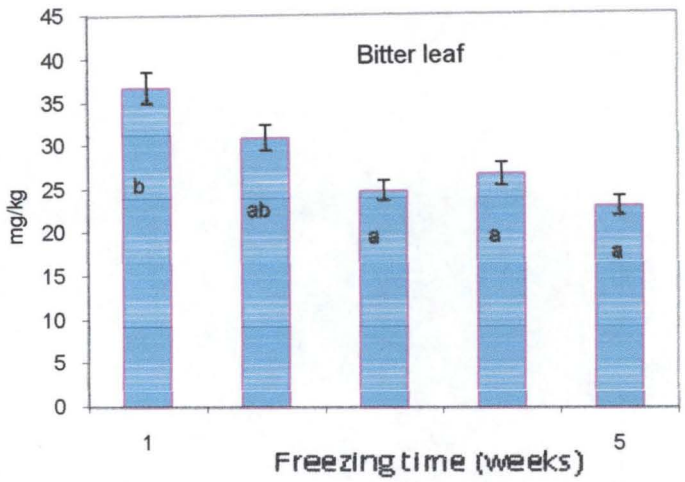


Figure 4.6.2: Effect of freezing time on copper content in the different fresh vegetables. In each bar chart, bars with the same letters were not significantly different from each other (P>0.05).

4.6.3 Magnesium Content

Results obtained from the analysis of Mg content in the different vegetables studied indicated that the Mg content decreases generally with freezing. The levels of Mg in the fresh, and those of one, two, three and four weeks frozen samples of *Amaranthus cruentus* were 27.78mg/kg, 26.44mg/kg, 23.97mg/kg, 22.90mg/kg and 22.21mg/kg, respectively (see Appendix 22). The results showed that the decreasing effect of freezing on Mg content in *Amaranthus cruentus* was not significant in one week of freezing. However, after two weeks of freezing the mineral concentration decreased significantly ($p < 0.05$). The values obtained for third and fourth weeks of freezing also indicated reduction in Mg levels which were not significantly ($p > 0.05$) different from the second weeks (see Figure 4.6.3).

The amount of Mg in fresh samples of *Hibiscus sabdariffa* decreased significantly after a week of freezing from 21.69mg/kg to 17.09mg/kg. In the subsequent second, third and fourth weeks, the Mg content also decreased insignificantly with time and the values obtained were 16.50mg/kg, 15.39mg/kg and 14.73mg/kg, respectively (as shown in Figure 4.6.3 and Appendix 27).

The concentrations of Mg in the fresh sample of *Corchorus olitorius* (61.79mg/kg), and those samples of the vegetable frozen for one week (59.26mg/kg), two weeks (54.24mg/kg), three weeks (52.44mg/kg) and four weeks (51.72mg/kg) indicated that the decreasing effect of freezing on Mg content in the vegetable was not significant in one week of freezing. However, after two weeks of freezing, the mineral content decreased significantly ($p < 0.05$). The values obtained for third and fourth weeks of

freezing also signified reduction in Mg levels which were not significantly different ($p > 0.05$) from the second weeks (as shown in Figure 4.6.3 and Appendix 28).

The Mg content of *Telfairia occidentalis* also decreases with freezing time. Significant reduction ($p < 0.05$) in the mineral concentration from 48.81mg/kg in fresh sample to 39.26mg/kg was observed after three weeks of storage in the freezer. The mean value obtained from the fourth weeks (37.57mg/kg) indicated reduction in Mg content which was not significantly different from second weeks (41.05mg/kg). The mineral content in first week (47.19mg/kg) was however significantly higher compared to those in the third weeks and fourth weeks (see Figure 4.6.3 and Appendix 29).

The levels of Mg in the fresh, and those of one, two, three and four weeks frozen samples of *Vernonia amygdalina* were 55.28mg/kg, 50.49mg/kg, 37.28mg/kg, 34.28mg/kg and 34.06mg/kg, respectively. The results showed that the decreasing effect of freezing on Mg content of vegetable was not significant in one week of freezing. However, after two weeks of freezing the Mg content decreased significantly ($p < 0.05$). The values obtained for third and fourth weeks of freezing also indicated reduction in Mg levels which were not significantly different ($p > 0.05$) from the second weeks (see Figure 4.6.3 and Appendix 30).

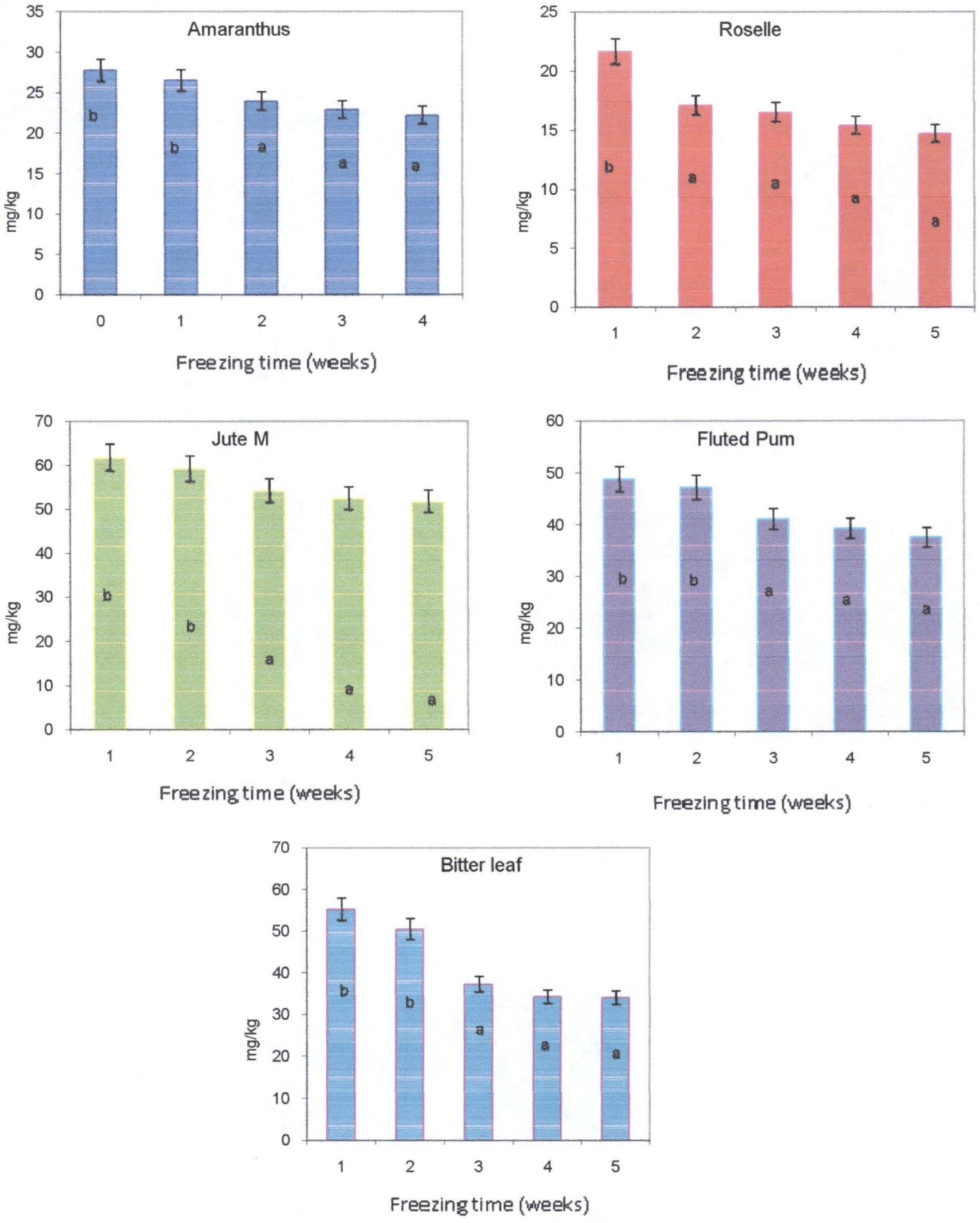


Figure 4.6.3: Effect of freezing time on magnesium content in the different fresh vegetables. In each bar chart, bars with the same letters were not significantly different from each other (P>0.05).

4.6.4 Sodium Content

The effect of freezing on sodium content in the different vegetables studies also indicated a general decreased in the mineral content with increasing freezing duration. The concentrations of Na in the fresh sample of *Amaranthus cruentus* (12.30mg/kg), and those samples of the vegetable frozen for one week (11.50mg/kg), two weeks (10.50mg/kg), three weeks (9.90mg/kg) and four weeks (9.53mg/kg) showed that the decreasing effect of freezing on mineral content in the vegetable was not significant in one week of freezing. However, after two weeks of freezing, the mineral content decreased significantly ($p < 0.05$). The mean values obtained for third and fourth weeks of freezing also indicated reduction in Na levels which were not significantly ($p > 0.05$) different from the second weeks (as shown in Figure 4.6.4 and Appendix 31).

In *Hibiscus sabdaliffa*, significant decreased ($p < 0.05$) in the Na content from 6.11mg/kg in fresh sample to 4.80mg/kg was observed only in four weeks of freezing. The reduction in the mineral content recorded in the first week (5.40mg/kg), second weeks (5.36mg/kg) and third weeks (4.80mg/kg) of freezing were not significant (Figure 4.6.4 and Appendix 32).

The Na levels were also found to decrease with freezing in *Corchorus olitorius*. Significant reduction of Na contents from 9.03mg/kg in fresh sample to 7.63mg/kg was observed after two weeks of freezing. The decrease in the first week (7.63mg/kg) was however not significant. The values obtained for the third weeks (5.34mg/kg) and fourth weeks (5.26mg/kg) also indicated reduction in the mineral content which were not significantly different from those of the first and second weeks (see Figure 4.6.4 and Appendix 33).

Similarly Na levels were also found to decrease with freezing in *Telfairia occidentalis*. Significant reduction ($p < 0.05$) of the mineral contents from 11.48mg/kg in fresh sample to 8.76mg/kg was observed after two weeks of storage in the refrigerator. The decrease in the first week (9.86mg/kg) was however not significant. The mean values obtained for the third weeks (8.48mg/kg) weeks and fourth weeks (8.10mg/kg) also indicated reduction in level which were not significantly different from those of the first and second weeks (as shown in Figure 4.6.4 and Appendix 34).

The decreasing effect of freezing on Na content was also observed in *Vernonia amygalina*. The amount of Na determined in fresh, and those frozen for one, two, three and four weeks were 8.03mg/kg, 7.34mg/kg, 6.96mg/kg, 6.45mg/kg and 6.44mg/kg, respectively. Results obtained showed that the reduction of the mineral content in the vegetable during freezing period was not significant (see Figure 4.6.4 and Appendix 35).

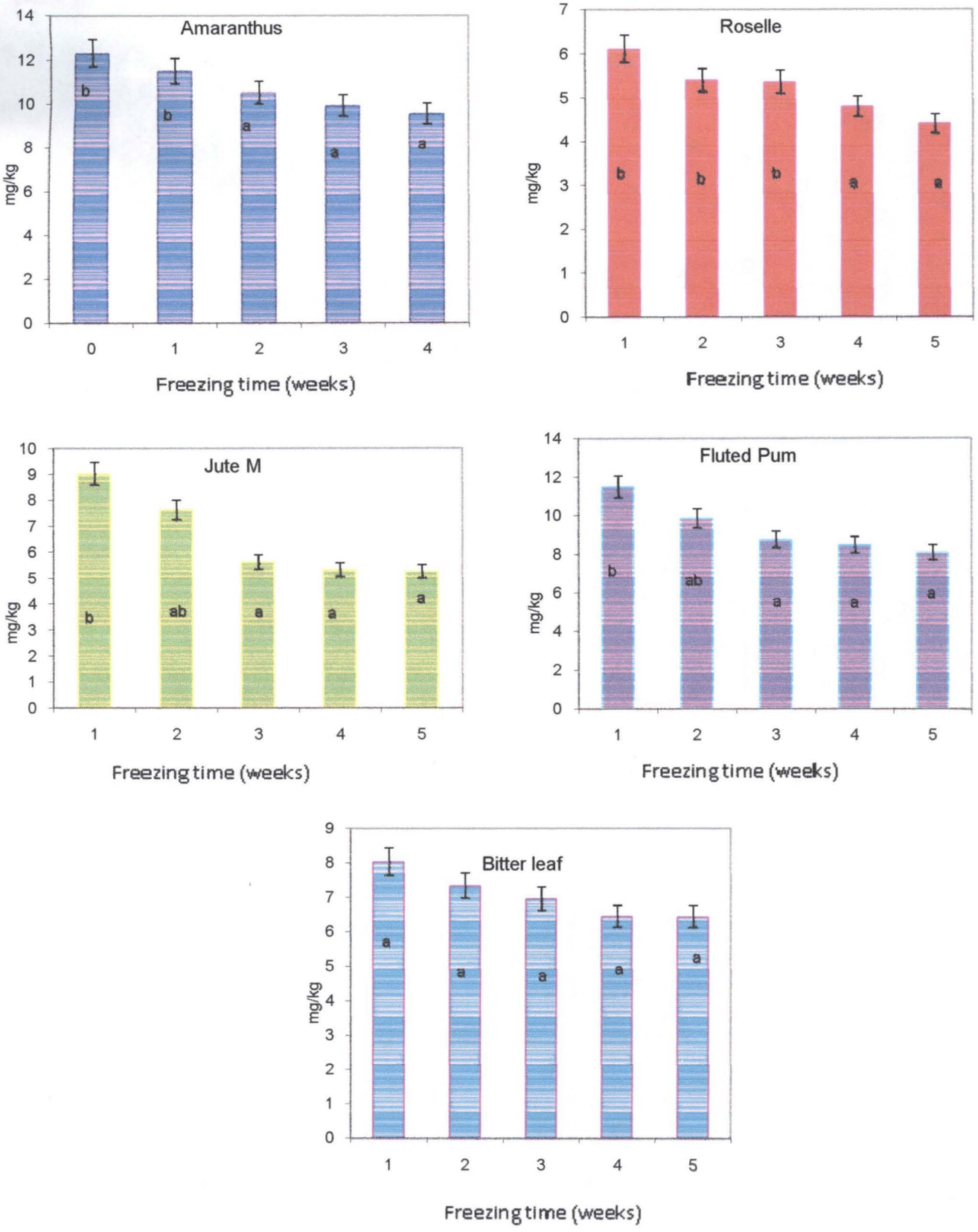


Figure 4.6.4: Effect of freezing time on sodium content in the different fresh vegetables. In each bar chart, bars with the same letters were not significantly different from each other (P>0.05).

4.6.5 Potassium Content

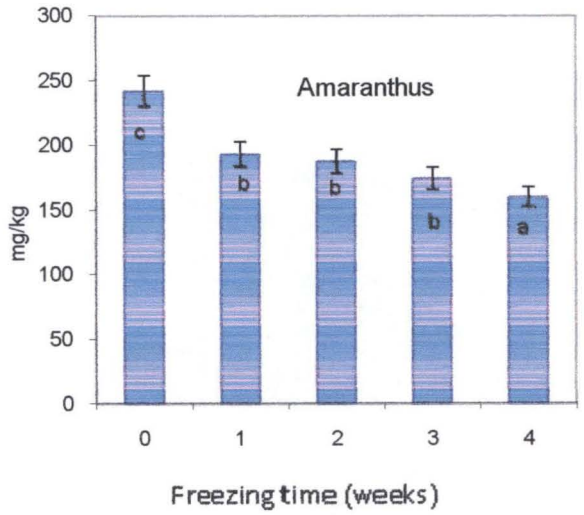
Determination of K content in fresh and frozen samples of the different vegetables studied revealed that freezing generally reduce the mineral content in all the vegetables studied. The amount of K in the fresh, and those samples of *Amaranthus cruentus* frozen for one week, two weeks, three weeks and four weeks were 241.88mg/kg, 192.92mg/kg, 187.50mg/kg, 174.40mg/kg and 159.78mg/kg respectively. The results obtained showed that freezing significantly ($p < 0.05$) decreased the K content in the first week and the values remain significantly unchanged till the fourth week, where further significant decreased was observed (see Figure 4.6.5 and Appendix 36).

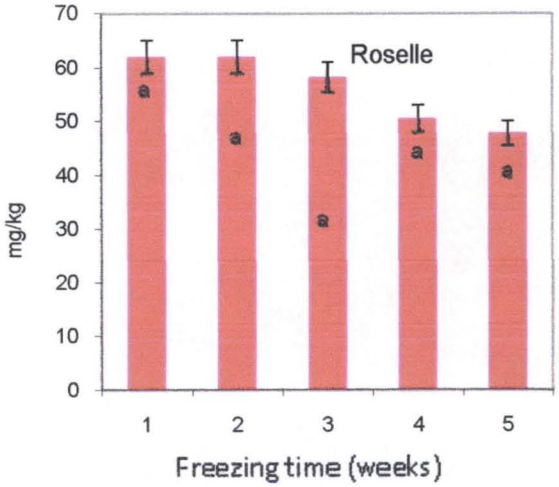
The decreasing effect of freezing on K content was also observed in *Hibiscus sabdariffa*. The levels determined in fresh, and those frozen for one, two, three and four weeks were 61.88mg/kg, 61.86mg/kg 58.13mg/kg, 50.46mg/kg, and 47.68mg/kg respectively. Data analysis showed that the reduction of the mineral content in the vegetable during freezing period was not significant (as shown in Figure 4.6.5 and Appendix 37).

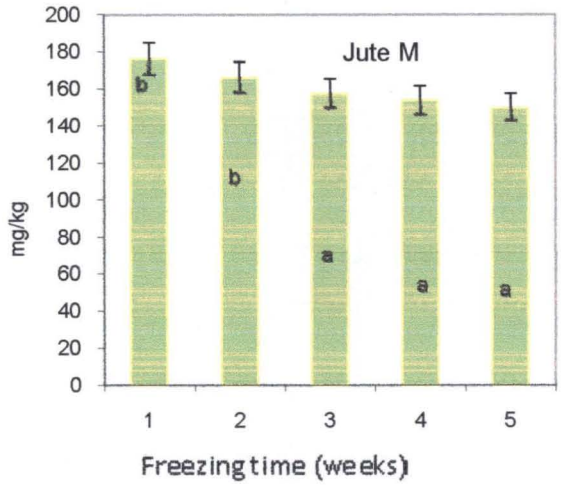
Similarly K levels were also found to decrease with freezing in *Corchorus olitorius*. Significant ($p < 0.05$) reduction of K contents from 176.25mg/kg in fresh sample to 157.50mg/kg was observed after two weeks of storage in the refrigerator. The decrease in the first week (166.13mg/kg) was however not significant. The mean values obtained for the third weeks (153.75mg/kg) and fourth weeks (149.92mg/kg) also indicated reduction in level which was not significantly different from those of the first and second weeks (see Figure 4.6.5 and Appendix 38).

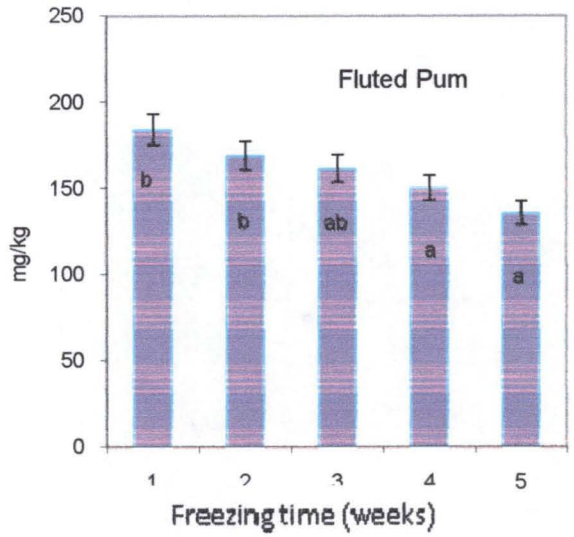
The K content of *Telfairia occidentalis* also decreases with freezing time. Significant reduction ($p < 0.05$) in the mineral concentration from 183.92mg/kg in fresh sample to 150.00mg/kg was recorded after three weeks of storage in the freezer. The mean value obtained from the fourth weeks (135.63mg/kg) indicated reduction in mineral content which was not significantly different from second weeks (161.25mg/kg). The K content in first week (168.75mg/kg) was however significantly higher ($p < 0.05$) than those in the third and fourth weeks (see Figure 4.6.5 and Appendix 39).

Similarly the K content in *Vernonia amygdalina* also decreases with freezing time. Significant reduction in the mineral concentration from 288.92mg/kg in fresh sample to 241.29mg/kg was observed after three weeks of freezing. The value obtained from the fourth weeks (225.17mg/kg) indicated reduction in K content which was not significantly different from second weeks (260.63mg/kg). The mineral content in first week (273.75mg/kg) was however significantly ($p < 0.05$) higher than the levels in the third and fourth weeks (as shown in Figure 4.6.5 and Appendix 40).









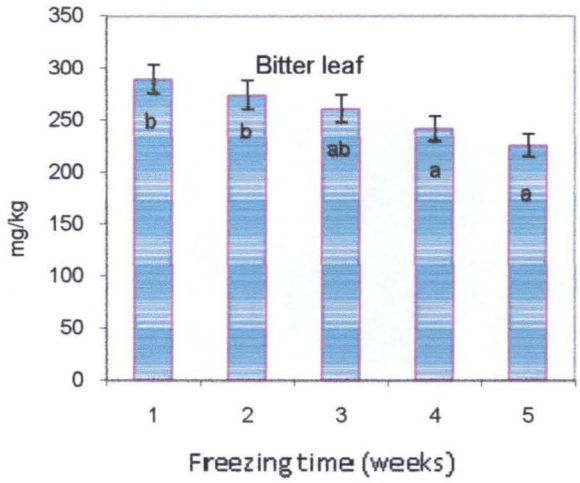


Figure 4.6.5: Effect of freezing time on potassium content in the different fresh vegetables. In each bar chart, bars with the same letters were not significantly different from each other (P>0.05).

4.7 Physical and Chemical Properties of Soil

Result of analyses of the soil used for pot experiment is presented in Table 4.1. The texture class of the soil is sandy loam indicating that the water holding capacity is moderate. The organic matter content, total nitrogen and available phosphorus are low. Sodium and calcium contents are moderate while magnesium and potassium contents are high. The CEC (cation exchange capacity) is moderate while base saturation percentage is high. Soil pH indicates that the soil is slightly acidic (FAO, 1984; Black, 1985; FDALR, 1985).

Table 4.1 Some Physical and Chemical Properties of the Soil (0 – 20cm) Used for Pot Experiment

Parameters	**Values**
Sand (%)	74.40
Silt (%)	18.00
Clay (%)	7.60
pH (in H_2O)	6.51
pH (in 0.1M C_aCI_2)	5.25
Organic Carbon (%)	0.83
Organic Matter (%)	1.43
Total nitrogen (%)	0.05
Available phosphorus (mg/kg)	6.69
K (cmol/kg)	0.92
Na (cmol/kg)	0.68
Mg (cmol/kg)	4.80
Ca (cmol/kg)	8.00
E. A ($H^+ + AL^{3+}$)(cmol/kg)	1.50
CEC (cmol/kg)	15.90
Base saturation (%)	90.57
Texture class	sandy loam

*Values represent means of triplicate determinations.

4.8 Effect of Soil Nitrogen Levels on Antinutrients and Vitamins content in vegetables.

4.8.1. *Amaranthus cruentus*

The investigation of the effects of soil nitrogen levels on cyanide concentrations in *Amaranthus cruentus* revealed that application of nitrogen fertilizer has significant ($p < 0.05$) increasing effects on cyanide content of the vegetable irrespective of the stage of plant development. The mean values for controls at market maturity and heading (223.10 ± 12.00 and 308.70 ± 19.00mg/kg) were significantly ($p < 0.05$) lower than (256.50 ± 9.50mg/kg and 435.00 ± 11.70mg/kg respectively) for vegetables grown on nitrogen treated soil (see Table 4.2.1).

Nitrate levels of the studied vegetable were significantly ($p < 0.05$) increased with application of nitrogen fertilizer. The mean nitrate concentrations in vegetables planted on nitrogen fertilized soils at market maturity (23.41 ± 1.07g/kg) and heading (18.72 ± 0.40g/kg) were significantly elevated as compared to level of controls (17.78 ± 1.42 and 7.62 ± 1.00g/kg respectively) as shown in Table 4.2.1.

The mean soluble oxalate content in control and test plants at maturity were 3.11 ± 0.22g/100g and 2.37 ± 0.05g/100g while at heading the values obtained were 3.85 ± 0.25g/100g and 3.67 ± 0.18g/100g. These results showed nitrogen fertilizer had no significant effect the soluble oxalate content of the vegetable irrespective of stage of plant development (as shown in Table 4.2.1).

The applied nitrogen fertilizer had no significant effect on total oxalate content of the vegetable. The mean values of the total oxalate obtained in control and nitrogen fertilized *Amaranthus cruentus* at market maturity were 4.40 ± 0.19g/100g and

3.75 ± 0.35g/100g. While the corresponding values recorded at heading were 5.27 ±0.24 and 5.04 ± 0.22g/100g respectively (see Table 4.2.1).

Results obtained from the determination of β-carotene content showed that nitrogen fertilizer significantly ($p < 0.05$) increased the levels of the provitamin irrespective of the stage of plant development. The mean values of β-carotene in vegetables planted on nitrogen fertilized soils at market maturity (8.03 ± 0.87mg/100g) and heading (4.85 ± 0.57mg/100g) were significantly higher ($p < 0.05$) compared to level of controls (7.45 ± 0.47mg/100g and 2.48 ± 0.33mg/100g respectively) as shown in Table 4.2.1.

The mean vitamin C concentrations of test and control vegetable at market maturity were 78.90 ± 4.50mg/100g and 94.60 ± 5.60mg/100g while at heading the values obtained were 160.50 ± 7.10mg/100g and 149.90 ± 8.20mg/100g. The results showed that the application of nitrogen fertilizer significantly reduced ($p < 0.05$) the vitamin content of the vegetables at maturity while no significant variation was observed at heading (see Table 4.2.1).

Table 4.2.1 Effect of soil nitrogen levels on antinutrients and vitamins content in *Amaranthus cruentus*

Antinutrients and vitamins analysed at market maturity and heading stages	Nitrogen levels	
	Control (No nitrogen applied)	Nitrogen applied
Cyanide at market maturity (mg/kg DW)	223.10 ± 12.00[a]	256.50 ± 9.50[b]
Cyanide at heading (mg/kg DW)	308.70 ± 19.0[a]	435.00 ± 117.00[b]
Nitrate at market maturity (g/kg DW)	17.78 ± 1.42[a]	23.41 ± 1.07[b]
Nitrate at heading (g/kg DW)	7.62 ± 1. 00[a]	18.72 ± 0.4[b]
Soluble oxalate at market maturity (g/100g DW)	3.11 ± 0.22[a]	2.37 ± 0.05[a]
Soluble oxalate at heading (g/100g DW)	3.85 ± 0.25[a]	3.67 ± 0.18[a]
Total oxalate at market maturity (g/100g DW)	4.40 ± 0.19[a]	3.75 ± 0.05[a]
Total oxalate at heading (g/100g DW)	5.27 ± 0.24[a]	5.04 ± 0.22[a]
β-carotene at market maturity (mg/100g FW)	7.45 ± 0.47[a]	8.04 ± 0.87[b]
β-carotene at heading (mg/100g FW)	2.48 ± 0.33[a]	4.85 ± 0.57[b]
Vitamin C at market maturity (mg/100g FW)	94.60 ± 5.60[b]	78.90 ± 4.50[a]
Vitamin C at heading (mg/100g FW)	160.50 ± 7.10[a]	149.90 ± 8.20[a]

DW = Dry weight, FW = Fresh weight. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.8.2 *Hibiscus sabdariffa*

The determination of the effects of soil nitrogen levels on cyanide concentrations in *Hibiscus sabdariffa* showed that the applied nitrogen fertilizer had no significant effect on cyanide content of the studied vegetable irrespective of the stage of plant development. The mean values for controls at market maturity (459.60 ± 21.00mg/kg) and fruiting (390.20 ± 32.00mg/kg) were not significantly different from the values (419.50 ± 21.00 and 410.60 ± 26.00mg/kg respectively) for vegetables grown on nitrogen fertilized soil (as shown in Table 4.2.2).

The mean nitrate contents in the vegetable planted on nitrogen treated soils at market maturity (101.90 ± 26.00mg/kg) and fruiting (344.40 ± 29.00mg/kg) were not significantly different from the level of controls (85.00 ± 28.00 and 285.20 ± 23.00mg/kg respectively) as shown in Table 4.2.2.

The mean soluble oxalate concentrations of control and nitrogen treated plants at market maturity were 1.62 ± 0.05g/100g and 1.37 ± 0.05g/100g while at fruiting the values obtained were 2.93 ± 0.15g/100g and 1.77 ± 0.07g/100g. The results showed that the application of nitrogen fertilizer significantly ($p < 0.05$) decreased the soluble oxalate content of the vegetable at vegetative and reproductive phase (see Table 4.2.2).

Similarly the applied nitrogen fertilizer significantly ($p < 0.05$) decreased the total oxalate of the plant irrespective of the stage of plant development. The mean values of the antinutrient recorded in the control and test vegetable at market maturity were 2.08 ± 0.07g/100g and 1.92 ± 0.04g/kg while at fruiting the values recorded were 4.04 ± 0.27g/100g and 3.22 ± 0.20g/100g (as shown in Table 4.2.2).

The mean β-carotene concentrations of control and test plants at market maturity were 5.41 ± 0.43mg/100g and 7.06 ± 0.27mg/100g while at fruiting the values obtained were 6.12 ± 0.38mg/100g and 6.48 ± 0.40mg/100g. Data analysis showed that with application of nitrogen fertilizer there was a significant elevation ($p < 0.05$) in the provitamin content at market maturity while no significant variation was recorded at fruiting (see Table 4.2.2).

The determination of vitamin C content in *Hibiscus sabdariffa* showed that the applied nitrogen fertilizer had no significant effect on the vitamin content of the vegetable at market maturity while at fruiting stage the vitamin decreased significantly. The mean values recorded in the test and control vegetable at market maturity were 12.51 ± 1.10mg/100g and 13.39 ± 1.30mg/kg while at fruiting the values recorded were 13.08 ± 0.77mg/100g and 16.08 ± 0.82mg/100g (see Table 4.2.2).

Table 4.2.2 Effect of soil nitrogen levels on antinutrients and vitamins content in *Hibiscus sabdaliffa*

Anti nutrients and vitamins analysed at market maturity and fruiting stages	Nitrogen levels	
	Control (No nitrogen applied)	Nitrogen applied
Cyanide at market maturity (mg/kg DW)	459.60 ± 21.00[a]	419.50 ± 21.00[a]
Cyanide at fruiting (mg/kg DW)	390.20 ± 32.00[a]	410.60 ± 26.00[a]
Nitrate at market maturity (mg/kg DW)	85.00 ± 28.00[a]	101.90 ± 26.00[a]
Nitrate at fruiting (mg/kg DW)	285.20 ± 23.00[a]	344.40 ± 29.00[a]
Soluble oxalate at market maturity (g/100g DW)	1.62 ± 0.04[b]	1.37 ± 0.05[a]
Soluble oxalate at fruiting (g/100g DW)	2.93 ± 0.15[b]	1.77 ± 0.15[a]
Total oxalate at market maturity (g/100g DW)	2.08 ± 0.07[b]	1.92 ± 0.04[a]
Total oxalate at fruiting (g/100g DW)	4.04 ± 0.27[b]	3.22 ± 0.20[a]
β -carotene at market maturity (mg/100g FW)	5.41 ± 0.43[a]	7.06 ± 0.27[b]
β-carotene at fruiting (mg/100g FW)	6.12 ± 0.38[a]	6.48 ± 0.40[a]
Vitamin C at market maturity (mg/100g FW)	13.39 ± 1.30[a]	12.51 ± 1.10[a]
Vitamin C at fruiting (mg/100g FW)	16.08 ± 0.82[b]	13.08 ± 0.77[a]

DW = Dry weight, FW = Fresh weight. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.8.3 *Corchorus olitorius*

The investigation of the effects of soil nitrogen levels on cyanide concentrations in *Corchorus olitorius* revealed that application of nitrogen fertilizer had no significant effects ($p > 0.05$) on cyanide content of the studied vegetable irrespective of the stage of plant development. The mean values for controls at market maturity (663.00 ± 47.00mg/kg) and fruiting (1325.00 ± 48.00mg/kg) were not significantly different from the values (618.00 ± 106.00 and 1220.00 ± 142.00mg/kg respectively) for vegetables grown on nitrogen fertilized soil (as shown in Table 4.2.3).

Nitrate levels of the studied vegetable were significantly ($p < 0.05$) increased with application of nitrogen fertilizer. The mean nitrate concentrations in vegetables planted on nitrogen fertilized soils at market maturity (2717.00 ± 370.00mg/kg) and fruiting (3500.00 ± 54.00mg/kg) were significantly elevated as compared to level of controls (2028.00 ± 412.00 and 230.00 ± 35.00mg/kg respectively) as shown in Table 4.2.7.

The applied nitrogen fertilizer had no significant effect on soluble and total oxalate content in both vegetative and reproductive phase of the plant. The mean soluble oxalate concentrations of control and test plants at maturity were 1.68 ± 0.14 and 2.18 ± 0.21g/100g while at fruiting the values obtained were 6.82 ± 0.48 and 5.96 ± 0.29g/100g. Similarly the mean values of total oxalate content in control and nitrogen fertilized *Corchorus olitorius* at market maturity were 3.15 ± 0.10g/100g and 3.20 ± 0.19g/100g while the values obtained at fruiting were 8.39 ± 0.54g/100g and 7.45 ± 0.2g/100g (see Table 4.3.2).

The mean β-carotene levels in control and nitrogen fertilized plants at market maturity were 2.62 ± 0.20mg/100g and 10.26 ± 0.58mg/100g while at fruiting the values

obtained were 10.28 ± 1.03mg/100g and 11.68 ± 0.64mg/100g. Data analysis revealed that the applied nitrogen significantly ($p < 0.05$) elevates the provitamin content at maturity while no significant variation was recorded at fruiting (see Table 4.2.3).

Results obtained from the analysis of vitamin C content of the vegetable indicated that the applied nitrogen fertilizer significantly decreased ($p < 0.05$) the vitamin content at both market maturity and fruiting stage of plant development. The levels of the vitamin obtained in control and nitrogen treated plant at market maturity were 101.70 ± 7.30mg/100g and 86.00 ± 8.60mg/100g while the corresponding values at fruiting were 47.77 ± 2.70mg/100g and 37.37 ± 2.30g/100g (as shown in Table 4.2.3).

Table 4.2.3 Effect of soil nitrogen levels on antinutrients and vitamins content in *Corchorus olitorius*

Anti nutrients and vitamins analysed at market maturity and fruiting stages	Nitrogen levels	
	Control (no nitrogen applied)	Nitrogen applied
Cyanide at market maturity (mg/kg DW)	663.00 ± 47.00[a]	618.00 ± 106.00[a]
Cyanide at fruiting (mg/kg DW)	1325.00 ± 48.00[a]	1220.00 ± 142.00[a]
Nitrate at market maturity (mg/kg DW)	2028.00 ± 412.00[a]	2717.00 ± 370.00[b]
Nitrate at fruiting (mg/kg DW)	250.00 ± 35.00[a]	350.00 ± 54.00[b]
Soluble oxalate at market maturity (g/100g DW)	1.68 ± 0.14[a]	2.18 ± 0.21[a]
Soluble oxalate at fruiting (g/100g DW)	6.82 ± 0.48[a]	5.96 ± 0.29[a]
Total oxalate at market maturity (g/100g DW)	3.15 ± 0.10[a]	3.20 ± 0.19[a]
Total oxalate at fruiting (g/100g DW)	8.39 ± 0.54[a]	7.45 ± 0.20[a]
β-carotene at market maturity (mg/100g FW)	2.62 ± 1.98[a]	10.26 ± 0.58[b]
β-carotene at fruiting (mg/100g FW)	10.28 ± 1.03[a]	11.68 ± 0.64[a]
Vitamin C at market maturity (mg/100g FW)	101.70 ± 7.30[b]	86.00 ± 8.60[a]
Vitamin C at fruiting (mg/100g FW)	46.77 ± 2.7[b]	37.37 ± 2.30[a]

DW = Dry weight, FW = Fresh weight, values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.8.4 *Telfairia occidentalis*

The results obtained from the determination of cyanide content in *Telfairia occidentalis* indicated that the applied nitrogen fertilizer significantly ($p < 0.05$) increased the cyanide content of the vegetable irrespective of the stage of plant development. The mean values of cyanide recorded in the control and nitrogen fertilized vegetable at market maturity were 438.00 ± 37.00mg/kg and 699.00 ± 48.00mg/kg while at fruiting the values recorded were 771.00 ± 21.00mg/kg and 885.00 ± 37.00mg/kg (see Table 4.2.4).

The applied nitrogen fertilizer significantly ($p < 0.05$) elevated the nitrate content of the vegetable irrespective of stages of plant development. The amount of nitrate in the control and test vegetable at market maturity were 550.00 ± 95.00mg/kg and 696.00 ± 117.00mg/kg while the corresponding values obtained at fruiting stage were 34.90.00 ± 5.1.00mg/kg and 45.10 ± 15.00mg/kg.

Results obtained from the analysis of soluble oxalate content of the vegetable grown on the soil fertilized with nitrogen showed nitrogen fertilizer had no significant effect ($p < 0.05$) on the oxalate content of the vegetable. However at fruiting the applied nitrogen fertilizer significantly increased ($p < 0.05$) the soluble oxalate. The mean value soluble oxalate contents of control and test plants at maturity were 1.64 ± 0.06g/100g and 1.82 ± 0.14g/100g while at fruiting the values obtained were 1.65 ± 0.09g/100g and 2.03 ± 0.06g/100g.

The mean total oxalate concentrations of control and nitrogen fertilized vegetable at market maturity were 2.18 ± 0.07g/100g and 2.07 ± 0.16g/100g while at fruiting the values obtained were 3.20 ± 0.09g/100g and 2.82 ± 0.04g/100g. The results showed that the application of nitrogen fertilizer significantly decreased ($p < 0.05$) the oxalate content

of the vegetables at fruiting while no signifi observed at market maturity (as shown in Table 4.2.4).

In *Telfairia occidentalis* the applied nit y ($p < 0.05$) increased the β-carotene content of vegetable at no significant ($p > 0.05$) difference in the provitamin content wage. The amount of β-carotene contents of control and the test were 15.50 ± 0.59mg/100g and 17.60 ± 0.10mg/100g while the lues obtained at fruiting were 10.38 ± 0.40mg/100g and 12.15 ± 0.28 .4).

The vitamin C levels of control and nitrogria *occidentalis* at market maturity were 208.40 ± 7.50mg/100g and mg/100g while the values obtained at fruiting were 224.60 ± 11.00mg/100 11.00mg/100g. The results revealed that the application of nitrogen nificantly decreased ($p < 0.05$) the vitamin content of the vegetables at marke nd fruiting (see Table 4.2.4).

Table 4.2.4 Effect of soil nitrogen levels on antinutrients and vitamins content in *Telfairia occidentalis*

Antinutrients and vitamins analysed at market maturity and fruiting stage	Nitrogen levels	
	Control (No nitrogen applied)	Nitrogen applied
Cyanide at market maturity (mg/kg DW)	438.00 ± 37.00^{a}	699.00 ± 48.00^{b}
Cyanide at fruiting (mg/kg DW)	771.00 ± 21.00^{a}	885.00 ± 37.00^{b}
Nitrate at market maturity (mg/kg DW)	550.00 ± 95.00^{a}	696.00 ± 117.00^{b}
Nitrate at fruiting (mg/kg DW)	34.90 ± 5.10^{a}	45.90 ± 15.00^{b}
Soluble oxalate at market maturity (g/100g DW)	1.64 ± 0.06^{a}	1.82 ± 0.14^{a}
Soluble oxalate at fruiting (g/100g DW)	1.65 ± 0.09^{a}	2.03 ± 0.06^{b}
Total oxalate at market maturity (g/100g DW)	2.18 ± 0.07^{a}	2.01 ± 0.16^{a}
Total oxalate at fruiting (g/100g DW)	3.20 ± 0.09^{b}	2.82 ± 0.04^{a}
β-carotene at market maturity (µg/100g FW)	15501.00 ± 591.00^{a}	1760.30 ± 100.00^{b}
β-carotene at fruiting (µg/100g FW)	10381.00 ± 395.79^{a}	12150.00 ± 276.00^{a}
Vitamin C at market maturity (mg/100g FW)	208.40 ± 7.50^{b}	191.60 ± 13.00^{a}
Vitamin C at fruiting (mg/100g FW)	224.60 ± 11.00^{b}	186.30 ± 11.00^{a}

DW = Dry weight, FW = Fresh weight, values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.8.5 *Vernonia amygdalina*

The investigation of the effects of soil nitrogen levels on cyanide content in *Vernonia amygdalina* showed that application of nitrogen fertilizer had no significant effects on cyanide content of the vegetable irrespective of the stage of plant development. The mean values for controls at market maturity (358.00 ± 108.00mg/kg) and heading (894.00 ± 57.00mg/kg) were not significantly different from the values (426.00 ± 78.00 and 994.00 ± 102.00mg/kg respectively) for vegetables grown on nitrogen fertilized soil (see Table 4.2.5).

Nitrate contents of the studied vegetable were significantly ($p < 0.05$) increased with application of nitrogen fertilizer. The mean nitrate contents in *Vernonia amygdalina* planted on nitrogen fertilized soils at maturity (891.00 ± 72.00mg/kg) and heading (4246.00 ± 170.00mg/kg) were significantly ($p < 0.05$) elevated as compared to level of controls (276.00 ± 47.00 and 3394.00 ± 228.00mg/kg respectively) as shown in Table below 4.2.5.

The applied nitrogen fertilizer had no significant ($p > 0.05$) effect on soluble oxalate content in both market maturity and heading stage of plant development. The mean soluble oxalate concentrations of control and test plants at maturity were 1.80 ± 0.03and 1.97 ± 0.11g/100g while at heading the values obtained were 2.33 ± 0.09 and 2.18 ± 0.04g/100g (see Table 4.2.5).

The amount of total oxalate content in control and nitrogen fertilized *Vernonia amygdalina* at market maturity were 2.23 ± 0.09g/100g and 2.51 ± 0.14g/100g while at heading the values obtained were 3.30 ± 0.08g/100g and 3.03 ± 0.06µg/100g. Data analysis showed that application of nitrogen fertilizer significantly ($p < 0.05$) elevates the

oxalate content at market maturity while no significant variation was observed at heading (see Table 4.2.5).

Similarly the analysis of β-carotene and vitamin C contents in control and nitrogen fertilized *Vernonia amygdalina* showed that the applied nitrogen fertilizer significantly ($p < 0.05$) increased and decreased the levels of these compounds respectively at market maturity stage while no significant difference was recorded at fruiting. The mean β-carotene concentrations of control and test plants at maturity were 11.17 ± 0.67mg/100g and 14.32 ± 0.43mg/100g while at heading stage the values obtained were 13.73 ± 0.28mg/100g and 14.42 ± 0.26mg/100g. Similarly, the mean values of vitamin C content in control and nitrogen fertilized vegetable at market maturity were 12.08 ± 0.62mg/100g and 9.00 ± 0.76mg/100g while the corresponding values obtained at heading were 14.75 ± 0.70mg/100g and 13.08 ± 1.10mg/100g (as shown in Table 4.2.5).

Table 4.2.5 Effect of soil nitrogen levels on antinutrients and vitamins content in *Vernonia amygdalina*

Anti nutrients and vitamins analysed at market maturity and fruiting stage	Nitrogen levels	
	Control (No nitrogen applied)	Nitrogen applied
Cyanide at market maturity (mg/kg DW)	358.00 ± 108.00[a]	426.00 ± 78.00[a]
Cyanide at heading (mg/kg DW)	894.00 ± 57.00[a]	994.00 ± 102.00[a]
Nitrate at market maturity (mg/kg DW)	276.00 ± 47.00[a]	891.00 ± 72.00[b]
Nitrate at heading (mg/kg DW)	3394.00 ± 228.00[a]	4246.00 ± 170.00[b]
Soluble oxalate at market maturity (g/100g DW)	1.80 ± 0.03[a]	1.97 ± 0.11[a]
Soluble oxalate at heading (g/100g DW)	2.33 ± 0.09[a]	2.18 ± 0.04[a]
Total oxalate at market maturity (g/100g DW)	2.23 ± 0.09[a]	2.51 ± 0.14[b]
Total oxalate at heading (g/100g DW)	3.30 ± 0.08[a]	3.03 ± 0.06[a]
β-carotene at market maturity (mg/100g FW)	11.17 ± 0.67[a]	14.32 ± 0.43[b]
β-carotene at heading (mg/100g FW)	13.73 ± 0.28[a]	14.42 ± 0.26[a]
Vitamin C at market maturity (mg/100g FW)	12.08 ± 0.62[b]	9.00 ± 0.76[a]
Vitamin C at heading (mg/100g FW)	14.75 ± 0.70[a]	13.08 ± 1.10[a]

DW = Dry weight, FW = Fresh weight, values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.9 Effect of Soil Nitrogen Level on Mineral Elements Content in Vegetables

4.9.1 *Amaranthus cruentus*

The determination of the effects of soil nitrogen levels on Fe concentrations in *Amaranthus cruentus* revealed that application of nitrogen fertilizer has significant ($p < 0.05$) decreasing effects on the mineral content of the vegetable at market maturity. However, no significant variation on the mineral content was found at heading stage. The mean Fe concentrations of control and nitrogen applied vegetable at market maturity were 33.53 ± 1.20mg/kg and 24.58 ± 1.30mg/kg while at heading the values obtained were 39.76 ± 2.30mg/kg and 45.70 ± 6.50mg/kg (see Table 4.3.1).

The investigation of the effects of soil nitrogen levels on Mg, Zn, Cu, Ca, Na and K content in control and nitrogen fertilized *Amaranthus cruentus* showed that the applied nitrogen fertilizer had no significant ($p > 0.05$) effect on these mineral contents in both vegetative and reproductive phase of the plant (see Table 4.3.1).

Table 4.3.1 Effect of soil nitrogen levels on mineral content in *Amaranthus cruentus*

Mineral analysed at market maturity and heading stages.	Nitrogen levels	
	Control (No nitrogen applied)	Nitrogen applied
Fe at market maturity (mg/kg)	33.53 ± 1.20[b]	24.58 ± 1.30[a]
Fe at heading (mg/kg)	39.76 ± 2.30[a]	45.70 ± 6.50[a]
Mg at market maturity (mg/kg)	26.26 ± 0.81[a]	27.12 ± 1.20[a]
Mg at heading (mg/kg)	25.54 ± 0.94[a]	27.98 ± 1.00[a]
Zn at market maturity (mg/kg)	0.08 ± 0.01[a]	0.06 ± 0.01[a]
Zn at heading (mg/kg)	0.05 ± 0.01[a]	0.06 ± 0.01[a]
Cu at market maturity (mg/kg)	4.55 ± 0.66[a]	5.05 ± 0.66[a]
Cu at heading (mg/kg)	2.78 ± 0.70[a]	2.94 ± 0.55[a]
Ca at market maturity (mg/kg)	30.28 ± 1.80[a]	29.49 ± 0.95[a]
Ca at heading (mg/kg)	29.49 ± 1.66[a]	30.60 ± 1.20[a]
Na at market maturity (mg/kg)	11.49 ± 1.10[a]	11.70 ± 1.40[a]
Na at heading (mg/kg)	8.81 ± 0.42[a]	8.19 ± 0.40[a]
K at market maturity (mg/kg)	209.70 ± 16.00[a]	219.30 ± 22.00[a]
K at heading (mg/kg)	245.30 ± 22.00[a]	223.90 ± 24.00[a]

Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.9.2 *Hibiscus sabdaliffa*

Analysis of Fe Mg, Zn, Cu, Ca, Na and K were conducted in control and in *Hibiscus sabdariffa* grown on soil treated with nitrogen with a view of determining the effect soil nitrogen levels on the mineral content of the vegetable. The results obtained showed that the applied nitrogen fertilizer had no significant effect on the mineral contents of the vegetable irrespective of the stage of plant development (see Table 4.3.2).

4.3.2 Effect of soil nitrogen levels on mineral content in *Hibiscus sabdaliffa*

Mineral analysed at market maturity and fruiting stages.	Nitrogen levels	
	Control (No nitrogen applied)	Nitrogen applied
Fe at market maturity (mg/kg)	33.17 ± 1.60[a]	31.77 ± 2.90[a]
Fe at fruiting (mg/kg)	28.44 ± 1.50[a]	35.20± 3.50[a]
Mg at market maturity (mg/kg)	18.78 ± 1.80[a]	20.79 ± 1.10[a]
Mg at heading (mg/kg)	17.99 ± 0.26[a]	17.19 ± 0.37[a]
Zn at market maturity (mg/kg)	0.04 ± 0.01[a]	0.03 ± 0.01[a]
Zn at fruiting (mg/kg)	0.03 ± 0.01[a]	0.03 ± 0.01[a]
Cu at market maturity (mg/kg)	2.07 ± 0.36[a]	2.89 ± 0.47[a]
Cu at fruiting (mg/kg)	2.28 ± 0.37[a]	1.88 ± 0.25[a]
Ca at market maturity (mg/kg)	24.14 ± 0.98[a]	24.81 ± 0.86[a]
Ca at fruiting (mg/kg)	24.31 ± 1.00[a]	22.52 ± 1.30[a]
Na at market maturity (mg/kg)	2.80 ± 0.18[a]	3.07 ± 0.14[a]
Na at fruiting (mg/kg)	3.17 ± 0.14[a]	2.83 ± 0.12[a]
K at market maturity (mg/kg)	39.18 ± 2.50[a]	38.65 ± 0.94[a]
K at fruiting (mg/kg)	36.01 ± 2.90[a]	42.33 ± 2.80[a]

Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.9.3 *Corchorus olitorius*

The determination of effect of soil nitrogen levels on minerals content in control and nitrogen fertilized *Corchorus olitorius* showed that nitrogen fertilizer significantly ($p < 0.05$) reduced the Fe content of plant the in vegetative phase and had no significant effect on the mineral content at reproductive phase. The mean Fe concentrations in control and nitrogen treated vegetable at maturity were 17.97 ± 1.90mg/kg and 10.29 ± 0.90mg/kg while the corresponding values obtained at heading were 7.31 ± 1.10mg/kg and 8.74 ± 0.86mg/kg (see Table 4.3.3).

Results from the analysis of Mg, Zn, Ca and Na levels in control and test *Corchorus olitorius* revealed that the applied nitrogen fertilizer had no significant effect on the mineral contents of vegetable (Table 4.3 3).

The mean Cu concentrations of control and nitrogen fertilized plants at maturity were 13.50 ± 3.80mg/kg and 6.59 ± 0.84mg/kg while at fruiting the values obtained were 2.00 ± 0.31mg/kg and 6.00 ± 1.90g/kg. The results revealed that with application of nitrogen fertilizer there is a significant ($p < 0.05$) decreased in the mineral content at market maturity while at fruiting the applied nitrogen fertilizer significantly increased the mineral of the vegetable (see Table 4.3.3).

The K contents of the studied vegetable were significantly decreased ($p < 0.05$) with application of nitrogen fertilizer. The mean K contents in *Corchorus olitorius* planted on nitrogen fertilized soils at maturity (166.89 ± 12..00mg/kg) and fruiting (123.00 ± 9.90mg/kg) were significantly lower as compared to level of controls (217.90 ± 26.00mg/kg and 194.00 ± 7.80mg/kg, respectively) as shown in Table 4.3.3).

4.3.3 Effect of soil nitrogen levels on minerals content in *Corchorus olitorius.*

Mineral analysed at market maturity and fruiting stages.	Nitrogen levels	
	Control (No nitrogen applied)	Nitrogen applied
Fe at Market maturity (mg/kg)	17.97 ± 1.90^{b}	10.29 ± 0.90^{a}
Fe at fruiting (mg/kg)	7.31 ± 1.10^{a}	8.74 ± 0.86^{a}
Mg at market maturity (mg/kg)	18.73 ± 0.46^{a}	18.74 ± 0.69^{a}
Mg at fruiting (mg/kg)	15.19 ± 0.99^{a}	17.10 ± 0.35^{a}
Zn at market maturity (mg/kg)	0.03 ± 0.01^{a}	0.02 ± 0.01^{a}
Zn at Fruiting (mg/kg)	0.02 ± 0.01^{a}	0.04 ± 0.01^{a}
Cu at market maturity (mg/kg)	13.50 ± 3.80^{b}	6.59 ± 2.84^{a}
Cu at fruiting (mg/kg)	2.00 ± 0.31^{a}	6.00 ± 1.90^{b}
Ca at market maturity (mg/kg)	15.41 ± 1.80^{a}	11.15 ± 1.50^{a}
Ca at fruiting (mg/kg)	16.97 ± 1.70^{a}	16.65 ± 1.80^{a}
Na at market maturity (mg/kg)	6.67 ± 0.24^{a}	5.64 ± 0.33^{a}
Na at fruiting (mg/kg)	4.63 ± 0.31^{a}	4.66 ± 0.18^{a}
K at market maturity (mg/kg)	217.90 ± 26.00^{b}	166.89 ± 12.00^{a}
K at fruiting (mg/kg)	194.00 ± 7.80^{b}	123.00 ± 9.90^{a}

Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.9.4 *Telfairia occidentalis*

The investigation of the effects of soil nitrogen levels on mineral concentrations in *Telfairia occidentalis* revealed that application of nitrogen fertilizer significantly ($p < 0.05$) increased Fe content irrespective of plant stage development. The mean Fe concentrations in vegetables planted on nitrogen treated soils at market maturity (13.63 ± 1.30mg/kg) and fruiting (28.19 ± 2.40mg/kg) were significantly higher when compared with the level of controls (9.76 ± 0.92mg/kg and 17.84 ± 2.40mg/kg respectively) as shown in Table 4.3.4.

The determination of the effects of soil nitrogen levels on Mg, Ca, Na and K concentrations in *Telfairia occidentali* indicated that the application of nitrogen fertilizer had no significant effects on the minerals content of the vegetable in both the vegetative and reproductive phase (see Table 4.3.4).

The Zn contents in control and test *Telfairia occidentalis* at maturity were 0.03 ± 0.01mg/kg and 0.05 ± 0.01mg/kg while the values obtained at fruiting were 0.01 ± 0.00mg/kg and 0.02 ± 0.01mg/kg. The results imply that with application of nitrogen fertilizer there is a significant ($p < 0.05$) elevation in the mineral content at market maturity while no significant variation was observed at fruiting (as shown in Table 4.3.4).

Similarly the applied nitrogen fertilizer significantly ($p < 0.05$) decreased the Cu levels of the plant at market maturity while at fruiting the mineral increased significantly. The mean values recorded in the control and test vegetable at market maturity were 3.67 ± 0.12mg/kg and 2.66 ± 0.53mg/kg while at fruiting the values obtained were 1.30 ± 0.51mg/kg and 8.78 ± 0.72mg/kg (see Table 4.3.4).

4.3.4 Effect of soil nitrogen levels on mineral content in *Telfairia occidentalis*

Mineral analysed at market maturity and fruiting stages.	Nitrogen levels	
	Control (No nitrogen applied)	Nitrogen applied
Fe at market maturity (mg/kg)	9.76 ± 0.92^{a}	13.63 ± 1.30^{b}
Fe at fruiting (mg/kg)	17.84 ± 2.40^{a}	28.19 ± 2.40^{b}
Mg at market maturity (mg/kg)	19.90 ± 1.00^{a}	20.34 ± 0.80^{a}
Mg at fruiting (mg/kg)	23.13 ± 2.24^{a}	23.59 ± 3.06^{a}
Zn at market maturity (mg/kg)	0.03 ± 0.01^{a}	0.05 ± 0.01^{b}
Zn at fruiting (mg/kg)	0.01 ± 0.01^{a}	0.02 ± 0.01^{a}
Cu at market maturity (mg/kg)	3.67 ± 0.12^{a}	2.66 ± 0.53^{a}
Cu at fruiting (mg/kg)	1.30 ± 0.51^{a}	8.78 ± 0.72^{b}
Ca at market maturity (mg/kg)	17.76 ± 3.20^{a}	16.27 ± 2.40^{a}
Ca at fruiting (mg/kg)	16.27 ± 2.00^{a}	14.95 ± 1.40^{a}
Na at market maturity (mg/kg)	5.40 ± 0.54^{a}	5.21 ± 0.16^{a}
Na at fruiting (mg/kg)	4.59 ± 0.38^{a}	3.71 ± 0.29^{a}
K at market maturity (mg/kg)	117.40 ± 3.40^{a}	112.90 ± 7.40^{a}
K at fruiting (mg/kg)	62.47 ± 3.00^{a}	67.40 ± 3.80^{a}

Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.9.5 *Vernonia amygdalina*

Determination of the effect of soil nitrogen levels on minerals content in *Venonia amygdalina* showed that the applied nitrogen fertilizer significantly ($p < 0.05$) increased the Mg content of the vegetable at market maturity and had no significant effect at heading. The mean values of Mg content in control and nitrogen fertilized vegetable at market maturity were 18.94 ± 0.5mg/kg and 20.53 ± 0.29mg/kg while the corresponding values obtained at heading were 18.30 ± 0.57mg/kg and 18.06 ± 0.50mg/kg (see Table 4.3.5).

Analysis of Fe, Zn, Cu, Ca and Na in control and in *Vernonia amygdalina* grown on soil treated with nitrogen showed that nitrogen fertilizer had no significant ($p > 0.05$) effect on the mineral contents of the vegetable irrespective of the stage of plant development (see Table 4.3.5).

The K levels of control and nitrogen fertilized *Vernonia amygdalina* at market maturity were 167.50 ± 9.10mg/kg and 174.50 ± 6.50mg/kg while the values obtained at heading were 142.40 ± 20.00mg/kg and 108.90 ± 8.30mg/kg. The results revealed that the application of nitrogen fertilizer significantly ($p < 0.05$) decreased the mineral content of the vegetables at heading while no significant ($p > 0.05$) variation was recorded at market maturity (as shown in Table 4.3.5).

4.3.5 Effect of soil nitrogen levels on mineral content in *Vernonia amygdalina*

Mineral analysed at market maturity and heading stages	Nitrogen levels	
	Control (No nitrogen applied)	Nitrogen applied
Fe at market maturity (mg/kg)	23.30 ± 4.50[a]	25.84 ± 0.79[a]
Fe at heading (mg/kg)	10.64 ± 2.20[a]	10.93 ± 1.10[a]
Mg at market maturity (mg/kg)	18.94 ± 0.50[a]	20.53 ± 0.29[b]
Mg at heading (mg/kg)	18.30 ± 0.57[a]	18.06 ± 0.50[a]
Zn at market maturity (mg/kg)	0.06 ± 0.02[a]	0.03 ± 0.02[a]
Zn at heading (mg/kg)	0.04 ± 0.01[a]	0.02 ± 0.01[a]
Cu at market maturity (mg/kg)	3.35 ± 0.98[a]	2.00 ± 0.42[a]
Cu at heading (mg/kg)	1.12 ± 0.62[a]	1.80 ± 0.54[a]
Ca at market maturity (mg/kg)	18.28 ± 2.10[a]	18.53 ± 2.10a
Ca at heading (mg/kg)	15.90 ± 2.40[a]	12.30 ± 1.70[a]
Na at market maturity (mg/kg)	4.53 ± 0.39[a]	4.37 ± 1.00a
Na at heading (mg/kg)	5.52 ± 0.69[a]	5.49 ± 0.55[a]
K at market maturity (mg/kg)	167.50 ± 9.10[a]	174.50 ± 6.50[a]
K at heading (mg/kg)	142.30 ± 20.00[b]	108.90 ± 8.30[a]

Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.10 Effect of Leaf Positions on Antinutrients and Vitamins Content in Vegetables at Market Maturity and Fruiting

4.10.1a *Amaranthus cruentus* at Market Maturity

The results obtained from the analysis showed that cyanide content was significantly highest ($p < 0.05$) in basal (258.38 ± 2.76mg/kg) followed by middle (219.34 ± 5.38mg/kg) and lowest in upper (188.18 ± 20.33mg/kg) leaves in control *Amaranthus cruentus* (see Table 4.4.1a). When the vegetable was treated with nitrogen, no significant ($p > 0.05$) differences in cyanide content was recorded between basal (261.90 ± 20.95mg/kg) and middle (288.09 ± 6.18mg/kg) leaves. However, the two leaf positions were significantly ($p < 0.05$) higher in the cyanide content than in upper leaf region (Table 4.4.1a).

Results obtained from the determination of nitrate in the vegetable indicated that the nitrate content was significantly ($p < 0.05$) highest in the middle leaf position followed by basal and lowest in upper leaf position irrespective of the fertilizer levels. The nitrate concentrations in the basal, middle and upper leaves in control were 15431.00 ± 277.00mg/kg, 26986.00 ± 494.00mg/kg and 10708.00 ± 361.00mg/kg respectively. While the corresponding values obtained with the application of nitrogen fertilizer were 24347.00 ± 378.00mg/kg, 30056.00 ± 87.00mg/kg and 15833.00 ± 614.00mg/kg.

The significant ($p < 0.05$) increased in the bioaccumulation of soluble oxalate in the three leaf positions in control *Amaranthus cruentus* was in the following order; Basal

(2.58 ± 0.03g/100g) > Middle (2.32 ± 0.02g/100g) > Upper (2.22 ± 0.04g/100g). With the application of nitrogen fertilizer, no significant difference was observed in the antinutrient contents between middle (2.75 ± 0.20g/100g) and upper (2.67 ± 0.32g/100g) leaf regions, however, the two leaf positions were significantly ($p < 0.05$) lower in the antinutrient content than basal (3.92 ± 0.28g/100g) leaf position. The total oxalate concentrations in control vegetable was significantly highest in basal (4.92 ± 0.11g/100g) closely followed by middle (3.81 ± 0.16g/100g) and least in the upper (2.52 ± 0.19g/100g) leaf positions. However, when the plant received nitrogen fertilizer, no significant difference in total oxalate content was observed between basal (4.53 ± 0.17g/100g) and middle (4.93 ± 0.16g/100g) leaf positions, the two leaf positions, had significant ($p < 0.05$) higher content of the oxalate than upper (3.37 ± 0.28g/100g) leaf region (as shown in Table 4.4.1a).

There was no significant ($p > 0.05$) difference in β-carotene content between basal (7.19 ± 0.69mg/100g) and middle (8.70 ± 0.16mg/100g) leaves, and basal and upper (6.46 ± 0.10mg/100g) leaves, however, middle leaf position was significantly ($p < 0.05$) higher in the provitamin than upper leaf position in the control *Amaranthus cruentus.* When the plant received nitrogen fertilizer, middle (11.03 ± 0.93mg/100g) leaf region was significantly ($p < 0.05$) higher in β-carotene content than the upper (7.05 ± 0.18mg/100g) and basal (6.03 ± 0.14mg/100g) leaf positions (see Table 4.4.1a).

Results from analysis of vitamin C revealed that there was no significant difference ($p > 0.05$) in the vitamin content between basal and upper leaves, however both leaf positions were significantly ($p < 0.05$) lower in vitamin C content than middle

leaf region irrespective of nitrogen levels. The amount of vitamin C in the three leaf positions in control were basal (76.75 ± 10.75mg/100g), middle (91.64 ± 10.37mg/100g) and upper (68.18 ± 9.42mg/100g) leaves. While the values of the vitamin recorded in nitrogen treated vegetable were; 84.34 ± 10.75mg/100g, 108.84 ± 17.42mg/100g and 90.78 ± 17.42mg/100g for basal, middle and upper leaves respectively (see Table 4.4.1a).

Table 4.4.1a Effect of leaf position on antinutrients and vitamins content in *Amaranthus cruentus* at market maturity stage

Antinutrients and vitamins	Leaf position		
	Basal leaves	Middle leaves	Upper leaves
Cyanide (mg/kg DW), Control	258.38 ± 2.76^{b}	219.34 ± 5.38^{a}	188.18 ± 20.33^{a}
Cyanide (mg/kg DW), Nitrogen applied	261.90 ± 20.95^{b}	288.09 ± 6.18^{a}	223.10 ± 1.27^{a}
Nitrate (mg/kg DW), Control	15431.00 ± 277.00^{b}	26986.00 ± 494.00^{c}	10708.00 ± 361.00^{a}
Nitrate (mg/kg DW), Nitrogen applied	24347.00 ± 378.00^{b}	30056.00 ± 87.00^{c}	15833.00 ± 614.00^{a}
Soluble oxalate (g/100g DW), Control	2.58 ± 0.03^{c}	2.32 ± 0.02^{b}	2.22 ± 0.04^{a}
Soluble oxalate (g/100g DW), Nitrogen applied	3.92 ± 0.28^{b}	2.75 ± 0.20^{a}	2.67 ± 0.32^{a}
Total oxalate (g/100g DW), Control	4.92 ± 0.11^{c}	3.81 ± 0.16^{b}	2.52 ± 0.19^{a}
Total oxalate (g/100g DW), Nitrogen applied.	4.53 ± 0.17^{b}	4.93 ± 0.16^{b}	3.37 ± 0.28^{a}
β-carotene (mg/100g FW), Control	7.18 ± 0.69^{ab}	8.67 ± 0.16^{b}	6.46 ± 0.10^{a}
β-carotene (mg/100g FW), Nitrogen applied	6.03 ± 0.14^{a}	11.03 ± 0.93^{b}	7.05 ± 0.18^{a}
Vitamin C (mg/100g FW), Control	76.75 ± 10.75^{a}	91.64 ± 10.37^{b}	68.18 ± 9.42^{a}
Vitamin C (mg/100g FW), Nitrogen applied	84.34 ± 9.92^{a}	108.84 ± 17.42^{b}	90.78 ± 15.04^{a}

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.10.1b *Amaranthus cruentus* at Heading

The analysis of effect of leaf position on antinutrients and vitamins content in *Amaranthus cruentus* at heading stage revealed that leaf position had no significant ($p > 0.05$) effect on cyanide content in the leaves of the vegetable in control. However, with the application of nitrogen fertilizer, no significant difference ($p > 0.05$) in cyanide content was observed between basal (363.87 ± 11.22mg/kg) and middle (314.64 ± 13.39mg/kg) leaves and between middle and upper (247.65 ± 52.52.76mg/kg) leaves. However, the cyanide content in basal leaves was significantly ($p < 0.05$) higher than in upper leaves (see Table 4.4.1b).

Analysis of nitrate content of the vegetable indicated that basal leaf position was significantly highest in nitrate content followed by middle leaf and lowest in the upper leaf position in both control and nitrogen fertilized vegetable. The levels of nitrate in the leaf positions in control were basal (10756.00 ± 457.00mg/kg), middle (8167.00 ± 44.00mg/kg) and upper (3939.00 ± 206.00mg/kg) leaves. While the values of nitrate recorded in nitrogen fertilized vegetable were; 26722.00 ± 614mg/kg, 24194.00 ± 156.00mg/kg and 5250.00 ± 583.00mg/kg for basal, middle and upper leaves respectively (Table 4.4.1b).

Studies conducted on soluble oxalate content in *Amaranthus cruentus* at heading showed that there was no significant difference in the antinutrient contents between basal and middle leaves, however, both leaf positions had significant ($p < 0.05$) higher content of the antinutrient than upper region in the control and nitrogen fertilized vegetables (as shown in Table 4.4.1b). Results from analysis of total oxalate revealed that no significant

difference in oxalate content was observed between basal (6.08 ± 0.27g/100g) and middle (5.18 ± 0.39g/100g) leaves and between middle and upper 4.55 ± 0.34g/100g) leaves, however, basal leaves had significant higher content of the parameter than upper leaves in control vegetable. With the application of nitrogen fertilizer though no significant difference in total oxalate content was observed between middle (4.85 ± 0.24g/100g) and upper (4.42 ± 0.27g/100g) leaves, the two leaf positions were significantly ($p < 0.05$) lower than the basal (5.85 ± 0.07g/100g) leaf position (see Table 4.4.1b).

The β-carotene content of the vegetable was significantly ($p < 0.05$) highest in upper (3.58 ± 0.11mg/100g) position closely followed by middle (2.37 ± 0.73mg/100g) and lowest in the basal (1.50 ± 0.08mg/100g) leaf regions in control *Amaranthus cruentus*. However, once the vegetable received nitrogen fertilizer, though no significant differences in the provitamin content was observed between middle (5.58 ± 0.12mg/100g) and upper (6.04 ± 0.60mg/100g) leaves, basal (2.94 ± 0.48mg/100g) leaves was significantly lower in the provitamin content than the two leaf positions (see Table 4.4.1b).

Similarly results obtained from the determination of vitamin C levels in the vegetable at heading revealed that no significant difference in the vitamin content was observed between basal and upper leaf region, however, the two leaf positions had lower significant ($p < 0.05$) content of the vitamin than middle leaf region irrespective of the nitrogen levels. The mean values for basal leaves in control (148.91 ± 8.09mg/100g) and nitrogen applied vegetable (133.73 ± 11.50mg/100g) were not significantly different from

the level in upper leaves (149.34 ± 11.41mg/100g and 138.46 ± 17.74mg/100g respectively). The mean value of the vitamin in the middle leaves for control (183.27 ± 20.79mg/100g) and nitrogen applied (177.55 ± 16.09mg/100g) were significantly ($p < 0.05$) elevated than the two leaf positions (see Table 4.4.1b).

Table 4.4.1b Effect of leaf position on antinutrients and vitamins content in *Amaranthus cruentus* at heading stage

Antinutrients and vitamins	Leaf position		
	Basal leaves	Middle leaves	Upper leaves
Cyanide (mg/kg DW), Control	513.50 ± 44.60^{a}	443.20 ±49.60^{a}	349.20 ± 38.30^{a}
Cyanide (mg/kg DW), Nitrogen applied	363.87 ± 11.22^{b}	314.64 ± 13.39^{ab}	247.65 ± 52.76^{a}
Nitrate (mg/kg DW), Control	10756.00 ± 457.00^{c}	8167.00 ± 44.00^{b}	3939.00 ± 206.00^{a}
Nitrate (mg/kg DW), Nitrogen applied	26722.00 ± 614.00^{c}	24194.00 ± 560.00^{b}	5250.00 ± 583.00^{a}
Soluble oxalate (g/100g DW), Control	4.58 ± 0.32^{b}	4.03 ± 0.17^{b}	2.96 ± 0.34^{a}
Soluble oxalate (g/100g DW), Nitrogen applied	4.58 ± 0.32^{b}	4.03 ± 0.17^{b}	2.96 ± 0.34^{a}
Total oxalate (g/100g DW), Control	6.08 ± 0.27^{b}	5.18 ± 0.39^{ab}	4.55 ± 0.34^{a}
Total oxalate (g/100g DW), Nitrogen applied	5.85 ± 0.07^{b}	4.85 ± 0.24^{a}	4.42 ± 0.27^{a}
β-carotene (mg/100g FW), Control	1.50 ± 0.08^{ab}	2.37 ± 0.13^{c}	3.58 ± 0.11^{b}
β-carotene (mg/100g FW), Nitrogen applied	2.94 ± 0.48^{a}	5.58 ± 0.19^{b}	6.05 ± 0.12^{b}
Vitamin C (mg/100g FW), Control	148.91 ± 8.09^{a}	183.27 ± 10.37^{b}	149.34 ± 11.41^{a}
Vitamin C (mg/100g FW), Nitrogen applied	133.73 ± 11.50^{a}	177.55 ± 16.09^{b}	138.46 ± 17.74^{a}

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.10.2a *Hibiscus sabdaliffa* at Market Maturity

The determination of effect of leaf position on antinutrients and vitamins content in *Hibiscus sabdaliffa* at market maturity showed that no significant difference in cyanide content was observed between basal (522.89 ± 30.42mg/kg) and middle (472.57 ± 6.83mg/kg) leaves, however, the two leaf positions was significantly ($p < 0.05$) higher in cyanide content than upper (383.45 ± 25.41mg/kg) region in control *Hibiscus sabdaliffa.* With the application of nitrogen fertilizer, no significant difference in cyanide content was observed between middle (428.92 ± 36.80mg/kg) and upper (362.84 ± 33.28mg/kg) leaves, however, basal (466.81 ± 75.17mg/kg) leaves had significant ($p < 0.05$) amount of the compound than upper leaves (see table 4.4.2a)

Results from analysis of nitrate revealed that basal leaves (179.22 ± 12.73mg/kg) had the highest significant ($p < 0.05$) amount of nitrate, followed by middle (37.72 ± 8.99mg/kg) and lowest in upper (17.79 ± 8.59mg/kg) leaves in control vegetable. Similarly with application of nitrogen fertilizer, basal leaves was highest in in nitrate (205.55 ± 4.81mg/kg), followed by middle leaves (57.22 ± 8.83mg/kg) and lowest in the upper (42.78 ± 16.55.76mg/kg) leaf positions.

Results obtained from analysis of soluble oxalate content in the vegetable revealed that leaf positions had no significant ($p > 0.05$) effect on the antinutrient content in the leaves of *Hibiscus sabdaliffa* without nitrogen fertilizer. However, with the application of nitrogen fertilizer, though no significant difference in soluble oxalate content was observed between basal (1.53 ± 0.06g/100g) and middle (1.35 ± 0.11g/100g) leaves and between middle, and upper (1.22 ± 0.05g/100g) leaves, basal leaves had

significant ($p < 0.05$) higher content of antinutrient than upper leaves. The total oxalate contents in middle leaves was not significantly ($p > 0.05$) different from upper leaves, however, basal leaves had significant ($p < 0.05$) higher content of compound than in the two leaf positions in both control and nitrogen treated *Hibiscus sabdaliffa.*

The significant ($p < 0.05$) increased in β-carotene content observed in the three leaf positions of the vegetable at market maturity irrespective of nitrogen levels is in the following order Middle > Upper > Basal leaves (see Table 4.4.2a).

Determination of vitamin C content in the vegetable showed that no significant difference in Vitamin contents was observed between basal and upper leaves, but the two leaf positions were significantly ($p < 0.05$) lower in the vitamin content than in the middle leaves in control and nitrogen fertilized plant. The mean values for basal leaves in control (10.45 ± 0.99mg/100g) and nitrogen applied vegetable (12.42 ± 1.49mg/100g) were not significantly different from the level in upper leaves (10.45 ± 0.99mg/100g and 11.03 ± 0.99mg/100g respectively). The mean value of the vitamin in the middle leaves for control (16.61 ± 2.20mg/100g) and nitrogen applied (18.19 ± 3.47mg/100g) were significantly ($p < 0.05$) higher than the two leaf positions (as shown in Table 4.4.2a).

Table 4.4.2a Effect of leaf position on antinutrients and vitamins content in *Hibiscus sabdaliffa* at market maturity stage

Antinutrients and vitamins	Leaf positions		
	Basal leaves	Middle leaves	Upper leaves
Cyanide (mg/kg DW), Control	522.89 ± 30.42^{b}	472.57 ± 6.83^{b}	383.45 ± 25.41^{a}
Cyanide (mg/kg DW). Nitrogen applied	466.81 ± 75.17^{b}	428.92 ± 36.80^{ab}	362.84 ± 33.28^{a}
Nitrate (mg/kg DW), Control	179.22 ± 12.73^{c}	37.72 ± 8.99^{b}	17.79 ± 8.59^{a}
Nitrate (mg/kg DW), Nitrogen applied	205.55 ± 4.81^{c}	57.22 ± 8.83^{b}	42.78 ± 16.55^{a}
Soluble oxalate (g/100g DW), Control	1.70 ± 0.09^{a}	1.63 ± 0.07^{a}	1.54 ± 0.17^{a}
Soluble oxalate (g/100g DW), Nitrogen applied	1.53 ± 0.06^{b}	1.35 ± 0.11^{ab}	1.22 ± 0.05^{a}
Total oxalate (g/100g DW), Control	2.33 ± 0.14^{b}	1.97 ± 0.09^{a}	1.93 ± 0.08^{a}
Total oxalate (g/100g DW), Nitrogen applied	2.04 ± 0.60^{b}	1.88 ± 0.07^{a}	1.85 ± 0.09^{a}
β-carotene (mg/100g FW), Control	3.70 ± 0.22^{a}	6.52 ± 0.08^{c}	5.99 ± 0.09^{b}
β-carotene (mg/100g FW), Nitrogen applied	6.11 ± 0.15^{a}	7.87 ± 0.16^{c}	7.22 ± 0.09^{b}
Vitamin C (mg/100g FW), Control	10.45 ± 0.99^{a}	16.61 ± 2.20^{b}	10.45 ± 0.99^{a}
Vitamin C (mg/100g FW), Nitrogen applied	12.42 ± 1.49^{a}	18.19 ± 3.47^{b}	11.03 ± 0.99^{a}

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.10.2b *Hibiscus sabdariffa* at Fruiting

Results obtained from the investigations of effect of leaf position on antinutrients and vitamins content in *Hibiscus sabdaliffa* at fruiting stage indicated that there was no significant difference in cyanide content between basal (464.39 ± 17.02mg/kg) and middle (437.40 ± 30.16mg/kg) leaves, however, both leaf positions were significantly ($p < 0.05$) higher in the parameter than upper (268.87 ± 32.97mg/kg) leaf position in control *Hibiscus sabdariffa.* With the application of nitrogen fertilizer, even though no significant differences in the cyanide content was observed between basal (480.08 ± 62.64mg/kg) and middle (414.67 ± 66.68mg/kg) leaves, and between middle and upper (337.08 ± 16.52mg/kg) leaves, basal leaves were significantly ($p < 0.05$) higher in the compound than upper leaves (as shown in Table 4.4.2b).

There was no significant difference in the nitrate content between basal (272.22 ± 41.95mg/kg) and upper (222.22 ± 25.46mg/kg) leaves, however, middle leaves (361.11 ± 34.70mg/kg) had significant ($p < 0.05$) higher amount of nitrate than upper leaves in control. With the application of nitrogen fertilizer, significant ($p < 0.05$) increased in the bioaccumulation of nitrate in the three leaf positions of *Hibiscus sabdaliffa* was observed and the order are middle (449.09 ± 32.01mg/kg) > basal (327.89 ± 28.00mg/kg) > upper (255.44 ± 23.00mg/kg) leaves (see Table 4.4.2b).

Studies conducted on soluble oxalate revealed that there was no significant difference in the antinutrients content between middle and upper leaves, however, both leaf positions were significantly ($p < 0.05$) lower in the antinutrients content than the basal leaves in control and nitrogen fertilized vegetable. The mean values for middle

leaves in control (1.73 ± 0.20g/100g) and nitrogen applied vegetable (2.76 ± 0.08g/100g) were not significantly different from the level in upper leaves (1.61 ± 0.11g/100g and 2.51 ± 0.10g/100g respectively). The mean value of the oxalate in the basal leaves for control (1.97 ± 0.18g/100g) and nitrogen applied (3.50. ± 0.23g/100g) were significantly ($p < 0.05$) elevated than the two leaf positions (Table 4.4.2b). Similarly results from analysis of total oxalate content of vegetable also indicated that the amount of oxalate in the middle leaves in control (3.07 ± 0.08g/100g) and nitrogen applied vegetable (3.74 ± 0.14g/100g) were not significantly different from the level in upper leaves (2.63 ± 0.20g/100g and 3.55 ± 0.10g/100g respectively). The oxalate content in the basal leaves for control (3.96 ± 0.28g/100g) and nitrogen applied (5.01 ± 0.56g/100g) were significantly ($p < 0.05$) higher than the two leaf positions (see Table 4.4.2b).

The amount of β-carotene was significantly ($p < 0.05$) highest in upper followed by middle and lowest in the basal leaf positions in control and nitrogen fertilized *Hibiscus sabdaliffa* (as shown in Table 4.4.2 b). Results from the determination of vitamin C indicated that no significant difference in the vitamin content was observed between basal (11.03 ± 0.99mg/100g) and upper (12.46 ± 0.75mg/100g) leaves, however, middle (15.75 ± 1.51mg/100g) leaves had significant ($p < 0.05$) higher amount of the vitamin than the two leaf regions in the control vegetable. However, with the application of nitrogen fertilizer, the vitamin content in the middle (18.60 ± 1.51mg/100g) was not significantly different from upper (16.32 ± 0.75mg/100g) leaves, but the two leaf positions had significant ($p < 0.05$) higher amount of the vitamin than basal (18.19 ± 3.47mg/100g) leaves (as shown in Table 4.4.2b).

Table 4.4.2b Effect of leaf position on antinutrients and vitamins content in *Hibiscus sabdaliffa* at fruiting stage

Antinutrients and vitamins	Leaf position		
	Basal leaves	Middle leaves	Upper leaves
Cyanide (mg/kg DW), Control	464.39 ± 17.02^{b}	437.40 ± 30.16^{b}	268.87 ± 32.97^{a}
Cyanide (mg/kg DW), Nitrogen applied	480.80 ± 62.64^{b}	414.67 ± 66.68^{ab}	337.08 ± 16.52^{a}
Nitrate (mg/kg DW), Control	272.22 ± 41.95^{ab}	361.11 ± 34.70^{b}	222.22 ± 25.46^{a}
Nitrate (mg/kg DW),Nitrogen applied	327.89 ± 28.00^{b}	449.09 ± 32.01^{b}	255.44 ± 23.00^{a}
Soluble oxalate (g/100g DW), Control	1.97 ± 0.18^{b}	1.73 ± 0.20^{a}	1.61 ± 0.11^{a}
Soluble oxalate (g/100g DW), Nitrogen applied	3.50 ± 0.23^{b}	2.76 ± 0.08^{a}	2.51 ± 0.10^{a}
Total oxalate (g/100g DW), Control	3.96 ± 0.28^{b}	3.07 ± 0.08^{a}	2.63 ± 0.20^{a}
Total oxalate (g/100g DW), Nitrogen applied	5.01 ± 0.56^{b}	3.74 ± 0.14^{a}	3.55 ± 0.10^{a}
β-carotene (mg/100g FW), Control	5.05 ± 0.13^{a}	5.74 ± 0.12^{b}	7.58 ± 0.20^{c}
β-carotene (mg/100g FW), Nitrogen applied	5.13 ± 0.87^{a}	6.38 ± 0.21^{b}	7.93 ± 0.10^{c}
Vitamin C (mg/100g FW), Control	11.03 ± 0.99^{a}	15.75 ± 1.51^{b}	12.46 ± 0.75^{a}
Vitamin C (mg/100g FW), Nitrogen applied	13.32 ± 0.75^{a}	18.60 ± 1.51^{b}	16.32 ± 0.75^{b}

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.10.3a *Corchorus olitorius* at Market Maturity

The determination of the effect of leaf position on antinutrients and vitamins content in *Corchorus olitorius* at market maturity indicated that leaf position generally affects the distributions of these substances in the plant. Results obtained revealed that there was no significant difference in the cyanide contents between basal and middle leaves, however, the two leaf positions had significant ($p < 0.05$) higher content of the compound than upper leaf position in control and nitrogen fertilized vegetable. The amount of cyanide in the basal leaves in control (769.43 ± 58.44mg/kg) and nitrogen applied vegetable (799.24 ± 71.42mg/kg) were not significantly ($p > 0.05$) different from the level in middle leaves (723.46 ± 70.54mg/kg and 849.26 ± 71.82mg/kg respectively). The cyanide content in the upper leaves for control (497.13 ± 77.79mg/kg) and nitrogen applied (204.31 ± 73.25mg/kg) was significantly ($p < 0.05$) lower than the two leaf positions (see Table 4.4.3a).

The nitrate content of the vegetable was significantly ($p < 0.05$) highest in the basal (3633.30 ± 83.30mg/kg) closely followed by middle (1544.40 ± 100.50mg/kg) and lowest in the upper (905.60 ± 38.50mg/kg) leaf regions in control vegetable. When the vegetable was treated with nitrogen fertilizer, no significant difference in the nitrate content was observed between middle (2105.50 ± 35.40mg/kg) and upper (1955.60 ± 371.30mg/kg) leaves, however, the two leaf positions had lower nitrate content than the basal (4088.90 ± 657.10mg/kg) leaves (as shown inTable 4.4.3a).

Determination of soluble oxalate in control *Corchorus olitorius* at market maturity showed that no significant difference in soluble oxalate content was observed

between middle (2.07 ± 0.23g/100g) and upper (1.78 ± 0.17g/100g) leaf positions, however, the two leaf positions were significantly ($p < 0.05$) higher in the antinutrient content than basal leaf (1.20 ± 0.16g/100kg) region. With the application of nitrogen fertilizer, no significant difference in the antinutreint content was recorded between basal (1.80 ± 0.45g/100g) and upper (1.80 ± 0.23g/100g) leaf regions; however, the soluble oxalate content in the middle leaf (2.94 ± 0.05g/100g) region was significantly ($p < 0.05$) higher than those of the basal and upper leaf positions (see Table 4.4.3a). Results obtained from analysis of total oxalate content of vegetable revealed that no significant difference in the level of antinutrient was observed between middle (3.47 ± 0.22g/100g) and upper (3.13 ± 0.04g/100g) leaves, and between upper and basal (2.85 ± 0.16g/100g) leaves, but middle leaves had higher significant ($p < 0.05$) amount of the antinutrient than basal leaves in the control. When the plant received nitrogen fertilizer, no significant differences between middle (3.77 ± 0.24g/100g) and basal (3.24 ± 0.34g/100g) leaves, and between basal and upper (2.57 ± 0.11g/100g) leaves was recorded, however, middle leaves had significant higher content of total oxalate than upper leaves (as shown in Table 4.4.3a).

The β-carotene content in basal leaves was not significantly different from the values obtained in upper leaves, however the amount of the provitamin was significantly ($p < 0.05$) higher in the middle leaves than in the two leaf positions in control and nitrogen fertilized vegetable. The amount of β-carotene in the basal leaves in control (2.36 ± 0.17mg/100g) and nitrogen applied vegetable (9.91 ± 0.20mg/100g) were not significantly different from the level in upper leaves (2.12 ± 0.06mg/100g and 9.67 ± 0.22mg/100g respectively). The β-carotene content in the middle leaves for control

(3.39 ± 0.08mg/100g) and nitrogen applied (11.20 ± 0.10mg/100g) were significantly ($p < 0.05$) higher than the basal and upper leaf positions (see Table 4.4.3a).

The levels of vitamin C in *Corchorus olitorius* at market maturity was significantly ($p < 0.05$) highest in the in middle leaves, followed by upper leaves and least in the basal leaves irrespective of the fertilizer levels. The vitamin C concentrations in the basal, middle and upper leaves in control were 53.98 ± 5.18mg/100kg, 112.54 ± 3.67mg/100g and 91.62 ± 2.79mg/100g respectively. While the corresponding values obtained with the application of nitrogen fertilizer were 74.89 ± 3.47mg/100g, 123.71 ± 3.67mg/100g and 106.53 ± 7.10mg/100g (see Table 4.4.3a).

Table 4.4.3a Effect of leaf position on antinutrients and vitamins content in *Corchorus olitorius* at market maturity stage

Antinutrients and vitamins	Leaf position		
	Basal leaves	Middle leaves	Upper leaves
Cyanide (mg/kg DW), Control	769.43 ± 58.44^{b}	723.46 ± 70.54^{b}	497.13 ± 77.79^{a}
Cyanide (mg/kg DW), Nitrogen applied	799.24 ± 71.42^{b}	849.26 ± 71.82^{b}	204.31 ± 73.25^{a}
Nitrate (mg/kg DW), Control	3633.30 ± 83.30^{c}	1544.40 ± 100.50^{b}	905.60 ± 38.50^{a}
Nitrate (mg/kg DW), Nitrogen applied	4088.90 ± 65.10^{b}	2105.50 ± 35.40^{a}	1955.60 ± 371.30^{a}
Soluble oxalate (g/100g DW), Control	1.20 ± 0.16^{a}	2.07 ± 0.23^{b}	1.78 ± 0.17^{b}
Soluble oxalate (g/100g DW), Nitrogen applied	1.80 ± 0.45^{a}	2.94 ± 0.05^{b}	1.80 ± 0.23^{a}
Total oxalate (g/100g DW), Control	2.85 ± 0.16^{a}	3.47 ± 0.22^{b}	3.13 ± 0.04^{ab}
Total oxalate (g/100g DW), Nitrogen applied	3.24 ± 0.34^{ab}	3.77 ± 0.24^{b}	2.57 ± 0.11^{a}
β-carotene (mg/100g FW), Control	2.36 ± 0.17^{a}	3.39 ± 0.08^{b}	2.12 ± 0.06^{a}
β-carotene (mg/100g FW), Nitrogen applied	9.91 ± 0.20^{a}	11.20 ± 0.10^{b}	9.67 ± 0.23^{a}
Vitamin C (mg/100g FW), Control	53.98 ± 5.18^{a}	112.54 ± 3.67^{c}	91.62 ± 2.79^{b}
Vitamin C (mg/100g FW), Nitrogen applied	74.89 ± 3.47^{a}	123.71 ± 3.67^{b}	106.53 ± 7.10^{b}

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.10.3b *Corchorus olitorius* at fruiting

The levels of antinutrients and vitamins were analyzed in *Corchorus olitorius* at fruiting in basal, middle and upper leaves of controls and vegetables grown on nitrogen treated soil with a view to determining the effect of leaf position on the studied antinutrients and vitamins. The results obtained showed that leaf position generally affect the bioaccumulation of the antinutrients and vitamins in the leaves of the plant. The cyanide content in the vegetable was significantly ($p < 0.05$) highest in the basal followed by middle and lowest in upper leaf positions irrespective of nitrogen levels. The concentrations of cyanide in the basal, middle and upper leaves in control were 1489.40 ± 57.70mg/kg, 1306.50 ± 39.60mg/kg and 1180.20 ± 36.70mg/kg respectively. While the corresponding values obtained with the application of nitrogen fertilizer were 1666.00 ± 151.70mg/kg, 1252.50 ± 238.90mg/kg and 742.10 ± 30.10mg/kg respectively (see Table 4.4.3b).

Results from analysis of nitrate indicated that no significant difference ($p > 0.05$) in the nitrate content was observed between basal and middle leaves, however, the two leaf positions were significantly higher ($p < 0.05$) in the parameter than upper leaf position in control and nitrogen fertilized vegetable. The mean values for basal leaves in control (400.00 ± 130.20mg/kg) and nitrogen applied vegetable (327.78 ± 9.62mg/kg) were not significantly different from the level in middle leaves (383.30 ± 104.10mg/kg and 272.22 ± 25.46mg/kg respectively). However, the mean value of the nitrate in the upper leaves for control (266.50 ± 245.90mg/kg) and nitrogen applied

(105.56 ± 45.10mg/kg) were significantly lower ($p < 0.05$) than the two leaf positions (as shown in Table 4.4.3b).

Studies conducted on soluble oxalate indicated that there was no significant difference in the antinutrients content between middle and upper leaves; however, both leaf positions were significantly ($p < 0.05$) lower in the antinutrients content than the basal leaves irrespective of fertilizer levels. The mean values for middle leaves in control (6.10 ± 0.42g/100g) and nitrogen applied vegetable (5.57 ± 0.57g/100g) were not significantly different from the levels in upper leaves (5.70 ± 0.10g/100g and 5.31 ± 0.28g/100g respectively). The mean value of the oxalate in the basal leaves for control (8.66 ± 0.49g/100g) and nitrogen applied (7.01 ± 0.17g/100g) were significantly ($p < 0.05$) elevated than the two leaf positions (Table 4.4.3b). Similarly, results from analysis of total oxalate content of the studied vegetable also indicated that the amount of oxalate in the middle (7.80 ± 0.31g/100g) leaves was not significantly different from the levels found in upper leaves (6.92 ± 0.31g/100g); however the oxalate content in these two leaf positions were significantly ($p < 0.05$) lower than in the basal leaves (10.44 ± 2.46g/100g) in the control. With the application of nitrogen fertilizer, leaf position had no significant effect on the total oxalate content of the vegetable (see Table 4.4.3b).

The amount of β-carotene was significantly ($p < 0.05$) highest in upper followed by middle and lowest in the basal leaf positions in control and nitrogen fertilized *Corchorus olitorius*. The of concentrations β-carotene in the basal, middle and upper leaves in control were 6.22 ± 0.26mg/100g, 11.63 ± 0.12mg/100g and

12.98 ± 0.32mg/100g respectively. While the corresponding concentrations of β-carotene in the nitrogen fertilized vegetable were 9.16 ± 0.10mg/100g, 12.54 ± 0.08g/100g and 13.33 ± 0.05mg/100g respectively (as shown inTable 4.4.3b).

Analysis of vitamin C showed that the amount of vitamin C in the control *Corchorus olitorius* was significantly ($p < 0.05$) highest in middle (55.84 ± 1.29mg/100g) closely followed by basal (46.68 ± 2.21mg/100g) and lowest in the upper (37.80 ± 3.67mg/100g) leaf regions. When the plant received nitrogen fertilizer, no significant difference in the vitamin content was observed between basal (37.23 ± 2.80mg/100g) and middle (44.82 ± 2.86mg/100g) leaves, and between basal and upper (30.07 ± 4.30mg/100g) leaves, however, middle leaves was significantly higher in the vitamin content than upper leaves (see Table 4.4.3b).

Table 4.4.3b Effect of leaf position on antinutrients and vitamins content in *Corchorus olitorius* at fruiting stage

Antinutrients and vitamins	Leaf position		
	Basal leaves	Middle leaves	Upper leaves
Cyanide (mg/kg DW), Control	1306.50 ± 39.60^{b}	1489.40 ± 57.70^{c}	1180.20 ± 36.70^{a}
Cyanide (mg/kg DW), Nitrogen applied	1666.00 ± 151.70^{c}	1252.50 ± 238.90^{b}	742.10 ± 30.10^{a}
Nitrate (mg/kg DW), Control	400.00 ± 130.20^{b}	383.30 ± 104.10^{b}	266.50 ± 45.90^{a}
Nitrate (mg/kg DW), Nitrogen applied	327.78 ± 9.62^{b}	272.22 ± 25.46^{b}	105.56 ± 45.10^{a}
Soluble oxalate (g/100g DW), Control	8.66 ± 0.49^{b}	6.10 ± 0.42^{a}	5.70 ± 0.10^{a}
Soluble oxalate (g/100g DW), Nitrogen applied	7.01 ± 0.17^{b}	5.57 ± 0.57^{a}	5.31 ± 0.28^{a}
Total oxalate (g/100g DW), Control	10.44 ± 2046^{b}	7.80 ± 0.31^{a}	6.92 ± 0.31^{a}
Total oxalate (g/100g DW),Nitrogen applied	7.85 ± 0.42^{a}	7.42 ± 0.81^{a}	7.09 ± 0.46^{a}
β-carotene (mg/100g FW), Control	6.22 ± 0.26^{a}	11.63 ± 0.12^{b}	12.98 ± 0.32^{c}
β-carotene (mg/100g FW), Nitrogen applied	9.16 ± 0.10^{a}	12.54 ± 0.08^{b}	13.33 ± 0.05^{c}
Vitamin C (mg/100g FW), Control	46.68 ± 2.21^{b}	55.84 ± 1.29^{c}	37.80 ± 3.67^{a}
Vitamin C (mg/100g FW), Nitrogen applied	37.23 ± 2.80^{ab}	44.82 ± 2.86^{b}	30.07 ± 4.30^{a}

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.10.4a *Telfairia occidentalis* at Market Maturity

Determination of effect of leaf position on antinutrients and vitamins content in *Telfairia occidentalis* at market maturity in control and nitrogen fertilized revealed that no significant difference ($p > 0.05$) was observed in the cyanide content between basal and middle leaves and between middle and upper leaves, however, basal leaves had significant higher ($p < 0.05$) content of cyanide than upper leaves (see Table 4.4.4a).

The levels of nitrate in control and nitrogen fertilized vegetable was ($p < 0.05$) highest in upper, followed by middle and lowest in the basal leaf positions. The mean values of nitrate in basal, middle and upper leaves in control were 272.22 ± 50.92mg/kg, 466.66 ± 28.87mg/kg and 911.11 ± 41.94mg/kg respectively. While the corresponding concentrations of nitrate in the nitrogen fertilized vegetable were 355.60 ± 134 mg/kg, 627.80.00 ± 122.90mg/kg and 1105.60 ± 160.20mg/kg respectively (as shown in Table 4.4.4a).

There was no significant difference in soluble oxalate content between basal (1.77 ± 0.02g/100g) and middle (1.67 ± 0.22g/100g) leaves and between middle, and upper (1.49 ± 0.13g/100g) leaves, but basal leaves had significant ($p < 0.05$) higher content of antinutrient than upper leaves in the control vegetable. With the application of nitrogen fertilizer no significant difference in soluble oxalate content was observed between basal (2.05 ± 0.30g/100g) and middle (2.04 ± 0.11g/100g) leaves, however, the mean value of the soluble oxalate in the upper leaves (1.36 ± 0.31g/100g) was significantly ($p < 0.05$) lower than the two leaf positions (see Table 4.4.4a). Similarly results obtained from the analysis of total oxalate content in control also indicated that

there was no significant difference in total oxalate content between basal (2.40 ± 0.08g/100g) and middle (2.28 ± 0.14g/100g) leaves and between middle, and upper (1.98 ± 0.14g/100g) leaves, however the levels of antinutrients in basal leaves was significantly ($p < 0.05$) higher than in upper leaves. When the vegetable received nitrogen fertilizer no significant difference in the total oxalate content was recorded between basal (2.59 ± 0.10g/100g) and middle (2.42 ± 0.14g/100g) leaves, but the oxalate levels in the upper leaves (1.60 ± 0.18g/100g) was significantly ($p < 0.05$) lower than in the two leaf positions (see Table 4.4.4a).

The levels of β-carotene was significantly ($p < 0.05$) highest in upper followed by middle and lowest in the basal leaf positions in control and nitrogen fertilized *Telfairia occidentalis*. The of concentrations β-carotene in the basal, middle and upper leaves in control were 13.70 ± 0.35mg/100g, 15.09 ± 0.18mg/100g and 17.70 ± 0.15mg/100g respectively. While the corresponding mean values of β-carotene in the nitrogen fertilized vegetable were 14.92 ± 0.54mg/100g, 16.45 ± 0.45mg/100g and 21.43 ± 1.17mg/100g, respectively (as shown in Table 4.4.4a).

Similarly results from analysis of vitamin C content of vegetable indicated that the amount of the vitamin in the middle leaves in control (205.61 ± 11.50mg/100g) and nitrogen applied vegetable (173.83 ± 23.70mg/100g) were not significantly different from the level in upper leaves (185.71 ± 10.13mg/100g and 162.24 ± 5.85mg/100g respectively). The vitamin content in the basal leaves for control (233.92 ± 5.86mg/100g) and nitrogen applied (238.69 ± 8.44mg/100g) was significantly ($p < 0.05$) elevated than in any the two leaf positions (see Table 4.4.4a).

Table 4.4.4a Effect of leaf position on antinutrients and vitamins content in *Telfairia occidentalis* at market maturity stage

Antinutrients and vitamins	Leaf positions		
	Basal leaves	Middle leaves	Upper leaves
Cyanide (mg/kg DW), Control	549.26 ± 59.39^{b}	414.70 ± 63.10^{ab}	351.03 ± 105.53^{a}
Cyanide (mg/kg DW), Nitrogen applied	813.60 ± 59.89^{b}	723.90 ± 110.60^{ab}	560.20 ± 58.50^{a}
Nitrate (mg/kg DW), Control	272.22 ± 50.92^{a}	466.66 ± 28.87^{b}	911.11 ± 41.94^{c}
Nitrate (mg/kg DW), Nitrogen applied	355.60 ± 134.70^{a}	627.80 ± 122.90^{b}	1105.60 ± 160.20^{c}
Soluble oxalate (g/100g DW), Control	1.77 ± 0.02^{b}	1.67 ± 0.22^{ab}	1.49 ± 0.13^{a}
Soluble oxalate (g/100g DW), Nitrogen applied	2.05 ± 0.30^{b}	2.04 ± 0.11^{b}	1.36 ± 0.31^{a}
Total oxalate (g/100g DW),Control	2.40 ± 0.08^{b}	2.28 ± 0.14^{ab}	1.98 ± 0.14^{a}
Total oxalate (g/100g DW),Nitrogen applied	2.59 ± 0.10^{b}	2.42 ± 0.14^{b}	1.60 ± 0.18^{a}
β-carotene (mg/100g FW), Control	13.71 ± 0.35^{a}	15.09 ± 0.18^{b}	17.71 ± 0.15^{c}
β-carotene (mg/100g FW), Nitrogen applied	14.92 ± 0.54^{a}	16.45 ± 0.45^{b}	21.43 ± 0.17^{c}
Vitamin C (mg/100g FW), Control	233.92 ± 5.86^{b}	205.61 ± 11.50^{a}	185.71 ± 10.13^{a}
Vitamin C (mg/100g FW), Nitrogen applied	238.69 ± 8.44^{b}	173.83 ± 23.70^{a}	162.24 ± 5.85^{a}

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.10.4b *Telfairia occidentalis* at Fruiting

The results of effect of leaf positions on antinutrients and vitamins content in *Telfairia occidentalis* at fruiting showed that there was significant ($p < 0.05$) difference in the cyanide content between the three leaf positions in control *Telfairia occidentalis*. The cyanide content was significantly highest ($p < 0.05$) in upper (1005.80 ± 29.90mg/kg), followed by middle (891.20 ± 23.60mg/kg) and lowest in basal (756.60 ± 33.50mg/kg) leaves. When the plant received nitrogen fertilizer, though no significant difference in cyanide levels was observed between basal (719.86 ± 3.46mg/kg) and middle (748.23 ± 20.48mg/kg) leaves, however, upper leaves (844.99 ± 17.47mg/kg) had significant ($p < 0.05$) higher content of the compound than in the two leaf positions (see Table 4.4.4b).

Similarly results obtained from the determination of the nitrate levels in the control vegetable also indicated that the nitrate content in the middle leaves (18.34 ± 2.89mg/kg) was not significantly different from the basal leaves (13.00 ± 3.18mg/kg), but the two leaf positions had lower significant ($p < 0.05$) content of the compound than the upper leaf (50.00 ± 5.00mg/kg) region. The same trend of results were obtained with the application of nitrogen fertilizer, no significant differences in the nitrate content was observed between basal leaves (22.06 ± 14.36mg/kg) and middle (32.76 ± 9.65mg/kg) leaves, however, the upper (103.89 ± 11.35mg/kg) leaves, had higher significant ($p < 0.05$) amount of the compound than the two leaf positions (as shown in Table 4.4.4b).

Results obtained from the determination of soluble oxalate content in the control vegetable showed that basal leaves (1.96 ± 0.07g/100g) had the highest significant ($p < 0.05$) content of the antinutrient followed by middle (1.65 ± 0.08g/100g) and lowest in the upper leaves (1.35 ± 0.16g/100g). When plant received nitrogen fertilizer, no significant difference in antinutrient content was observed between the three leaf positions (Table 4.4.4b). Similarly, the total oxalate content of the vegetable was significantly ($p < 0.05$) highest in the basal leaves (3.52 ± 0.08g/100g) followed by middle leaves (3.15 ± 0.07g/100g) and least in the upper leaves (2.93 ± 0.07g/100g). When *Telfairia occidentalis* was treated with nitrogen fertilizer no significant difference in the total oxalate content was recorded between the leaf positions (see Table 4.4.4b).

Analysis of β-carotene showed that there was a significant ($p < 0.05$) difference in provitamin content between the three leaf positions in both control and nitrogen fertilized vegetable (see Table 4.4.4b). The increased order are upper > middle > basal leaves.

The amount of vitamin C in middle leaves (214.35 ± 7.10mg/100g) of control *Telfairia occidentalis* was not significantly different from the basal leaves (194.30 ± 15.98mg/100g). However, upper leaves (265.03 ± 4.30mg/100g) had significantly ($p < 0.05$) higher content of the vitamin than the two leaf positions. When the vegetable was grown on the soil fertilized with nitrogen, the concentration of the vitamin was significantly ($p < 0.05$) highest in the upper leaf (217.64 ± 6.4mg/100g) closely followed by middle leaf (199.03 ± 5.12mg/100g) and lowest in basal leaf (142.18 ± 4.55mg/100g) positions (see Table 4.4.4b).

Table 4.4.4b Effect of leaf position on antinutrients and vitamins content in *Telfairia occidentalis* at fruiting stage

Antinutrients and vitamins	Leaf positions		
	Basal leaves	Middle leaves	Upper leaves
Cyanide (mg/kg DW), Control	756.60 ± 33.50^{a}	891.20 ± 23.60^{b}	1005.80 ± 29.90^{c}
Cyanide (mg/kg DW), Nitrogen applied	719.86 ± 3.46^{a}	748.23 ± 20.84^{a}	844.99 ± 17.47^{b}
Nitrate (mg/kg DW), Control	13.00 ± 3.18^{a}	18.34 ± 2.89^{a}	50.00 ± 5.00^{b}
Nitrate (mg/kg DW),Nitrogen applied	22.06 ± 14.46^{a}	32.76 ± 9.65^{a}	103.89 ± 11.35^{b}
Soluble oxalate (g/100g DW), Control	1.96 ± 0.07^{c}	1.65 ± 0.08^{b}	1.35 ± 0.16^{a}
Soluble oxalate (g/100g DW), Nitrogen applied	2.12 ± 0.11^{a}	2.06 ± 0.17^{a}	1.90 ± 0.17^{a}
Total oxalate (g/100gDW), Control	3.52 ± 0.08^{c}	3.15 ± 0.07^{b}	2.93 ± 0.07^{a}
Total oxalate (g/100g DW), Nitrogen applied	2.95 ± 0.03^{a}	2.78 ± 0.15^{a}	2.75 ± 0.04^{a}
β-carotene (mg/100g FW), Control	8.21 ± 0.20^{a}	9.82 ± 0.17^{b}	13.11 ± 0.33^{c}
β-carotene (mg/100g FW), Nitrogen applied	1.00 ± 0.17^{a}	10.65 ± 0.32^{b}	15.80 ± 0.14^{c}
Vitamin C (mg/100g FW), Control	194.30 ± 15.98^{a}	214.35 ± 7.10^{a}	265.03 ± 4.30^{b}
Vitamin C (mg/100g FW), Nitrogen applied	142.18 ± 4.55^{a}	199.03 ± 5.12^{b}	217.64 ± 6.11^{c}

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.10.5a *Vernonia amygdalina* at Market Maturity

Results obtained from the determination of effect of leaf positions on antinutrients and vitamins content in *Vernonia amygdalina* at market maturity revealed that there was no significant difference in the cyanide content between middle (600.20 ± 138.80mg/kg) and basal (489.90 ± 238.50mg/kg) leaves, and between basal and upper (187.90 ± 86.80mg/kg) leaves, however, the middle leaves had significantly ($p < 0.05$) higher content of the cyanogenic glycoside than upper leaves in the control vegetable, when plant received nitrogen fertilizer, the cyanide content in the middle (493.45 ± 29.22mg/kg) and basal (442.56 ± 74.75mg/kg) leaves were significantly ($p < 0.05$) higher than upper leaves (137.01 ± 11.11mg/kg) as shown in Table 4.4.5a.

Analysis of nitrate in control and nitrogen treated *Vermonia amygdalina* indicated that the nitrate content was significantly ($p < 0.05$) highest in the upper leaves, followed by middle leaves and lowest in the basal leaves (see Table 4.4.5a). Studies conducted on soluble oxalate content in control and nitrogen fertilized vegetable showed that there was no significant difference in the oxalate concentrations between the three leaf positions (Table 4.45a). Similarly no significant difference in the total oxalate content was observed between the three leaf regions in the control vegetable. However, with the application of nitrogen fertilizer, even though no significant difference in total oxalate content was recorded between middle (2.56 ± 0.21g/100g) and upper (2.71 ± 0.20g/100g) leaves, and between middle and basal (2.28 ± 0.03g/100g) leaves, but upper leaves was significantly ($p < 0.05$) higher in antinutrient content than basal leaves (as shown in Table 4.4.5a).

Results from the analysis of β-carotene revealed that the provitamin contents in control and nitrogen fertilized *Vernonia amygdalina* was significantly ($p < 0.05$) highest in upper leaves, followed by middle leaves lowest in basal leaves, as shown in Table 4.4.5a.

The vitamin C content in middle leaves (11.46 ± 1.51mg/100g) was not significantly different from upper leaves (9.02 ± 0.75mg/100g), and that of upper leaves was not significantly different form basal leaves (6.73 ± 0.99mg/100g), however, middle leaves had higher significant ($p < 0.05$) content of the vitamin than basal leaves in the control vegetable. When the plant received nitrogen fertilizer, middle leaves was significantly ($p < 0.05$) higher in the vitamin than the other two leaf positions.

Table 4.4.5a Effect of leaf position on antinutrients and vitamins content in *Vernonia amygdalina* at market maturity stage

Antinutrients and vitamins	Leaf positions		
	Basal leaves	Middle leaves	Upper leaves
Cyanide (mg/kg DW), Control	489.90 ± 38.50^{ab}	600.20 ± 38.80^{b}	187.90 ± 86.80^{a}
Cyanide (mg/kg DW), Nitrogen applied	442.56 ± 74.75^{b}	493.45 ± 29.22^{b}	137.01 ± 11.11^{a}
Nitrate (mg/kg DW), Control	161.11 ± 9.63^{a}	205.56 ± 19.25^{b}	461.11 ± 9.62^{c}
Nitrate (mg/kg DW),Nitrogen applied	277.80 ± 19.20^{a}	700.00 ± 342.00^{b}	1694.40 ± 401.80^{c}
Soluble oxalate (g/100g DW), control	1.82 ± 0.07^{a}	1.76 ± 0.08^{a}	1.84 ± 0.12^{a}
Soluble oxalate (g/100g DW), Nitrogen applied	1.82 ± 0.06^{a}	2.03 ± 0.03^{a}	2.05 ± 0.47^{a}
Total oxalate (g/100g DW), Control	2.49 ± 0.12^{a}	2.11 ± 0.27^{a}	2.08 ± 0.28^{a}
Total oxalate (g/100g DW),Nitrogen applied	2.26 ± 0.03^{a}	2.56 ± 0.21^{ab}	2.71 ± 0.20^{b}
β- carotene (mg/100g FW), Control	8.63 ± 0.57^{a}	11.84 ± 0.21^{b}	13.04 ± 0.14^{c}
β- carotene (mg/100g FW), Nitrogen applied	8.95 ± 0.65^{a}	15.99 ± 0.56^{b}	18.01 ± 0.25^{c}
Vitamin C (mg/100g FW), Control	6.73 ± 0.99^{a}	11.46 ± 1.51^{b}	9.02 ± 0.75^{ab}
Vitamin C (mg/100g FW), Nitrogen applied	9.02 ± 0.75^{a}	15.75 ± 1.51^{b}	11.46 ± 1.51^{a}

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.10.5b *Vernonia amygdalina* at Heading

Investigations of effect of leaf position on antinutrients and vitamins content in *Vernonia amygdalina* at heading showed that the cyanide content in basal leaves (1162.20 ± 94.40mg/kg) was not significantly different from the middle leaves (1044.90 ± 90.00mg/kg), however, upper leaf (474.10 ± 71.50mg/kg) region had lower significant ($p < 0.05$) level of the parameter than the two leaf regions in the control. With the application of nitrogen fertilizer, basal leaves (1276.80 ± 21.50mg/kg) was significantly ($p < 0.05$) highest in the cyanide content, followed by middle (110.20 ± 11.50mg/kg) and lowest in the upper (596.50 ± 27.10mg/kg) leaves (see Table 4.4.5b).

Analysis of nitrate content revealed that the concentrations of nitrate in middle leaves (2183.30 ± 44.10mg/kg) was significantly ($p < 0.05$) higher than basal leaves (1650.00 ± 86.60mg/kg), however upper leaves (6350.00 ± 126.70mg/kg) had significant higher amount of the compound than the two leaf positions in the control vegetable. When the plant received nitrogen fertilizer, the same trend of results was obtained in which nitrate content was significantly highest in upper leaf (6316.70 ± 258.40mg/kg) region, followed by middle (3983.30 ± 76.40mg/kg) and lowest in the basal leaf (2439.00 ± 359.20mg/kg) regions (see Table 4.4.5b).

Results obtained from the analysis of soluble oxalate content showed that there was no significant difference in the antinutrient content between basal (2.60 ± 0.30g/100g) and middle (2.13 ± 0.13g/100g) leaves, and between middle and upper leaves (2.01 ± 0.17g/100g), however, the antunutrient content in the basal leaves was significantly ($p < 0.05$) higher than the in upper leaves in control vegetables. With

the application of nitrogen fertilizer, leaf position had no significant effect on the soluble oxalate content in the leaves of the vegetable. The determination of total oxalate content of vegetable showed that there was no significant difference in the oxalate content between basal and middle leaves, and between middle and upper leaves however, the antunutrient level in the basal leaves was significantly ($p < 0.05$) higher than values found in the upper position in both control and nitrogen fertilized vegetables (as shown in Table 4.4.5b).

The β-carotene contents in upper leaves were not significantly different from the basal leave, however, the provitamin content in the two leaf positions were significantly ($p < 0.05$) lower than in the middle leaf position in both control and nitrogen fertilized vegetable (see Table 4.4.5a).

Studies conducted on vitamin C content indicated that there were no significant differences in the levels of vitamin between middle and upper leaves, and between upper and basal leaves, however middle leaves was significantly ($p < 0.05$) higher in the vitamin than basal leaves in both control and nitrogen fertilized vegetable (see Table 4.4.5b).

Table 4.4.5b Effect of leaf position on antinutrients and vitamins content in *Vernonia amygdalina* at heading stage

Antinutrients and vitamins	Leaf positions		
	Basal leaves	Middle leaves	Upper leaves
Cyanide (mg/kg DW), Control	1162.20 ± 94.40^{b}	1044.90 ± 90.00^{b}	474.10 ± 71.50^{a}
Cyanide (mg/kg DW) , Nitrogen applied	1276.80 ± 21.50^{b}	1108.20 ± 11.50^{b}	596.50 ± 27.10^{a}
Nitrate (mg/kg DW), Control	1650.00 ± 86.60^{a}	2183.30 ± 44.10^{b}	6350.00 ± 126.70^{c}
Nitrate (mg/kg DW), Nitrogen applied	2439.00 ± 359.20^{a}	3983.30 ± 76.40^{b}	6316.70 ± 258.40^{c}
Soluble oxalate (g/100g DW), Control	2.60 ± 0.30^{b}	2.37 ± 0.13^{ab}	2.01 ± 0.17^{a}
Soluble oxalate (g/100g DW), Nitrogen applied	2.28 ± 0.12^{a}	2.19 ± 0.11^{a}	2.19 ± 0.08^{a}
Total oxalate (g/100g DW), Control	3.72 ± 0.13^{b}	3.29 ± 0.18^{ab}	2.90 ± 0.45^{a}
Total oxalate (g/100g DW), Nitrogen applied	3.20 ± 0.07^{b}	3.05 ± 0.08^{ab}	2.84 ± 0.10^{a}
β- carotene (mg/100g FW), Control	12.70 ± 0.12^{a}	15.40 ± 0.37^{b}	13.10 ± 0.22^{a}
β- carotene (mg/100g FW), Nitrogen applied	13.19 ± 0.21^{a}	15.97 ± 0.10^{b}	14.10 ± 0.26^{a}
Vitamin C (mg/100g FW), Control	11.03 ± 0.99^{a}	14.75± 0.99^{b}	13.46 ± 0.99^{ab}
Vitamin C (mg/100g FW), Nitrogen applied	12.89 ± 1.29^{a}	16.61 ± 2.20^{b}	14.75 ± 0.97^{ab}

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.11 Effect of Leaf Positions on Mineral Elements Content in Vegetables

4.11.1a *Amaranthus cruentus* at Market Maturity

Determination of the effect of leaf positions on minerals content in *Amaranthus cruentus* at market maturity showed that leaf position had no significant effect on the Fe content in the leaves in the control. But when the plant received nitrogen fertilizer though no significant difference in the mineral content was observed between middle (23.67 ± 2.20mg/kg) and upper (22.53 ± 5.33mg/kg) leaves, basal leaves (27.53 ± 3.37mg/kg) had significant ($p < 0.05$) higher content of mineral than the two leaf positions (see Table 4.5.1a).

The significant ($p < 0.05$) increasing order observed in Mg content in the three leaf positions irrespective of fertilizer levels is as follows; basal > middle > upper leaves (Table 4.5.1a). Results obtained from analysis of Zn in control and nitrogen fertilized vegetable indicated that there were no significant difference in the mineral content between basal and upper leaves, however, middle leaves had significant higher content of the minerals than the leaves obtained from the two leaf position (see Table 4.5.1a).

Studies conducted on Cu indicated that there was no significant difference in the mineral content between basal (5.79 ± 0.14mg/kg) and middle (5.24 ± 2.17mg/kg) leaves, the mineral content in the two leaf positions were significantly ($p < 0.05$) elevated compared to upper leaf (2.63 ± 1.57mg/kg) region in control vegetable. With the application of nitrogen fertilizer, leaf positions had no significant effect on the minerals content in the leaves of the studied vegetable (as shown in Table 4.5.1a). Similarly results

from the determination of Ca and K in control and nitrogen plant also indicated that leaf positions had no significant effect in the mineral contents (see Table 4.5.1a). The level of Na in middle leaves was not significantly different from the levels in the basal and middle leaves, however, basal leaves had significant ($p < 0.05$) higher content of the mineral than upper leaves in control and nitrogen treated vegetable (see Table 4.5.1a).

Table 4.5.1a Effect of leaf position on minerals content in *Amaranthus cruentus* at market maturity stage

Minerals	Leaf position		
	Basal leaves	Middle leaves	Upper leaves
Fe (mg/kg), Control	34.58 ± 1.85^{a}	33.50 ± 1.71^{a}	32.50 ± 6.19^{a}
Fe (mg/kg) , Nitrogen applied	27.53 ± 3.37^{b}	23.67 ± 2.20^{a}	22.53 ± 5.33^{a}
Mg (mg/kg), Control	28.49 ± 0.71^{c}	26.98 ± 1.15^{b}	23.32 ± 0.59^{a}
Mg (mg/kg), Nitrogen applied	30.52 ± 1.40^{c}	27.96 ± 1.09^{b}	22.88 ± 1.24^{a}
Zn (mg/kg), Control	0.07 ± 0.04^{a}	0.11 ± 0.03^{b}	0.07 ± 0.03^{a}
Zn (mg/kg), Nitrogen applied	0.05 ± 0.02^{a}	0.10 ± 0.02^{b}	0.04 ± 0.02^{a}
Cu (mg/kg), Control	5.79 ± 0.14^{b}	5.24 ± 2.17^{b}	2.63 ± 1.57^{a}
Cu (mg/kg), Nitrogen applied	6.08 ± 2.58^{a}	4.99 ± 2.11^{a}	4.09 ± 1.24^{a}
Ca (mg/kg), Control	30.89 ± 2.52^{a}	30.49 ± 1.64^{a}	29.46 ± 1.52^{a}
Ca (mg/kg), Nitrogen applied	29.87 ± 1.28^{a}	29.65 ± 1.03^{a}	28.96 ± 0.49^{a}
Na (mg/kg), Control	14.33 ± 1.15^{b}	11.90 ± 3.52^{ab}	8.24 ± 0.99^{a}
Na (mg/kg), Nitrogen applied	16.47 ± 2.03^{b}	10.74 ± 2.61^{ab}	7.90 ± 0.53^{a}
K (mg/kg), Control	174.95 ± 42.32^{a}	219.87 ± 17.78^{a}	234.10 ± 66.10^{a}
K (mg/kg), Nitrogen applied	177.09 ± 65.20^{a}	231.61 ± 67.66^{a}	249.34 ± 78.83^{a}

Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.11.1b *Amaranthus cruentus* at Heading

The determination of the effect of leaf positions on minerals content in *Amaranthus cruenntus* at heading showed that leaf positions had no significant ($p > 0.05$) effect on Fe, Zn, Cu, Ca and K content in the leaves in the control and nitrogen fertilized vegetable (Table 4.5.1b). Analysis of Mg content of the vegetable indicated that there was no significant difference in the mineral content between basal and middle leaves, however, basal leaves had significant ($p < 0.05$) higher amount of Mg than upper leaves irrespective of the fertilizer levels. The concentrations of Mg in the basal, middle and upper leaves in control were 28.23 ± 2.70mg/kg, 25.65 ± 1.28mg/kg and 22.74 ± 0.54mg/kg respectively. While the corresponding concentrations of the mineral in nitrogen treated vegetable were 29.44 ± 1.03mg/kg, 25.01 ± 2.82mg/kg and 23.50 ± 1.45mg/kg respectively (as shown in Table 4.5.1b).

Similarly results obtained from the analysis of Na also revealed that there was no significant difference in the mineral content between basal and middle leaves, however, basal leaves had significant ($p < 0.05$) higher amount of Na than upper leaves in control and nitrogen fertilized vegetable (Table 4.5.1b). The mineral levels recorded in the three leaf positions for control were basal (14.33 ± 1.15mg/kg), middle (11.90 ± 3.52mg/kg) and upper (8.24 ± 0.99mg/kg) leaves. While the observed concentrations in the three leaf positions in nitrogen fertilized vegetable were basal (16.47 ± 2.03mg/kg), middle (10.74 ± 2.61mg/kg) and upper (7.90 ± 0.53mg/kg) leaves (see Table 4.5.1b).

Table 4.5.1b Effect of leaf position on minerals content in *Amaranthus cruentus* at heading stage

Minerals	Leaf position		
	Basal leaves	Middle leaves	Upper leaves
Fe (mg/kg), Control	36.00 ± 1.47[a]	38.57 ± 5.29[a]	44.70 ± 9.66[a]
Fe (mg/kg) , Nitrogen applied	39.10 ± 9.77[a]	23.67 ± 6.69[a]	56.90 ± 22.00[a]
Mg (mg/kg), Control	28.23 ± 2.70[b]	25.65 ± 1.29[ab]	22.74 ± 0.54[a]
Mg (mg/kg), Nitrogen applied	29.44 ± 1.03[b]	25.01 ± 2.28[ab]	23.50 ± 1.45[a]
Zn (mg/kg), Control	0.04 ± 0.02[a]	0.06 ± 0.02[a]	0.04 ± 0.02[a]
Zn (mg/kg), Nitrogen applied	0.04 ± 0.01[a]	0.07 ± 0.02[a]	0.06 ± 0.03[a]
Cu (mg/kg), Control	3.10 ± 3.51[a]	2.75 ± 0.25[a]	2.49 ± 2.18[a]
Cu (mg/kg), Nitrogen applied	3.31 ± 0.49[a]	2.85 ± 2.64[a]	2.65 ± 1.83[a]
Ca (mg/kg), Control	30.16 ± 0.38[a]	29.26 ± 2.40[a]	29.05 ± 1.96[a]
Ca (mg/kg), Nitrogen applied	31.48 ± 0.43[a]	30.60 ± 0.52[a]	29.72 ± 1.72[a]
Na (mg/kg), Control	10.21 ± 0.32[b]	8.68 ± 0.84[ab]	7.50 ± 0.27[a]
Na (mg/kg), Nitrogen applied	9.40 ± 0.11[b]	8.23 ± 1.11[ab]	6.95 ± 0.39[a]
K (mg/kg), Control	243.25 ± 77.08[a]	291.90 ± 82.35[a]	227.68 ± 30.33[a]
K (mg/kg), Nitrogen applied	245.45 ± 66.22[a]	251.04 ± 106.54[a]	175.14 ± 17.51[a]

Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.11.2a *Hibiscus sabdariffa* at Market Maturity

The studies conducted on the effect of leaf positions on mineral contents in *Hibiscus sabdariffa* at market maturity revealed that there was no significant difference in the Fe content between basal (35.90 ± 5.30mg/kg) and middle (34.50 ± 1.42mg/kg) leaves, but the two leaf positions had significant ($p < 0.05$) higher content of the mineral than upper leaves (29.10 ± 4.99mg/kg) in the control vegetable. When the plant received nitrogen fertilizer, no significant difference in the Fe content was observed between basal (39.60 ± 8.81mg/kg) and middle (31.90 ± 6.61mg/kg) leaves, and between middle and upper (23.80 ± 1.90mg/kg) leaves, however basal leaves had significant ($p < 0.05$) higher concentrations of the mineral than upper leaves (see Table 4.5.2a).

Results from analysis of Mg, Zn and K indicated that leaf positions had no significant effect on mineral contents in the leaves of *Hibiscus sabdariffa* irrespective of the nitrogen fertilizer levels (Table 4.5.2a). The amount of Cu in the middle leaves (1.83 ± 0.20mg/kg) was not significantly different from upper leaves (1.36 ± 0.15mg/kg); however, both leaf positions were significantly ($p < 0.05$) lower in the mineral content than the basal leaf (3.02 ± 0.03mg/kg) in the control. When nitrogen fertilizer was applied, no significant difference in Cu content was recorded between basal (3.40 ± 0.29mg/kg) and middle (3.29 ± 0.96mg/kg) leaves; the two leaf positions were significantly ($p < 0.05$) higher in the mineral content than the upper (1.99 ± 0.24mg/kg) leaf region (see Table 4.5.2a).

Results from analysis of Na indicated that there was no significant difference in the mineral content between middle and upper leaves; however, basal leaves had

significant higher Na content than the two leaf positions in control and nitrogen fertilized *Hibiscus sabdariffa* (Table 4.5.2a). Analysis of Ca showed leaf positions had no significant effect on the mineral content of the vegetable in control. However, when the vegetable was grown on the soils fertilized with nitrogen, no significant difference in the mineral content between middle (23.82 ± 3.79mg/kg) and upper (23.64 ± 1.36mg/kg) leaves; however, basal leaves (26.96 ± 0.50mg/kg) had significant ($p < 0.05$) higher Ca content than in the middle and upper leaves (see Table 4.5.2a).

Table 4.5.2a Effect of leaf position on mineral content in *Hibiscus sabdaliffa* at market maturity stage

Minerals	Leaf positions		
	Basal leaves	Middle leaves	Upper leaves
Fe (mg/kg), Control	35.90 ± 5.30^{b}	34.50 ± 1.42^{b}	29.10 ± 4.99^{a}
Fe (mg/kg) , Nitrogen applied	39.60 ± 8.81^{b}	31.90 ± 6.61^{ab}	23.80 ± 1.90^{a}
Mg (mg/kg), Control	17.87 ± 0.59^{a}	18.41 ± 0.97^{a}	19.92 ± 10.80^{a}
Mg (mg/kg), Nitrogen applied	19.09 ± 0.39^{a}	20.02 ± 0.71^{a}	23.27 ± 5.21^{a}
Zn (mg/kg), Control	0.04 ± 0.02^{a}	0.03 ± 0.01^{a}	0.03 ± 0.01^{a}
Zn (mg/kg), Nitrogen applied	0.03 ± 0.01^{a}	0.02 ± 0.01^{a}	0.02 ± 0.01^{a}
Cu (mg/kg), Control	3.02 ± 0.03^{b}	1.83 ± 0.20^{a}	1.36 ± 0.15^{a}
Cu (mg/kg), Nitrogen applied	3.40 ± 0.29^{b}	3.29 ± 0.96^{b}	1.99 ± 0.24^{a}
Ca (mg/kg), Control	25.42 ± 3.89^{a}	24.11 ± 1.23^{a}	22.89 ± 3.59^{a}
Ca (mg/kg), Nitrogen applied	26.96 ± 0.50^{b}	23.82 ± 3.79^{a}	23.64 ± 1.36^{a}
Na (mg/kg), Control	3.38 ± 0.42^{b}	2.54 ± 0.37^{a}	2.48 ± 0.33^{a}
Na (mg/kg), Nitrogen applied	3.38 ± 0.21^{b}	2.96 ± 0.04^{a}	2.86 ± 0.64^{a}
K (mg/kg), Control	38.28 ± 3.00^{a}	33.08 ± 6.74^{a}	46.18 ± 5.88^{a}
K (mg/kg), Nitrogen applied	38.09 ± 2.93^{a}	36.98 ± 3.37^{a}	40.87 ± 0.05^{a}

Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.11.2b *Hibiscus sabdaliffa* at Fruiting

The investigations of the effect of leaf positions on the mineral contents in *Hibiscus sabdaliffa* at fruiting revealed that there were no significant difference in the Fe content between middle (25.87 ± 2.54mg/kg) and upper (25.67 ± 1.67mg/kg) leaves, however, both leaf positions were significantly lower in the mineral content than basal (33.80 ± 1.74mg/kg) leaves in the control vegetable. When vegetable received nitrogen fertilizer, leaf positions had no significant effect on the Fe content in the leaves of the vegetable (see Table 4.5.2b).

Result of Mg, Zn and Na also revealed that leaf positions had no significant effect on the minerals content in the leaves of the vegetable irrespective of the nitrogen fertilizer levels (Table 4.5.2b). No significant difference in the Cu content was recorded between upper and middle leaves and between middle and basal leaves; however, upper leaves had significant higher content of the mineral than basal leaves in both control and nitrogen fertilizer vegetable (see Table 4.5.2a).

Analysis of Ca showed that the mineral content in basal leaves was not significantly different from middle leaves. However, the two leaf positions had significant higher content of the mineral than upper leaves in control and nitrogen fertilized vegetable (Table 4.5.2b). There was no significant difference in the K content observed between upper (43.87 ± 0.0mg/kg) and middle (35.03 ± 10.12mg/kg) leaves and between middle and basal (29.19 ± 5.84mg/kg) leaves; however, upper leaves had significant higher content of the mineral than basal leaves in control. However, when *Hibiscus sabdaliffa* received nitrogen fertilizer, though no significant difference in the

Table 4.5.2b Effect of leaf position on minerals content in *Hibiscus sabdaliffa* at fruiting stage

Minerals	Leaf positions		
	Basal leaves	Middle leaves	Upper leaves
Fe (mg/kg), Control	33.80 ± 1.74^{b}	25.87 ± 2.54^{a}	25.67 ± 1.67^{a}
Fe (mg/kg) , Nitrogen applied	34.73 ± 4.16^{a}	35.60 ± 4.33^{a}	35.40 ± 19.86^{a}
Mg (mg/kg), Control	18.61 ± 0.67^{a}	17.98 ± 0.82^{a}	17.38 ± 0.44^{a}
Mg (mg/kg), Nitrogen applied	16.31 ± 1.38^{a}	17.92 ± 0.80^{a}	17.35 ± 0.52^{a}
Zn (mg/kg), Control	0.03 ± 0.01^{a}	0.03 ± 0.02^{a}	0.04 ± 0.02^{a}
Zn (mg/kg), Nitrogen applied	0.02 ± 0.01^{a}	0.03 ± 0.01^{a}	0.04 ± 0.01^{a}
Cu (mg/kg), Control	1.54 ± 0.99^{a}	2.07 ± 0.55^{ab}	3.23 ± 1.19^{b}
Cu (mg/kg), Nitrogen applied	1.15 ± 0.06^{a}	2.00 ± 0.79^{ab}	2.50 ± 0.55^{b}
Ca (mg/kg), Control	26.47 ± 3.34^{b}	25.22 ± 1.75^{b}	21.24 ± 1.83^{a}
Ca (mg/kg), Nitrogen applied	24.88 ± 3.79^{b}	23.79 ± 1.79^{b}	18.88 ± 3.28^{a}
Na (mg/kg), Control	3.03 ± 0.12^{a}	2.89 ± 0.12^{a}	3.57 ± 0.53^{a}
Na (mg/kg), Nitrogen applied	2.81 ± 0.26^{a}	2.81 ± 0.36^{a}	2.88 ± 0.53^{a}
K (mg/kg), Control	29.19 ± 5.84^{a}	35.03 ± 10.12^{ab}	43.87 ± 0.02^{b}
K (mg/kg), Nitrogen applied	32.11 ± 2.92^{a}	46.70 ± 5.84^{b}	48.17 ± 2.55^{b}

Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.11.3a *Corchorus olitorius* at Market Maturity

The determinations of effect of leaf position on minerals content in (*Corchorus olitorius)* at market maturity showed that leaf positions had no significant effect on the distribution of Fe in the leaves of *Corchorus olitorius* without nitrogen fertilizer. With the application of nitrogen fertilizer, though, no significant difference in Fe content was observed between basal (10.21 ± 1.42mg/kg) and middle (13.13 ± 1.63mg/kg) leaves and between basal and upper (7.53 ± 1.00mg/kg) leaves, middle leaves had significant higher content of mineral than upper leaves (see Table 4.5.3a).

The analysis of Mg in the vegetable revealed that leaf positions had no significant effect on the mineral content in the leaves of the control vegetable. However, when plant received nitrogen fertilizer, no significant difference in Mg content was recorded between basal (19.25 ± 1.17mg/kg) and middle (20.49 ± 1.59mg/kg) leaves; upper (16.49 ± 0.69mg/kg) leaves had lower content of mineral than the two leaf positions (see Table 4.5.3a).

The Zn levels in basal and upper leaves were no significantly different from each other, however, middle leaves had significant higher amount of the mineral than the level found in the two leaf positions in control and nitrogen fertilized *Corchorus ollitorius* (Table 4.5.3a). Analysis of Cu content in the control and nitrogen fertilized vegetable showed that there were no significant difference in the mineral level between middle and upper leaves, but the two leaf regions had significant lower Cu content than basal leaves (see Table 4.5.3a). The Ca content in basal leaves was not significantly different from middle leaves, however, the two leaf positions had significant higher amount of the

mineral than upper leaves irrespective of the nitrogen levels. Results obtained from Na revealed that leaf positions had no significant effect on the mineral content in the control and nitrogen fertilized vegetable (Table 4.5.3a). Similarly analysis of K in *Corchorus olitorius* showed that the mineral content in upper leaves was not significantly different from middle leaves. However, the two leaf positions had higher significant content of the mineral than basal leaf region in control and nitrogen fertilized vegetable (Table 4.5.3a).

Table 4.5.3a Effect of leaf position on minerals content in *Corchorus olitorius* at market maturity stage

Minerals	Leaf positions		
	Basal leaves	Middle leaves	Upper leaves
Fe (mg/kg), Control	18.57 ± 5.76[a]	20.71 ± 6.12[a]	14.63 ± 5.54[a]
Fe (mg/kg) , Nitrogen applied	10.21 ± 1.42[ab]	13.13 ± 1.63[b]	7.53 ± 1.00[a]
Mg (mg/kg), Control	18.67 ± 2.49[a]	19.38 ± 0.23[a]	18.14 ± 0.41[a]
Mg (mg/kg), Nitrogen applied	19.25 ± 1.17[b]	20.49 ± 1.59[b]	16.49 ± 0.69[a]
Zn (mg/kg), Control	0.02 ± 0.01[a]	0.05 ± 0.03[b]	0.01 ± 0.01[a]
Zn (mg/kg), Nitrogen applied	0.02 ± 0.01[a]	0.04 ± 0.03[b]	0.01 ± 0.01[a]
Cu (mg/kg), Control	19.30 ± 5.03[b]	10.90 ± 0.31[a]	10.30 ± 0.97[a]
Cu (mg/kg), Nitrogen applied	8.40 ± 0.80[b]	5.99 ± 2.85[a]	5.38 ± 2.97[a]
Ca (mg/kg), Control	19.76 ± 3.06[b]	17.23 ± 2.81[b]	9.25 ± 2.19[a]
Ca (mg/kg), Nitrogen applied	15.29 ± 2.10[b]	12.49 ± 2.38[b]	5.66 ± 0.74[a]
Na (mg/kg), Control	7.37 ± 0.88[a]	6.40 ± 0.41[a]	6.25 ± 0.09[a]
Na (mg/kg), Nitrogen applied	6.22 ± 0.96[a]	5.42 ± 0.85[a]	5.42 ± 0.55[a]
K (mg/kg), Control	164.00 ± 40.45[a]	250.03 ± 86.36[b]	239.61 ± 8.77[b]
K (mg/kg), Nitrogen applied	132.47 ± 16.82[a]	190.61 ± 32.53[b]	177.36 ± 36.59[b]

Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.11.3b *Corchorus olitorius* at Fruiting

The results obtained from the analysis of effect of leaf position on mineral content in *Corchorus olitorius* at fruiting, showed no significant difference in the Fe content was observed between basal (10.17 ± 1.68mg/kg) and middle (8.37 ± 1.24mg/kg) leaves, however, the two leaf positions were significantly higher in the mineral content than upper leaves (3.40 ± 1.82mg/kg) in the vegetable without nitrogen fertilizer. When the vegetable received nitrogen fertilizer, leaf positions had no significant effect on the Fe content in the leaves of the vegetable (see Table 4.5.3b).

The Mg content in middle leaves (16.20 ± 0.33mg/kg) was not significantly different from the upper leaves (16.72 ± 0.24mg/kg), however, the mineral content in both leaf positions were significantly elevated compare to basal leaves (12.63 ± 4.51mg/kg) in control vegetable. When the plant was fertilized with nitrogen, the increasing significant order of Mg content observed in the leaf positions was upper (18.18 ± 0.40mg/kg) > middle (17.26 ± 0.29mg/kg) > basal (15.85 ± 0.24mg/kg) leaves (Table 4.5.3b). Results obtained from determination of Zn, Na and K indicate that leaf positions had no significant effect on the minerals content in the leaves of *Corchorus olitorius* irrespective of the nitrogen levels (see Table 4.5.3b).

The Cu content in basal leaves was not significantly different from middle leaves, however, the two leaf positions had significant higher amount of the mineral than upper leaves irrespective of the nitrogen levels (Table 4.5.3b). The amount of Ca in the basal leaves (20.56 ± 6.29mg/kg) was not significantly different from middle leaves (16.97 ± 4.24mg/kg), and the level in middle was not significantly different from the

upper (13.38 ± 2.46mg/kg) leaves, however, basal leaves had significant higher Ca content than upper leaves in control vegetable. With the application of nitrogen fertilizer, the order of significant increased in the mineral content in the different leaf positions are as follows basal (22.21 ± 2.16mg/kg) > Middle (17.63 ± 0.50mg/kg) > Upper (10.18 ± 0.98mg/kg) leaves (as shown in Table 4.5.3b).

Table 4.5.3b Effect of leaf position on minerals content in *Corchorus olitorius* at fruiting stage

Minerals	Leaf positions		
	Basal leaves	Middle leaves	Upper leaves
Fe (mg/kg), Control	10.17 ± 1.68^{b}	8.37 ± 1.24^{b}	3.40 ± 1.82^{a}
Fe (mg/kg) , Nitrogen applied	10.00 ± 3.03^{a}	7.53 ± 1.57^{a}	7.40 ± 2.28^{a}
Mg (mg/kg), Control	12.63 ± 4.51^{a}	16.20 ± 0.33^{b}	16.72 ± 0.24^{b}
Mg (mg/kg), Nitrogen applied	15.85 ± 0.24^{a}	17.26 ± 0.29^{b}	18.18 ± 0.40^{c}
Zn (mg/kg), Control	0.03 ± 0.01^{a}	0.03 ± 0.02^{a}	0.01 ± 0.01^{a}
Zn (mg/kg), Nitrogen applied	0.04 ± 0.02^{a}	0.04 ± 0.03^{a}	0.03 ± 0.01^{a}
Cu (mg/kg), Control	2.66 ± 0.26^{b}	2.38 ± 0.54^{b}	0.96 ± 0.48^{a}
Cu (mg/kg), Nitrogen applied	7.47 ± 9.15^{b}	6.25 ± 6.14^{b}	4.36 ± 2.16^{a}
Ca (mg/kg), Control	20.56 ± 6.29^{b}	16.97 ± 4.24^{ab}	13.38 ± 2.46^{a}
Ca (mg/kg), Nitrogen applied	22.15 ± 2.16^{c}	17.63 ± 0.50^{b}	10.18 ± 0.98^{a}
Na (mg/kg), Control	4.30 ± 1.06^{a}	4.58 ± 0.64^{a}	5.00 ± 1.20^{a}
Na (mg/kg), Nitrogen applied	4.51 ± 0.44^{a}	4.58 ± 0.65^{a}	4.89 ± 0.65^{a}
K (mg/kg), Control	192.13 ± 14.06^{a}	192.90 ± 15.59^{a}	197.05 ± 41.82^{a}
K (mg/kg), Nitrogen applied	108.96 ± 13.46^{a}	112.80 ± 33.31^{a}	147.88 ± 28.81^{a}

Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.11.4a *Telfairia occidentalis* at Market Maturity

The determinations of effect of leaf positions on minerals content in *Telfairia occidentalis* at market maturity showed that leaf positions had no significant effect on Fe content in the leaves of the plant in control. However, when nitrogen fertilizer was applied, basal leaves (17.17 ± 4.02mg/kg) had significant higher mineral content than middle (12.73 ± 3.34mg/kg) and upper (11.00 ± 2.00mg/kg) leaves (see Table 4.5.4a).

Results obtained from analysis of Mg and Zn showed that the mineral contents in basal leaves were not significantly different from middle leaves, but both leaf positions had significant higher content of the minerals than levels obtained in the upper leaves in control and nitrogen fertilized *Telfairia occidentalis* (see Table 4.5.4a). Similarly results obtained from the determinations of Cu and Na in control and nitrogen fertilized vegetable indicated that leaf positions had no significant effect on these minerals (as shown in in Table 4.5.4a).

The amount of Ca in basal leaves (23.02 ± 5.57mg/kg) was not significantly different from middle leaves (23.29 ± 8.57mg/kg); however, the two leaf regions had significantly higher content of the mineral than upper leaf (6.98 ± 2.72mg/kg) region in the control. When the plant received nitrogen fertilizer, the concentration of Ca was significantly highest in the basal (29.28 ± 0.93mg/kg) followed by middle (25.62 ± 2.46mg/kg) and lowest in the upper (7.77 ± 0.22mg/kg) leaves (see Table 4.5.4a).

The results obtained from the analysis of K content of the vegetable showed that the level of the mineral in upper leaves was not significantly different from basal leaves,

but the two leaf positions had significant lower content of the mineral than middle leaves in control *Telfairia occidentalis.* When the plant received nitrogen fertilizer, no significant difference in the mineral content was recorded between middle and upper leaves, and between upper and basal leaves , however, the levels of mineral in the middle leaves was significantly higher than in the basal leaves (as shown in Table 4.5.4a).

Table 4.5.4a Effect of leaf position on minerals content in *Telfairia occidentalis* at market maturity stage

Minerals	Leaf positions		
	Basal leaves	Middle leaves	Upper leaves
Fe (mg/kg), Control	10.50 ± 1.95^{a}	10.07 ± 4.71^{a}	8.70 ± 1.38^{a}
Fe (mg/kg) , Nitrogen applied	17.17 ± 4.02^{b}	12.73 ± 3.34^{a}	11.00 ± 2.00^{a}
Mg (mg/kg), Control	20.49 ± 1.11^{a}	22.10 ± 3.08^{b}	17.12 ± 2.85^{a}
Mg (mg/kg), Nitrogen applied	21.45 ± 0.91^{b}	22.19 ± 1.30^{b}	17.37 ± 0.77^{a}
Zn (mg/kg), Control	0.05 ± 0.02^{b}	0.06 ± 0.02^{b}	0.00 ± 0.00^{a}
Zn (mg/kg), Nitrogen applied	0.05 ± 0.03^{b}	0.06 ± 0.02^{b}	0.02 ± 0.01^{a}
Cu (mg/kg), Control	3.64 ± 0.21^{a}	3.74 ± 0.16^{a}	3.62 ± 0.66^{a}
Cu (mg/kg), Nitrogen applied	2.48 ± 1.18^{a}	2.94 ± 2.89^{a}	2.56 ± 0.43^{a}
Ca (mg/kg), Control	23.02 ± 5.57^{b}	23.29 ± 8.57^{b}	6.98 ± 2.72^{a}
Ca (mg/kg), Nitrogen applied	29.28 ± 0.93^{c}	25.62 ± 2.46^{b}	7.77 ± 0.22^{a}
Na (mg/kg), Control	6.55 ± 2.34^{a}	4.37 ± 1.04^{a}	5.28 ± 0.42^{a}
Na (mg/kg), Nitrogen applied	5.42 ± 0.53^{a}	5.06 ± 0.73^{a}	5.14 ± 0.12^{a}
K (mg/kg), Control	110.92 ± 11.31^{a}	124.55 ± 10.42^{b}	116.74 ± 5.84^{a}
K (mg/kg) , Nitrogen applied	91.73 ± 9.28^{a}	128.44 ± 23.36^{b}	118.48 ± 14.37^{ab}

Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.11.4b *Telfairia occidentalis* at fruiting

Results obtained from the investigations of the effect of leaf positions on minerals content in *Telfairia occidentalis* at fruiting indicated that leaf position generally affects the bioaccumulation of some mineral elements in the leaves of the vegetable. The concentration of Fe in the middle (16.83 ± 2.77mg/kg) and upper (16.47 ± 11.54mg/kg) leaf regions were not significantly different from each other; however, the two leaf positions had significant lower content of the mineral than basal leaf (20.23 ± 7.25mg/kg) in control. With the application of nitrogen fertilizer the Fe content in the basal leaves (35.43 ± 4.30mg/kg) was significantly highest, followed by middle (29.73 ± 1.36mg/kg) and lowest in upper (19.40 ± 1.10mg/kg) leaves (see Table 4.54b).

Results from Mg showed that there were no significant difference in the mineral content between basal and middle leaves, however, the two leaf positions had significant higher amount of the mineral than upper region in both nitrogen fertilizer levels (Table 4.5.4b). Studies conducted on Zn and Na of the vegetable revealed that leaf positions had no significant effect on the mineral content in the leaves of vegetable irrespective of nitrogen levels. Similarly, leaf positions had no significant effect on the Cu content of the vegetable in the control. With the application of nitrogen fertilizer, the Cu content in middle leaves (11.28 ± 1.91mg/kg) was significantly higher than basal (7.53 ± 0.57mg/kg) and upper (7.52 ± 0.67mg/kg) leaves (see Table 4.5.4b).

The increasing significant order of Ca content recorded in the three leaf positions in control vegetable was in the following order basal (25.61 ± 1.41mg/kg) > middle (13.58 ± 2.02mg/kg) > upper (9.61 ± 0.91mg/kg) leaves. When the vegetable received

nitrogen fertilizer, the same trend of results was obtained, the Ca content was significantly highest in basal leaves (21.07 ± 4.53mg/kg) closely followed by middle leaves (14.05 ± 4.31mg/kg) and lowest in the upper leaves (9.73 ± 2.37mg/kg), as shown in Table 4.5.4b.

Similarly, no significant difference was observed in K content between basal (56.43 ± 5.52mg/kg) and middle (58.98 ± 8.38mg/kg) leaves, however, the two leaf positions were significantly lower in the mineral content than the upper leaf (72.00 ± 4.74mg/kg) position in control. When plant was fertilized with nitrogen, the K content in the upper leaves (79.79 ± 8.92mg/kg) was not significantly different from the middle leaves (66.04 ± 1.36mg/kg) and the middle leaves was not significantly different from the basal leaves (56.27 ± 4.24mg/kg), however, upper leaves had significant higher mineral content than the basal leaves (see Table 4.5.4b).

Table 4.5.4b Effect of leaf position on minerals content in *Telfairia occidentalis* at fruiting

Minerals	Leaf position		
	Basal leaves	Middle leaves	Upper leaves
Fe (mg/kg), Control	20.23 ± 7.25^{b}	16.83 ± 2.77^{a}	16.47 ± 11.54^{a}
Fe (mg/kg) , Nitrogen applied	35.43 ± 43.00^{c}	29.73 ± 1.36^{b}	19.40 ± 1.10^{a}
Mg (mg/kg), Control	23.98 ± 1.68^{b}	24.70 ± 1.92^{b}	20.72 ± 0.34^{a}
Mg (mg/kg), Nitrogen applied	24.85 ± 1.99^{b}	25.83 ± 1.46^{b}	20.11 ± 1.78^{a}
Zn (mg/kg), Control	0.04 ± 0.02^{a}	0.01 ± 0.01^{a}	0.02 ± 0.01^{a}
Zn (mg/kg), Nitrogen applied	0.04 ± 0.01^{a}	0.02 ± 0.01^{a}	0.03 ± 0.01^{a}
Cu (mg/kg), Control	0.95 ± 1.64^{a}	1.93 ± 2.32^{a}	1.03 ± 0.58^{a}
Cu (mg/kg), Nitrogen applied	7.53 ± 0.57^{a}	11.28 ± 1.91^{b}	7.52 ± 0.67^{a}
Ca (mg/kg), Control	25.61 ± 1.41^{c}	13.58 ± 2.02^{b}	9.61 ± 0.91^{a}
Ca (mg/kg), Nitrogen applied	21.07 ± 4.53^{c}	14.05 ± 4.31^{b}	9.73 ± 2.37^{a}
Na (mg/kg), Control	5.42 ± 1.41^{a}	4.33 ± 0.95^{a}	4.01 ± 0.76^{a}
Na (mg/kg), Nitrogen applied	3.94 ± 0.88^{a}	3.80 ± 1.06^{a}	3.38 ± 0.92^{a}
K (mg/kg), Control	56.43 ± 5.52^{a}	58.98 ± 8.38^{a}	72.00 ± 4.74^{b}
K (mg/kg), Nitrogen applied	56.27 ± 4.24^{a}	66.04 ± 1.63^{ab}	79.79 ± 8.92^{b}

Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.11.5a V*ernonia amygdalina* at Market Maturity

Results obtained from the analysis of the effect of leaf positions on minerals content in *Vernonia amygdalina* at market maturity revealed that there was no significant difference in the Fe content between middle and upper leaves, the two leaf positions were significantly lower in the mineral content than the basal leaves in control and nitrogen fertilized *Vernonia Amygdalina* (Table 4.5.5a). The Mg content in basal leaves was not significantly different from middle leaves, but the two leaf positions had significantly higher amount of the mineral than upper leaf region irrespective of the nitrogen levels (see Table 4.5.5a).

Similarly, results from Zn also showed that there was no significant difference in the mineral content between middle (0.04 ± 0.03mg/kg) and upper (0.01 ± 0.01mg/kg) leaves, but basal leaves (0.12 ± 0.08mg/kg) had significant higher amount of the mineral than upper leaves in control. When plant received nitrogen fertilizer, no significant difference in the Zn content was observed between middle (0.02 ± 0.02mg/kg) and upper (0.01 ± 0.00mg/kg) leaves, however, the level of the mineral in the two leaf positions were significantly lower than the basal leaves (0.06 ± 0.01mg/kg), as shown in Table 4.5.5a).

Results obtained from analysis of Cu also indicated that the Cu content in basal leaves was not significantly different from middle leaves, but the mineral level in two leaf positions was significantly higher than upper leaf region irrespective of the nitrogen levels (Table 4.5.5a). The significant increased in Ca content observed in the three leaf positions in *Vernonia amygdalina* without nitrogen fertilizer was in the following order;

basal (25.34 ± 1.11mg/kg) > middle (18.26 ± 2.26mg/kg) > upper (11.23 ± 2.88mg/kg) leaf positions. When the plant received nitrogen fertilizer, the same trend of results was obtained, the Ca content was significantly highest in basal leaves (25.69 ± 2.53mg/kg) closely followed by middle leaves (17.29 ± 5.68mg/kg) and lowest in the upper leaves (12.60 ± 6.88mg/kg) as shown in Table 4.5.5a.The results obtained from analysis of Na showed that leaf positions had no significant effect on mineral content of the vegetable irrespective of the nitrogen levels (see Table 4.5.5a).

Similarly results obtained from the analysis of Na and K also indicated leaf positions had significant effect on mineral contents of the vegetable. However, when the vegetable was fertilizer with nitrogen, the amount of K in the upper leaves (228.14 ± 76.68mg/kg) was significantly higher than basal (153.73 ± 39.74mg/kg) and middle (141.11 ± 6.09mg/kg) leaves (see Table 4.5.5a).

Table 4.5.5a Effect of leaf position on minerals content in *Vernonia amygdalina* at market maturity stage

Minerals	Leaf position		
	Basal leaves	Middle leaves	Upper leaves
Fe (mg/kg), Control	38.93 ± 10.57^{b}	17.68 ± 2.68^{a}	13.13 ± 5.44^{a}
Fe (mg/kg) , Nitrogen applied	30.87 ± 7.36^{b}	23.63 ± 1.40^{a}	23.03 ± 8.28^{a}
Mg (mg/kg), Control	20.49 ± 1.12^{b}	19.17 ± 0.05^{b}	17.16 ± 0.59^{a}
Mg (mg/kg), Nitrogen applied	22.50 ± 1.02^{b}	20.13 ± 0.80^{b}	18.97 ± 0.44^{a}
Zn (mg/kg), Control	0.12 ± 0.08^{b}	0.04 ± 0.03^{ab}	0.01 ± 0.01^{a}
Zn (mg/kg), Nitrogen applied	0.06 ± 0.01^{b}	0.02 ± 0.02^{a}	0.01 ± 0.00^{a}
Cu (mg/kg), Control	5.16 ± 3.01^{b}	4.34 ± 2.56^{b}	0.54 ± 0.94^{a}
Cu (mg/kg), Nitrogen applied	2.77 ± 0.54^{b}	2.52 ± 2.98^{b}	0.71 ± 0.93^{a}
Ca (mg/kg), Control	25.34 ± 1.11^{c}	18.26 ± 2.26^{b}	11.23 ± 2.88^{a}
Ca (mg/kg), Nitrogen applied	25.69 ± 2.53^{c}	17.29 ± 5.68^{b}	12.60 ± 6.88^{a}
Na (mg/kg), Control	4.77 ± 0.98^{a}	3.66 ± 0.88^{a}	5.21 ± 1.34^{a}
Na (mg/kg), Nitrogen applied	5.21 ± 2.32^{a}	3.10 ± 0.32^{a}	4.90 ± 2.84^{a}
K (mg/kg), Control	161.85 ± 36.10^{a}	159.57 ± 16.85^{a}	180.98 ± 30.89^{a}
K (mg/kg), Nitrogen applied	153.73 ± 39.74^{a}	141.11 ± 6.09^{a}	228.14 ± 76.68^{b}

Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.11.5b *Vernonia amygdalina* at Heading

The results obtained from the determinations of effect of leaf positions on minerals content in *Vernonia amygdalina* at heading stage indicated that leaf positions had no significant effect ($p > 0.05$) on Fe, Mg, Zn, Na and K content in the leaves of the vegetable irrespective of the nitrogen levels (see Table 4.5.5b).

The concentration of Cu in upper leaves (1.53 ± 0.22mg/kg) of the vegetable was not significantly different from the middle leaves (1.33 ± 0.65mg/kg); the mineral levels in the two leaf positions were significantly higher than in basal leaves (0.49 ± 0.20mg/kg) in the control plant. With the application of nitrogen fertilizer, no significant difference in the mineral content was observed between middle (1.15 ± 1.00mg/kg) and basal (1.11 ± 0.97mg/kg) leaves, however, the two leaf positions were significantly lower in the mineral content than upper leaf (3.15 ± 0.15mg/kg) region (see Table 4.5.5b).

Analysis of Ca showed that there was no significant difference in the mineral content between basal (21.46 ± 4.50mg/kg) and middle (17.40 ± 4.05mg/kg) leaves, and between middle and upper (8.85 ± 0.95mg/kg) leaves, however basal leaves had significant higher amount of the mineral than the upper leaves in the control. When the vegetable received nitrogen fertilizer, basal leaves (17.10 ± 4.45mg/kg) was found to have significant higher content of the mineral than middle (11.82 ± 4.73mg/kg) and upper (7.79 ± 2.03mg/kg) leaves (see Table 4.5.5b).

Table 4.5.5b Effect of leaf position on minerals content in *Vernonia amygdalina* at heading

Minerals	Leaf positions		
	Basal leaves	Middle leaves	Upper leaves
Fe (mg/kg), Control	11.57 ± 0.72[a]	9.27 ± 2.11[a]	11.10 ± 3.64[a]
Fe (mg/kg), Nitrogen applied	10.43 ± 4.19[a]	12.30 ± 2.82[a]	10.07 ± 3.72[a]
Mg (mg/kg), Control	18.94 ± 0.84[a]	18.61± 0.27[a]	17.34 ± 0.34[a]
Mg (mg/kg), Nitrogen applied	18.52 ± 1.75[a]	18.16 ± 2.03[a]	17.50 ± 0.98[a]
Zn (mg/kg), Control	0.04 ± 0.02[a]	0.03 ± 0.03[a]	0.04 ± 0.02[a]
Zn (mg/kg), Nitrogen applied	0.03 ± 0.02[a]	0.02 ± 0.01[a]	0.02 ± 0.01[a]
Cu (mg/kg), Control	0.49 ± 0.20[a]	1.33 ± 0.65[b]	1.53 ± 0.22[b]
Cu (mg/kg), Nitrogen applied	1.11 ± 0.97[a]	1.15 ± 1.00[a]	3.15 ± 0.15[b]
Ca (mg/kg), Control	21.46 ± 4.50[b]	17.40 ± 4.05[ab]	8.85 ± 0.95[a]
Ca (mg/kg), Nitrogen applied	17.10 ± 4.45[b]	11.82 ± 4.73[a]	7.97 ± 2.03[a]
Na (mg/kg), Control	4.65 ± 3.47[a]	5.85 ± 4.82[a]	6.06 ± 1.50[a]
Na (mg/kg), Nitrogen applied	4.87 ± 1.69[a]	5.35 ± 0.61[a]	6.26 ± 2.48[a]
K (mg/kg), Control	130.36 ± 26.33[a]	138.04 ± 8.88[a]	159.32 ± 9.25[a]
K (mg/kg), Nitrogen applied	103.14 ± 16.85[a]	108.64 ± 32.69[a]	114.81 ± 32.15[a]

Control = No nitrogen applied. Values represent means of triplicate determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.12 Effect of Fruiting on Antinutrients and Vitamins content in Vegetables

4.12.1 *Amaranthus cruentus*

The investigation of the effects of heading on cyanide concentrations in *Amaranthus cruentus* showed that the cyanide content of the vegetable increased significantly during heading irrespective of nitrogen levels. The mean values of cyanide in vegetables at heading in control (308.70 ± 19.70mg/kg) and nitrogen applied (435.00 ± 117.00mg/kg) were significantly higher compared to levels at market (223.10 ± 12.00g/kg and 256.28 ± 9.50mg/kg, respectively) as shown in Table 4.6.1.

In *Amaranthus cruentus* heading significantly reduced ($p < 0.05$) the nitrate content of vegetable in control; however with the application of nitrogen fertilizer heading had no significant effect ($p > 0.05$) on the nitrate content of the vegetable. The amount of nitrate at market maturity and heading of the vegetable in control were 17708.00 ± 2420.00mg/kg and 7620.00 ± 997.00mg/kg while the corresponding values obtained with the application of nitrogen fertilizer were 23412.00 ± 2070.00mg/kg and 18722.00 ± 3401.00mg/kg (see Table 4.6 .1).

The mean soluble oxalate concentrations at market maturity and heading in control were 3.11 ± 0.22g/100g and 3.86 ± 0.25g/100g while the values obtained with the application of nitrogen fertilizer 2.37 ± 0.05g/100g and 3.67 ± 0.18g/100g. This data showed that fruiting significantly elevated ($p < 0.05$) the soluble oxalate content of the vegetable in the control and nitrogen applied (Table 4.6.1). Results obtained from the determination of total oxalate content showed that heading of *Amaranthus cruentus* significantly increased ($p < 0.05$) the levels of the antinutrients content irrespective of the nitrogen levels. The mean values of total oxalate at heading in control

(5.27 ± 0.24g/100g) and nitrogen applied (5.04 ± 0.22g/100g) were significantly higher compared to levels at market maturity (4.40 ± 0.19g/100g and 3.75 ± 0.35g/100g respectively) as shown in Table 4.6.1.

The investigation of the effects of headings on β-carotene content in *Amaranthus cruentus* revealed that heading has significant decreasing effects on the provitamin content of the vegetable irrespective of the nitrogen levels. The mean values of β-carotene at market maturity for controls (7.45 ± 0.47mg/100g) and nitrogen applied (8.037 ± 0.86mg/100g) were significantly higher than values (2.48 ± 0.33mg/100g and 4.86 ± 0.57mg/100g respectively) at heading (as shown in Table 4.6.1).

Results obtained from the determination of vitamin C content showed that heading of the vegetable significantly increased the levels of the vitamin irrespective of the nitrogen levels. The amount of vitamin C in the vegetable at heading for control (160.50 ± 7.10mg/100g) and nitrogen applied (149.90 ± 8.20mg/100g) were significantly elevated compared to level obtained at market maturity (94.60 ± 5.60mg/100g and 78.90 ± 4.50mg/100g respectively) as shown in Table 4.6.1.

Table 4.6.1 Effect of heading on antinutrients and vitamins content in *Amaranthus cruentus*

Antinutrients and vitamins	Stage of analysis	
	Market maturity	Heading
Cyanide (mg/kg DW), Control	223.10 ± 12.00^{a}	308.70 ± 19.00^{b}
Cyanide (mg/kg DW) , Nitrogen applied	256.50 ± 9.50^{a}	435.00 ± 117.00^{b}
Nitrate (mg/kg DW), Control	17708.00 ± 2420.00^{b}	7620.00 ± 997.00^{a}
Nitrate (mg/kg DW), Nitrogen applied	23412.00 ± 2070.00^{a}	18722.00 ± 3401.00^{a}
Soluble oxalate (g/100g DW), Control	3.11 ± 0.22^{a}	3.86 ± 0.25^{b}
Soluble oxalate (g/100g DW), Nitrogen applied	2.37 ± 0.05^{a}	3.67 ± 0.18^{b}
Total oxalate (g/100g DW), Control	4.40 ± 0.19^{a}	5.27 ± 0.24^{b}
Total oxalate (g/100g DW), Nitrogen applied	3.75 ± 0.35^{a}	5.04 ± 0.22^{b}
β-carotene (mg/100g FW), Control	7.45 ± 0.47^{b}	2.48 ± 0.33^{a}
β-carotene (mg/100g FW), Nitrogen applied	8.04 ± 0.87^{b}	4.86 ± 0.57^{a}
Vitamin C (mg/100g FW), Control	94.60 ± 5.60^{a}	160.50 ± 7.10^{b}
Vitamin C (mg/100g FW), Nitrogen applied	78.90 ± 4.50^{a}	149.90 ± 8.20^{b}

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.12.2 *Hibiscus Sabdariffa*

The determination of effect of fruiting on cyanide, β-carotene and vitamin C content in *Hibiscus sabdariffa* indicated that fruiting of the vegetable had no significant effect on these compounds irrespective of nitrogen levels (see Table 4.6.2). Fruiting of the vegetable however, significantly elevated its nitrate content in control and nitrogen applied. The amount of nitrate at market maturity and fruiting in control were 85.00 ± 28.00mg/kg and 285.20 ± 23.00mg/kg while the corresponding values obtained with the application of nitrogen fertilizer were 101.90 ± 26.00mg/kg and 344.40 ± 29.00mg/kg (as shown in Table 4.6.2).

The mean soluble oxalate concentrations at market maturity and fruiting of the plants in control were 1.62 ± 0.04g/100g and 2.93 ± 0.15g/100g while the corresponding values obtained with the application of nitrogen fertilizer were 1.37 ± 0.05g/100g and 1.77 ± 0.07g/100g. The results revealed that fruiting significantly elevates the soluble oxalate content of the vegetable irrespective of the soil nitrogen levels (see Table 4.6.2). Similarly results obtained from the analysis of total oxalate showed that fruiting significantly increased the antinutrient content of the vegetable irrespective of the nitrogen levels. The mean values of total oxalate at fruiting in control (4.04 ± 0.27g/100g) and nitrogen applied (3.22 ± 0.20g/100g) were significantly higher compared to levels at market maturity (2.08 ± 0.07g/100g and 1.92 ± 0.04g/100g respectively (as shown in Table 4.6.2).

Table 4.6.2 Effect of fruiting on antinutrients and vitamins content in *Hibiscus sabdaliffa*

Antinutrients and vitamins	Stage of analysis	
	Market maturity	Fruiting
Cyanide (mg/kg DW), Control	419.60 ± 21.00[a]	390.20 ± 32.00[a]
Cyanide (mg/kg DW) , Nitrogen applied	459.50 ± 21.00[a]	410.60 ± 26.00[a]
Nitrate (mg/kg DW), Control	85.00 ± 28.00[a]	285.20 ± 23.00[b]
Nitrate (mg/kg DW), Nitrogen applied	101.90 ± 26.00[a]	344.40 ± 29.00[b]
Soluble oxalate (g/100g DW), Control	1.62 ± 0.04[a]	2.93 ± 0.15[b]
Soluble oxalate (g/100g DW), Nitrogen applied	1.37 ± 0.05[a]	1.77 ± 0.07[b]
Total oxalate (g/100g DW), Control	2.08 ± 0.07[a]	4.04 ± 0.27[b]
Total oxalate (g/100g DW), Nitrogen applied	1.92 ± 0.04[a]	3.22 ± 0.02[b]
β-carotene (mg/100g FW), Control	5.41 ± 0.43[a]	6.12 ± 0.38[a]
β-carotene (mg/100g FW), Nitrogen applied	7.07 ± 0.27[a]	6.48 ± 0.41[a]
Vitamin C (mg/100g FW), Control	13.89 ± 1.30[a]	16.08 ± 0.82[a]
Vitamin C (mg/100g FW), Nitrogen applied	12.51 ± 1.10[a]	13.08 ± 0.77[a]

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.12.3 *Corchorus olitorius*

The investigation of the effects of fruiting on cyanide content in *Corchorus olitorius* showed that the cyanide content of the vegetable increased significantly during fruiting irrespective of nitrogen levels. The mean values of cyanide in vegetables at fruiting in control (1220.00 ± 142.00mg/kg) and nitrogen applied (1325.00 ± 48.00mg/kg) were significantly elevated compared to level at market maturity (618.00 ± 106.00mg/kg and 663.00 ± 48.00mg/kg respectively) as shown in Table 4.6.3).

The determination of the effect of fruiting on nitrate content in the studied vegetable indicated that fruiting significantly decreased the nitrate content of the vegetable irrespective of the nitrogen levels. The mean values of nitrate at market maturity for controls (2028.00 ± 412.00mg/kg) and nitrogen applied (2717.00 ± 370.00mg/kg) were significantly higher than values (350.00 ± 54.00mg/kg and 235.00 ± 35.00mg/kg respectively) at fruiting (see Table 4.6.3).

The soluble oxalate content of the vegetable increased significantly during fruiting in control and nitrogen applied. The mean values of the oxalate obtained at market maturity and fruiting in control were 2.18 ± 021g/100g and 6.82 ± 0.48g/100g while the corresponding values obtained with the application of nitrogen fertilizer were 1.68.00 ± 0.14g/100g and 5.96 ± 0.29g/100g (see Table 4.6.3). Results obtained from the analysis of total oxalate content revealed that fruiting significantly increased the antinutrient content of the vegetable irrespective of the nitrogen levels. The mean values of total oxalate at fruiting in control (8.79 ± 0.54g/100g) and nitrogen applied (7.45 ± 0.20g/100g) were significantly higher compared to levels at market maturity (3.20 ± 0.19g/100g and 3.15 ± 0.10g/100g respectively) as shown in Table 4.6.3.

The mean β-carotene concentrations at market maturity and fruiting in control were 2.63 ± 0.2mg/100g and 10.27 ± 1.03mg/100g while the values obtained with the application of nitrogen fertilizer 10.26 ± 0.58mg/100g and 11.68 ± 0.64mg/100g. This data implies that the provitamin content of vegetable increased significantly during fruiting in control; however with the application of nitrogen fertilizer, fruiting had no significant effect on β-carotene content of the vegetable (see Table 4.6.3).

The results obtained from the analysis of the effects of fruiting on vitamin C content in *Corchorus olitorius* revealed that fruiting has significant decreasing effects on the vitamin content of the vegetable irrespective of the nitrogen levels. The mean values of vitamin C at market maturity for controls (101.70 ± 7.30mg/100g) and nitrogen applied (86.00 ± 8.60mg/100g) were significantly higher than the values (46.77 ± 2.70mg/100g and 37.37 ± 2.30mg/100g respectively) at fruiting (see Table 4.6.3).

Table 4.6.3 Effect of fruiting on antinutrients and vitamins content in *Corchorus olitorius*

Antinutrients and vitamins	Stage of analysis	
	Market maturity	Fruiting
Cyanide (mg/kg DW), Control	618.00 ± 106.00[a]	1220.00 ± 142.00[b]
Cyanide (mg/kg DW) , Nitrogen applied	663.00 ± 47.00[a]	1325.00 ± 48.00[b]
Nitrate (mg/kg DW), Control	2028.00 ± 412.00[b]	350.00 ±56.00[a]
Nitrate (mg/kg DW), Nitrogen applied	2717.00 ± 370.00[b]	235.00 ± 35.00[a]
Soluble oxalate (g/100g DW), Control	218.00 ± 0.21[a]	6.82 ± 0.48[b]
Soluble oxalate (g/100g DW), Nitrogen applied	1.68.00 ± 0.41[a]	5.96 ± 0.29[b]
Total oxalate (g/100g DW), Control	3.20 ± 0.10[a]	8.78 ± 0.54[b]
Total oxalate (g/100g DW), Nitrogen applied	3.15 ± 0.19[a]	5.04 ± 0.20[b]
β-carotene (mg/100g FW), Control	2.63 ± 0.20[a]	10.28 ± 1.03[b]
β-carotene (mg/100g FW), Nitrogen applied	10.26 ± 0.58[a]	11.68 ± 0.64[a]
Vitamin C (mg/100g FW), Control	101.7.30 ± 7.30[b]	46.77± 2.70[a]
Vitamin C (mg/100g FW), Nitrogen applied	86.00 ± 8.60[b]	37.37 ± 2.30[a]

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.12.4 *Telfairia occidentalis*

The results obtained from the determination of effect of fruiting on cyanide content in *Telfairia occidentalis* showed that fruiting significantly elevated the cyanide content of the vegetable in the control and nitrogen applied. The mean cyanide concentrations at market maturity and fruiting in control were 438.00 ± 37.00mg/kg and 771.00 ± 21.00mg/kg while the values obtained with the application of nitrogen fertilizer were 699.00 ± 48.00mg/kg and 885.00 ± 37.00mg/kg (see Table 4.6.4).

Results obtained from the analysis of nitrate in the studied vegetable indicated that fruiting significantly decreased the nitrate content of the vegetable irrespective of the nitrogen levels. The mean values of nitrate at market maturity for controls (550.00 ± 95.00mg/kg) and nitrogen applied (696.00 ± 117.00mg/kg) were significantly higher than values (45.10 ± 15.00mg/kg and 34.90 ± 5.10mg/kg respectively) at fruiting (see Table 4.6.4). Studied conducted on soluble oxalate and vitamin C content in *Telfairia occidentalis* showed that fruiting had no significant effect on the levels of these compounds in control and nitrogen fertilized vegetable (see Table 4.6.4). Results obtained from the analysis of total oxalate showed that fruiting significantly increased the antinutrient content of the vegetable irrespective of the nitrogen levels. The mean values of total oxalate at fruiting in control (3.20 ± 0.09g/100g) and nitrogen applied (2.82 ± 0.04g/100g) were significantly higher compared to levels at market maturity (2.22 ± 0.07g/100g and 2.21 ± 0.16g/100g respectively, as shown in Table 4.6.4.

The investigation of the effects of fruiting on β-carotene content in the studied vegetable revealed that fruiting has significant ($p < 0.05$) decreasing effects on the

provitamin content of the vegetable irrespective of the nitrogen levels. The mean values of β-carotene at market maturity for controls (15.50 ± 0.59mg/100g) and nitrogen applied (17.60 ± 1.00mg/100g) were significantly higher than values (10.38 ± 0.72mg/100g and 12.15 ± 0.92mg/100g respectively) at fruiting (see Table 4.6.4).

Table 4.6.4 Effect of fruiting on antinutrients and vitamins content in *Telfairia occidentalis*

Antinutrients and vitamins	Stage of analysis	
	Market maturity	Fruiting
Cyanide (mg/kg DW), Control	438.00 ± 37.00[a]	771.00 ± 21.00[b]
Cyanide (mg/kg DW) , Nitrogen applied	699.00 ± 48.00[a]	885.00 ± 37.00[b]
Nitrate (mg/kg DW), Control	550.00 ± 95.00[b]	45.10 ± 15.60[a]
Nitrate (mg/kg DW), Nitrogen applied	696.00 ± 117.00[b]	34.90 ± 5.10[a]
Soluble oxalate (g/100g DW), Control	1.82 ± 0.14[a]	2.03 ± 0.06[a]
Soluble oxalate (g/100g DW), Nitrogen applied	1.64 ± 0.06[a]	1.65 ± 0.09[a]
Total oxalate (g/100g DW), Control	2.22 ± 0.07[a]	3.20 ± 0.09[b]
Total oxalate (g/100g DW), Nitrogen applied	2.21 ± 0.16[a]	2.82 ± 0.04[b]
β-carotene (mg/100g FW), Control	15.50 ± 0.59[b]	10.38 ± 0.72[a]
β-carotene (mg/100g FW), Nitrogen applied	17.60 ± 1.01[b]	12.15 ± 0.92[a]
Vitamin C (mg/100g FW), Control	208.40 ± 7.50[a]	224.60 ± 11.00[a]
Vitamin C (mg/100g FW), Nitrogen applied	191.60 ± 13.00[a]	186.30 ± 11.00[a]

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.12.5 *Vernonia amygdalina.*

The investigation of the effects of heading on cyanide concentrations in *Vernonia amydalina* showed that the cyanide content of the vegetable increased significantly during heading irrespective of nitrogen levels. The mean values of cyanide in vegetables at heading in control (894.00 ± 108.00mg/kg) and nitrogen applied (994.00 ± 102.00mg/kg) were significantly elevated compared to level at market maturity (358.00 ± 57.00mg/kg and 426.00 ± 78.00mg/kg respectively (see Table 4.6.5).

Heading of *Vernonia amygdalina* significantly ($p < 0.05$) elevated its nitrate content in control and when nitrogen fertilizer was applied. The amount of nitrate at market maturity and heading in control were 276.00 ± 47.00mg/kg and 3394.00 ± 772.00mg/kg while the corresponding values obtained with the application of nitrogen fertilizer were 891.00 ± 228.00mg/kg and 4246.00 ± 568.00mg/kg (see Table 4.6.5).

The mean soluble oxalate concentrations at market maturity and heading in control were 1.80 ± 0.03g/100g and 2.33 ± 0.11g/100g while the values obtained with the application of nitrogen fertilizer 1.97 ± 0.09g/100g and 2.18 ± 0.04g/100g. Data analysis indicated that heading significantly ($p < 0.05$) elevated the soluble oxalate content of the vegetable in the control, however with the application of nitrogen fertilizer no significant variations in the oxalate levels was observed between market maturities and heading stages of plant development (see Table 4.6.5). Results obtained from the determination of total oxalate content showed that heading of *Vernonia amygdalina* significantly ($p < 0.05$) increased the antinutrients content irrespective of the nitrogen levels. The mean values of total oxalate at heading in control (3.30 ± 0.14g/100g) and nitrogen applied

(3.04 ± 0.06g/100g) were significantly ($p < 0.05$) higher compared to levels at market maturity (2.23 ± 0.09g/100g and 2.51 ± 0.08g/100g respectively, as shown in Table 4.6.5.

The mean β-carotene concentrations at market maturity and heading in control were 11.17 ± 0.6mg/100g and 13.73 ± 0.43mg/100g while the values obtained with the application of nitrogen fertilizer 14.32 ± 0.58mg/100g and 14.42 ± 0.61mg/100g. Data analysis revealed that the β-carotene content of vegetable increased significantly ($p < 0.05$) during heading in control, however with the application of nitrogen fertilizer, fruiting had no significant on β-carotene content of the vegetable (see Table 4.6.5).

Results obtained from the determination of vitamin C showed heading of the vegetable significantly increased the vitamin C content irrespective of the nitrogen levels. The amount of vitamin C in the vegetable at heading for control (14.75 ± 0.70mg/100g) and nitrogen applied (13.08 ± 0.62mg/100g) and was significantly elevated compared to levels obtained at market maturity (12.08 ± 1.10mg/100g and 9.07 ± 0.76mg/100g respectively) as shown in Table 4.6.5.

Table 4.6.5 Effect of heading on antinutrients and vitamins content in *Vernonia amygdalina*

Antinutrients and vitamins	Stage of analysis	
	Market maturity	Fruiting
Cyanide (mg/kg DW), Control	358.00 ± 57.00[a]	894.00 ± 108.00[b]
Cyanide (mg/kg DW) , Nitrogen applied	426.00 ± 78.00[a]	994.00 ± 102.00[b]
Nitrate (mg/kg DW), Control	276.00 ± 47.00[a]	3394.00 ± 772.00[b]
Nitrate (mg/kg DW), Nitrogen applied	891.00 ± 228.00[a]	4246.00 ± 568.00[b]
Soluble oxalate (g/100g DW), Control	1.80 ± 0.03[a]	2.33 ± 0.11[b]
Soluble oxalate (g/100g DW), Nitrogen applied	1.97 ± 0.09[a]	2.18 ± 0.04[a]
Total oxalate (g/100g DW), Control	2.23 ± 0.09[a]	3.30 ± 0.14[b]
Total oxalate (g/100g DW), Nitrogen applied	2.51 ± 0.8[a]	3.04 ± 0.06[b]
β-carotene (mg/100g FW), Control	11.17 ± 0.67[a]	13.73 ± 0.43[b]
β-carotene (mg/100g FW), Nitrogen applied	14.32 ± 0.58[a]	14.42 ± 0.61[a]
Vitamin C (mg/100g FW), Control	12.08 ± 1.10[a]	14.75 ± 0.76[b]
Vitamin C (mg/100g FW), Nitrogen applied	9.00 ± 0.70[a]	13.08 ± 1.10[b]

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.13 Effect of Fruiting on Minerals Content in Vegetables.

4.13.1 *Amaranthus cruentus*

The determinations of the effects of heading on Fe concentrations in *Amaranthus cruentus* showed that the Fe content of the vegetable increased significantly ($p < 0.05$) during heading irrespective of nitrogen levels. The mean values of the mineral in vegetable at fruiting in control (39.76 ± 2.30mg/kg) and nitrogen applied (45.70 ± 6.50mg/kg) were significantly ($p < 0.05$) higher compared to levels at market maturity (33.53 ± 1.20mg/kg and 24.58 ± 1.30mg/kg respectively), as shown inTable 4.7.1.

The results obtained from the analysis of Mg, Zn, Ca and k indicated heading had no significant effect on the minerals content in control and nitrogen fertilized vegetable (Table 4.7.1). The concentrations of Cu obtained in the in the studied vegetable decreased significantly ($p < 0.05$) during heading irrespective of the nitrogen levels. The mean values of the mineral at market maturity for controls (4.55 ± 0.66mg/kg) and nitrogen applied (5.05 ± 0.66mg/kg) were significantly ($p < 0.05$) higher than values (2.78 ± 0.70mg/kg and 2.94 ± 0.55mg/kg respectively) at heading (see Table 4.7.1).

Similarly, results obtained from the analysis of Na in the vegetable also revealed that heading has a decreasing effect on the mineral content in control and nitrogen fertilized vegetable. The mineral content at market maturity in control (11.49 ± 1.10mg/kg) and nitrogen fertilized (11.70 ± 1.40mg/kg) were significantly elevated compared to the values (8.81 ± 0.42mg/kg and 8.19 ± 0.40mg/kg respectively) at heading (as shown in Table 4.7.1).

Table 4.7.1 Effect of heading on minerals content in *Amaranthus cruentus*

Minerals	Stage of analysis	
	Market maturity	Heading
Fe (mg/kg), Control	33.53 ± 1.20[a]	39.76 ± 2.30[b]
Fe (mg/kg) , Nitrogen applied	24.58 ± 1.30[a]	45.70 ± 6.50[b]
Mg (mg/kg), Control	26.25 ± 0.81[a]	25.54 ± 0.94[a]
Mg (mg/kg), Nitrogen applied	27.12 ± 1.20[a]	25.98 ± 1.00[a]
Zn (mg/kg), Control	0.08 ± 0.01[a]	0.05 ± 0.01[a]
Zn (mg/kg), Nitrogen applied	0.06 ± 0.01[a]	0.06 ± 0.01[a]
Cu (mg/kg), Control	4.55 ± 0.66[b]	2.78 ± 0.70[a]
Cu (mg/kg), Nitrogen applied	5.05 ± 0.66[b]	2.94 ± 0.55[a]
Ca (mg/kg), Control	30.28 ± 0.60[a]	29.49 ± 0.55[a]
Ca (mg/kg), Nitrogen applied	29.49 ± 0.32[a]	30.60 ± 0.40[a]
Na (mg/kg), Control	11.49 ± 1.10[b]	8.81 ± 0.42[a]
Na (mg/kg), Nitrogen applied	11.70 ± 1.40[b]	8.19 ± 0.40[a]
K (mg/kg), Control	209.70 ± 16.00[a]	254.30 ± 22.00[a]
K (mg/kg), Nitrogen applied	219.30 ± 22.00[a]	223.90 ± 24.00[a]

Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.13.2 *Hibiscus sabdariffa*

The investigation of effect of fruiting on Fe content in *Hibiscus sabdariffa* revealed that fruiting significantly reduced ($p < 0.05$) the mineral content of vegetable in control , however no significant difference ($p > 0.05$) in the Fe levels was recorded with the application of nitrogen fertilizer. The amount of Fe at market maturity and fruiting of the vegetable in control were 33.17 ± 1.60mg/kg and 28.44 ± 1.50mg/kg while the corresponding values obtained with the application of nitrogen fertilizer were 31.73 ± 2.90mg/kg and 35.20 ± 3.50mg/kg, respectively (see Table 4.7 .2).

Results from the analysis of Mg in *Hibiscus sabdariffa* showed that fruiting had no significant effect on the mineral content of the vegetable in the control. However, when plant received nitrogen fruiting significantly decreased its Mg content. The mean values of the mineral obtained at market maturity and fruiting of the vegetable in control were 18.73 ± 1.80mg/kg and 17.99 ± 0.26mg/kg while the corresponding values obtained when nitrogen fertilizer was applied were 20.79 ± 1.10mg/kg and 17.19 ± 0.37mg/kg, respectively (Table 4.7 .2). The levels of Zn, Cu, Ca, Na, and K in the vegetable were not significantly affected by fruiting irrespective of nitrogen fertilizer levels (see Table 4.7.2).

Table 4.7.2 Effect of fruiting on minerals content in *Hibiscus sabdaliffa*

Minerals	Stage of analysis	
	Market maturity	Fruiting
Fe (mg/kg), Control	33.17 ± 1.60[b]	28.44 ± 1.50[a]
Fe (mg/kg) , Nitrogen applied	31.73 ± 2.90[a]	35.20 ± 3.50[a]
Mg (mg/kg), Control	18.73 ± 1.80[a]	17.99 ± 0.26[a]
Mg (mg/kg), Nitrogen applied	20.79 ± 1.10[b]	17.19 ± 0.37[a]
Zn (mg/kg), Control	0.04 ± 0.01[a]	0.03 ± 0.01[a]
Zn (mg/kg), Nitrogen applied	0.03 ± 0.01[a]	0.03 ± 0.01[a]
Cu (mg/kg), Control	2.07 ± 0.36[a]	2.28 ± 0.37[a]
Cu (mg/kg), Nitrogen applied	2.89 ± 0.47[a]	1.88 ± 0.25[a]
Ca (mg/kg), Control	24.14 ± 0.98[a]	24.31 ± 1.10[a]
Ca (mg/kg), Nitrogen applied	24.81 ± 0.86[a]	22.52 ± 1.30[a]
Na (mg/kg), Control	2.80 ± 0.18[a]	3.16 ± 0.14[a]
Na (mg/kg), Nitrogen applied	3.07 ± 0.14[a]	2.83 ± 0.12[a]
K (mg/kg), Control	39.18 ± 2.50[a]	36.01 ± 2.90[a]
K (mg/kg), Nitrogen applied	38.65 ± 0.94[a]	42.33 ± 2.80[a]

Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$)

4.13.3 *Corchorus Olitorius*

Results obtained from the analysis of effect of fruiting on Fe content in *Corchorus olitorius* showed that fruiting significantly decreased ($p < 0.05$) the mineral content of vegetable in control , however no significant variation ($p > 0.05$) in the Fe content was observed when nitrogen fertilizer was applied. The mean values of Fe at market maturity and fruiting of the vegetable in control were 17.79 ± 1.90mg/kg and 7.31 ± 1.10mg/kg while the corresponding values obtained with the application of nitrogen fertilizer were 10.29 ± 0.90mg/kg and 8.31 ± 0.86mg/kg, respectively (see Table 4.7.2).

Similarly results from the determination of effect of fruiting on Mg content of vegetable also indicated that fruiting has a decreasing effect on the mineral content in control and had no significant effect in nitrogen fertilized vegetable. The Mg content of studied vegetable at market maturity in control (18.73 ± 0.46mg/kg) and nitrogen fertilized (18.74 ± 0.69mg/kg) while the values at fruiting were (15.19 ± 0.99mg/kg and 17.10 ± 0.35mg/kg respectively). The determination of Zn and Na in the vegetable showed that fruiting had no significant effect on the mineral content in control and nitrogen fertilized vegetable (as shown in Table 4.7.3).

Results obtained from the investigation of effect of fruiting on Cu level in *Corchorus olitorius* equally revealed that fruiting significantly decreased ($p < 0.05$) the mineral content of the vegetable in control , however no significant difference ($p < 0.05$) in the mineral content was recorded when nitrogen fertilizer was applied. The amount of Cu at market maturity and fruiting of the vegetable in control were 13.50 ± 3.80mg/kg and 2.00 ± 0.31mg/kg while the corresponding values obtained when the nitrogen

fertilizer was applied were 6.59 ± 0.84mg/kg and 6.000 ± 1.90mg/kg, respectively (see Table 4.7 .3).

Determination of Ca in the vegetable indicated that fruiting had no significant effect on the mineral content of the vegetable in control, however, with the application of nitrogen fertilizer fruiting significantly elevated the Ca content of the vegetable (see Table 4.7.3). Similarly Na level of the vegetable was not significantly affected during fruiting in control, however with the application of nitrogen fertilizer; the mineral content declined significantly (see Table 4.7.3).

Table 4.7.3 Effect of fruiting on minerals content in *Corchorus olitorius*

Minerals	Stage of analysis	
	Market maturity	Fruiting
Fe (mg/kg), Control	17.79 ± 1.90^{b}	7.31 ± 1.10^{a}
Fe (mg/kg) , Nitrogen applied	10.29 ± 0.90^{a}	8.31 ± 0.86^{a}
Mg (mg/kg), Control	18.73 ± 0.46^{b}	15.19 ± 0.99^{a}
Mg (mg/kg), Nitrogen applied	18.74 ± 0.69^{a}	17.10 ± 0.35^{a}
Zn (mg/kg), Control	0.03 ± 0.01^{a}	0.02 ± 0.01^{a}
Zn (mg/kg), Nitrogen applied	0.02 ± 0.01^{a}	0.04 ± 0.01^{a}
Cu (mg/kg), Control	13.50 ± 3.8^{b}	2.00 ± 0.31^{a}
Cu (mg/kg), Nitrogen applied	6.59 ± 0.84^{a}	6.00 ± 1.90^{a}
Ca (mg/kg), Control	15.41 ± 1.80^{a}	16.67 ± 1.70^{a}
Ca (mg/kg), Nitrogen applied	11.51 ± 1.50^{a}	16.65 ± 1.80^{b}
Na (mg/kg), Control	6.67 ± 0.24^{a}	4.43 ± 0.31^{a}
Na (mg/kg), Nitrogen applied	5.64 ± 0.33^{a}	4.66 ± 0.18^{a}
K (mg/kg), Control	214.90 ± 26.00^{a}	194.00 ± 7.80^{a}
K (mg/kg), Nitrogen applied	166.80 ± 12^{b}	123.20 ± 9.90^{a}

Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.13.4 *Telfairia occidentalis*

The determination of effect of fruiting on Fe content in *Tefairia occidentalis* showed that the Fe content of the vegetable increased significantly ($p < 0.05$) during fruiting irrespective of nitrogen levels. The mean values of the mineral in vegetable at fruiting in control (17.84 ± 2.40mg/kg) and nitrogen applied (28.19 ± 2.40mg/kg) were significantly ($p < 0.05$) higher compared to level at market maturity (9.76 ± 0.92mg/kg and 13.63 ± 1.30mg/kg respectively (see Table 4.7.4).

Results obtained from the analysis of Mg showed fruiting of the vegetable significantly increased the mineral content irrespective of the nitrogen levels. The amount of Mg in the vegetable at fruiting for control (23.13 ± 0.75mg/kg) and nitrogen applied (23.59 ± 1.00mg/kg) was significantly ($p < 0.05$) elevated compared to level obtained at market maturity (19.90 ± 1.00mg/kg and 20.34 ± 0.80mg/kg respectively (see Table 4.7.4).

Analysis of Zn and Ca in the vegetable revealed that fruiting had no significant effect on the minerals content in control and nitrogen fertilized vegetable (Table 4.7.4). The determination of Cu in the vegetable, gave two fashions of results; whereas fruiting significantly decreased the Cu content in control, the mineral element was significantly increased at fruiting when nitrogen fertilizer was applied. The levels of Cu in the vegetable at maturity and fruiting in control 3.66 ± 0.12mg/kg and 1.30 ± 0.51mg/kg while the corresponding values obtained with the application of nitrogen fertilizer were 2.66 ± 0.53mg/kg and 8.78 ± 0.72mg/kg, respectively (as shown in Table 4.7.4).

Results from the analysis of Na in *Telfairia occidentalis* showed that fruiting had no significant effect on the mineral content of the vegetable in the control. However,

when plant received nitrogen fruiting significantly decreased the mineral content. The mean values of the mineral obtained at market maturity and fruiting of the vegetable in control were 5.40 ± 0.54mg/kg and 4.59 ± 0.38mg/kg while the corresponding values obtained when nitrogen fertilizer was applied were 5.21 ± 0.16mg/kg and 3.71 ± 0.2mg/kg, respectively (see Table 4.7 .4).

Results obtained from the analysis of K in the studied vegetable indicated that fruiting significantly decreased the mineral content of the vegetable irrespective of the nitrogen levels. The mean values of the mineral at market maturity for controls (117.40 ± 3.40mg/kg) and nitrogen applied (112.90 ± 7.30mg/kg) were significantly ($p < 0.05$) higher than values (62.47 ± 3.00mg/kg and 67.40 ± 3.80mg/kg respectively), at fruiting (as shown in Table 4.7.4).

Table 4.7.4 Effect of fruiting on minerals content in *Telfairia occidentalis*

Minerals	Stage of analysis	
	Market maturity	Fruiting
Fe (mg/kg) , Control	9.76 ± 0.92[a]	17.84 ± 2.40[b]
Fe (mg/kg) , Nitrogen applied	13.36 ± 1.30[a]	28.19 ± 2.40[b]
Mg (mg/kg), Control	19.00 ± 1.00[a]	23.13 ± 0.75[b]
Mg (mg/kg), Nitrogen applied	20.34 ± 0.80[a]	23.59 ± 1.00[b]
Zn (mg/kg), Control	0.03 ± 0.01[a]	0.01 ± 0.01[a]
Zn (mg/kg), Nitrogen applied	0.05 ± 0.01[a]	0.02 ± 0.01[a]
Cu (mg/kg), Control	3.66 ± 0.12[b]	1.30 ± 0.51[a]
Cu (mg/kg), Nitrogen applied	2.66 ± 0.53[a]	8.78 ± 0.72[b]
Ca (mg/kg), Control	17.26 ± 3.20[a]	16.27 ± 2.40[a]
Ca (mg/kg), Nitrogen applied	20.90 ± 3.40[a]	14.95 ± 2.00[a]
Na (mg/kg), Control	5.40 ± 0.54[a]	4.59 ± 0.38[a]
Na (mg/kg), Nitrogen applied	5.21 ± 0.16[b]	3.71 ± 0.29[a]
K (mg/kg), Control	117.40 ± 3.40[b]	62.47 ± 3.00[a]
K (mg/kg), Nitrogen applied	112.90 ± 7.30[b]	67.40 ± 3.80[a]

Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

4.13.5 *Vernonia amygdalina*

The results obtained from the investigation of effect of heading on Fe content in *Vernonia amygdalina* indicated that heading significantly reduced the mineral content of the vegetable irrespective of the nitrogen levels. The mean values of Fe at market maturity for controls (23.30 ± 4.50mg/kg) and nitrogen applied (25.84 ± 2.20mg/kg) were significantly ($p < 0.05$) higher than values (10.64 ± 0.79mg/kg and 10.93 ± 1.10mg/kg respectively) at heading (see Table 4.7.5).

Results from the analysis of Mg in *Vernonia amygdalina* showed that heading had no significant effect on the mineral content of the vegetable in the control. However, when plant received nitrogen heading significantly decreased its Mg content. The mean values of the mineral obtained at market maturity and heading of the vegetable in control were 18.94 ± 0.50mg/kg and 18.30 ± 0.29mg/kg while the corresponding values obtained when nitrogen fertilizer was applied were 20.53 ± 0.57mg/kg and 18.06 ± 0.50mg/kg respectively (as shown in Table 4.7 .5).

The levels of Zn, Cu, and Na in the vegetable were not significantly affected by heading irrespective of nitrogen fertilizer levels (Table 4.7.5). Similarly heading of the vegetable had no significant effect on the Ca concentrations in the control; however with the application of nitrogen fertilizer heading has significant decreasing effects on the mineral content of the vegetable. The amount of the mineral recorded at market maturity and heading of the vegetable in control were 18.58 ± 2.10mg/kg and 15.90 ± 2.10mg/kg while the corresponding values obtained when nitrogen fertilizer was applied were 18.53 ± 2.40mg/kg and 12.30 ± 1.70mg/kg, respectively (see Table 4.7 .5).

The results obtained from the analysis of the effects of heading on K content in *Vernonia amygdalina* revealed that heading has significant decreasing effects on the mineral content of the vegetable irrespective of the nitrogen levels. The mean values of K at market maturity for controls (167.50 ± 9.10mg/kg) and nitrogen applied (174.30 ± 20.00mg/kg) were significantly higher ($p < 0.05$) than the values (142.60 ± 6.50mg/kg and 108.90 ± 8.30mg/kg respectively) at heading (as shown in Table 4.7.5).

Table 4.7.5 Effect of heading on minerals content in *Vernonia amygdalina*

Minerals	Stage of analysis	
	Market maturity	Heading
Fe (mg/kg) , Control	23.30 ± 4.50[b]	10.64 ± 0.79[ag]
Fe (mg/kg) , Nitrogen applied	25.84 ± 2.20[b]	10.93 ± 1.10[a]
Mg (mg/kg), Control	18.94 ± 0.50[a]	18.30 ± 0.29[a]
Mg (mg/kg), Nitrogen applied	20.53 ± 0.57[b]	18.06 ± 0.50[a]
Zn (mg/kg), Control	0.06 ± 0.02[a]	0.04 ± 0.01[a]
Zn (mg/kg), Nitrogen applied	0.03 ± 0.01[a]	0.02 ± 0.01[a]
Cu (mg/kg), Control	3.35 ± 0.98[a]	1.12 ± 0.42[a]
Cu (mg/kg), Nitrogen applied	2.00 ± 0.62[a]	1.80 ± 0.54[a]
Ca (mg/kg), Control	18.58 ± 2.10[a]	15.90 ± 2.10[a]
Ca (mg/kg), Nitrogen applied	18.53 ± 2.40[b]	12.30 ± 1.70[a]
Na (mg/kg), Control	4.53 ± 0.39[a]	5.52 ± 1.00[a]
Na (mg/kg), Nitrogen applied	4.37 ± 0.69[a]	5.49 ± 0.55[a]
K (mg/kg), Control	167.50 ± 9.10[b]	142.60 ± 6.50[a]
K (mg/kg), Nitrogen applied	174.30 ± 20.00[b]	108.90 ± 8.30[a]

Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other ($P > 0.05$).

CHAPTER FIVE

DISCUSSION

The nutritionists' interest in some vegetable species such as *Amaranthus cruentus*, *Hibiscus sabdariffa*, *Corchorus olitorius*, *Telfairia occidentalis* and *Vernonia amygdalina* stems from their rich contents of essential amino acids, vitamins and minerals which are needed for normal metabolic activities of the body. Vegetables are also good sources of dietary fibres that are important for bowel movement. However, the presence of some inherent anti nutrients and toxic substances in vegetables have been a major obstacle in harnessing the full benefits of these nutritional values, hence the need to determine the processing methods and storage conditions that will significantly reduce the levels of these substances without compromising their nutritional values. The effect of soil nitrogen levels, leaf positions on the plant, vegetative and reproductive phases of the plant on the bioaccumulation of these substances were equally determined.

The observed higher levels of cyanide, nitrate, soluble oxalate, total oxalate, β-carotene (except in leaves boiled for 5 minutes where the β-carotene levels was elevated), vitamin C and mineral elements (Fe, Cu, Mg, Na and K) in the fresh samples of the different vegetables studied compared to their corresponding processed samples, agreed with the submission of several authors (Aster-Dumas, 1975; Augustine *et al.*, 1981; Olaofe, 1992; Abakr and Ragaa, 1996; USDA, 1998; George, 1999; Shahnaz *et al.*, 2003; Waclaw and Stefan, 2004; Oboh, 2005; Anjana and Muhammed, 2006; McDonald, 2006; Anjana *et al.*, 2007; Rickman *et al.*, 2007; Ojiako and Igwe, 2008). These authors reported that various food processing methods reduced the nutrients, antinutrients and toxic substances in the vegetables. In the current study, boiling of *Amaranthus cruentus,*

Hibiscus sabdariffa, Corchorus olitorius, Telfairia occidentalis and *Vernonia amygdalina* significantly decreased the amounts of antinutrients (soluble and total oxalates), toxic substances (cyanide and nitrate) and vitamin C and mineral elements (Fe, Cu, Mg, Na and K). This observation is in agreement with the reports of Olaofe (1992), Abakr and Ragaa (1996), George (1999), Aganga and Tshwenyane (2003), EJoh *et al.* (2005), Ogbadoyi *et al.* (2006) and Rickman *et al.* (2007). These authors independently observed that boiling of the vegetables in water rupture the cell walls and subsequently cause the leaching of the cell contents including the antinutrients, toxic substances and some micronutrients. Waclaw and Stefan (2004) further stressed that degradation of nitrate by heat to other compound can as well reduce the nitrate content during boiling. Losses of vitamin C during boiling in addition to leaching, was attributed to the thermo sensitive, labile and hydrophilic nature of the vitamin (Olaofe, 1992); George, 1999; EJoh *et al.* 2005; Rickman *et al.* 2007). The higher β-carotene content in leaves boiled for 5 minutes than those boiled for 10 minutes and fresh samples of the vegetables is in accordance with the report of USDA, (1998) that moderate cooking increases the availability of β-carotene in the vegetables; it helps in breaking down the plant cell walls of the vegetable, and that repeated cooking at high temperature however, destroys some of the provitamins. Rickman *et al.* (2007) further added that loss of soluble solids and the release of protein-bound β-carotenes that occurred during boiling may equally contribute to the observed increase in the provitamin content. The negligible amount of the β-carotene found in 5 and 10 minutes decoctions compared to high amount in the fresh and boiled vegetables justifies the hydrophobic nature of β-carotene (Olaofe, 1992; George, 1999; Khalid *et al.*, 2004; Ejoh *et al.*, 2005; Rickman *et al.*, 2007).

The generally higher content of the analysed antinutrients, toxic substances and nutrients in the leaves boiled for 5 minutes compare with those boiled for 10 minutes is in accordance with the verdict of Mathook and Imungi (1994), Abakr and Ragaa (1996), Rickman *et al.* (2007) that the amount of antinutrients and nutrients lost in vegetables increases with cooking time.

The significant decrease in cyanide, nitrate, soluble and total oxalates, vitamin C and β-carotene concentrations during sundrying of vegetables in this study in accordance with the reports of various researchers (Fafunso and Basir, 1976; Addo, 1983; Keshinro and Ketiku, 1985; Richard, 1991; Olaofe, 1992; Abakr and Ragaa, 1996; Aganga and Tshwenyane, 2003; Ejoh *et al.*, 2005; Anjana and Muhammed, 2006; Adeboye and Babajide, 2007; Anjana *et al.*, 2007; Rickman *et al.*, 2007) to the effect that solar drying reduced the levels of antinutrients and vitamins in plants. Reduction of cyanide during sundrying is due to volatile nature of the compound and can be dissipated while drying (Richard, 1991; Aganga and Tshwenyane, 2003), while that of β-carotene is the oxidation of conjugated double bonds by molecular oxygen and isomerisation of the naturally predominant all-trans carotenoids to cis conformations (Rickman *et al.*, 2007). Similarly wilting and oxidation of the vitamin C which is one of the biochemical changes caused by the inherent enzymes (vitamin C oxidase and peroxidase) found alongside the vitamin could be accountable for the vitamin C losses during sundrying (Fafunso and Basir, 1976; Addo, 1983; Keshinro and Ketiku, 1983; Olaofe, 1992). Sundrying had no significant effect on the mineral (Fe, Cu, Mg, Na and K) contents in the studied vegetables. This observation is in line with the finding of Chweya and Nameus (1997) who have shown that the mineral elements in the vegetables were not significantly affected by sundrying

the vegetables. The reason for the observation may be that sundrying is a mere gradual evaporation process which does not involve leaching. It should also be noted that minerals are generally non-volatile substances.

The recorded significant amount of cyanide, nitrate, soluble and total oxalate, in sundried samples compared to the levels found in the leaves boiled for 5 and 10 minutes indicated that boiling may be superior in the reduction of these compounds than sundrying. The reason may be attributed to the fact that boiling lead to break down of the plant cell wall which permit the leakage of cell content (Aganga and Tshwenyane, 2003; Ogbadoyi *et al.*, 2006) while sundrying is a mere gradual evaporation process. Similarly the generally higher levels of β-carotene and vitamin C in boiled vegetables than in the sundried samples implies that moderate boiling/cooking is superior in conserving these micronutrients than sundrying (USDA, 1998; Ejoh *et al.*, 2005; Rickman *et al.*, 2007). This observation further supports the earlier submission that boiling as a processing method is superior to sundrying.

Cyanide content of fresh samples appears to be lower in *Hibiscus sabdariffa* and *Amaranthus cruentus,* and is relatively higher in other vegetables, especially in *Telfairia occidentalis* (170.80mg/kg) and *Vernonia amygdalina* (199.11mg/kg). The values of the cyanide in the vegetables are close to maximum permissible level of 200mg/kg fresh weight of vegetables or forages (Everist, 1981; Richard, 1991). The implication of these results is that regular consumption of unprocessed leaves of these vegetables as in ethnomedical practices may likely deliver toxic levels of the compound to the body. Should this happen, disease conditions associated with cyanide overload such as hypoxia, flushing, headache, tachynea, dizziness, respiratory depression which progresses rapidly

to coma seizure are likely to occur (Ames *et al.* 1981; Ellenhoro and Bercelonx, 1988). Interestingly, the various processing methods used, significantly reduced the cyanide content in the vegetables. Sundrying is not effective when compared to boiling. This finding may therefore suggest that boiling method of processing may be preferred for vegetable processing to sundrying with regard to cyanide content.

Vegetables may be classified as containing high or low nitrate content. Vegetables with nitrate levels of 1000 – 4000mg/kg are classified as high nitrate content (JECFA, 2003; Anjana *et al.*, 2007). It follows therefore that the vegetables studied, with nitrate levels 1281.50 – 4335.21mg/kg are high nitrate vegetables. The levels of nitrate in the fresh vegetables except for *Hibiscus sabdariffa* and *Vernonia amygdalina* are more than the acceptable daily intake (ADI) of 3.65mg/kg for 60kg body weight (219.00mg/day) if 100g samples are consumed per day. The implication of the finding is that regular consumption of raw (unprocessed) samples of these vegetables (especially *Amaranthus cruentus*, *Corchorus olitorius*, and *Telfairia occidentalis*) may likely overload the body with nitrate with attendant health problems of methaemoglobinaemia and cancers (Galler, 1997; Waclaw and Stefan, 2004; Onyesom and Okoh, 2006; Anjana *et al.*, 2007). All the processing methods studied greatly reduced the nitrate content of the vegetable to the acceptable levels, except in *Amaranthus cruentus* where nitrate content in the leaves boiled for 5 minutes exceed the Acceptable Daily Intake (ADI) of 219.00mg/day (if 100g/day consumed). It may be appropriate to boil the leaves for 10 minutes in order to reduce the nitrate content to tolerable levels, since 10 minutes boiling reduce the nitrate content of this vegetable to 1560.24mg/kg. From the results obtained for the soluble oxalate content in the different fresh vegetable samples analysed, only *Hibiscus*

sabdariffa had this antinutrient content within the permissible level of 250mg/100g fresh sample (Oguchi *et al.*, 1996). Other vegetables had their soluble oxalate content above the permissible levels. The results thus revealed that regular consumption of fresh raw samples of the vegetables without proper processing could deliver toxic levels of the antinutrient into the body with attendant health problems of oxalate toxicosis. This may lead to hypocalcaemia (Mandel, 1996; Nakata, 2003; Shingeru *et al.*, 2003; Antia *et al.*, 2006), formation of kidney stone (Fabola, 1990; Sealy *et al.*, 1990; Aletor and Omodara, 1994; Nakata, 2003, Proph *et al.*, 2006) and reduced bioavailability of some minerals to the body (Hodgking *et al.*, 1968; Aletor and Omodara, 1994; Sandberg *et al.*, 1996; Okon and Akpanyung, 2005). However, all the processing methods studied (especially boiling) significantly reduced the soluble oxalate content of the vegetables to tolerable levels, except in *Amaranthus cruentus* where the residual soluble oxalate in the leaves boiled for 5 minutes was still more than the permissible level. With this vegetable, boiling for 10 minutes will be more effective in reducing the antinutrient to the tolerable levels. The residual soluble oxalate in sundried samples of *Amaranthus cruentus* and *Corchorus olitorius* and total oxalate in all the sundried vegetables except in *Telfairia occidentalis* were still more than the accepted tolerable level. It therefore, implied that sundrying of the vegetables in an attempt to reduce the soluble oxalate content to acceptable levels is not effective. The total oxalate content in the vegetables boiled for 5 minutes is higher than the permissible level of 250m/100g. This signified that the antinutrient cannot be reduced effectively to tolerable level by 5 minutes of boiling. Except in *Amaranthus cruentus* and *Corchorus olitorius* boiling for 10 minutes appeared to reduce the total oxalate content of most studied vegetables to the safe levels.

The fresh leaves of the vegetables contained over and above the recommended adult daily allowance of 900μg vitamin A (George, 1999; Akanya, 2004). Leaves boiled for 5 minutes had more β-carotene. Although, sundrying significantly decreased the β-carotene content in the vegetables, the residual β-carotene content in sundried leaves can meet adult recommended daily allowance except in *Hibiscus sabdariffa.* From the results obtained in this study, only fresh sample of *Telfairia occidentalis, Corchorus olitorius* and *Amaranthus cruentus* could supply enough of vitamin C that is above the recommended daily allowance of 60mg (Olaofe, 1992; George, 1999) if 100g of the samples are consumed. However, some of the vegetables contained toxic levels of some antinutrients and toxic substances that need to be reduced to tolerable levels through various food processing methods. Among the processing methods studied, 5 minutes boiling retained and conserved more of the vitamin in the vegetable leaves than other processing methods, even though the vitamin content was lower than the recommended daily allowance. Considering the pivotal roles of this water soluble vitamin in human health and the associated diseases resulting from its deficiency, pharmaceutical supplementation of the vitamin will be necessary to augment its losses during the various food processing methods. This will enable the body to meet the dietary requirement of the vitamin.

Comparing the values Fe in the studied vegetables with the available literature, the vegetables contain an appreciable amount of the mineral. Adequate intake of any of the vegetables could provide the body with the recommended daily intake of 18mg/day of Fe for normal adult (Tietz *et al.*, 1994). Sundried samples of the vegetables could also furnish the body with daily recommended intake of the mineral, since sundrying had no

significant effect on the mineral content of the vegetable (Chweya and Nameus, 1997). From the results obtained, boiled sample of the vegetables could only meet the recommended daily intake of this important mineral involved in cellular metabolism if the water used in boiling (decoctions) is retained. Since controlled boiling and discarding the water used in boiling is one of the effective ways of reducing some of the plant toxins to safe levels (Ogbadoyi *et al.*, 2006), fruits and pharmaceuticals products may be required as a supplement to augment the lost of Fe during boiling. The results obtained indicate that the vegetables used in this study are excellent sources of iron. Iron is involved in normal carbohydrate and lipid metabolism (Hambidge *et al.*, 1987).

The concentrations of the Cu in fresh sample, dried sample and leaves boiled for 5 minutes could meet the range of the recommended daily allowance of 1.5 - 3.0mg/day of Cu (Tietz *et al.*, 1994), if 100g of samples were consumed. However, in leaves boiled for 10 minutes, only *Hibiscus sabdariffa* with 16.70mg Cu/kg and *Vernonia amygdalina* with16.52mg/kg could meet the range of the recommended daily allowance. With the other vegetables to meet the recommended daily allowance, the water used in boiling must be included in the meal preparation. But since it is necessary to discard the decoctions in order to reduce the levels of some antinutrients in the vegetables, fruits and pharmaceutical supplementation may be necessary if the vegetable is to be boiled for 10 minutes.

The levels of Mg (21.69 - 61.69mg/kg) in the vegetables studied are lower than the levels reported in the available literature on some leafy vegetables. For example, 3700mg/kg was reported for *Amaranthus hybridus* and 3259mg/kg for *Corchorus olitorius* (Bolanle *et al.*, 2004), 860mg/kg for *Cleome gynandra* (Chweya and Nameus,

1997), 550mg/kg for spinach (George, 1999) and 266.80mg/kg for *Cnidoscolus acontifolus* (Oboh, 2005). The results obtained in this work indicated that the Mg content in fresh samples of the vegetables is low and even lower when they are processed. Thus the vegetables are not likely to supply enough of the mineral to meet the recommended daily allowance of 350mg of Mg/day for normal adult (George, 1999). The implication of this observation is that complete dependency on the vegetables to provide this important cofactor of enzymes involved in cell respiration, glycolysis and transmembrane transporter (Ryan, 1991; Tietz *et al.*, 1994) may lead to the deficiency of the mineral. To avoid this condition, there is a need to balance up the nutrient contents of the soil, to improve the Mg uptake by the plants or by the inclusion of cereals and nuts, which are rich in Mg in our diets as supplements (George, 1999).

The range of 6.11 – 12.30mg/kg obtained for Na in the leafy vegetables used in this study fall far below those reported in available literature. Values of the mineral reported by authors are: 336.00mg/kg for Cleome gynadra (Chweya and Nameus, 1997), 325.50mg/kg for *Cnidoscolus acontifolus* (Oboh, 2005), 42.30mg/kg for *Ipomoea batatas* (Antia *et al.*, 2006), 966.60mg/kg and 481.90mg/kg for red and green of *Hibiscus sabdariffa* respectively (Adanlawo and Ajibade, 2006), 390mg/kg for *Hibiscus sabdariffa* and 300mg/kg for *Corchorus olitorius* (Aliyu and Morufu, 2006). Thus complete dependency on the studied vegetables as a major source of the mineral may not meet the body's need. Interestingly, this important mineral, essential for maintenance of fluid balance and normal osmotic pressure in the body for cellular activities (Wayne and Dale, 1989; Titz *et al.*, 1994; Aliyu and Morufu, 2006) is added in almost every home in the food preparations as condiments to taste in the form of NaCl or table salt (Magmus, 1979;

Wayne and Dale, 1989; George, 1999). This supplementation with sodium chloride will compensate for the low levels of the mineral in analysed vegetables.

The K contents of the studied vegetables range from 61.88mg/kg in *Hibiscus sabdariffa* to 288.92mg/kg in *Vernonia amygdalina*. The same trend of the results was obtained by Morufu and Aliyu (2006), who found that among the analysed leafy vegetables, *Hibiscus sabdariffa* and *Vernonia* amygdalina had the lowest and highest levels of potassium respectively. Results obtained indicated that the analysed vegetables contained an appreciable quantity of K in their fresh samples except *Hibiscus sabdariffa*. Thus, the vegetables could be regarded as excellent sources of the mineral (Oyenuga and Fetuga, 1975). However, during cooking, significant amount of the mineral was leached into the boiling water. Discarding the decoctions may lead to significant loss of the minerals. Since it is necessary to discard the water used in boiling in order to reduce some of the antinutrients in the vegetables (Ogbadoyi *et al.*, 2006), supplementation of the mineral with fruits and whole grains may be necessary.

The differences in the mineral content observed in vegetables of the same species by different researchers are probably a reflection of differences in the soil/location and other environmental factors of site in which the vegetables were grown. The differences in the mineral levels of the different vegetables studied may be attributed to differences in the genetic makeup of vegetables (Harris and Loessecke, 1960; Takebe and Yoneyama, 1997; Grazyna and Waldemar, 1999; Bolanle *et al.*, 2004; Signh, 2005; Aliyu and Morufu, 2006; Weerakkody, 2006).

The decreasing effect of freezing on cyanide, nitrate, soluble and total oxalates, β-carotene, vitamin C and mineral elements (Fe, Cu, Mg, Na and K) contents in

the studied vegetables had also been reported by some researchers (Richard, 1991; Booth, 1992; Olaofe, 1992; Yadav and Sehgal, 1995; Abakr and Ragaa, 1996; Polo *et al.*, 1997; Pruthi, 1999; Yadav and Sehgal, 1997; Fellow, 2000; Lisiewka and Kmiecik, 2000; Hui *et al.*, 2004; Ejoh *et al.*, 2005; Berguist *et al.*, 2006; McDonald *et al.*, 2006; Ogbadoyi *et al.*, 2006; Piotr *et al.*, 2006). These authors reported that freezing ruptures the plant cells which resulted in the release (leaching) of antinutrients and nutrients content of the cell. Budavaris *et al.* (1989) also reported that the decrease in cyanide during freezing can be attributed to the solubility of the compound in water. Thus cyanide may be trapped in the ice and released during thawing. Similarly Booth *et al.* (1992) further stressed that, in addition to cell ruptures and leaching that occur during freezing, the observed decrease in the β-carotene content could be as a result of enzymatic activity coupled with oxidation associated with conjugated double bond in the compound. Olaofe (1992) on the other hand, reported that decrease in vitamin C content during refrigerated storage is partly due to the enzymatic activities of vitamin C oxidase, cytochrome oxidase and vitamin C peroxidase that were endogenously present. The findings agreed with the report of Bergquist *et al.* (2006) that during freezing of vegetables the ascorbic acid content decreased considerably and the dehydroascorbic acid/vitamin C ratio increased. The generally insignificant differences recorded in the β-carotene content in second to fourth weeks and vitamin C content in first to fourth week of storage could be seen as a result of decrease in endogenous enzymatic activity and reduction of oxidation of the compound as freezing storage progresses. Similarly the insignificant decrease in some minerals observed throughout the freezing duration in some vegetables, although contrary to Abakr and Ragaa, (1996), and Hui *et al.* (2004) support the finding of Polo *et al.* (1997).

The author stressed that, even though there was a decrease in the mineral element in vegetables during freezing, it is not significant. These two factions of the results obtained could imply that the retention of the mineral element in the frozen samples or reductions of mineral in vegetables during freezing storage depend to a great extent on the plant species/cultivars and the form in which the mineral exist; such as in chemical compound, molecular complexes and some may even exist as a free ion (Hui *et al.*, 2004; Piotr *et al.*, 2006). It is believed that mineral elements that are chemically bond or form complexes with other compounds may not be easily leached out during freezing when compared with those that exist as free ions.

The cyanide levels of 170.83 and 199.11mg/kg in the fresh samples of *Telfairia occidentalis* and *Vernonia amygdalina* respectively, that were very close to the maximum permissible level of 200mg/kg of cyanide in fresh weight (Everist, 1981; Richard, 1991) were reduced by more than half of this value after one and subsequent weeks of freezing. Results obtained thus indicate that the cyanide content of the vegetable could be reduced to safe level by freezing. Except in *Hibicus sabdariffa* and *Vernonia amydalina* the nitrate content of fresh samples of the studied vegetables, were higher than the Acceptable Daily Intake of 220mg (Macrae *et al.*, 1997) and 219mg (Anjana *et al.*, 2007) for a 60kg person (if 100g/day is consumed). Thus consumption of raw samples of the vegetables with high nitrate content could lead to nitrate overload and could subject the body to disease conditions associated with nitrate toxicities such as metheamoglobinaemia and cancer (Galler, 1997; Macrae, 1997; Mevissen, 1997; Waclaw and Stefan, 2004; Anjana., *et al.*, 2007). Results obtained indicate that the nitrate content in the fresh and frozen samples of *Hibiscus sabdariffa* and *Vernonia amygdalina* are

lower than the recommended Acceptable Daily Intake and the levels of the compound in the vegetable samples can be well tolerated in our meal. While *Corchorus olitorius* required three weeks of freezing, *Telfairia occidentalis* only one week of freezing to reduce the nitrate content to the recommended Acceptable Daily Intake. Results of freezing on nitrate content of *Amaranthus cruentus* clearly imply that the nitrate content of the vegetable could not be reduced to the recommended Acceptable Daily Intake throughout the freezing period of four weeks. With this vegetable, there might be need to increase the freezing duration above the present one. The differential residual nitrate content in frozen samples in the studied vegetables is in harmony with findings of Redmond *et al.* (2004) and Piotr *et al.* (2006) who showed that the chemical content of the frozen vegetables depend to a large extent on the retention of chemical constituent of the vegetable. Freezing duration (Abakr and Ragaa, 1996) and the initial nitrate levels may as well influence the residual nitrate in the different vegetables.

The soluble and total oxalates in fresh samples and four weeks frozen products are more than the permissible level of 250mg/kg fresh weight as reported by Oguchi *et al.* (1996). The results thus revealed that the decreasing effect of freezing during refrigerated storage could not reduce the oxalate content in *Amaranthus cruentus* to a tolerable level. The soluble oxalate content in fresh and frozen samples in *Hibiscus sabdariffa* was lower than acceptable level of the oxalate in the vegetable (Oguchi *et al.*, 1996). However, the total oxalate content of the various frozen samples of the vegetable was more than the permissible level. *Corchorus olitorius* require two weeks of freezing to reduce the soluble content to an acceptable level, while the total oxalate in the frozen samples are still more than the permissible level. Results of freezing in *Telfairia occidentalis*

indicated that one and two weeks of freezing are required respectively to reduce the soluble and total oxalates content to the permissible level of 250mg/100g (Oguchi *et al.*, 1996). Similarly one and three weeks of freezing are required to reduce the soluble and total oxalate content respectively in *Vernonia amygdalina* to tolerable level. This observation on the differential residual content in frozen samples in the vegetables is in agreement with the findings of Redmond *et al.* (2004) and Piotr *et al.* (2006) which revealed that the chemical content of the frozen products depend to a large extent on the retention of chemical constituent of the vegetable. Freezing duration and the initial chemical content may as well account for this differential (Abakr and Ragaa, 1996).

The fresh and frozen leaves of the vegetables contained over and above the recommended adult daily allowance of 900µg of vitamin A (George, 1999; Akanya, 2004) except in *Hibiscus sabdariffa* where the freezing for two to four weeks decreased the provitamin content to below the normal adult daily recommended allowance. The implication of the results is that because the provitamin is abundant in *Amaranthus cruentus*, *Corhorus olitorius, Telfairia occiddentalis* and *Vernonia amygdalina*, and non-hydrosoluble, the residual β-carotene of these vegetables are high enough to meet the normal adult recommended daily allowance. The results obtained therefore, imply that freezing of these vegetables within the studied periods of storage may not require any pharmaceutical supplements. To obtain adequate concentration of β-carotene from *Hibiscus sabdariffa*, the vegetable should not be frozen for more than one week as this will reduce the provitamin content below the normal adult recommended daily allowance of 5400µg which is equivalent to 900µg vitamin A (George, 1999; Akanya, 2004).

From the results obtained, only fresh sample of *Telfairia occidentalis, Corchorus olitorius* and *Amaranthus cruentus* could supply enough of vitamin C to meet the recommended daily allowance of 60mg (Olaofe, 1992; George, 1999) if 100g of the samples are consumed. Though, the vegetables contained toxic levels of antinutrients and toxic substances, these could be reduced to tolerable level through freezing. However, the residual vitamin C content in all the frozen vegetables was lower than the recommended daily allowance. Since vitamin C play important roles in human health and diseases associated from its deficiency, pharmaceutical supplementation of the vitamin will be necessary to augment its losses during freezing storage. This will enable the body to meet the dietary requirement of the vitamin.

The significantly higher content of β-carotene and nitrate in all the vegetables (except nitrate content in *Hibiscus sabdariffa*) and cyanide in *Amaranthus cruentus, Telfairia occidentalis* and *Vernonia amygdalina* grown on soil fertilized with nitrogen compared with the control signifies that nitrogen fertilizer elevates the levels of these compounds in the vegetables (Kriedenman, 1964; Jones and Ford, 1972; Richard, 1991; Yang, 1992; Chweya, 1993; Oladele *et al.*, 1997; Muramoto, 1999; Peter and Birger 2002; Waclaw and Stefan, 2004; Kansal *et al.* (2005); Carmen *et al.*, 2007; Anjana and Muhammad, 2007; Anjana *et al.*, 2007; Rolinda and Ma, 2008). The reason for the increase of β-carotene may be due to elevation in the content and activity of chlorophyll and associated light absorbing pigments (including caroteniods) following the application of nitrogen fertilizer (Taiz and Zeiger, 2002; Havling *et al.*, 2006). Virginia (2001) stressed that plants require nitrogen for normal growth and for the synthesis of proteins, however if nitrogen is applied in excess of what the plant requires for protein production,

the excess is accumulated as nitrates and stored predominantly in the green leafy part of the plant. Thus the insignificant difference in the nitrate content recorded between nitrogen applied *Hibiscus sabdariffa* and the control, may infer that, the amount of nitrogen supplied to the vegetable is adequate for optimum utilization for normal growth and protein formation or that the control has enough nitrogen for normal growth and protein formation for the particular species. Similarly, Peter and Birger (2002) further stated that increase in cyanide content following nitrogen fertilization is because the applied nitrogen stimulates the enzymatic conversion of tyrosine to p - hydroxymandelonitrile which ultimately lead to increase in the biosynthesis of cyanogenic glycoside.

The generally lower levels of vitamin C in the vegetables, soluble and total oxalates in *Amaranthus cruentus* and *Hibiscus sabdariffa* grown in soil supplied with nitrogen fertilizer compared with the control indicate that the applied nitrogen fertilizer significantly reduced the levels of these compounds in the vegetables (Chweya 1993; Virginia, 2001; Mozafar, 2005; Singh 2005). Virginia (2001) also stated that the observed decreased in vitamin C content results from the increase in protein production and decrease in carbohydrate production following the application of nitrogen fertilizer. Because vitamin C is formed from carbohydrates, its synthesis is also reduced. Singh (2005) stated that not only nitrogen fertilizers decrease the oxalate content of the vegetables, but anions generally reduce the levels of the antinutrients since they compete with oxalate for cations and depress the oxalate synthesis. The decreased in oxalates concentrations in the vegetables following nitrogen fertilization may be attributed to

decreasing effect of nitrogen on vitamin C content, since oxalates are synthesised via vitamin C (John, 2005).

The significantly higher levels of Fe, Zn, and Cu in nitrogen applied *Telfairia occidentalis* and Mg in nitrogen fertilized *Vernonia amygdalina* agreed with the findings of other workers. Ojeniyi and Adeniyan (1999), Tarfa *et al.* (2001), Kansal *et al.* (2005), Safaa and Abd El Fattah (2007) reported that nitrogen fertilizer increased the mineral content in maize leaf, *Spinacea oleracea* and lettuce plants, respectively. Safaa and Abd El Fattah (2007) attributed the increase in the minerals content (especially Fe) to increase in the levels of chlorophyll following the application of nitrogen fertilizer. The observations by these authors however, disagrees with the results of Chweya (1993) who reported that application of nitrogen fertilizer to *Gynandropsis gynandra* decreases the Fe content of the vegetable and has no significant effect on the Ca and Na content. Similarly, the decrease in Fe content in nitrogen treated *Amaranthus cruentus* and *Corchorus olitorius* compared with the control is in line with the findings of Chweya (1993) and contrary to the report of Ojiniyi and Adeniyan (1999), Tarfa *et al.* (2001), Kansal *et al.* (2005) and Safaa and Abd El Fattah (2007). The observed variations in the minerals content in the different studied vegetables following the application of nitrogen fertilizer could be as a result of species differences. This factor which is genetically determined has been reported to influence the bioaccumulation of chemical content of plants. The variation between this study and those of others in respect of mineral content may be due to differences in the environmental factors, such as season of the year, temperature, length of day, light intensity and chemical and physical properties of the soil. These factors have been reported to influence the bioaccumulation of chemical content of the

plants (Harris, 1975; Samson, 1977; Watanabe *et al.*, 1994; Takebe *et al.*, 1995; Grevsen and Kaack, 1996; Oguchi *et al.*, 1996; Chweya and Nameus, 1997; Takebe and Yoneyama, 1997; Grazyna and Waldemar, 1999; Bolanle *et al.*, 2004; Singh, 2005; Aliyu and Morufu, 2006; Lisiewska *et al.*, 2006; Rickman *et al.*, 2007).

This study has also revealed that leaf age (which is linked to position on mother- plant) had significant effect on the accumulation of nutrients, antinutrients and toxic substances in the selected vegetables. The generally higher cyanide contents in the basal than upper leaves in *Amaranthus cruentus, Hibiscus sabdariffa, Corchorus olitorius* and *Vernonia amydalina* at market maturity and fruiting is in harmony with the report of Cleveland and Soleri (1991) and Carmen *et al.* (2007), which revealed that the cyanide content increased with age in cassava leaves and crucifers respectively. The reason for higher level cyanide in basal leaves than the upper leaves could be that the enzymes responsible for synthesis of the cyanide may be more active in fully developed leaves where the metabolic activities are at maximum than the immature leaves. These results however, disagree with the report of Richard (1991) and Rodney and Elba (2006), who observed that the level of this respiratory poison is concentrated in younger leaves of sorghum than the older leaves. The observed variations in the cyanide content in the different leaf position of the studied vegetables from those of the previous work reported by different authors may be due to difference in cultivars and environmental factors. Similarly, the significantly higher cyanide content in the basal leaves than the upper leaves at market maturity in the control and nitrogen applied *Telfairia occidentalis* is in line with the report of Cleveland and Soleri (1991) and Carmen *et al.* (2007). While the significantly higher cyanide content in the upper, followed by middle and lowest basal

the two leaf regions is in accordance with the submission of Anjana *et al.* (2007). The results of higher nitrate content observed in the upper leaves, followed by middle and least in the basal leaves in *Vernonia amygdalina* disagrees with the report of Beis *et al.* (2007) and Anjana *et al.* (2007). The results however support the finding of Shigeru *et al.* (2003) and Carmen (2007) that the nitrate content in cassava leaves and setaria grass decrease with leaf age. In general, the higher and lower nitrate contents observed in the different leaf positions may be due to the lower and higher nitrate reductase activity respectively in those leaf regions.

The generally highest level of soluble and total oxalates in basal leaves followed by middle and least in the upper leaf region in *Amaranthus cruentus, Hibiscus sabdariffa, Telfairia occidentalis* and *Vernonia amygdalina* at market maturity and fruiting and that of *Corchorus olitorius* at fruiting are in harmony with the submission of Ekpedema *et al.* (2000) and Beis *et al.* (2007) that the oxalates (soluble and total) were higher in older leaves than younger ones in *Telfairia occidentalis* and *Spinacia oleracea* respectively. The reason for this observation could be that the older leaves are fully matured with optimum metabolic activity leading to the production of oxalates. The results however, disagree with the finding of Bassey *et al.* (2007) and Oscarson and Savarge (2007). These authors independently observed that oxalate contents in younger leaves were slightly higher than in the older leaves in *Diplazium sammatil* and *Colocasia esculenta* respectively.

The significantly higher level of β-carotene in the middle than upper leaves in *Amaranthus cruentus, Hibiscus sabdariffa, Corchorus olitorius* at market maturity and *Vernonia amygdalina* at fruiting agrees with the report of Bergquist *et al.* (2007) and

Mou and Ryder (2007) to the effect that β-carotene content was highest in the oldest leaves than the younger ones in baby spinach and lettuce. Significantly higher content of the provitamin A in the middle than basal leaves in the studied vegetables disagreed with the results of Bergquist *et al.* (2007) and Mou and Ryder (2007). The variations on β-carotene content observed in the present work from the works of these researchers, beside environmental and cultivars difference may be due to the variation in the experimental design. In the present work, the leaves on the studied vegetables were divided into three equal parts and levels of some antinutrients and nutrients (including β-carotene) were analyzed in the leaf positions. While in the work by Bergquist *et al.* (2007) and Mou and Ryder (2007) such clear division of leaves into three different regions was not done. Instead a comparison of nutrient contents between the older and younger leaves of the vegetables was made. The higher β-carotene in the upper than middle leaves in *Hibiscus sabdariffa* and *Corchorus olitorius* at fruiting and *Vernonia amygdalina* at market maturity compared with the level at market maturity and fruiting respectively, could suggest that stages of plant development influence the distribution patterns of provitamin A into different leaf locations on these vegetables. Highest β-carotene content in the upper leaves followed by middle and least in the basal leaves of *Telfairia occidentalis* at market maturity and fruiting disagreed with results of Bergquist *et al.* (2007) and Mou and Ryder (2007) that β-carotene content was highest in the oldest leaves than the younger ones in baby spinach and lettuce respectively. The results could also signify that stage of plant development had no influence in the distribution pattern of β-carotene into the different leaf locations of the vegetable.

β-carotene content in *Telfairia occidentalis* and *Vernonia amygdalina* at market maturity and fruiting in the three leaf regions are well above the adult recommended daily allowance of 900μg of vitamin A (5400μg β-carotene) if 100g samples are consumed (George, 1999; Akanya, 2004). In flowering *Amaranthus cruentus,* the three leaf positions in the control and basal leaf location in N applied had lower level of the provitamin, below the recommend daily allowance. However, at market maturity the provitamin contents in the three leaf regions were above the recommended daily allowance. The provitamin contents in *Hibiscus sabdariffa* were only lower than adult recommended daily allowance in basal leaves in the control at market maturity and basal leaves in both control and N applied at fruiting. In *Corchorus olitorius*, the β-carotene levels in the basal, middle and upper leaves from the control plants were lower than adult recommended daily allowance.

Significantly higher content of vitamin C in the middle leaves than the basal leaves in *Amaranthus cruentus, Hibiscus sabdariffa, Corchorus olitorius, Vernonia amygdalina* and *Telfairia occidentalis* at market maturity and fruiting agrees with the report of Bergquist *et al.* (2007) which show that vitamin C content was highest in younger leaves of spinach than the older leaves. These results are however, at variance with the submission of Bergquist *et al.* (2007). In the present work, the observed higher levels of vitamin C in middle leaves than the basal and upper leaves of the studied vegetables could be an indication that the leaves in the middle region of plants are fully matured with optimum physiological and metabolic activities leading to the production of vitamin C. Whereas in the in basal leaves, though they are fully matured, the leaves in this region are withdrawing some oxidizable nutrients due to aging (Taiz and Zeiger,

2002). Wilting which occurs in older lower leaves may be another reason responsible for the lower vitamin C content in basal leaves compared to middle leaves. This observation may be correct because wilting decreases the vitamin C content (Fafunso and Basir, 1976; Ado, 1983; Keshinro and ketiku, 1983; Olaofe, 1992). Leaves in the upper region of the plants are still developing and are immature with low physiological and metabolic activities leading to the formation of the vitamin.

The vitamin C content in the three leaf locations of *Amaranthus cruentus,* and *Telfairia occidentalis* at market maturity and flowering/fruiting stage of plant development are well above the adult recommended daily allowance of 60mg (Olaofe, 1992; George, 1999). In *Corchorus olitorius* at market maturity, only basal leaves in the nitrogen applied vegetable had the vitamin C content lower than the recommended daily allowance. However, at fruiting stage the vitamin C content in the three leaf regions were below the adult recommended daily allowance.

The generally higher Fe and Ca contents in the basal and middle leaves than the upper leaves concur with the findings of Taiz and Zeiger (2002), Hochmuth *et al.* (2004) and Bassey *et al.* (2004), who reported that these minerals in plant are generally higher in older leaves than the younger ones. Taiz and Zeiger (2002) and Hochmuth *et al.* (2004), attributed the higher level of these minerals in the older leaves compared to the younger leaves due to their immobile nature in the plant. The low mobility of Fe in the plant is probably due to its precipitation in the older leaves as insoluble oxides or phosphates or to the formation of complexes with phytoferritin, an iron- binding protein found in the leaf and other plant parts (Oh *et al.*, 1996; Taiz and Zeiger, 2002).

The observed higher level of K in upper than basal leaves in *Hibiscus sabdariffa, Corchorus olitorius, Telfairia occidentalis and Vernonia amygdalina* justify the highly mobile nature of this mineral that play an important role in regulation of the osmotic potential of plant cell (Taiz and Zeiger, 2002). Since K can be mobilized readily to younger leaves, the concentration appears to be higher in the upper leaf region than the basal leaf position (Taiz and Zeiger, 2002; Hochmuth *et al.* 2004). Although Taiz and Zeiger 2002 and Hochmuth *et al.* 2004 reported that Mg is a highly mobile mineral element in plants, the results obtained in this present work revealed that the mineral content was significantly higher in the basal than in the upper leaves in the studied vegetables except in *Corchorus olitorius,* where at fruiting the Mg content was higher in the upper leaf than the middle and basal leaf regions. This observation may likely suggest that besides the degree of mobility of the mineral element that are known to influence their translocation into the different leaf positions on the plant, other factors such as cultivar and some unknown factors could equally influence the nutrient distributions in the plants. The hidden factors may be responsible for the observed variations.

The observed variation in the distribution patterns of Cu, Zn and Na in the studied vegetables which seem to be at variant with the results of other investigated minerals (Fe, Mg, Ca and K) is in agreement with the finding of Lanyasunya *et al.* (2007) that the mineral content in the different leaf positions of *Vicia villosa* were not consistent.

Significant increase in cyanide content in *Amaranthus cruentus, Corchorus olitorius, Telfairia occidentalis* and *Vernonia amydalina* during fruiting compared with values at market maturity is in agreement with the report of Cleveland and Soleri (1991) and Carmen *et al.* (2007). The authors independently observed that the cyanide content in

the leaves of Crucifers and cassava increase with the age of the plants respectively. The reason for the increase may likely be that during fruiting, the gene responsible for the synthesis of cyanogenic glycoside may be triggered by some hormonal action associated with fruit initiation and development to produce more of the compound for onward translocation into the fruiting body. This observation is likely to be correct since one of the functions of cyanogenic glycoside in some plants is to protect the plants and their products from predators in order to ensure the continuity of their generation (Peter and Birger, 2002). The insignificant differences observed in the cyanide content between the market maturity and fruiting stage in *Hibiscus sabdariffa* may probably suggest that fruits formation in the vegetable had no significant effect on its cyanide metabolism.

The significantly lower nitrate content in *Amaranthus cruentus, Corchorus olitorius,* and *Telfairia occidentails* at fruiting compared to market maturity is in line with report of Richard (1991) and Brown (1993) that young plant in the vegetative stage generally contains more nitrate than mature plants of the same species. Shigeru *et al.* (2003), Waldemar *et al.* (2005) and Carmen *et al.* (2007) also found the same trend in setaria grasses, *Anethum graveolens* and cassava leaves respectively. This decrease in the nitrate content during fruiting of the vegetables may spell two things; firstly that during fruiting there could be an increase in the activity of nitrate reductase enzyme leading to an increase in amino acids and proteins required for fruiting and seeds development. This observation is likely to be correct since there is a report of significant negative correlation between nitrate content in the plant and nitrogen reductase activity (Anjana *et al.*, 2007). Secondly, there is likelihood of the translocation of some of nitrate contents in the leaves during fruiting to the developing fruits. This observation is supported by the report of

Noggle and Fritz (2006) that during the stage of fruit development, metabolites for cellular synthesis and the growth substances are translocated to the developing fruits from the leaves, stems, and roots. They further stressed that growing fruit is an active sink that diverts and draws water and solutes from other regions of the plant. Results of higher nitrate content at fruiting than at market maturity in *Hibiscus sabdariffa* and *Vernonia amygdalina* which is at variance with the above results may imply that during fruits formation in the vegetables, the activity of nitrate reductase enzyme responsible for the conversion of nitrate to protein may be reduced or brought down to a halt due to some physiological and biochemical changes that may likely be associated with fruits development and thereby resulting in the accumulation of nitrate in the vegetables. Noggle and Fritz (2006) reported that change in protein profile during fruiting in some plants may suggest that some enzymes probably disappear or become inactive during this stage of plant development.

Higher oxalates (soluble and total) content observed at fruiting than at market maturity in all the studied vegetables concur with the finding of Waldemar *et al.* (2005) that older plant had higher oxalates than the younger plant in *Anethum graveolens.* The reason for this could be that many substances, such as the so - called secondary plant substances (secondary metabolites) accumulate in tissues and organs during aging (Noggle and Fritz, 2006).

Decrease in β-carotene content during fruiting in *Amaranthus cruentus, Telfairia occidentalis* and *Vernonia amydalina* agrees with the report of Barros *et al.*(2007a) and Barros *et al*, (2007b) that the provitamin A content decreased in mature fruiting body of mushroom and *Lactarius piperatus* . The likely reason for the decrease of the compound

in the vegetables may be due to the possible translocation of some of its content to the developing fruits and a decline in the content and activity of chlorophyll and associated light absorbing pigments (including caroteniods) following senescence induced by fruit formation and maturation (Noggle and Fritz, 2006).

Observed decrease in vitamin C content in *Corchorus olitorius* during fruiting is in line with the finding of Zofia *et al.* (2006) and Bergquist *et al.* (2007) that vitamin C content is higher in the younger *Anethum graveolus* and baby spinach respectively than in older ones. The observation is supported by Noggle and Fritz (2006) that growing fruit is an active sink that diverts and draws water and solutes from other regions of the plant. While the insignificant differences in the vitamin C content between market maturity and fruiting stage in *Hibiscus sabdariffa* and *Telfairia occidentalis* may imply that translocation of vitamin C into the developing fruit may not have significant effect on its content in the leaves of the vegetables. The increase in the vitamin C content during heading in *Amaranthus cruentus* and *Vernonia amygdalia*, though contrary to the above observations, agreed with the submission of Chweya (1993) and Chweya and Nameus (1997) that vitamin C content increased significantly with plant age in *Gynandropsis gynandra* and *Cleome gynandra* respectively. Barros *et al.* (2007b) reported the same trend of results in *Lactarius piperatus* that vitamin C content in *Lactarius piperatus* was highest at maturity and lowest at immaturity stage. The variations in the vitamin C content in the different studied vegetables at fruiting stage may have resulted from differences in cultivar (Guillermo *et al.*, 2005; Signh, 2005; Aliyu and Morufu, 2006; Weerakkody, 2006).

Observed significant decrease in some of mineral elements in the studied vegetables during fruiting compare to higher values at market maturity is in line with finding of Noggle and Fritz (2006), to the effect that during fruit initiation and development, some metabolites for cellular synthesis and growth substances are translocated from the leaves, stems, and roots to the developing fruits. Lanyasunya *et al.* (2007) observed that the rapid uptake of mineral by plants during early growth and the gradual dilution that occurs as plant matures would have been responsible for the decrease in some of the mineral content during fruiting.

The elevated levels of some mineral in some vegetable leaves during fruiting (especially Fe in *Amaranthus cruentus* and *Telfairia occidentalis*; Mg in *Telfairia occidentalis*) may likely indicate that the possible physiological and biochemical changes during fruit initiation and development could lead to an increase uptake of the minerals from the soil by the plant for an onward translocation into the fruiting body. This observation is likely to be true since Noggle and Fritz (2006) concluded that the chemical composition of fruit at maturity reflect the presence of materials translocated from other parts of the plant as well as materials formed by metabolic activities of the fruit tissues.

A significant positive correlation existing between the levels of the cations (Mg, Na, Fe, Zn and Ca) and oxalates (soluble and total) in the studied vegetables is in agreement with the finding of Gilbert *et al.*(1951) that cations content in tung leaves correlated directly with organic acid content. The authors have also reported a specific positive significant correlation between oxalates and Ca, K and Mg levels in tung leaves and they attributed the direct correlation relating to their different ionic properties as affected by cation - anion balance. Similarly Olumuyiwa *et al.* (2003) reported significant

positive correlation between some cations (Fe, Mg and Zn) and citric acid in composite diets which concur with the report of Gilbert (1951). Likewise, positive correlation between Nitrate and K, Ca and Mg contents in potato tubers reported by Cieslik and Sikora (1998) is in agreement with the present findings. This showed that nitrate content in the studied vegetables correlated significantly and positively with Mg, Na, Ca, Zn and K. Cyanide content in the studied vegetables also correlated significantly positive with Mg, Na, Fe, and K. However, no available literature was found in connection with correlation of cyanide with some cations. It is most likely that the significantly positive correlation existing between cyanide and the cations in the vegetables may be as results of their opposite charges that may be required for the interactions in order to maintain ionic balance within the plants.

5.1 Summary

1. The levels of antinutrients and nutrients are reduced in leafy vegetables with boiling and sundrying.
2. Boiling method preserved more of the vitamin C and β-carotene compared to sundrying method.
3. 5 minutes boiling increased the level of β-carotene in the vegetables.
4. Sundrying had no effect on mineral elements in all the vegetables analysed.
5. The levels of nutrients, antinutrients and toxic substances generally decreased with freezing in the vegetables studied.
6. Application of nitrogen fertilizer generally increased the levels of cyanide and nitrate, and reduced the soluble and total oxalates content of the vegetables.
7. Similarly the level of vitamin C decreased while β-carotene content increased with the application of nitrogen fertilizer in the vegetables.
8. Cyanide content was generally higher in the older leaves compared to the younger ones in the vegetables irrespective of the stage of plant development except in *Telfairia occidentalis* at fruiting where the cyanide content was higher in the younger than older leaves.
9. The nitrate content are generally higher in the older compared to younger leaves in *Amaranthus cruentus, Hibiscus sabdariffa* and *Corchorus olitorius* while its content was higher in the younger leaves than the older ones in *Telfairia occidentalis* and *Vernonia amygdalina*.

10. The soluble and total oxalates in the studied vegetables increased with leaf age except in *Corchorus olitorius,* at market maturity where the oxalates seem to concentrate more in the middle leaves than in the other leaf regions.
11. Vitamin C contents were concentrated more in the middle leaf region compared to basal and upper leaf positions in the vegetables except in *Telfairia occidentalis* at market maturity, where the vitamin was highest in the upper leave than the two leaf positions.
12. The distribution of β-carotene into the different leaf positions to some extent depends on the cultivars and stages of plant development. The provitamin A content was highest in the middle and upper leaves in *Amaranthus cruentus* and *Telfairia occidentalis,* respectively. While in *Hibiscus sabdariffa* and *Corchorus olitorius* the provitamin was highest in the middle and upper leaves at market maturity and fruiting, respectively. Similarly the level of β-carotene content in *Vernonia amygdalina* was highest in upper and middle leaves at market maturity and fruiting, respectively.
13. Levels of Fe, Ca and Mg in the studied vegetables were generally highest in the older compared to younger leaves, while the K content was highest in the younger leaves than the older ones.
14. The antinutrients and toxic substances were generally elevated during fruiting in the studied vegetables except that the nitrate content was found to decrease in *Amaranthus cruentus, Corchorus olitorius* and *Telfairia occidentalis* with fruiting.

15. The contents of β-carotene in the *Amaranthus cruentus* and *Telfairia occidentalis* decrease with fruiting, while the provitamin level increased with fruiting in *Corchorus olitorius* and *Vernonial amygalina*.
16. Fruiting reduced vitamin C content in *Corchorus olitorius*, increased the vitamin content in *Amaranthus cruentus* and *Vernonia amygdalina* and had no significant effect on the vitamin C content in *Hibiscus sabdariffa* and *Telfairia occidentalis*.

5.2 Conclusions

From the foregoing the following conclusions could be made:

1. Boiling method of processing (5 minutes of boiling) should be encouraged over sundrying.
2. Where possible we must keep away from application of nitrogen fertilizer or overdosage of nitrogen fertilizer when growing vegetables. This practice increases the accomulations of cyanide and nitrate in the studied vegetables.
3. Older leaves of the studied vegetables must be avoided as they contained more of the plant toxins than the younger ones.
4. We must prefer genetically low antinutrients and toxic substances storable varieties.
5. We must avoid consumption of vegetables during reproductive phase since the antinutrients and toxic substances are generally concentrated more during this stage of plant development.

5.3 Recommendations

In continuations of this work, the following recommendations are made;

1. Comparison of effect of organic and conventional fertilizers on the micronutrients and antinutrients content in some leafy vegetables and possibly the interplay of these cultural methods with various post-harvest handlings.

2. Elucidation of biochemical mechanisms of nutrients and antinutrients uptake in some common Nigerian vegetables.

3. Determination of the nitrate reductase enzyme along side with nitrate and protein content in the different leaf regions of the vegetable in order to establish the relationship existing between them.

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APPENDICES

Appendix 1: Effect of freezing on cyanide, β-carotene and vitamin C contents in *Amaranthus cruentus* obtained from different locations in Minna town.

Concentration of cyanide (mg/kg), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(56.87) [12861.33] {71.07}	(54.69) [9426.00] {11.07}	(47.05) [9354.00] {11.07}	(45.47) [8069.00] {9.49}	(39.72) [7436.00] {9.49}	(48.76^{a}) [9429.27^{a}] {22.44^{a}}
Chanchaga	(62.08) [12851.00] {69.58}	(54.69) [9426.00] {11.07}	(53.11) [10372.00] {11.07}	(54.56) [9587.00] {11.07}	(50.32) [1621.00] {11.07}	(54.83^{a}) [9907.20^{a}] {23.72^{a}}
maikunkele	(146.59) [10158.00] {67.39}	(60.99) [8842.00] {13.15}	(59.65) [7538.00] {11.50}	(56.87) [7489.00] {9.86}	(49.71) [7445.00] {9.86}	(74.76^{b}) [8294.40^{a}] {22.35^{a}}
Column mean	(88.51^{a}) [11956.80^{c}] {69.35^{b}}	(56.59^{b}) [9557.00^{b}] {113.34^{a}}	(53.27^{a}) [9088.00^{b}] {11.21^{a}}	(52.30^{a}) [8381.70^{ab}] {10.14^{a}}	(46.58^{a}) [7067.30^{a}] {10.14^{a}}	

( ) = cyanide, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 2: Effect of freezing on cyanide, β-carotene and vitamin C contents in *Hibiscus sabdariffa* obtained from different loc... in Minna town.

Concentration of cyanide (mg/kg), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(54.20) [15491.00] {14.20}	(49.77) [3532.00] {6.30}	(46.68) [3245.00] {4.02}	(40.74) [2986.00] {3.96}	(40.74) [2978.00] {4.11}	(46.43^{a}) [3646.40^{a}] {6.52^{a}}
Chanchaga	(66.93) [3344.00] {36.90}	(61.23) [2651.00] {17.63}	(60.02) [2473.00] {16.02}	(58.44) [2370.00] {16.02}	(60.29) [2312.00] {14.42}	(61.38^{b}) [2630.00^{a}] {20.20^{a}}
maikunkele	(70.81) [17483.00] {31.23}	(51.77) [12564.00] {14.79}	(44.56) [7935.00] {13.15}	(42.32) [6318.00] {11.50}	(40.00) [6154.00] {9.86}	(49.89^{a}) [10090.00^{b}] {22.35^{b}}
Column mean	(6398^{b}) [8772.67^{b}] {27.44^{b}}	(54.26^{ab}) [6249.00^{ab}] {12.91^{a}}	(50.42^{a}) [4551.00^{a}] {11.06^{a}}	(57.17^{a}) [3891.63^{a}] {10.49^{a}}	(47.01^{a}) [3814.67^{a}] {9.46^{a}}	

( ) = cyanide, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 3: Effect of freezing on cyanide, β-carotene and vitamin C contents in *Corchorus olitorius* obtained from different locations in Minna town.

Concentration of cyanide (mg/kg), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(85.12) [13649.00] {57.53}	(23.65) [12252.00] {14.79}	(13.70) [11759.00] {13.15}	(12.13) [11433.00] {11.50}	(11.28) [11399.00] {11.50}	(28.30^{a}) [12098.40^{a}] {21.70^{a}}
Chanchaga	(155.20) [18657.00] {105.20}	(79.06) [17066.00] {19.71}	(72.75) [16304.00] {18.08}	(69.84) [15541.00] {14.79}	(69.36) [14684.00] {13.15}	(89.24^{b}) [16450.00^{b}] {34.19^{b}}
maikunkele	(202.98) [22991.00] {73.96}	(99.67) [19592.00] {14.79}	(82.45) [17962.00] {11.50}	(64.26) [16741.00] {9.86}	(60.75) [15421.00] {8.22}	(102.02^{b}) [18541.40^{b}] {23.67^{a}}
Column mean	(147.77^{b}) [18432.3^{b}] {78.90^{b}}	(67.46^{a}) [16303.30^{ab}] {16.34^{a}}	(56.30^{a}) [15341.70^{a}] {14.34^{a}}	(48.74^{a}) [14571.70^{a}] {12.05^{a}}	(47.33^{a}) [13834.70^{a}] {10.96^{a}}	

( ) = cyanide, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 4: Effect of freezing on cyanide, β-carotene and vitamin C contents in *Telfairia occidentalis* obtained from different locations in Minna town.

Concentration of cyanide (mg/kg), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(87.65) [17336.00] {113.40}	(60.25) [15472.00] {8.01}	(30.13) [15391.00] {11.50}	(38.20) [14168.00] {11.50}	(38.20) [14464.00] {9.86}	(50.89^{a}) [15366.20^{a}] {32.85^{a}}
Chanchaga	(312.25) [20986.00] {182.45}	(129.73) [19611.00] {19.72}	(112.53) [19113.00] {16.43}	(90.93) [18816.00] {14.79}	(81.48) [18557.00] {14.79}	(145.38^{b}) [19416.60^{b}] {49.64^{b}}
maikunkele	(112.60) [18256.00] {281.00}	(108.65) [17198.00] {19.72}	(110.85) [13712.00] {14.79}	(82.85) [11841.00] {11.50}	(81.45) [11049.00] {9.86}	(99.28^{b}) [14411.20^{a}] {67.67^{b}}
Column mean	(170.83^{b}) [18859.00^{b}] {192.28^{b}}	(99.54^{ab}) [17427.00^{ab}] {19.15^{a}}	(84.51^{a}) [16072.00^{a}] {14.24^{a}}	(70.66^{a}) [14941.70^{a}] {12.60^{a}}	(69.04^{a}) [14690.00^{a}] {11.50^{a}}	

( ) = cyanide, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 5: Effect of freezing on cyanide, β-carotene and vitamin C contents in *Vernonia amygdalina* obtained from different locations in Minna town.

Concentration of cyanide (mg/kg), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(227.00) [19754.00] {39.44}	(60.75) [20639.00] {13.16}	(51.89) [19788.00] {11.50}	(37.45) [15984.00] {11.50}	(46.60) [12688.00] {9.86}	(84.75^{ab}) [17770.60^{b}] {17.01^{a}}
Chanchaga	(222.70) [25280.00] {32.87}	(85.05) [15282.00] {16.43}	(78.88) [14367.00] {11.50}	(73.00) [14311.00] {11.50}	(55.55) [13553.00] {9.86}	(103.75^{ab}) [16528.00^{ab}] {16.43^{a}}
Maikunkele	(147.56) [13512.00] {19.72}	(63.42) [13664.00] {13.15}	(46.10) [13357.00] {9.86}	(47.95) [13177.00] {8.86}	(41.85) [9579.00] {9.86}	(69.38^{a}) [12657.80^{a}] {12.49^{a}}
Column mean	(199.11^{b}) [19515^{b}] {30.88^{b}}	(69.74^{a}) [16528.30^{ab}] {14.25^{a}}	(58.96^{a}) [15837.30^{a}] {10.95^{a}}	(52.80^{a}) [14490.70^{a}] {10.95^{a}}	(48.00^{a}) [11940.00^{a}] {9.86^{a}}	

( ) = cyanide, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 6: Effect of freezing on nitrate, β-carotene and vitamin C contents in *Amaranthus cruentus* obtained from different locations in Minna town.

Concentration of nitrate (mg/kg), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(3936.17) [12861.33] {71.07}	(3766.67) [9426.00] {11.07}	(3372.50) [9354.00] {11.07}	(3180.67) [8069.00] {9.49}	(3169.50) [7436.00] {9.49}	(3485.10^{a}) [9429.27^{a}] {22.44^{a}}
Chanchaga	(3747.28) [12851.00] {69.58}	(3706.66) [9426.00] {11.07}	(3155.56) [10372.00] {11.07}	(3766.67) [9587.00] {11.07}	(3575.66) [1621.00] {11.07}	(3590.37^{a}) [9907.20^{a}] {23.72^{a}}
maikunkele	(5335.22) [10158.00] {67.39}	(5316.67) [8842.00] {13.15}	(3097.22) [7538.00] {11.50}	(2916.67) [7489.00] {9.86}	(2702.77) [7445.00] {9.86}	(3871.11^{a}) [8294.40^{a}] {22.35^{a}}
Column mean	(4335.22^{b}) [11956.80^{c}] {69.35^{b}}	(4263.33^{b}) [9557.00^{b}] {11.34^{a}}	(3208.43^{a}) [9088.00^{b}] {11.21^{a}}	(3288.00^{a}) [8381.70^{ab}] {10.14^{a}}	(3149.31^{a}) [7067.30^{a}] {10.14^{a}}	

( ) = nitrate, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 7: Effect of freezing on nitrate, β-carotene and vitamin C contents in *Hibiscus sabdariffa* obtained from different locations in Minna town.

Concentration of nitrate (mg/kg), β-carotene (μg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(1991.67) [5491.00] {14.20}	(1852.67) [3532.00] {6.30}	(1850.01) [3245.00] {4.02}	(1790.00) [2986.00] {3.96}	(1770.10) [2978.00] {4.11}	(1850.89^{c}) [3646.40^{a}] {6.52^{a}}
Chanchaga	(694.50) [3344.00] {36.90}	(75.17) [2651.00] {17.63}	(75.09) [2473.00] {16.02}	(72.17) [2370.00] {16.02}	(74.02) [2312.00] {14.42}	(98.19^{a}) [2630.00^{a}] {20.20^{b}}
Maikunkele	(1158.33) [17483.00] {31.23}	(708.33) [12564.00] {14.79}	(477.78) [7935.00] {13.15}	(172.22) [6318.00] {11.50}	(141.67) [6154.00] {9.86}	(531.67^{d}) [10090.00^{b}] {22.35^{b}}
Column mean	(1281.50^{b}) [8772.67^{b}] {27.44^{b}}	(878.72^{ab}) [6249.00^{ab}] {12.91^{a}}	(800.96^{a}) [4551.00^{a}] {11.06^{a}}	(678.13^{a}) [3891.63^{a}] {10.49^{a}}	(661.93^{a}) [3814.67^{a}] {9.46^{a}}	

( ) = nitrate, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 8: Effect of freezing on nitrate, β-carotene and vitamin C contents in *Corchorus olitorius* obtained from different locations in Minna town.

Concentration of nitrate (mg/kg), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(1969.44) [13649.00] {57.53}	(1191.63) [12252.00] {14.79}	(830.56) [11759.00] {13.15}	(630.55) [11433.00] {11.50}	(588.89) [11399.00] {11.50}	(1042.22^{a}) [12098.40^{a}] {21.70^{a}}
Chanchaga	(3497.22) [18657.00] {105.20}	(2944.44) [17066.00] {19.71}	(2777.79) [16304.00] {18.08}	(2694.44) [15541.00] {14.79}	(2608.33) [14684.00] {13.15}	(2904.44^{b}) [16450.00^{b}] {34.19^{b}}
Maikunkele	(3855.55) [22991.00] {73.96}	(3180.55) [19592.00] {14.79}	(3063.89) [17962.00] {11.50}	(3067.11) [16741.00] {9.86}	(2913.89) [15421.00] {8.22}	(3222.20^{b}) [18541.40^{b}] {23.67^{a}}
Column mean	(3107.40^{b}) [18432.30^{b}] {78.90^{b}}	(2438.89^{a}) [16303.30^{ab}] {16.34^{a}}	(2224.08^{a}) [15341.70^{a}] {14.34^{a}}	(2140.70^{a}) [14571.70^{a}] {12.05^{a}}	(2035.00^{a}) [13834.70^{a}] {10.96^{a}}	

( ) = nitrate, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 9: Effect of freezing on nitrate, β-carotene and vitamin C contents in *Telfairia occidentalis* obtained from different locations in Minna town.

Concentration of nitrate (mg/kg), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(3069.33) [17336.00] {113.40}	(2294.33) [15472.00] {8.01}	(2027.67) [15391.00] {11.50}	(1500.00) [14168.00] {11.50}	(1430.50) [14464.00] {9.86}	(2064.37^{b}) [15366.20^{a}] {32.85^{a}}
Chanchaga	(3961.11) [20986.00] {182.45}	(1141.61) [19611.00] {19.72}	(1072.22) [19113.00] {16.43}	(1008.33) [18816.00] {14.79}	(1000.00) [18557.00] {14.79}	(1636.67^{a}) [19416.60^{b}] {49.64^{b}}
Maikunkele	(1366.67) [18256.00] {281.00}	(1108.50) [17198.00] {19.72}	(919.33) [13712.00] {14.79}	(708.33) [11841.00] {11.50}	(675.00) [11049.00] {9.86}	(755.57^{a}) [14411.20^{a}] {67.67^{c}}
Column mean	(2799.04^{b}) [18859.00^{b}] {192.28^{b}}	(1514.83^{a}) [17427.00^{ab}] {19.15^{a}}	(1339.83^{a}) [16072.00^{a}] {14.24^{a}}	(1072.22^{a}) [14941.70^{a}] {12.60^{a}}	(1035.17^{a}) [14690.00^{a}] {11.50^{a}}	

( ) = nitrate, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 10: Effect of freezing on nitrate, β-carotene and vitamin C contents in *Vernonia amygdalina* obtained from different locations in Minna town.

Concentration of nitrate (mg/kg), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(1030.50) [19754.00] {39.44}	(1000.00) [20639.00] {13.16}	(933.33) [19788.00] {11.50}	(777.83) [15984.00] {11.50}	(597.17) [12688.00] {9.86}	(867.77^{a}) [17770.60^{b}] {17.01^{a}}
Chanchaga	(1613.83) [25280.00] {32.87}	(1566.07) [15282.00] {16.43}	(1461.66) [14367.00] {11.50}	(1218.13) [14311.00] {11.50}	(1220.00) [13553.00] {9.86}	(1415.94^{b}) [16528.00^{ab}] {16.43^{a}}
Maikunkele	(1397.33) [13512.00] {19.72}	(1395.87) [13664.00] {13.15}	(813.16) [13357.00] {9.86}	(765.79) [13177.00] {8.86}	(709.60) [9579.00] {9.86}	(1016.34^{a}) [12657.80^{a}] {12.49^{a}}
Column mean	(1347.22^{b}) [19515.00^{b}] {30.88^{b}}	(1320.65^{b}) [16528.30^{ab}] {14.25^{a}}	(1069.38^{a}) [15837.30^{a}] {10.95^{a}}	(920.57^{a}) [14490.70^{a}] {10.95^{a}}	(842.26^{a}) [11940.00^{a}] {9.86^{a}}	

( ) = nitrate, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 11: Effect of freezing on oxalate, β-carotene and vitamin C contents in *Amaranthus cruentus* obtained from different locations in Minna town

Concentration of oxalate (g/100g), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(4.17) (9.34} [12861.33] {71.07}	(3.38)(6.4} [9426.00] {11.07}	(3.38)(6.4} [9354.00] {11.07}	(3.04)(5.9} [8069.00] {9.49}	(2.59)(4.5} [7436.00] {9.49}	(3.31^{b})(6.55^{b}} [9429.27^{a}] {22.44^{a}}
Chanchaga	(4.17) (7.54} [12851.00] {69.58}	(3.38)(7.0} [9426.00] {11.07}	(3.38)(6.7} [10372.00] {11.07}	(3.04)(5.9} [9587.00] {11.07}	(2.82)(5.6} [1621.00] {11.07}	(3.36^{b})(6.60^{b}} [9907.20^{a}] {23.72^{a}}
maikunkele	(3.72) (7.09} [10158.00] {67.39}	(3.08)(5.2} [8842.00] {13.15}	(3.04)(5.2} [7538.00] {11.50}	(3.04)(5.2} [7489.00] {9.86}	(2.59)(4.8} [7445.00] {9.86}	(3.09^{a})(5.56^{a}} [8294.40^{a}] {22.35^{a}}
Column mean	(4.02^{c})(7.99} [11956.80^{c}] {69.35^{b}}	(3.28^{b})(6.2} [9557.00^{b}] {113.34^{a}}	(3.28^{b})(6.1} [9088.00^{b}] {11.21^{a}}	(3.04^{b})(5.7} [8381.70^{ab}] {10.14^{a}}	(2.67)(5.0} [7067.30^{a}] {10.14^{a}}	

( ) = soluble oxalate, { } = total oxalate, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 12: Effect of freezing on oxalate, β-carotene and vitamin C contents in *Hibiscus sabdariffa* obtained from different locations in Minna town.

Concentration of oxalate (g/100g), β-carotene (μg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One weeks freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(1.69) (4.84} [5491.00] {14.20}	(1.46)(4.5} [3532.00] {6.30}	(1.46)(4.5} [3245.00] {4.02}	(1.35) (4.16} [2986.00] {3.96}	(1.13) (4.05} [2978.00] {4.11}	(1.42)(4.41^{b}} [3646.40^{a}] {6.52^{a}}
Chanchaga	(2.59) (5.63} [3344.00] {36.90}	(2.25)(4.2} [2651.00] {17.63}	(2.25)(4.1} [2473.00] {16.02}	(2.25) (4.16} [2370.00] {16.02}	(2.25) (4.16} [2312.00] {14.42}	(2.32^{c})(4.48^{b}} [2630.00^{a}] {20.20^{b}}
Maikunkele	(1.46) (2.59} [17483.00] {31.23}	(1.13)(1.9} [12564.00] {14.79}	(1.13)(1.9} [7935.00] {13.15}	(1.13) (1.16} [6318.00] {11.50}	(0.79) (4.16} [6154.00] {9.86}	(1.13^{a})(1.87^{a}} [10090.00^{b}] {22.35^{b}}
Column mean	(1.91^{c})(4.35} [8772.67^{b}] {27.44^{b}}	(1.61)(3.56^{a}} [6249.00^{ab}] {12.91^{a}}	(1.60^{b})(3.52^{a}} [4551.00^{a}] {11.06^{a}}	(1.58^{b})(3.26^{a}} [3891.63^{a}] {10.49^{a}}	(1.39^{a})(3.22^{a}} [3814.67^{a}] {9.46^{a}}	

( ) = soluble oxalate, (} = total oxalate, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 13: Effect of freezing on oxalate, β-carotene and vitamin C contents in *Corchorus olitorius* obtained from different locations in Minna town.

Concentration of oxalate (g/100g), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(3.38)(5.29} [13649.00] {57.53}	(2.90)(4.5} [12252.00] {14.79}	(1.92)(3.7} [11759.00] {13.15}	(1.47) (3.38} [11433.00] {11.50}	(1.47) (3.38} [11399.00] {11.50}	$(2.17^{a})(4.05^{a}\}$ $[12098.40^{a}]$ $\{21.70^{a}\}$
Chanchaga	(3.38)(5.97} [18657.00] {105.20}	(2.59)(4.8} [17066.00] {19.71}	(2.59)(4.84} [16304.00] {18.08}	(2.25) (4.50} [15541.00] {14.79}	(1.92) (4.17} [14684.00] {13.15}	$(2.55^{ab})(4.86^{b}\}$ $[16450.00^{b}]$ $\{34.19^{b}\}$
Maikunkele	(3.72)(6.30} [22991.00] {73.96}	(3.04)(5.2} [19592.00] {14.79}	(2.59)(4.84} [17962.00] {11.50}	(2.59)(4.84} [16741.00] {9.86}	(2.55)(4.50} [15421.00] {8.22}	$(2.84^{b})(5.15^{b}\}$ $[18541.40^{b}]$ $\{23.67^{a}\}$
Column mean	$(3.49^{d})(5.85\}$ $[18432.30^{b}]$ $\{78.90^{b}\}$	$(2.74^{c})(4.88\}$ $[16303.30^{ab}]$ $\{16.34^{a}\}$	$(2.37^{b})(4.67^{b}\}$ $[15341.70^{a}]$ $\{14.34^{a}\}$	$(2.10^{ab})(4.24^{ab}\}$ $[14571.70^{a}]$ $\{12.05^{a}\}$	$(1.88^{b})(4.02\}$ $[13834.70^{a}]$ $\{10.96^{a}\}$	

( ) = soluble oxalate, { } = total oxalate, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 14: Effect of freezing on oxalate, β-carotene and vitamin C contents in *Telfairia occidentalis* obtained from different locations in Minna town.

Concentration of oxalate (g/100g), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(2.59)(4.17} [17336.00] {113.40}	(1.92) (3.59} [15472.00] {8.01}	(1.92)(3.04} [15391.00] {11.50}	(1.47) (2.59} [14168.00] {11.50}	(1.47) (2.59} [14464.00] {9.86}	$(1.87^{b})(3.00^{a}\}$ $[15366.20^{a}]$ $\{32.85^{a}\}$
Chanchaga	(3.38)(4.84} [20986.00] {182.45}	(3.04) (3.92} [19611.00] {19.72}	(3.04)(3.72} [19113.00] {16.43}	(2.82) (3.60} [18816.00] {14.79}	(3.38) (5.29} [18557.00] {14.79}	$(2.97^{b})(3.09^{a}\}$ $[19416.60^{b}]$ $\{49.64^{b}\}$
Maikunkele	(2.59)(4.17} [18256.00] {281.00}	(2.25) (3.04} [17198.00] {19.72}	(1.92)(3.04} [13712.00] {14.79}	(1.92) (3.04} [11841.00] {11.50}	(1.47) (2.59} [11049.00] {9.86}	$(2.03^{a})(3.09^{a}\}$ $[14411.20^{a}]$ $\{67.67^{b}\}$
Column mean	$(2.85)(4.39^{b}\}$ $[18859.00^{b}]$ $\{192.28^{b}\}$	$(2.40^{b})(3.12^{a}\}$ $[17427.00^{ab}]$ $\{19.15^{a}\}$	$(2.29^{b})(3.12^{a}\}$ $[16072.00^{a}]$ $\{14.24^{a}\}$	$(2.07^{ab})(3.08^{a}\}$ $[14941.70^{a}]$ $\{12.60^{a}\}$	$(1.84^{a})(2.86^{a}\}$ $[14670.70^{a}]$ $\{11.50^{a}\}$	

( ) = soluble oxalate, { } = total oxalate, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 15: Effect of freezing on oxalate, β-carotene and vitamin C contents in *Vernonia amygdalina* obtained from different locations in Minna town.

Concentration of oxalate (g/100g), β-carotene (µg/I00g) and vitamin C (mg/l00g).

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	(2.59)(4.16} [19754.00] {39.44}	(1.91)(2.81} [20639.00] {13.16}	(1.69)(2.25} [19788.00] {11.50}	(1.46)(2.25} [15984.00] {11.50}	(1.46)(2.74} [12688.00] {9.86}	(1.82^{b})(2.74^{a}} [17770.60^{b}] {17.01^{a}}
Chanchaga	(3.71)(5.29} [25280.00] {32.87}	(2.25)(4.17} [15282.00] {16.43}	(2.07)(3.15} [14367.00] {11.50}	(1.91)(2.29} [14311.00] {11.50}	(1.69)(2.25} [13553.00] {9.86}	(2.32^{c})(3.43^{b}} [16528.00^{ab}] {16.43^{a}}
Maikunkele	(2.25)(4.84} [13512.00] {19.72}	(1.13)(2.25} [13664.00] {13.15}	(1.13)(2.25} [13357.00] {9.86}	(1.13)(2.25} [13177.00] {8.86}	(0.79)(2.25} [9579.00] {9.86}	(1.29^{a})(2.77^{a}} [12657.80^{a}] {12.49^{a}}
Column mean	(2.85^{b})(4.76^{b}} [19515^{b}] {30.88^{b}}	(1.76^{b})(3.08^{a}} [16528.30^{ab}] {14.25^{a}}	(1.62^{a})(2.55^{a}} [15837.30^{a}] {10.95^{a}}	(1.50^{a})(2.26^{a}} [14490.70^{a}] {10.95^{a}}	(1.31^{a})(2.55a} [11940.00^{a}] {9.86^{a}}	

( ) = soluble oxalate, (} = total oxalate, [ ] = β-carotene, { } = vitamin C. Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row means carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 16: Effect of freezing on Fe content in *Amaranthus cruentus* obtained from different locations in Minna town.

	Concentration of Fe (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	22.70	20.27	18.41	15.16	15.16	18.40^{b}
Chanchaga	20.70	19.82	19.46	16.22	14.19	18.08^{b}
Maikunkele	14.19	13.78	13.38	12.16	10.14	12.73^{a}
Column mean	19.20^{b}	19.70^{b}	17.08^{b}	14.60^{a}	13.16^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 16: Effect of freezing on Fe content in *Hibisscus sabdariffa* obtained from different locations in Minna town.

Concentration of Fe (mg/kg)

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	17.43	16.62	15.00	14.19	14.19	15.49^{a}
Chanchaga	18.65	18.24	18.24	15.41	13.70	16.85^{ab}
Maikunkele	19.46	17.83	17.50	17.05	15.41	17.45^{b}
Column mean	18.51^{b}	17.56^{b}	16.91^{ab}	15.55^{a}	14.43^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 18: Effect of freezing on Fe content in *Corchorus olitorus* obtained from different locations in Minna town.

	Concentration of Fe (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	31.25	30.02	28.00	23.44	23.44	27.23^{a}
Chanchaga	23.44	23.00	15.63	15.63	15.63	18.67^{a}
Maikunkele	23.40	23.40	18.30	18.01	18.03	20.23^{a}
Column mean	26.03^{b}	25.47^{b}	20.64^{a}	19.03^{a}	19.03^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 19: Effect of freezing on Fe content in *Telfairia occidentalis* obtained from different locations in Minna town.

	Concentration of Fe (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	23.40	15.63	15.43	15.00	15.01	16.89^{a}
Chanchaga	23.44	23.00	15.63	15.63	15.23	17.99^{a}
Maikunkele	23.44	23.00	18.17	15.63	15.63	19.17a
Column mean	23.43^{c}	19.55^{b}	16.41^{ab}	15.42^{a}	15.29^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 20: Effect of freezing on Fe content in *Vernonia amygdalina* obtained from different locations in Minna town.

	Concentration of Fe (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	23.44	23.44	23.20	23.20	15.63	21.78^{a}
Chanchaga	15.63	15.63	15.63	15.43	15.43	17.55^{a}
Maikunkele	31.25	31.25	30.25	25.65	25.23	28.73^{b}
Column mean	26.77^{b}	23.44^{ab}	23.03^{ab}	21.43^{a}	18.76^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 21: Effect of freezing on Cu content in *Amaranthus cruentus* obtained from different locations in Minna town.

Concentration of Cu (mg/kg)

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	33.33	26.67	26.67	26.67	26.08	27.88^{c}
Chanchaga	16.06	16.67	13.33	13.33	12.87	14.45^{a}
Maikunkele	23.33	23.33	18.21	16.67	16.67	19.64^{b}
Column mean	24.24^{b}	22.22^{b}	19.40^{ab}	18.89^{a}	18.54^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 22: Effect of freezing on Cu content in *Hibiscus sabdariffa* obtained from different locations in Minna town.

	Concentration of Cu (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	23.33	23.05	23.00	22.00	22.01	22.68^{a}
Chanchaga	26.67	23.33	20.50	20.03	20.00	22.11^{a}
Maikunkele	30.00	25.30	25.00	25.00	20.50	25.16^{a}
Column mean	26.67^{a}	23.89^{a}	22.83^{a}	22.34^{a}	20.84^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 23: Effect of freezing on Cu content in *Corchorus olitorius* obtained from different locations in Minna town.

Concentration of Cu (mg/kg)

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	27.52	27.42	27.52	27.52	27.30	27.46^{ab}
Chanchaga	36.70	32.70	27.50	27.51	27.42	30.37^{b}
Maikunkele	27.50	26.81	24.90	24.18	24.06	25.49^{a}
Column mean	30.57^{a}	28.98^{a}	26.64^{a}	26.40^{a}	26.26^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 24: Effect of freezing on Cu content in *Telfairia occidentalis* obtained from different locations in Minna town.

Concentration of Cu (mg/kg)

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	18.35	18.35	18.35	17.52	17.52	17.98[a]
Chanchaga	19.40	18.75	18.75	18.35	18.35	18.58[a]
Maikunkele	18.35	18.35	18.35	13.90	11.90	16.17[b]
Column mean	18.70[a]	18.48[a]	18.35[a]	16.59[a]	15.76[a]	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 25: Effect of freezing on Cu content in *Vernonia amygdalina* obtained from different locations in Minna town.

Concentration of Cu (mg/kg)

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	27.52	27.52	18.35	18.35	18.35	24.02^{a}
Chanchaga	36.70	27.52	27.52	24.35	23.50	27.92^{ab}
Maikunkele	45.87	37.52	28.35	27.20	27.09	33.21^{b}
Column mean	36.70^{b}	30.85^{ab}	24.74^{a}	26.63^{a}	22.98^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 26: Effect of freezing on Mg content in *Amaranthus cruentus* obtained from different locations in Minna town.

	Concentration of Mg (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	26.92	26.03	25.13	21.79	21.07	24.19^{a}
Chanchaga	29.49	26.92	24.36	25.13	24.30	26.44^{a}
Maikunkele	26.92	24.36	22.43	21.79	21.25	23.35^{a}
Column mean	27.78^{b}	26.44^{b}	23.97^{a}	22.90^{a}	22.21^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 27: Effect of freezing on Mg content in *Hibiscus sabdariffa* obtained from different locations in Minna town.

Concentration of Mg (mg/kg)

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	23.72	16.67	15.34	13.46	11.54	16.19^{a}
Chanchaga	20.83	17.30	16.67	16.67	16.65	17.62^{a}
Maikunkele	21.69	17.09	16.50	15.39	14.73	17.43^{a}
Column mean	21.69^{b}	17.09^{a}	16.50^{a}	15.39^{a}	14.73^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 28: Effect of freezing on Mg content in *Corchorus olitorius* obtained from different locations in Minna town.

	Concentration of Mg (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	48.78	43.90	43.25	39.02	39.02	42.79^{a}
Chanchaga	58.54	58.29	49.27	50.00	47.92	52.80^{b}
Maikunkele	78.05	75.60	70.20	68.29	68.21	72.02^{c}
Column mean	61.79^{b}	59.26^{b}	54.24^{a}	52.44^{a}	51.72^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 29: Effect of freezing on Mg content in *Telfairia occidentalis* obtained from different locations in Minna town.

	Concentration of Mg (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	48.88	48.78	39.27	39.27	39.04	43.05^{b}
Chanchaga	39.02	34.25	34.15	34.15	29.27	34.17^{a}
Maikunkele	58.54	58.54	49.72	44.35	44.39	51.11^{c}
Column mean	48.81^{b}	47.19^{b}	41.05^{ab}	39.26^{a}	37.57^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 30: Effect of freezing on Mg content in *Vernonia amygdalina* obtained from different locations in Minna town.

Concentration of Mg (mg/kg)

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	78.05	73.17	43.17	39.17	39.17	54.55^{b}
Chanchaga	53.65	48.78	43.90	39.05	39.02	44.48^{b}
Maikunkele	34.15	28.51	24.63	24.63	24.63	27.38^{a}
Column mean	55.28^{b}	50.49^{b}	37.28^{a}	34.28^{a}	34.06^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 31: Effect of freezing on Na content in *Amaranthus cruentus* obtained from different locations in Minna town.

Concentration of Na (mg/kg)

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	11.70	11.70	10.80	9.90	9.89	10.80^{a}
Chanchaga	12.15	12.01	9.45	9.23	8.55	10.28^{ab}
Maikunkele	13.05	11.70	11.25	10.58	10.13	11.34^{b}
Column mean	12.30^{b}	11.50^{ab}	10.50^{a}	9.90^{a}	9.53^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 32: Effect of freezing on Na content in *Hibicus sabdariffa* obtained from different locations in Minna town.

Concentration of Na (mg/kg)

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	5.50	4.28	4.05	4.05	4.00	4.58^{a}
Chanchaga	5.40	4.50	4.05	4.05	3.15	4.23^{a}
Maikunkele	7.43	7.43	6.98	6.30	6.08	6.84^{a}
Column mean	6.11^{b}	5.40^{b}	5.36^{b}	4.80^{ab}	4.41^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 33: Effect of freezing on Na content in *Corchorus olitorius* obtained from different locations in Minna town.

	Concentration of Na (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	12.38	11.20	7.20	6.75	6.30	8.77^{a}
Chanchaga	3.90	3.60	3.38	3.15	3.38	3.48^{a}
Maikunkele	10.80	8.10	6.80	6.11	6.11	7.48^{a}
Column mean	9.03^{b}	7.63^{ab}	5.63^{a}	5.34^{a}	5.26^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 34: Effect of freezing on Na content in *Telfairia occidentalis* obtained from different locations in Minna town.

	Concentration of Na (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	10.58	6.30	6.30	5.63	5.40	6.84^{a}
Chanchaga	11.70	11.25	8.18	8.18	7.96	9.45^{b}
Maikunkele	12.15	12.04	11.80	11.63	10.94	11.71^{c}
Column mean	11.48^{b}	9.86^{ab}	8.76^{a}	8.48^{a}	8.10^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 35: Effect of freezing on Na content in *Vernonia amygdalina* obtained from different locations in Minna town.

	Concentration of Na (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	6.08	6.08	6.03	5.63	5.59	5.68[a]
Chanchaga	6.53	5.83	5.63	5.40	5.40	5.76[a]
Maikunkele	11.48	11.10	9.23	8.33	8.33	9.69[a]
Column mean	8.03[a]	7.34[a]	6.96[a]	6.45[a]	6.44[a]	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova.Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 36: Effect of freezing on K content in *Amaranthus cruentus* obtained from different locations in Minna town.

Concentration of K (mg/kg)

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	208.13	180.00	168.75	157.57	135.57	170.00
Chanchaga	247.50	196.25	191.26	163.13	146.25	188.90^{b}
Maikunkele	270.00	202.50	202.50	202.20	197.51	215.00^{c}
Column mean	241.88^{c}	192.92^{b}	187.50^{b}	174.40^{b}	159.78^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location, respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 37: Effect of freezing on K content in *Hibiscus sabdariffa* obtained from different locations in Minna town.

Concentration of K (mg/kg)

Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	61.88	61.88	56.25	50.63	45.00	55.13^{b}
Chanchaga	56.25	56.25	50.63	45.00	45.00	50.63^{a}
Maikunkele	67.50	67.50	67.50	55.75	53.07	62.26^{c}
Column mean	61.88^{b}	61.86^{b}	58.13^{a}	50.46^{a}	47.69^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 38: Effect of freezing on K content in *Corchorus olitorius* obtained from different locations in Minna town.

	Concentration of K (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	247.50	541.88	236.25	236.25	236.00	239.58^{c}
Chanchaga	151.88	135.00	123.75	123.75	112.50	129.38^{b}
Maikunkele	129.38	121.50	112.50	101.25	101.25	113.18^{a}
Column mean	176.25^{b}	166.13^{ab}	157.50^{a}	153.75^{a}	149.92^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 39: Effect of freezing on K content in *Telfairia occidentalis* obtained from different locations in Minna town.

	Concentration of K (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	241.88	213.75	213.75	196.88	163.13	202.88^{b}
Chanchaga	163.13	146.25	146.25	129.38	129.38	142.88^{a}
Maikunkele	146.75	146.25	123.75	123.75	114.38	130.98^{a}
Column mean	183.92^{b}	168.75^{b}	161.25^{a}	150.00^{a}	135.63^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 40: Effect of freezing on K content in *Vernonia amygdalina* obtained from different locations in Minna town.

	Concentration of K (mg/kg)					
Location	Fresh sample	One week freezing	Two weeks freezing	Three weeks freezing	Four weeks freezing	Row mean
Bosso	258.75	241.8	230.63	219.38	219.38	235.13^{b}
Chanchaga	281.75	264.38	258.75	234.50	225.50	252.98^{a}
Maikunkele	326.25	315.00	295.00	264.38	230.63	285.75^{b}
Column mean	288.92^{b}	273.75^{b}	260.00^{ab}	241.29^{a}	225.17^{a}	

Values represent means of triplicate determinations. Column and row mean data represent sample treatment and location respectively and are obtained from two way anova. Column/Row mean data carrying the same superscript do not differ significantly from each other ($p > 0.05$).

Appendix 41a: Correlation of Antinutrients and Nutrients in *Amaranthus cruentus* at market maturity

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00																									
2	0.16	1.00																								
3	0.29	0.51	1.00																							
4	0.44	0.50	0.86*	1.00																						
5	0.55	-0.08	0.33	0.13	1.00																					
6	0.35	0.03	0.22	0.34	0.13	1.00																				
7	0.22	0.44	0.62	0.81*	0.07	0.26	1.00																			
8	0.08	0.59	0.27	0.49	0.23	0.08	0.38	1.00																		
9	-0.29	0.06	0.24	0.27	0.06	-0.47	0.56	0.00	1.00																	
10	-0.27	-0.13	0.53	0.23	0.20	-0.17	0.28	-0.49	0.50	1.00																
11	0.31	0.62	0.87*	0.74	0.14	0.27	0.37	0.22	0.00	0.30	1.00															
12	0.15	0.54	0.90*	0.71	0.14	-0.16	0.41	0.23	0.26	0.56	0.83*	1.00														
13	-0.09	-0.62	-0.50	-0.46	-0.09	0.27	-0.64	-0.01	-0.66	-0.42	-0.46	-0.55	1.00													
14	-0.56	-0.31	-0.52	-0.54	-0.18	-0.38	-0.48	-0.06	0.24	-0.23	-0.36	-0.43	0.24	1.00												
15	-0.06	0.07	0.34	0.34	0.33	0.17	0.35	0.13	0.54	0.15	0.32	0.12	-0.26	0.46	1.00											
16	-0.18	-0.11	-0.17	-0.02	0.10	0.15	0.10	0.18	0.36	-0.27	-0.12	-0..38	0.05	0.71	0.85*	1.00										
17	0.18	0.03	0.53	0.23	0.58	0.57	-0.03	-0.09	-0.34	0.29	0.49	0.30	0.21	-0.22	0.30	0.02	1.00									
18	0.07	-0.09	0.11	-0.02	0.60	0.47	0.16	-0.32	0.16	0.16	0.07	-0.23	-0.11	0.19	0.68	0.60	0.54	1.00								
19	-0.16	-0.15	-0.61	-0.61	-0.43	-0.63	-0.59	-0.20	-0.25	-0.24	-0.46	-0.23	0.16	0.10	-0.78	-0.53	-0.64	-0.71	1.00							
20	0.04	0.53	0.42	0.26	-0.14	-0.61	0.05	0.13	0.16	0.30	0.46	0.76	-0.53	-0.29	-0.33	-0.61	-0.22	-0.62	0.43	1.00						
21	0.06	-0.01	0.47	0.44	0.46	0.62	0.47	0.11	0.22	0.23	0.30	0.08	-0.02	0.01	0.77	0.59	0.67	0.79	-0.98*	-0.57	1.00					
22	0.12	0.17	0.73	0.69	0.39	0.56	0.61	0.26	0.26	0.35	0.54	0.40	-0.16	-0.16	0.72	0.41	0.67	0.57	-0.97*	-0.29	0.94*	1.00				
23	0.22	0.59	0.80*	0.87*	-0.13	-0.08	0.67	0.44	0.39	0.34	0.74	0.86*	-0.63	-0.44	0.15	-0.23	-0.05	-0.35	-0.24	0.65	0.04	0.37	1.00			
24	0.00	0.06	0.26	0.24	0.32	0.73	0.37	-0.09	0.10	0.15	0.23	-0.13	-0.06	0.05	0.68	0.59	0.58	0.89*	-0.87*	-0.67	0.91*	0.76	-0.14	1.00		
25	0.30	0.46	0.94*	0.94*	0.12	0.13	0.69	0.33	0.32	0.48	0.81*	0.89*	-0.51	-0.53	0.26	-0.20	0.28	-0.12	-0.48	0.48	0.34	0.62	0.93*	0.10	1.00	
26	0.27	0.29	0.77	0.73	0.52	0.51	0.76	0.17	0.36	0.43	0.54	0.44	-0.40	-0.38	0.62	0.50	0.59	0.61	-0.92*	-0.18	-0.86*	0.93*	0.42	0.82*	0.66	1.00

* Significant ($P < 0.01$)

Appendix 41b: Correlation of Antinutrients and Nutrients in *Amaranthus cruentus* at Heading

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00																									
2	0.57	1.00																								
3	-0.58	-0.18	1.00																							
4	-0.21	-0.04	0.62	1.00																						
5	0.19	-0.19	0.11	0.21	1.00																					
6	-0.21	0.12	-0.02	-0.29	-0.23	1.00																				
7	0.26	-0.02	0.32	0.03	0.64	-0.52	1.00																			
8	0.21	-0.39	0.13	-0.09	0.04	-0.12	0.39	1.00																		
9	-0.21	0.45	0.26	0.53	-0.10	-0.19	-0.20	-0.81*	1.00																	
10	-0.09	0.34	0.58	0.72	-0.20	0.09	-0.14	-0.03	0.48	1.00																
11	-0.41	-0.52	0.65	0.78	0.10	-0.26	0.06	0.37	0.05	0.58	1.00															
12	-0.41	-0.54	0.69	0.67	0.14	-0.09	0.13	0.52	-0.14	0.54	0.96*	1.00														
13	-0.18	-0.09	0.32	0.16	0.80*	0.04	0.44	-0.34	0.22	-0.16	-0.08	-0.03	1.00													
14	-0.40	-0.33	0.39	0.45	0.07	-0.07	-0.16	-0.50	0.63	0.21	0.15	0.05	0.49	1.00												
15	-0.26	-0.29	0.07	-0.40	-0.09	0.26	-0.03	0.13	-0.24	-0.20	-0.15	-0.05	0.22	0.38	1.00											
16	0.30	0.05	-0.19	-0.09	0.42	-0.01	0.15	-0.08	0.04	0.05	-0.10	0.08	0.40	0.21	0.52	1.00										
17	0.43	0.30	-0.74	-0.90*	-0.34	0.31	-0.16	0.04	-0.45	-0.61	-0.84*	-0.76	-0.36	-0.55	0.08	-0.13	1.00									
18	0.61	0.10	-0.74	-0.74	0.08	0.31	-0.05	0.29	-0.66	-0.56	-0.63	-0.50	-0.09	-0.39	0.33	0.36	0.74	1.00								
19	-0.41	0.24	0.51	0.20	0.26	-0.03	0.33	-0.58	0.61	0.15	-0.08	-0.10	0.62	0.32	-0.12	-0.08	-0.29	-0.59	1.00							
20	-0.18	-0.19	0.71	0.70	0.06	-0.46	0.32	0.37	0.19	0.65	0.80*	0.75	-0.00	0.35	0.12	0.14	-0.79	-0.56	0.01	1.00						
21	-0.59	-0.40	0.85*	0.79	0.08	-0.15	0.07	0.15	0.28	0.65	0.90*	0.87*	0.17	0.47	0.10	0.01	-0.92*	-0.74	0.21	0.85	1.00					
22	-0.53	-0.43	0.77	0.68	0.24	-0.13	0.15	0.12	0.24	0.57	0.81*	0.80*	0.33	0.51	0.29	0.29	-0.91*	-0.59	0.21	0.83	0.95*	1.00				
23	-0.68	-0.45	0.83*	0.62	0.06	-0.15	0.15	0.13	0.24	0.57	0.84*	0.82*	0.15	0.29	0.10	-0.00	-0.82*	-0.77	0.35	0.76	0.93	0.91*	1.00			
24	-0.44	-0.54	0.45	0.62	-0.11	-0.25	-0.13	0.29	0.07	0.54	0.92*	0.86*	-0.26	0.09	-0.03	0.03	-0.72	-0.56	-0.18	0.72	0.81*	0.76	0.81*	1.00		
25	-0.56	-0.50	0.74	0.64	0.01	-0.52	0.24	0.21	0.23	0.36	0.80*	0.72	0.05	0.42	0.08	-0.16	-0.79	-0.76	-0.17	0.84*	0.87*	0.79	0.84*	0.74	1.00	
26	-0.56	-0.16	0.85*	0.81*	-0.15	-0.27	0.06	0.03	0.47	0.71	0.80*	0.72	-0.03	0.42	-0.15	0.30	0.82*	-0.90*	0.32	0.81*	0.90*	0.75	0.85*	0.70	0.87*	1.00

* Significant ($P < 0.01$

Appendix 42a: Correlation of Antinutrients and Nutrient in *Hibiscus sabdariffa* at market maturity

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00																									
2	0.21	1.00																								
3	0.40	-0.26	1.00																							
4	-0.56	-0.36	-0.50	1.00																						
5	0.08	0.48	-0.10	-0.09	1.00																					
6	0.44	0.55	-0.16	-0.56	-0.11	1.00																				
7	0.06	0.62	-0.79	0.18	0.18	0.13	1.00																			
8	-0.04	0.30	-0.38	-0.52	0.19	0.33	0.32	1.00																		
9	-0.00	0.21	-0.13	-0.56	-0.40	0.46	0.17	0.72	1.00																	
10	0.23	0.50	-0.02	-0.48	0.20	-0.05	0.35	0.12	0.25	1.00																
11	0.22	0.85*	-0.18	-0.11	0.20	0.38	0.66	-0.07	0.02	0.51	1.00															
12	-0.08	0.42	-0.85*	0.14	-0.02	0.18	0.93*	0.51	0.44	0.26	0.44	1.00														
13	-0.31	-0.16	0.25	0.44	0.09	-0.13	-0.26	-0.70	-0.44	0.24	0.12	-0.36	1.00													
14	-0.63	-0.46	0.08	0.23	-0.36	0.06	-0.26	-0.03	0.41	0.08	-0.26	-0.07	0.29	1.00												
15	0.06	-0.04	-0.14	-0.06	-0.10	0.04	-0.07	0.25	0.06	-0.34	-0.34	-0.09	-0.70	-0.20	1.00											
16	0.12	0.07	-0.14	-0.21	-0.09	0.16	0.02	0.39	0.07	-0.38	-0.21	0..02	-0.84*	-0.22	0.96*	1.00										
17	-0.35	-0.60	0.12	0.29	-0.25	-0.03	-0.64	-0.20	-0.25	-0.57	-0.76	-0.56	-0.03	0.08	0.59	0.42	1.00									
18	-0.09	-0.55	0.12	0.17	-0.32	-0.14	-0.56	-0.14	-0.16	-0.59	-0.76	-0.47	-0.21	-0.14	0.65	0.49	0.94*	1.00								
19	0.67	0.65	-0.22	-0.59	0.30	0.02	0.62	0.57	0.38	0.37	0.49	0.55	-0.63	-0.58	0.11	0.28	-0.64	-0.43	1.00							
20	0.65	0.25	-0.31	-0.44	0.24	-0.37	0.59	0.45	0.18	0.11	0.20	0.56	-0.63	-0.51	0.13	0.26	-0.53	-0.28	0.86*	1.00						
21	0.42	0.73	- 0.19	-0.41	0.17	0.17	0.71	0.32	0.39	0.65	0.82*	0.62	-0.16	-0.18	-0.37	-0.20	-0.94*	-0.85*	0.78	0.56	1.00					
22	0.43	0.68	-0.12	-0.49	0.21	0.15	0.64	0.40	0.43	0.62	0.25	0.58	-0.19	-0.15	-0.39	-0.20	-0.95*	-0.87*	0.79	0.58	0.99*	1.00				
23	0.73	0.41	0.14	-0.06	0.23	-0.34	0.34	-0.41	-0.47	0.26	0.60	0.02	-0.02	-0.56	0.04	0.06	-0.41	-0.29	0.48	0.45	0.46	0.39	1.00			
24	0.65	0.55	-0.14	-0.35	0.22	-0.11	0.66	0.26	0.10	0.31	0.64	0.51	-0.47	-0.39	0.01	0.20	-0.76	-0.60	-0.87*	-0.82*	0.82*	0.82*	0.70	1.00		
25	0.56	0.67	-0.10	-0.24	0.40	-0.06	0.66	0.04	-0.15	0.45	0.83*	0.44	-0.05	-0.42	-0.36	-0.21	-0.89*	-0.79	0.73	0.63	0.87*	0.86*	0.44	0.88*	1.00	
26	0.38	0.61	-0.31	-0.03	0.36	-0.04	0.77	0.07	-0.45	0.32	0.79	0.56	-0.20	-0.28	-0.12	0.03	-0.78	-0.73	0.67	0.63	0.79	0.75	0.71	0.90*	0.92*.	100

* Significant ($P < 0.01$)

Appendix 42b: Correlation of Antinutrients and Nutrients in *Hibiscus sabdariffa* at fruiting

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00																									
2	0.09	1.00																								
3	0.38	-0.37	1.00																							
4	-0.29	0.18	-0.42	1.00																						
5	-0.19	0.22	-0.23	-0.08	1.00																					
6	-0.42	-0.33	-0.66	0.16	0.29	1.00																				
7	-0.30	0.42	-0.63	0.49	0.07	0.06	1.00																			
8	-0.61	-0.06	-0.67	0.50	0.07	0.70	0.27	1.00																		
9	0.38	0.09	0.68	-0.25	-0.01	-0.48	-0.80*	-0.38	1.00																	
10	0.44	0.28	0.70	0.06	-0.08	-0.84	-0.32	-0.59	0.76	1.00																
11	-0.16	-0.07	-0.55	-0.02	0.51	0.66	0.45	0.26	-0.67	-0.69	1.00															
12	-0.11	-0.43	0.02	-0.21	0.27	0.22	0.18	-0.35	-0.50	-0.33	0.53	1.00														
13	-0.70	-0.29	-0.01	0.12	0.19	0.17	0.39	0.32	-0.43	-0.29	0.38	0.31	1.00													
14	-0.88*	0.02	-0.63	0.44	0.48	0.67	0.35	0.72	-0.43	-0.52	0.43	0.14	0.54	1.00												
15	-0.60	0.21	-0.19	0.45	-0.27	0.02	0.10	0.23	0.02	0.05	-0.36	-0.15	0.08	0.46	1.00											
16	-0.74	0.01	-0.32	0.63	-0.31	0.15	0.35	0.45	-0.31	-0.16	-0.23	-0.03	0.33	0.58	0.88*	1.00										
17	-0.65	0.05	-0.65	0.32	0.17	0.52	0.67	0.76	-0.71	-0.67	-0.60	-0.01	0.70	0.67	0.05	0.33	1.00									
18	-0.81*	0.00	-0.63	0.33	0.25	0.61	0.62	0.75	-0.68	-0.67	0.57	0.09	0.77	0.81*	0.22	0.46	0.92*	1.00								
19	0.57	0.31	0.64	-0.15	-0.34	-0.68	-0.55	-0.70	-0.75	0.80*	-0.77	-0.21	-0.67	-0.66	0.17	-0.18	-0.94	-0.92*	1.00							
20	0.62	-0.19	0.52	-0.20	0.14	-0.39	-0.47	-0.58	0.47	0.55	-0.38	0.15	-0.53	-0.54	-0.42	-0.46	-0.79*	-0.78	0.63	1.00						
21	-0.17	-0.10	0.49	0.28	-0.38	-0.40	-0.38	-0.20	0.53	0.59	-0.77	-0.18	-0.09	-0.05	0.71	0.56	-0.50	-0.35	0.66	0.18	1.00					
22	-0.16	-0.14	0.35	0.25	-0.14	-0.17	-0.28	-0.18	0.51	0.47	-0.62	-0.02	-0.23	0.08	0.66	0.48	-0.58	-0.40	0.64	0.34	0.92*	1.00				
23	0.63	-0.32	0.61	-0.28	0.18	-0.37	-0.41	-0.64	0.36	0.49	-0.20	0.32	-0.32	-0.55	-0.57	-0.56	-0.69	0.69	0.49	0.95*	0.06	0.18	1.00			
24	0.93*	-0.08	0.63	-0.32	-0.24	-0.56	-0.45	-0.76	0.51	0.61	-0.37	0.00	-0.65	-0.91*	-0.48	-0.63	-0.83*	-0.93*	0.75	0.78	0.11	0.12	0.78	1.00		
25	0.81*	-0.20	0.80*	-0.49	-0.20	-0.52	-0.71	-0.76	0.71	0.63	-0.41	-0.04	-0.53	-0.84*	-0.41	-0.64	-0.86*	-0.91*	0.77	0.70	0.23	0.23	0.72	0.92*	1.00	
26	0.86*	-0.11	0.76	-0.32	-0.20	-0.65	-0.50	-0.71	0.63	0.71	-0.45	-0.13	-0.49	-0.89*	-0.53	-0.65	-0.77	-0.86*	-0.71	0.77	0.15	0.09	0.80*	0.95*	0.93*	1.00

* Significant ($P < 0.01$)

Appendix 43a: Correlation of Antinutrients and Nutrients in *Corchorus olitoriu* at market maturity

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00																									
2	0.23	1.00																								
3	-0.26	0.24	1.00																							
4	0.77	0.63	0.04	1.00																						
5	0.27	0.73	0.73	0.53	1.00																					
6	0.15	0.55	0.20	0.31	0.76	1.00																				
7	0.54	-0.10	-0.44	0.32	0.25	0.11	1.00																			
8	-0.20	0.38	-0.01	-0.08	0.10	0.47	0.09	1.00																		
9	0.32	0.51	0.49	0.65	0.31	0.30	-0.03	0.33	1.00																	
10	0.12	0.59	0.43	0.54	0.31	0.17	0.01	0.48	0.89*	1.00																
11	0.36	0.17	-0.56	0.38	-0.19	-0.09	0.87	0.44	0.38	0.49	1.00															
12	0.34	0.17	-0.23	0.09	0.15	0.46	0.57	0.74	0.19	0.20	0.41	1.00														
13	0.33	-0.14	-0.03	0.15	0.45	0.13	0.44	-0.64	-0.42	-0.52	-0.52	-0.17	1.00													
14	0.23	0.21	-0.14	0.00	0.55	-0.08	-0.29	-0.33	-0.37	-0.33	-0.22	-0.17	0.19	1.00												
15	0.13	0.34	0.10	0.16	0.39	0.26	-0.27	- 0.45	-0.36	-0.44	-0.62	-0.33	0.54	0.66	1.00											
16	0.21	0.26	0.15	0.18	0.39	0.14	-0.22	-0.59	-0.36	-0.43	-0.64	-0..39	0.64	0.72	0.97*	1.00										
17	0.53	0.82*	0.25	0.79	0.73	0.46	0.11	-0.13	0.37	0.33	-0.09	-0.05	0..30	0.39	0.64	0.64	1.00									
18	0.48	0.10	0.07	0.47	0.53	0.01	0.65	-0.41	-0.05	-0.01	-0.18	0.01	0.78	0.03	0.30	0.42	0.48	1.00								
19	0.10	0.71	0.24	0.63	0.40	0.23	0.02	0.40	0.78	0.92*	0.54	0.05	-0.44	-0.30	-0.30	-0.33	0.44	0.03	1.00							
20	0.36	0.86*	0.29	0.78	0.57	0.46	0.07	0.43	0.84*	0.89*	0.46	0.26	-0.32	-0.12	-0.09	-0.13	0.67	0.12	0.91*	1.00						
21	0.28	0.68	0.30	0.42	0.61	0.39	-0.26	-0.27	0.66	0.02	-0.41	-0.24	0.36	0.61	0.89*	0.87*	0.90*	0.35	0.13	0.36	1.00					
22	0.48	0.72	0.22	0.76	0.65	0.49	-0.09	-0.24	0.32	0.18	-0.18	-0.18	0.34	0.29	0.71	0.67	0.94*	0.38	0.33	0.54	0.89*	1.00				
23	0.30	0.21	0.12	0.18	0.17	0.06	-0.31	-0.50	-0.27	0.40	-0.56	-0.28	0.43	0.76	0.92*	0.93*	0.60	0.25	-0.37	-0.11	0.83*	0.64	1.00			
24	0.58	0.72	0.01	0.69	0.68	0.42	0.16	-0.16	0.10	0.10	-0.08	0.06	0.43	0.56	0.73	0.73	0.94*	0.55	0.24	0.49	0.89*	0.86*	0.68	1.00		
25	0.22	0.38	0.44	0.31	0.58	0.42	-0.30	-0.49	0.00	-0.22	-0.68*	-0.37	0.57	0.46	085*	0.87*	0.69	0.31	-0.15	0.08	0.85*	0.78	0.79	0.65	1.00	
26	0.41	0.93*	0.14	0.81*	0.80*	0.68	0.13	0.23	0.55	056	0.25	0.14	0.06	0.05	0.29	0.23	0.84*	0.48	0.72	0.86*	0.62	0.79	0.13	0.74	0.40	1.00

* Significant ($P < 0.01$)

Appendix 43b: Correlation of Antinutrients and Nutrients in *Corchorus olitorius* at fruiting

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00																									
2	0.29	1.00																								
3	-0.28	-0.07	1.00																							
4	-0.83*	-0.42	0.52	1.00																						
5	0.41	0.19	-0.47	-0.42	1.00																					
6	0.01	0.12	0.08	0.09	-0.35	1.00																				
7	0.88*	0.45	-0.30	-0.67	0.65	0.11	1.00																			
8	0.06	0.77	-0.06	-0.22	0.19	-0.31	0.20	1.00																		
9	0.71	0.39	0.09	-0.67	0.19	0.38	0.64	-0.12	1.00																	
10	0.83*	0.37	-0.69	-0.90*	0.49	0.10	0.77	0.16	0.53	1.00																
11	-0.30	-0.13	0.60	0.15	-0.66	-0.08	-0.60	-0.03	0.03	-0.41	1.00															
12	-0.26	0.11	-0.06	0.34	0.57	0.05	0.13	-0.06	-0.10	-0.23	-0.55	1.00														
13	-0.32	0.38	0.22	0.05	-0.46	0.59	-0.28	0.25	0.17	-0.09	0.48	-0.18	1.00													
14	-0.60	-0.04	0.17	0.52	0.20	0.22	-0.27	-0.22	-0.12	-0.51	-0.18	0.84	0.18	1.00												
15	0.63	-0.06	0.03	-0.41	0.26	-0.01	0.57	0.12	0.33	0.54	-0.04	-0.39	-0.09	-0.56	1.00											
16	0.63	-0.10	0.07	-0.42	0.35	-0.12	0.57	0.08	0.37	0.50	-0.02	-0.32	-0.17	-0.48	0.98*	1.00										
17	-0.76	0.43	0.64	0.95*	- 0.35	0.01	-0.62	-0.15	-0.59	-0.87*	0.28	0.28	0.10	0.46	-0.18	-0.17	1.00									
18	-0.74	-0.49	0.64	0.94*	-0.37	0.02	-0.64	-0.22	-0.57	-0.86*	0.31	0.25	0.08	0.45	-0.17	-0.15	0.99*	1.00								
19	0.56	0.22	0.10	-0.25	0.19	0.19	0.62	0.29	0.30	0.46	-0.13	-0.16	0.06	-0.44	0.85*	0.78	-0.06	-0.07	1.00							
20	0.81*	0.42	-0.51	-0.90*	0.45	0.06	0.78	0.26	0.61	0.90*	-0.37	-0.29	-0.04	-0.47	0.54	0.52	-0.87*	-0.88*	0.36	1.00						
21	0.49	-0.22	-0.45	-0.22	0.55	-0.25	0.57	-0.18	-0.02	0.39	-0.79	0.19	-0.85*	-0.21	0.27	0.28	-0.30	-0.30	0.15	0.38	1.00					
22	0.88*	0.22	-0.45	-0.90	0.39	-0.01	0.74	0.15	0.59	0.92*	-0.22	-0.45	-0.11	0.65	0.73	0.71	-0.80*	-0.79	0.52	0.93*	0.37	1.00				
23	0.65	0.51	-0.70	-0.87*	0.40	-0.05	0.60	0.30	0.44	0.01	-0.41	-0.21	-0.10	-0.40	0.11	0.09	-0.96*	-0.98*	-0.00	0.87*	0.36	0.73	1.00			
24	0.70	0.35	-0.56	-0.93*	0.53	-0.12	0.60	0.07	0.65	0.79	-0.26	-0.13	-0.14	-0.26	0.18	0.23	-0.93*	-0.93*	-0.04	0.84*	0.29	0.76	0.89*	1.00		
25	0.73	0.49	-0.63	-0.94*	0.39	-0.09	0.63	0.31	0.52	0.86*	-0.30	-0.32	-0.09	-0.50	0.25	0.24	-0.98*	-0.99*	0.10	0.92*	0.31	0.83	0.98*	0.92*	1.00	
26	0.55	0.34	-0.05	-0.71	0.41	-0.12	0.43	0.09	0.73	0.49	0.24	-0.04	-0.11	-0.11	0.29	0.38	-0.54	-0.51	0.21	0.44	-0.21	0.51	0.36	0.67	0.47	1.00

* Significant ($P < 0.01$)

Appendix 44a: Correlation of Antinutrients and Nutrients in *Telfairia ocidentalis* at market maturity

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00																									
2	-0.25	1.00																								
3	0.48	-0.06	1.00																							
4	0.34	0.35	0.68	1.00																						
5	0.19	0.03	0.52	0.60	1.00																					
6	0.41	-0.12	0.34	0.46	0.29	1.00																				
7	0.47	-0.03	-0.19	-0.00	0.24	-0.03	1.00																			
8	-0.74	0.11	-0.23	-0.14	0.34	0.05	-0.18	1.00																		
9	0.32	0.35	0.81*	0.45	0.65	0.24	0.08	0.03	1.00																	
10	0.37	0.52	0.67	0.91*	0.68	0.43	0.08	-0.07	0.81*	1.00																
11	0.05	0.05	-0.15	-0.15	0.20	0.59	-0.03	0.38	0.04	0.10	1 .00															
12	-0.41	0.28	-0.07	-0.25	0.29	0.04	-0.07	0.74	0.34	0.06	0.63	1.00														
13	0.14	-0.67	0.31	0.14	0.58	0.20	0.09	0.24	0.03	-0.02	-0.03	-0.11	1.00													
14	0.56	-0.42	0.39	-0.11	-0.20	-0.34	-0.15	-0.19	0.12	-0.29	-0.68	-0.26	0.26	1.00												
15	0.24	0.67	0.48	0.64	0.39	0.24	-0.08	-0.13	0.71	0.83*	0.20	0.23	-0.44	-0.42	1.00											
16	0.39	0.57	0.19	0.54	0.31	0.39	0.04	-0.26	0.34	0.72	0.43	0.02	-0.33	-0.75	0.81*	1.00										
17	-0.30	-0.63	-0.55	-0.84*	-0.57	-0.50	-0.00	0.02	-0.74	-0.96*	-0.27	-0.15	0.16	0.44	-0.87*	-0.81*	1.00									
18	-0.30	-0.56	-0.61	-0.91*	-0.58	-0.46	0.01	0.07	-0.75	-0.97*	-0.11	-0.05	0.14	0.35	-0.89*	-0.74	0.96*	1.00								
19	-0.02	0.60	0.35	0.34	0.52	0.17	-0.15	0.30	0.62	-0.63	0.49	0.61	-0.08	-0.39	0.64	0.60	-0.71	-0.56	1.00							
20	0.48	0.64	0.52	0.71	0.12	0.23	0.05	-0.51	0.60	0.78	-0.13	-0.24	-0.42	-0.11	0.74	0.68	-0.79	-0.77	0.44	1.00						
21	-0.37	-0.62	-0.56	-0.83*	-0.59	-0.48	-0.13	0.05	0.79	-0.92*	-0.24	-0.16	0.17	0.40	-0.87*	-0.78	0.99*	0.96*	-0.68	-0.81*	1.00					
22	-0.25	-0.71	-0.47	-0.69	-0.61	-0.17	-0.23	-0.02	-0.83*	-0.90*	-0.15	-0.31	0.24	0.35	-0.88*	-0.70	0.90*	0.87*	-0.74	-0.73	0.98*	1.00				
23	0.50	0.26	0.27	0.76	0.53	0.40	0.28	-0.31	0.29	0.74	0.08	-0.34	0.06	-0.57	0.60	0.78	-0.71	-0.75	0.22	0.54	-0.70	0.58	1.00			
24	0.39	0.58	0.39	0.84*	0.34	0.36	0.33	-0.25	0.57	0.83*	-0.14	-0.21	-0.26	-0.23	0.67	0.58	-0.80*	-0.85*	0.24	0.82*	-0.84*	-0.76	0.71	1.00		
25	0.31	0.54	0.38	0.87*	0.57	0.34	0.16	-0.15	0.52	0.90*	0.02	-0.15	-0.10	-0.50	0.79	0.80*	-0.87*	-0.92*	0.41	0.69	-0.87*	-0.80*	0.92*	0.85*	1.00	
26	0.25	0.70	0.55	0.83*	0.60	0.29	0.18	-0.00	0.83*	0.95*	0.03	0.17	-0.20	-0.27	0.86*	0.64	s -0.92*	-0.95*	0.59*	0.76	-0.95*	-0.96*	0.64	0.88*	0.86*	1.00

* Significant ($P < 0.01$)

Appendix 44b: Correlation of Antinutrients and Nutrients in *Telfairia occidentalis* at fruiting

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00																									
2	0.17	1.00																								
3	0.23	0.76	1.00																							
4	-0.04	0.72	0.73	1.00																						
5	0.52	-0.27	-0.16	-0.52	1.00																					
6	-0.35	-0.56	-0.06	-0.19	0.10	1.00																				
7	-0.14	0.00	0.29	0.43	-0.48	0.30	1.00																			
8	-0.36	0.12	0.25	0.41	0.07	0.15	0.02	1.00																		
9	0.14	0.85*	0.40	0.48	-0.20	-0.60	-0.10	-0.18	1.00																	
10	0.02	0.68	0.26	0.58	-0.18	-0.41	-0.01	0.05	0.89*	1.00																
11	0.06	0.46	0.13	0.39	-0.60	-0.46	0.39	-0.27	0.53	0.46	1.00															
12	0.22	0.22	0.17	0.01	0.33	0.02	0.30	0.05	0.31	0.32	0.33	1.00														
13	-0.37	-0.70	-0.64	-0.61	0.06	0.23	-0.38	-0.15	0.65	-0.66	-0.45	-0.74	1.00													
14	-0.57	-0.87*	-0.67	-0.56	-0.14	0.60	0.16	-0.02	-0.79	-0.66	-0.28	-0.28	0.75	1.00												
15	-0.07	-0.91	-0.64	-0.83*	0.28	0.46	-0.14	-0.26	-0.86*	-0.88*	-0.46	-0.29	0.79	0.81*	1.00											
16	-0.31	-0.88*	-0.46	-0.43	0.10	0.66	0.17	0.23	-0.98*	-0.80*	-0.50	-0.31	0.65	0.87*	0.81*	1.00										
17	-0.15	-0.99*	-0.75	-0.76	0.27	0.52	-0.06	-0.17	-0.87*	-0.76	-0.50	-0.30	0.77	0.87*	0.95*	0.87*	1.00									
18	-0.15	-0.96*	-0.79	-0.83*	0.24	0.48	-0.09	-0.36	-0.74	-0.67	-0.43	-0.26	0.76	0.84*	0.93*	0.75	0.97*	1.00								
19	-0.24	-0.97*	-0.65	-0.58	0.25	0.63	0.03	0.08	-0.91*	-0.70	-0.58	-0.32	0.70	0.86*	0.84*	0.94*	0.96*	0.88*	1.00							
20	-0.09	-0.83*	-0.56	-0.83*	0.22	0.47	-0.12	-0.33	-0.79	-0.88*	-0.38	-0.24	0.75	0.79	0.98*	0.74	0.88*	0.89*	0.75	1.00						
21	-0.26	-0.93*	-0.82*	-0.81*	0.11	0.45	-0.11	-0.37	0.70	-0.65	-0.35	-0.32	0.82*	0.88*	0.92*	0.73	0.95*	0.99*	0.84*	0.88*	1.00					
22	-0.11	-0.74	-0.28	-0.57	0.30	0.74	-0.04	-0.20	-0.73	-0.72	-0.74	-0.35	0.63	0.64	0.78	0.71	0.78	0.78	0.77	0.77	0.73	1.00				
23	0.31	0.90*	0.61	0.59	-0.17	-0.63	0.16	-0.06	0.89*	0.74	0.59	0.48	-0.84*	-0.86*	-0.87*	-0.91*	-0.92*	-0.85*	-0.94*	-0.81*	-0.85*	-0.79	1.00			
24	0.29	0.68	0.68	0.35	-0.18	-0.34	0.35	-0.11	0.46	0.15	0.56	0.53	-0.68	-0.54	-0.45	-0.54	-0.65	-0.62	-0.73	-0.31	-0.63	-0.49	0.72	1.00		
25	0.07	0.93*	0.50	0.55	-0.26	0.66	-0.13	-0.04	0.97*	0.81*	0.47	0.20	-0.60	-0.81*	-0.88*	-0.96*	-0.92*	-0.83*	-0.94*	-0.82*	-0.78	-0.76	0.90*	0.51	1.00	
26	-0.01	0.71	0.24	0.34	-0.48	-0.83	-0.26	-0.19	0.70	0.45	0.52	-0.23	-0.12	-0.53	-0.72	-0.68	-0.64	-0.57	-0.74	-0.48	-0.47	-0.66	0.62	0.40	0.81*	1.00

* Significant ($P < 0.01$)

Appendix 45a: Correlation of Antinutrients and Nutrients in *Vernonia amygdalina* at market maturity

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00																									
2	-0.33	1.00																								
3	0.74	-0.48	1.00																							
4	0.89*	0.46	0.90*	1.00																						
5	0.84*	0.13	0.71	0.88*	1.00																					
6	0.68	0.44	0.55	0.50	0.29	1.00																				
7	0.65	-0.02	0.69	0.76	0.75	0.20	1.00																			
8	0.27	0.42	0.59	0.56	0.29	-0.07	0.63	1.00																		
9	0.72	0.53	0.98*	0.87*	0.66	0.65	0.55	0.46	1.00																	
10	0.65	0.51	0.88*	0.88*	0.73	0.30	0.52	0.56	0.88*	1.00																
11	0.11	0.31	-0.26	0.05	0.23	-0.12	-0.24	-0.25	-0.22	-0.03	1.00															
12	-0.11	0.40	0.14	0.09	-0.23	0.19	-0.28	0.17	0.26	0.32	-0.16	1.00														
13	0.48	0.38	-0.39	-0.50	-0.61	0.11	-0.76	0.38	-0.25	-0.40	0.32	0.31	1.00													
14	-0.31	-0.17	-0.45	-0.24	-0.17	-0.43	-0.39	-0.26	-0.39	-0.05	0.27	0.42	-0.06	1.00												
15	-0.64	-0.45	-0.37	-0.67	-0.57	-0.33	-0.32	-0.31	-0.40	-0.53	-0.47	-0.40	0.13	-0.21	1.00											
16	-0.48	-0.60	-0.23	-0.47	-0.31	-0.39	-0.01	-0.19	-0.31	-0.38	-0.54	-0.49	-0.23	-0.13	0.92*	1.00										
17	-0.89*	-0.49	-0.90	-0.95*	-0.79	-0.71	-0.67	-0.43	-0.91*	-0.80*	-0.01	-0.19	0.32	0.35	-0.67	0.54	1.00									
18	-0.88*	-0.65	-0.86*	-0.87*	-0.67	-0.78	-0.46	-0.36	-0.90*	-0.78	-0.05	-0.19	0.15	0.40	0.60	0.58	0.94*	1.00								
19	0.24	-0.19	0.60	0.039	0.39	0.31	0.56	0.12	0.59	0.37	-0.58	-0.08	-0.37	-0.38	0.23	0.43	-0.44	-0.27	1.00							
20	0.49	0.10	0.80*	0.62	0.57	0.39	0.76	0.41	0.73	0.52	-0.45	-0.26	-0.45	-0.62	0.11	0.30	-0.62	-0.51	0.87*	1.00						
21	-0.66	-0.34	-0.93*	-0.78	-0.64	-0.56	-0.73	-0.50	-0.89*	-0.68	0.36	0.12	0.39	0.66	0.11	-0.03	0.79	0.75	-0.75	-0.95*	1.00					
22	-0.72	-0.44	-0.82*	-0.75	-0.56	-0.65	-0.75	-0.56	-0.75	-0.50	0.21	0.16	0.26	0.76	0.27	0.20	0.80*	0.77	-0.50	-0.80*	-0.89	1.00				
23	0.03	0.29	0.02	0.28	0.32	-0.31	0.00	0.14	0.04	0.40	0.59	0.35	-0.04	0.70	-0.56	0.44	-0.12	-0.03	-0.22	-0.24	0.21	0.29	1.00			
24	0.47	0.14	-0.46	-0.44	-0.38	-0.19	-0.31	-0.23	-0.46	-0.56	0.45	-0.25	0.63	-0.12	0.24	0.09	0.40	0.40	-0.21	0.18	-0.29	-0.11	0.09	1.00		
25	0.42	0.66	0.67	0.73	0.52	0.26	0.40	0.59	0.69	0.77	0.20	0.53	0.00	-0.02	-0.72	-0.65	-072	-0.63	0.20	0.31	0.46	-0.46	0.58	-0.08	1.00	
26	0.82*	-0.39	-0.62	0.68	-0.51	-0.75	0.63	-0.39	-0.58	-0.33	0.05	0.13	0.23	0.63	0.48	0.43	0.78	0.77	-0.19	-0.49	0.65	-0.89*	0.31	0.17	0.33	100

* Significant ($P < 0.01$)

	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
A	-0.06	0.42																				
0.44	-0.33	-0.34	-0.14	1.00																		
-0.04	0.39	0.16	-0.26	-0.15	1.00																	
-0.49	0.27	0.20	0.43	-0.26	-0.59	1.00																
0 0.88*	0.79	0.43	0.32	0.37	0.08	0.75	1.00															
0.77	0.03	0.64	-0.10	-0.25	0.38	- 0.20	0.04	1.00														
.42 0.05	0.00	0.05	- 0.19	-0.39	0.17	- 0.49	- 0.30	- 0.07	1.00													
0.17 - 0.68		0.33	-0.34	0.30	0.45	-0.39	-0.32	0.44	-0.13	1.00												
0.35		0.16	0.12	-0.44	0.32	0.07	-0.14	0.19	-0.09	0.36	1.00											
2 .55 -0.15	-0.16	0.30	- 0.26	0.26	0.30	-0.46	-0.42	-0.03	0.24	0.02	0.06	1.00										
0.51 .26 -0.34	-0.34	0.18	- 0.43	0.02	0.18	-0.36	-0.16	0.43	0.44	0.11	- 023	0.67	1.00									
.01 -0.20	0.33	0.14	- 0.01	- 0.18	0.10	-0.15	0.04	-0.10	0.20	0.06	-0.09	-0.02	0.75	0.79	1.00							
-0.55 032 0.16		-0.17	- 0.33	0.33	-0.03	-0.12	-0.28	0.19	-0.12	0.14	0.05	0.81*	0.71	0.93*	1.00							
3 -0.41 0.27 0.05	-0.00	-0.03	0.10	-0.04	-0.51	0.84*	0.71	-0.13	-0.28	-0.63	-0.12	-0.27	-0.07	0.23	0.03	1.00						
9 -0.18 0.16 0.78	0.38	0.03	0.19	-0.32	-0.62	0.87*	0.70	-0.17	-0.34	-0.65	-0.20	-0.37	-0.17	0.14	- 0.05	0.98*	1.00					
0 -0.03 0.10 0.82*	0.29	-0.03	0.12	-0.13	0.04	0.74	-0.82*	-0.58	0.22	0.43	0.58	0.35	0.29	0.10	-0.24	-0.10	-0.93*	-0.96*	1.00			
21 -0.12 -0.01 -0.83*	- 0.18	0.10	-0.26	0.26	0.60	-0.84*	0.68	0.22	0.41	0.70	0.25	0.47	0.33	0.03	0.20	-0.93*	-0.97*	0.93*	1.00			
22 -0.08 -0.04 -0..81*	-0.22	0.09	0.49	0.11	-0.51	0.90*	0.68	-0.29	- 0.74	-0.26	-0.03	-0.44	-0.53	-0.10	-0.13	0.71	0.80*	- 0.83*	-0.86*	1.00		
23 0.31 -0.11 0.64	-0.05	-0.28	0.41	0.02	-0.75	0.66	0.44	-0.53	-0.26	-0.83	-0.84	-0.32	-0.35	-0.04	-0.20	0.63	0.70	-0.72	-0.73	0.65	1.00	
24 0.31 0.41 0. 89*	0.18	0.03	-0.09	-0.88*	0.77	0.44	-0.30	-0.27	-0.48	-0.31	-067	-0.41	-0.17	-0.33	0.68	0.79	-0.82*	-0.81*	0.81*	0.68	1.00	
25 0.50 -0.21 0.65	-0.11	0.04	0.46	-0.56	0.67	0.64	-0.15	0.01	-0.81*	-0.38	-0.43	-0.11	-0.00	-0.28	0.86*	0.89*	-0.80*	-0.89*	0.81*	0.45	0.76	1.00
26 -0.07 -0.10 0.62	0.30																					

* Significant (P < 0.01

Key to Correlation Table of Appendices 41a to 45b

1 = Fe in control, 2 = Fe in N applied, 3 = Mg in control, 4 = Mg in N applied, 5 = Zn in control, 6 = Zn in N applied, 7 = Cu in control, 8 = Cu N in applied, 9 = Ca in control, 10 = Ca in N applied, 11 = Na in control, 12 = Na in N applied, 13 = K in control, 14 = K in N applied, 15 = vitamin C in control, 16 = vitamin C in N applied, 17 = β-carotene in control, 18 = β-carotene in N applied, 19 = cyanide in control, 20 = cyanide in N applied, 21 = nitrate in control, 22 = nitrate in N applied, 23 = soluble oxalate in control, 24 = soluble oxalate in N applied, 25 = total oxalate in control and 26 = total oxalate in N applied.