# NUTRITIONAL QUALITY AND ANTI-OXIDANT PROPERTIES OF MINIMALLY PROCESSED AFRICAN INDIGENOUS LEAFY VEGETABLES

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# Nutritional Quality and Anti-Oxidant Properties of Minimally Processed African Indigenous Leafy Vegetables

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## DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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

**Grace Cheptoo Kosgey**

This thesis has been submitted for examination with our approval as the supervisors.

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## DEDICATION

I dedicate this thesis to my parents, Mr. and Mrs. Kosgey, my husband and my brothers and sisters.

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## ABSTRACT

African indigenous vegetables (AIVs) are excellent sources of β-carotene, vitamin C, iron as well as minerals, fiber and bioactive compounds. In the recent past, AIVs have gained commercial importance as a result of increased awareness of their nutritional and health benefits and are now produced in both formal and informal marketing channels. One of the challenges in production, marketing and consumption of AIVs is that they are highly perishable and there is inadequate capacity for their storage in fresh state. This is because most storage techniques require low temperatures, which are nonexistent for AIVs in Kenya. Minimal processing can enable AIVs produced in far flung locations to be stabilized and transported to the markets in urban areas. However, this can affect the color, texture, flavor, and nutritional quality of AIVs. This study aimed at; examining the influence of harvest maturity and minimal processing techniques on the nutritional, phytochemical and anti-oxidant capacity in stinging nettle, amaranth and black nightshade. The results indicated significant differences between treatments and stages of maturity. Results further show that the highest contents of β-carotene in fresh state, at young stage was 47.82±1.32 mg/100g in amaranth and mature stage was 71.22±0.87 mg/100g in black night shade. For vitamin C, the highest content was 142.06 mg/100g±2.71 in stinging nettle at young stage while amaranth had the highest content of vitamin C at mature stage as 193.52±3.04 mg/100g. The highest phenol content in fresh state was in black night shade at 1.09±0.14 g/100g and 1.29±0.12 g/100g at young stage and mature stage respectively. Among the processed, the highest content of vitamin C was detected in Freeze-Dried Unsliced Unblanched black nightshade at both young and mature stage as 86.64±4.37mg/100g and 111.14±2.41 mg/100g respectively. For β-carotene, the highest content was observed in Freeze-Dried Unsliced Blanched in amaranth as 30.24±1.35mg/100g at young stage and mature stage had 57.12±1.23mg/100g in black nightshade. This study also aimed at 2; examining the retention of β-carotene and vitamin C content of blanched and unblanched vegetable amaranth, African nightshade and stinging nettle, subjected to Ziploc® and Xtend® bag packaging under freezing and room temperature conditions. Both mature and young fresh amaranth leaves had the highest β-carotene content at 75.08±1.3 mg/100g and 44.53±3.1 respectively. African Nightshade had the lowest β-carotene content of 45.05±1.9 and 37.12±3.0 mg/100g respectively. Stinging nettle exhibited the highest Vitamin C content at 197.75±6.9 and 149.7±6.1 mg/100g at both the young and mature stages respectively. Blanching had a significant difference ($P<0.05$) on both β- carotene and vitamin C retention as the contents in blanched samples were lower by about 10-15% as compared to fresh leaves samples. Under Ziploc® bag packaging in frozen temperatures, both young and mature amaranth leaves were able to retain a significantly higher (at least 50%) β-carotene content by week 4, with the highest retention being observed in unblanched samples. Blanching of young African nightshade and stinging nettle leaves led to least retention of β- carotene by week 4 (~30%). However, in all the AIVs, the retention of Vitamin C was lower with less than 50% of the initial Vitamin C content retained by week 4. The AIVs were able

to keep their marketability for 5-7 days in Xtend® bag packaging under room conditions. However, nutrient loss was quite high with fresh amaranth losing over 80% of its initial β-carotene and vitamin C content. This study indicates that modified atmosphere packaging in Ziploc® bag and Xtend® bags, stage of maturity and blanching, had significant effect on the on the stability of β-carotene and vitamin C of the AIVs. The results of this study can be useful to AIV farmers as it can help in extending the shelf life of the vegetables while maintaining their nutritional quality and improving safety thus preventing post-harvest losses.

# CHAPTER ONE

## INTRODUCTION

Unhealthy and imbalanced diets have led to malnutrition in sub-Saharan Africa. This has promoted public awareness and advocacy for diversifying diets in nutritious foods inclusive of food fortification (Kansiime *et al.*, 2018). African indigenous vegetables (AIVs), include all plants that originate on the continent, and whose fruits, leaves and roots are used and accepted as vegetables (Ambrose-Oji 2012). They have potential to improve nutrition and increase the dietary diversity of rural households. AIVs. Promoting their consumption, can help reduce food insecurity and improving Nutrition (Batchep, & Kamga, 2013; Grubben *et al.*, 2014).

Nutrition security refers to access by all people at all times to the adequate utilization, absorption of nutrients in order for them to live healthy and active lives (Ministry of Health, 2012). Undernourishment usually results to malnutrition which can include; hunger, under-nutrition, micro-nutrient deficiencies and obesity (Zhou *et al.*, 2016). This is a worldwide problem where approximately 821million are undernourished (FAO-FAD-UNICEF-WFP and WHO, 2018). Nutrition insecurity in Kenya according to KNBS (2018), reveals that, close to one in every three Kenyans suffers from poor nutrition and chronic food insecurity annually. 30% children are stunted, 13% moderately wasted and 7% moderately wasted countrywide. Micronutrient deficiency in Kenya is estimated that 84% of children below 5 years are deficient of vitamin A, 73.45 in iron, and 51% in zinc. In addition, 60% of pregnant women are deficient of iron and 39% vitamin A (Government of Kenya, 2011).

AIVs has several essential micro-nutrients like, zinc, iron and vitamin A in addition to phytochemicals which is a non-nutrient substance. They have the potential to combat hidden hunger (Mwaura *et al.*, 2013). Consumption of fruits and vegetables by any population is being depended on, for nutrition conditions. Health complications of non-

communicable disease, are indication of inadequate intake of fruits and vegetables (WHO 2015). About 400g of fruits and vegetables are recommended for consumption per person per day. However, there is inadequate consumption in Kenya and the lowest level reported in poorest people (van der Lans *et al.* 2012).

Production of AIVs in Kenya, and income generated from AIVs have shown an increasing trend (Ministry of Agriculture, 2013). However, current status of AIVs is still low in comparison to exotic vegetables species. The Ministry of Agriculture (2013), report showed that about 85,550 ha of farm land was allocated to AIVs production. This yielded metric tons of 176, 736MT with a revenue of (Kshs) 3.579 billion in contrast to exotic vegetables on a 252,651 ha yielded a metric ton of 4,202,393MT with a revenue of (Kshs) 65.992 billion (Leny 2015). Never the less, various attempts have been made to improve production of AIVs to smallholder in Kenya and other sub-Saharan countries with success. Agriculture activities in Kenya tend to follow agro-ecological zones patterns which tend to associate certain crops with specific agroecological zones. For example, certain species of AIVs resist harsh climatic conditions (Ntawuruhunga *et al.*, 2019.

The AIVs have gained commercial importance over the past 15 years as a result of the enormous growth in demand and market (Irungu *et al.*, 2007). The AIVs are now retailed in supermarket chains and other lucrative markets, resulting to better incomes. To respond to this increase in demand, there has been a tremendous increase in production of AIVs in the country. For instance, 200 AIV varieties have been documented and many of these are either cultivated or gathered from the wild (Onyango and Imungi, 2007).

High postharvest losses are incurred during harvesting, transport and retailing due to lack of adequate capacity to maintain cold chains in these AIVs (Habwe, 2008). The high perishability is mainly attributed to the high moisture content. In addition, large portions are lost after harvesting due to poor handling and marketing conditions (Habwe

2008). In Africa and Kenya in particular, a significant portion is wasted during the in-season abundance (Habwe, 2008; Abukutsa *et al.*, 2005). Therefore, to extend the consumption period of these vegetables all year round, appropriate preservation and adequate storage methods are necessary.

Use of processing technologies can increase the shelf life of AIVs by maintaining quality, improve safety and thus prevent losses. Minimal processing of AIVs has the potential to create new market opportunities with employment at various levels and maximize returns from fresh produce. Minimal processing technologies such as blanching was selected because of its retention of nutrients in AIVs (Gogo *et al.*, 2016). However some processing techniques alter nutrient content of plants (Frances *et al.*, 2013). Drying on the other hand was selected to reduce its weight and bulk, for easy transportation, handling and distribution; and to improve its keeping quality by reducing the water activity. Its disadvantage is that, it requires longer cooking period than fresh and do not retain their flavor. Though, drying leads to loss of water-soluble vitamins, fat soluble vitamins are well retained (Chege *et al.*, 2014).

Minimal Processing, however, can affect the color, texture, flavor, and nutritional quality (Barret *et al.*, 2010). Hence there is need to determine the effect of minimal processing on the nutritional and phytochemical quality of some AIVs.

The objective of this study was to evaluate the influence of harvest maturity and minimal processing on the nutritional, phytochemical and anti-oxidant capacity in stinging nettle, amaranth and black nightshade. The AIVs; amaranth and black nightshade, were selected because of their higher consumption and availability in the market whereas stinging nettle was selected for comparison due to its traditional consumption as an AIV.

## 1.1 Problem statement and justification

High postharvest losses of vegetables are incurred during harvesting, transport and retailing due to lack of adequate capacity to maintain cold chains (Habwe 2008). The high perishability is mainly attributed to the high moisture content. In Africa and Kenya in particular, a significant portion is wasted during the in-season abundance (Habwe 2008). Postharvest losses in AIVs can be as high as 50% (Aseno-Okyere, 2012).

Moreover, these vegetables are seasonal crops leading to fluctuating prices and high losses during glut but become expensive during low supply seasons.

AIVs is an inexpensive source of macronutrient such as; fibre, fats, protein and starch and micro nutrients such as minerals and vitamins (Makobo et at al., 2010; Kwenin *et al.*, 2011). Significant amount of vitamin C, folate and riboflavin have been reported in AIVs. Approximately, 100g vegetable cooked without oil contribute to 45% of vitamin A requirements of daily intake (Mnkeni *et al.*, 2007). For this reason and prevention of non-communicable diseases, consumption of diets containing more than 400g/day of fresh vegetables and fruits have been encouraged by nutritional policy especially in sub-Saharan Africa where many people are likely to suffer from vitamin A deficiency (Venneria *et al.*,2012).

Processing of AIVs affects color, texture aroma and nutritional quality of the vegetables. Vitamin C is greatly affected by cooking and processing methods including oxidative, photodegradation and enzymatic activities. African indigenous vegetables are highly perishable, hence susceptible to rapid deterioration leading to post harvest lost.

Good nutrition is a prerequisite for the national development of countries and for the well-being of individuals. In children, adequate nutrition is critical to growth and development (KDHS, 2014). Prevalence rates of micronutrient which can be attributed to poor consumption of vegetables remain high leading to devastating poor health and productivity. African Indigenous vegetables are common in developing countries in

rural communities (Haas *et al.,* 2016). African leafy vegetables have become a new growth industry for small holder farmers around major urban centers in Kenya. This has been fueled by intense public promotion campaign to change perceptions, and boost consumer awareness of the nutritive value of these vegetables. Currently these vegetables are appreciated by all income levels. The vegetables have also been incorporated in the cuisine of high-end hotels and restaurants in the major urban centers (Neugart *et al.*, 2017).

Minimal processing is a current trend for marketing of ALVs. The vegetables are harvested at specific maturity, washed, blanched, trimmed/sliced, dried, packaged and stored before selling to consumers (Saini *et al.*, 2017). Since thermal and other drastic processing conditions are not used, minimally processed products are expected to retain fresh or fresh like properties and good nutritional quality.

## 1.2 Objectives

### 1.2.1 Main objective

To evaluate the effect of postharvest minimal processing on the nutritional quality, phytochemical and anti-oxidant properties of selected ALVs

### 1.2.2 Specific Objectives

i. To determine the effect of harvest maturity on the nutritional quality and anti-oxidant properties of the selected ALVs.
ii. To determine the effect of minimal processing (slicing, blanching and drying techniques) on the nutritional quality and anti-oxidant properties of the selected ALVs.
iii. To assess the effect of different packaging materials on the nutritional stability of the minimal processed ALVs.

### 1.2.3 Hypothesis

1. There is no significant difference in harvest maturity of *Urtica dioica (Stinging nettle), Solanum (Black nightshade)* and, *Amaranthus hybridus (Amaranth)* subjected to slicing, blanching, solar drying and freeze drying.

2. There is no significance on the minimal processed *Urtica dioica (Stinging nettle), Solanum (black nightshade)* and, *Amaranthus hybridus (Amaranth)* subjected to slicing, blanching, solar drying and freeze drying.

3. There is no significance difference on different packaging materials on the nutritional stability of the minimal processed *Urtica dioica (Stinging nettle), Solanum (Black nightshade)* and, *Amaranthus hybridus (Amaranth).*

## 1.3 Significance of the study

Vegetable farmers will benefit since adopting this processing methods will help increase shelf life of vegetables by maintaining the nutritional quality and improve safety.

It will also help the policy makers, to adopt the use of appropriate storage methods and processing. This will prevent postharvest food loss and waste especially during in seasons of AIVs.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Overview of African leafy vegetables (ALVs)

African indigenous vegetables (AIVs) are those whose natural habitat originated in Africa and have been integrated into cultures through natural or selective processes (Gido *et al.*, 2017). African leafy vegetables are ingredients for many African diets contributing to a healthy diet (Baldermann *et al.*, 2016). They are presently accepted in some communities in East Africa and gaining its popularity. In Kenya, they are found in supermarkets and seed companies are increasingly bringing up more tradition varieties (Cernansky, 2015). In addition, due to its increased in demands, it is nowdays common in hotels, restaurant and public canteens. Commonly AIVs dishes are, amaranth (*Amaranthus cruentus*), spiderplant (*Cleome gynandra*), African nightshade (*Solanum scabrum)*, cowpea (*Vigna unguiculata*) etc. They are cooked with different combinations or solely (Neugart *et al.*, 2017).

## 2.2 Production of AIVS

Production of AIVs is mainly in home gardens or intercropping with the main staple crops (Afari-Sefa *et al.*, 2015). Leaves, fruit, roots, stem, bark, and seed from AIVs have been utilized for nutrition and medicinal purposes in Africa (Kamga *et al.*, 2013).

Promoting consumption of tradition vegetables helps improve nutrition and reduces food insecurity. ALVs can also improve income opportunities through diversifying farming enterprises and generating cash. In addition, it also important in households since it improves dietary diversity (Ochieng *et al.*, 2017a; Ochieng *et al.*, 2017b). ALVs play an important role since it's the source of minerals, amino acid, dietary fiber, vitamins and health promoting Phytochemicals with antioxidant properties which are required in the human body for normal function and development Ochieng *et al.*,

2017a). The vegetables are also known to add taste, flavor, variety and even color to food.

### 2.3 Importance of AIVs

Worldwide there are about 13,000 species of plants used as food. The Plant Resources of Tropical Africa (PROTA) reported an estimated 6,376 useful indigenous African plants of which 397 are vegetables. Examples of some ALVs found across Eastern and Central Africa include African nightshade (*Solanum spp*), spider plant (*Cleome gynandra*), amaranth (*Amaranthus spp*), slender leaf (*Crotalaria spp*), jute mallow (*Corchorus olitorius*), cowpea (*Vigna unguiculata*), pumpkin (*Curcurbita muschata*), African kale (*Brassica carinata*), *Basella alba*, *Commelina africana* and stinging nettle among many others (Gido *et al.,* 2016, Schippers, 2000; Kimiywe *et al.,* 2007; Onim and Mwaniki, 2008; Abukutsa, 2010)

### 2.4 Black nightshade

*Solanum*, the Black nightshade, belongs to the family *Solanaceae* which also includes a number of important food crops namely; tomato, eggplant and potato. *Solanum nigrum* is native to North Africa, Europe and West Asia, and is renowned for its poisonous berries and leaves. *Solanum scabrum* is broad leaved and cultivated widely in many regions in Africa. It is recognized by its large dark purple fruit. It is an herbaceous plant which grows to 1.5m height. According to Ojiewo *et al.*, 2013, black nightshade leaves and herbs are mostly used in most parts of West and East Africa. Increase in demand for this vegetable is steadily increasing probably due to its medicinal value, nutritional value or ability of the vegetable to generate income (Rono *et al.,* 2018).

#### 2.4.1 Black nightshade production in Kenya

There is low cultivation of black nightshade since it is subsistence produced where it is homestead grown or collected from wild. However, seeds from previous crop that was saved by a farmer or from local seed traders are used by farmers to grow the vegetables.

This will result to insufficient purity by mixing different cultivars Onyango *et al.,* 2013).

### 2.4.2 Importance of Black Nightshade (Solanum)

Black nightshade plays an important role as a vegetable. According to Mwai *et al.,* 2013, black nightshade has important nutritional value, contribute to generation of income, increases dietary diversity and has medicinal value. Their leaves contain appreciable levels of protein, fiber and carbohydrate. It is a good source of magnesium, phosphorus and the water-soluble vitamins such as vitamin C, B and folic acid. The high levels of vitamins and micronutrients are especially important to people at risk of malnutrition and disease, particularly HIV/AIDS. The leaves are also used to treat a wide range of ailments in various parts of the world (Maphosa *et al.,* 2008).

Black nightshade provides good levels of vitamins, minerals and trace elements at seven times the amounts derived from cabbage. In addition to serving as vegetables, Solanum exhibit medicinal potency. They have been known and reported to have health protecting properties and uses (Okeno *et al.,* 2003) especially for households in poor economic settings. Several of these have been used and continue to be used for prophylactic and therapeutic purposes by rural communities. According to a survey conducted by Kimiywe *et al.,* (2007) in Nairobi, Kenya, the ALVs have a medicinal value attached to it. For example, many ALVs especially the sour or bitter ones like spider plant, slender leaf and African nightshades have been reported to heal stomach related ailments such as stomach cancer, gastritis, peptic ulcers, gastroparesis. and malaria. However, the leaves have also been reported to contain relatively high levels of oxalate and cyanide, but the processing and cooking done prior to consumption reduces the content of these bitter and potentially toxic compounds (Kamga *et al.,* 2013).

## 2.5 Stinging nettle (*Urtica dioica*)

*Urtica dioica*, often called common nettle or stinging nettle, is an herbaceous perennial flowering plant, native to Europe, Asia, northern Africa, and western North America, and is the best-known member of the nettle genus Urtica (Bisht *et al.*, 2012). The species is divided into six subspecies, five of which have many hollow stinging hairs called trichomes on the leaves and stems, which act like hypodermic needles, injecting histamine and other chemicals that produce a stinging sensation when contacted by humans and other animals (Per Brodal, 2010).

The plant has a long history of use as a source of medicine, food, and fiber. In Nepal and Poland, the specie remains popular for food and medicine although not fully domesticated (Prety *et al.*, 2012 and Łuczaj *et al.*, 2012). The leaves and stems are very hairy with most subspecies bearing many stinging hairs (trichomes), whose tips come off when touched, transforming the hair into a needle that can inject several chemicals: acetylcholine, histamine, 5-HT (serotonin), moroidin, leukotrienes, and wild flower finder, (2012) possibly formic acid (Louis *et al.*, 2012). This mixture of chemical compounds causes a painful sting or paresthesia from which the species derives one of its common names, stinging nettle, as well as the colloquial names burn nettle, burn weed, and burn haze Brodal P (2010).

### 2.5.1 Therapeutic value of stinging nettle

Presence of flavonoid, phenylpropanoids, carotenoids and fatty acid in leaves and roots of stinging nettle plays a major medicinal importance (Farag *et al.*, 2013; Upton, 2013). According to Orˇci ´c *et al.*, 2014, stinging nettle treats gout, eczema, urinary bladder, kidneys problem, inflammation, hypoglycemia, hypotension, benign prostatic and cardiovascular problems. It can also exhibit antimicrobial, antiviral, antioxidant and antiulcer activity (Gulcin *et al.*, 2004, Mekhfi *et al.*, 2002, Cushnie and Lamb, 2000).

Stinging nettle have been shown to have an effect as an antioxidant (Nair MP *et al.*, 2006), anti-inflammatory (Kumar *et al.*, 2013), antidiabetic (Tian *et al.*, 2008), anti-traumatic (Selloum *et al.*, 2003) and anticancer (Golalipour *et al.*, 2010). It can also be used to locally treat some skin and hair diseases such as eczema, inflammatory diseases, and even hair loss.

The root extracts of the nettle have been shown by human clinical trials as a treatment for symptoms of Benign Prostate Hyperplasia, (BPH). It acts as an insecticide (Barbosa *et al.*, 2011). It can also be used by pediatric as alternative medicine. On the other hand, the herb is used as a tea for anemic children. It helps in cleansing the digestive tract and helps with stomach problems. Nutritionally it's high in beta-carotene, vitamin C, D and K and is also rich in iron, manganese, potassium and calcium (Mihaljev *et al.*, 2014; Upton, 2013).

### 2.5.2 Other uses of stinging nettle

Verdinelli *et al.* (2013) confirmed the antifeedant effects of water extracts of stinging nettle on aphids, especially of those obtained from leaves that showed the presence of caffeic acid derivative compounds and ceramides. In Scotland, stinging nettle was cultivated for making durable linen cloth from the fibre stalk. Fibre can also be used for small-scale papermaking (Bisht *et al.*, 2012).

## 2.6 Amaranth (Amaranthus hybridus)

*Amaranthus hybridus*, commonly called green amaranth, slim amaranth, smooth amaranth, smooth pigweed, or red amaranth, is a species of annual flowering plant. It is a weedy species found over much of North America and introduced to Africa, Europe and Eurasia. Amaranth belongs to the Amaranthaceae family (Carrnel, 2012). Amaranth is divided into two types namely; Grain amaranth (examples are like *A. hybridus, A. cruentus, A. caudatus L* and *A. hypochondricus*) and vegetable amaranth like; *A.*

*dubious, A. tricolor* and *A. lividus*. Origin of grain amaranth is from south and Central America while vegetable amaranth is from Southeast Asia (Hcorke and YZcai, 2016).

Amaranth is consumed in over 50 countries. According to (Achigan-Dako *et al.,* 2014) consumption can be majorly across sub-Saharan Africa and Southeast Asia. This vegetable is readily available during raining season and if not preserved within few days after harvest will begin to decay.

### 2.6.1 Production of Amaranthus (*Amaranthus hybridus*)

Amaranth prefer bright sunlight that is hot which is distributed from the tropics to the semi-arid regions. Enoch *et al.,* 2014 added, the vegetable grows well at above 25$^{o}$C temperature of the day and lower than 15$^{o}$C at night. Amaranth possesses a high yield stress tolerance to alkalinity, acid soil condition and drought.

Amaranth is among the cheapest dark green leafy vegetables in tropical markets because of its low production cost (Varalakshmi 2004). Amaranthus is the most important vegetables in Africa, due to their easy of cultivation, low pest and diseases incidence, wide occurrence, high nutritional value and low labour input (Maundu *et al.* 2009).

### 2.6.2 Nutritional importance of amaranth

Leaves of amaranth according to James *et al.*, 2010 and Scho¨nfeldt and Pretorius (2011) are rich in calcium, iron, zinc, phosphorus, calcium, vitamin C and beta-carotene. In addition, Akubugwo *et al.* (2007) reported Crude protein of *A. caudatus* was higher than of A. hybridus.

A study done on species of amaranth (Amaranthus species, *A. blitum*, *A. spinosus*, *A. tricolor*, and *A. viridis*) showed that *A. spinosus* while *A. viridis* had the highest amount of proteins, carbohydrates and calcium (Srivastava 2011; Andini *et al.*, 2013).

## 2.7 Phytochemical composition of ALVs

Phytochemicals are naturally occurring; biologically active chemical compound found in plants and act as antioxidant (Rajurkar and Gaikwad, 2012). Antioxidant has a positive impact on human health. They react with the free oxygen molecules or free radicals in the body subsequently; they act as a natural defense system for host plants (Saxena *et al.*, 2013). Several polyphenols, mostly found in plants are antioxidant and are as well important for health. They are linked to protection against cardiovascular, some forms of cancer and other degenerative diseases (Ofor *et al.*, 2015). In addition, phytochemicals provide aroma, color and flavor (Osei, 2012).

Intake of phytochemicals should be from dietary sources rather than from supplements or pills. This is because supplements or pills are less effective than a serving of fruits and vegetables. Therefore, since phytochemicals are found in all plant products, it is advised that a wide variety of fruits and vegetables should be consumed in order to gain maximum benefit from the nutrients and phytochemicals they contain (Liu RH 2003).

## 2.8 Post harvest practices and Preservation of AIVs

Food preservation is a method of treating foods to delay deterioration by changing raw products into more stable forms that can be stored for longer (Adegoke and Olapade, 2012).

High moisture content of ALVs renders them perishable while their seasonal availability limits their utilization all year round (Dev & Raghavan, 2012). Hence preservation will be crucial to prevent nutrient loss and postharvest losses.

Currently, ALVs have been reported in Kenya, to suffer postharvest losses of up to 50 %. (Aseno-Okyere, 2012). Inadequate postharvest handling and facilities for storage and transport, inappropriate processing methods for product preservation, insufficient hygiene conditions in the markets and poor infrastructure aggravate these problems, leading to massive losses along the consumer chain (FAO 2011).

In many parts in Africa, subsistence smallholder farmers cannot afford construction of expensive cold storage facilities and/or the use of refrigerated trucks, thus after harvesting ALVs, simple methods (shading products, charcoal cooler storage facilities) are applied (Lyatuu *et al.,* 2010). However, alternative technologies that should be explored for adoption are: on-farm evaporative coolers and modified atmosphere packaging (MAP). The commonly used, local preservation methods include blanching, air-drying, solar-drying and fermentation. However, despite their wide adoption, some of these result in significant loss of nutritional product quality and in microbiological contamination (Lyatuu *et al.*, 2010).

Reducing the postharvest losses by appropriate technologies of ALVs would increase food availability to the growing population. Fellows (2009) argued that improving post-harvest handling and processing of vegetables can help overcome perishability thus high-quality food supply.

This study will focus on effect of slicing, blanching, solar drying and freeze drying on the selected ALVs nutritional quality as well as packaging of the minimal processed product to improve the availability and shelf life of black nightshade, Stinging nettle and Amaranth.

### 2.8.1 Blanching

Blanching involves a short heat treatment prior to preservation aiming at inactivating enzymes in vegetables. Blanching can be done by immersing in hot water Gogo *et al.,* 2016). Blanching water in some cases, can be used repeatedly to build up concentration of dissolved solids to the point where leaching losses are small.

Dehydrated vegetables are blanched prior to blanching in order to refresh more readily and arrest undesirable enzymes action. According to (Kendall *et al.*,2003) enzymes are sensitive to moist heat conditions.

### 2.8.2 Drying

This is the oldest procedure for food preservation involving removal of biological active water which provides microbiological stability, reduces deteriorative chemical reactions and extends the shelf life of dried products (Mongi, 2013). Drying procedure is important since it reduces weight and volume thus packaging, storage and transportation cost is minimized (Guiamba, 2016). The energy input used for drying is less as compared to other preservation methods.

During drying process, low humidity allows moisture to move quickly from the food to the air while warm temperature enables the moisture to evaporate. Drying process is hastened up by air current which moves the surrounding moist air away from the food. Vegetables need to be dried to a brittle or crisp texture containing approximately 10 %. moisture.

Drying is used in production of convenient foods. Its less expensive in energy forms and are economical in their storage requirements. Dried products disadvantages are that they require a longer cooking period than the fresh products and do not retain their flavor. Sun drying, is the oldest preservation technique practiced by Kenyan farmers. Its cost is low (Oniang'o *et al.*, 2008).

The sun's ultraviolet rays can also inhibit the growth of microorganisms. The radiant energy of the sun provides the heat to evaporate the water.

Drying proceeds well in warm and dry weather, however, at night and during the rainy seasons sun-drying is not effective. The temperatures of vegetables during sun drying are usually 5–15 ˚C above ambient temperatures (Abukutsa-Onyango, 2003). The time of drying ALVs can be 3 to 4 days or longer depending on the product and prevailing weather conditions

#### 2.8.2.1 Solar drying

During the process of solar drying, the leaves are completely protected against rain, dust, insects and animals. It is deemed as an economically feasible method for preservation at a local level (Masarirambi *et al.*, 2010). The main aim of the procedure is to reduce the water activity of the fresh produce in order to slow down food spoilage (Kiremire *et al.*, 2010). Solar drying is more preferred because drying time is shorter since the drying temperatures are higher. It also enables the dried product to be stored longer since the micronutrient concentration in the dried products is increased (James and Matemu, 2016).

Drying time of solar dried is shorter whereas dying temperature are higher. Bioavailability of minerals like zinc and iron are affected by phytic acid and Tanin content in food. Processing methods including solar drying, alters antinutrients. Solar drying, lowers oxalic acid, phytates and polyphenols. According to (Chege *et al.*, 2014), solar drying concentrate per unit nutrients of vegetable amaranth of ß-carotene, iron and zinc retention of 77.5 %, 94.3 %, and 95.4 % for β-carotene,

#### 2.8.2.2 Freeze drying

Freeze-drying is a process whereby water is removed by dehydration, through sublimation of ice in the materials. It's a drying method that is advanced providing drying products with porous structure with negligible and small shrinkage, retention of aroma and flavor and improved rehydration compared to other drying methods. It is also, important in the preservation of biological heat sensitive material. Freeze drying is used to extend the shelf life of foods by retarding lipid oxidation as well as preventing microbial growth (Marques *et al.*, 2009). In addition, it's used on industrial scale preservation as long-term storage of foods (Perez *et al.*, 2011). Products of freeze dried are believed to have the same characteristics as fresh products. Preservation and retention of attributes like taste, appearance, nutrients, color, flavor and texture makes this drying process most applicable for drying food materials.

## 2.9 Packaging and shelf life

Food packaging plays an important role in preserving food throughout the distribution chain (Gogo *et al.*, 2016). Without packaging, the processing of food can become compromised as it is contaminated by direct contact with physical, chemical, and biological contaminants. Packaging of food as combined with improved traditional methods of processing can reduce post-harvest losses and prolong storage life (Ayua and Omware, 2013). For food to be protected against any undesirable alteration, proper packaging materials should be applied. As reported by Nyaura *et al.*, (2014), packaging material should possess certain properties such as; permeability of gases ($O_2$, $CO_2$, ethylene, water vapour) and degradative agent from outside. Packaging can as well minimize oxidation and undesirable aroma substance in the food product. Nyaura et al., 2014).

There are two methods used to extend shelf life of perishable foods, these are Modified Atmospheric Packaging and Controlled Atmosphere (CA). They alter the proportions of atmospheric gases surrounding the food (Oloo, 2010). Modified atmosphere packaging, is a technique applied to different packaging technologies to modify the composition of the internal atmosphere of a package. It improves the shelf-life of fresh or minimally processed food products and slow product degradation (Robertson, 2003).

Currently, Xtend®, formally Active® bags are now being used as emerging technologies in packaging of fresh fruits and vegetables in Kenya. These polyethylene films possess the ability to control exchange of gases such as oxygen, carbon dioxide, and ethylene through the walls of the film. These bags too, have the ability to extend the shelf life of vegetables. However, the knowledge of appropriate packaging for ALVs is limited. Farmers still store ALVs in non-perforated clear polythene bags. Due to the high physiological activity of ALVs, e.g. high transpiration and respiration rates, water condenses inside such polythene bags, thus creating avenues for microbial development.

Therefore, it’s important to assess the different packaging material on the nutritional stability of minimal processed AIVs.

# CHAPTER THREE

# MATERIAL AND METHODS

## 3.1 Plant material

Seeds of Amaranth (*Amaranthus dubious*) and African nightshade *(Solanum scabrum*) were purchased from Simlaw Seeds Company, Kenya. They were grown in a randomized block design at Jomo Kenyatta University of Agriculture and Technology (Juja, Kenya), experimental research farm. Plots were divided into thirds, having a size of 5m by 4m with each having 3 replicates. Ploughing was done twice and land well leveled. Seeds were directly sown into furrows at an inter-row spacing of 40 cm. During planting, compost manure was sprinkled at the rate of 10 tons/hectare. Irrigation to the crops was done daily as well as weeding and hoeing. Planting was done during the month of 2nd December 2016 – 23rd February 2017. Two weeks after germination, the plants were thinned to a spacing of 15 cm between the plants. Stinging nettle (*Urtica dioica*) was sourced from a commercial farmer in Juja farm. It was not grown because of its growth conditions. Stinging nettle requires organic rich, loamy soil and fertile moist soil. Therefore, before harvesting, age of the leaves was important. Experiment was conducted to find out how long a shoot would sprout after tagging the plants for some time. It was noted later; a new shoot sprouts up after 7days. This now determined stage of harvesting of stinging nettle. Young stage of the leaves was harvested on the $5^{th}$ week and mature stage on $10^{th}$ week.

### 3.2 Harvesting and sample preparation

#### 3.2.1 Flow chart

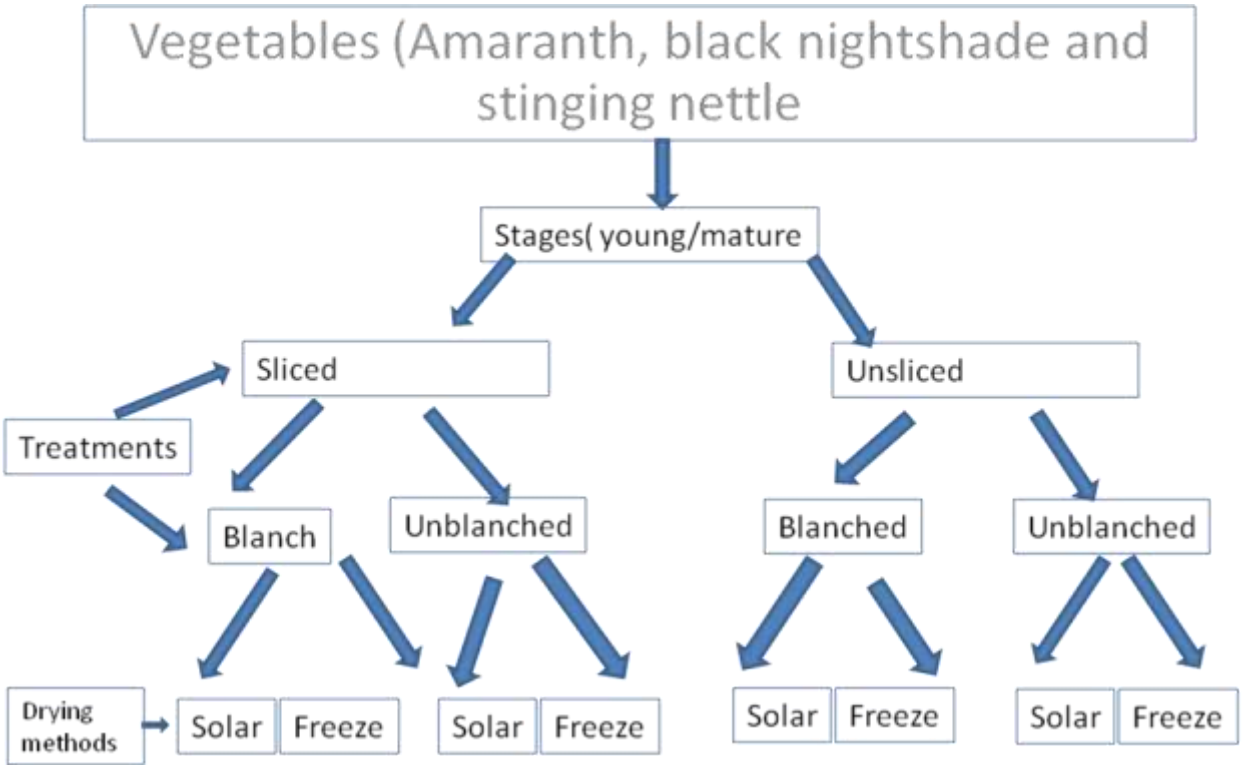



**Figure 3.1: Flow chart post-harvest treatment of AIVs**

The post-harvest treatment of AIVs followed a particular pattern to ensure proper drying and preservation (Figure 3.1). Slicing of the samples involved cutting the fresh leaves into small pieces of dimensions approximately 0.3cm × 0.5cm thickness. Blanching was done on the sliced and unsliced samples using hot water at $95\pm1^{0}$C for 30seconds with the ratio of 1:7 vegetables to water (g/ml) according to the method by Tanongkankit *et al.*, 2010. The blanched samples were removed and immediately dipped in ice cold water ($4^{0}$C) to stop any enzymatic activity. The blanched samples were then left in a wire mesh bucket to drain water. These samples were then solar dried or freeze dried together with the unblanched samples.

### 3.2.2 Pre-harvest stages

Leaves of the AlVs were harvested at two stages; young stage (5weeks) and mature stage (10weeks) after planting. After harvesting, AlVs were washed, with portable water, and allowed to drain the excess water, then divided into four portions for minimal processing treatments. Treatments involved blanching and unblanching; slicing and unslicing of leaf samples then subjecting them to either solar or freeze drying. Fresh samples (no treatment) were used as a control.

## 3.3 Drying processes

### 3.3.1 Solar-drying

The processed AlV samples were spread in a single layer in 40 x 60 cm rectangular chambers. The solar drier structure measured 185 cm wide by 273 cm long by 255 cm high with door dimensions measuring 60 cm wide by 180 cm high. The top part of the structure was semicircular in shape with a radius of 50 cm and was entirely covered with a polyvinyl chloride (PVC) material. The PVC material filters radiation which can destroy light sensitive nutrients in the dried samples (Leon and bhattacharya, 2002). The drying chamber temperature ranged between 42 and 63$^{o}$C while that of the solar dryer's leaf collector was between 40 and 73$^{o}$C. In addition, Solar heated air temperature of 50 to 60°C was used for drying vegetables.

Moisture content (M.C) of the AIV leaves was determined during and after drying. Drying was finalized when the vegetables were brittle after 3days of drying and the dried samples were stored in zip lock bags at -20$^{o}$C for further analysis. Experiment was carried out in replicates and all results expressed in dry weight (dw) except antioxidant activity which was expressed in fresh weight (fw) basis.

### 3.3.2 Freeze drying

A freeze-drier (Alpha1-4 LD plus-Martin Christ Model-101541; Germany) was used. Processed samples were placed in airtight zip lock bags and frozen in a freezer at -21$^{o}$C for 72hrs. Before placing in a freeze drier, zip lock bags were perforated to attain several vents. These allowed good balance of pressure and temperature inside and outside the bags during drying. The initial and final drying were carried out at temperature and pressure conditions recommended by the drier manufacturer which were -41$^{o}$C, 0.11 mbar, -47$^{o}$C, 0.055 mbar, respectively for 48hrs.

## 3.4 Packaging

Different types of packaging materials were used to determine the nutritional stability of the minimally processed ALVs. These packaging materials were: Xtend, formally active bags which were stored at room temperature (20$^{o}$C) and zip lock bags where samples were frozen at -18$^{o}$C.

Fresh and processed leaf samples (blanched) were divided into two batches. One of the batches were packed in a zip lock bags and sealed. Then frozen in a freezing chamber at (-18$^{o}$C) for a month and stability of the nutrients analyzed weekly. On the other portion, samples were packed in various Xtend, active bags namely the green line striped, white line striped and black line stripped. They were then stored at room temperature (20$^{o}$C) and stability of the nutrients were analyzed after 2days intervals for 7 days. The active bags were obtained from Amiran Kenya where they are being used to store herbs and vegetables.

## 3.5 Nutrient Analysis

### 3.5.1 Determination of moisture content

The moisture content was determined according to method 984.25 (AOAC, 2005).

About 5g of the ALVs samples was weighed and placed in a moisture dish and the weight of the dish and sample taken. It was then placed in a moisture oven at a temperature of 105°C. The samples were dried for 3 hours in a desiccator and weighed. The moisture content in the samples was calculated using the formula;

$$\% \text{ Moisture} = \frac{\text{Wt of sample before drying} - \text{Wt of sample after drying}}{\text{Wt of sample before drying}} \times 100$$

### 3.5.2 Determination of Crude fiber

Two grams of the sample, initial weight (w0) of vegetable was weighed into a conical flask and 200mL of 1.25% sulphuric acid, added and the solution boiled for 1hour. The content was then filtered using a glass wool and washed with hot water. The residue was transferred to a 500mL conical flask and 200mL of 1.25%NaOH added and the solution was then boiled for 1hour. The solution was then filtered using a glass wool. The residue was then washed with 7mL of hot water, 1%HCL, methanol and petroleum ether and air dried for about 30minutes. The glass filter was then dried in an oven at $105^0$C for 1hour, and the first weight (w1) recorded. The glass filter was then put in a muffle furnace at $600^0$C for 1hour, and second weight (w2) recorded. The crude fiber was then calculated as follows:

$$crude\ fiber = \frac{W1 - W2}{W0} * 100$$

Where

w0 - initial weight of the sample

w1 – weight of the extracted fiber before ashing

w2 – weight of the fiber after ashing

### 3.5.3 Determination of Beta carotene

Beta carotene content was analyzed spectrophotometrically as described by Rodriquez-Amaya and Kimura (2004).

Two grams of AIV samples were weighed and ground thoroughly in a motor and pestle using acetone. The acetone extract was then transferred to volumetric flask and the residue extracted again with acetone. This was repeated until the residue no longer gave (orange) color to acetone. Twenty-five mL of the extract was evaporated to dryness on a rotary vacuum evaporator and the residue dissolved in petroleum ether. The solution was introduced into chromatographic column and eluted with petroleum ether and collected up to 25mL. The absorbance of the solution was determined at 440nm using UV-vis spectrophotometer (Shimadzu model UV-1601 PC, Kyoto, Japan) and plotted against their corresponding standard concentrations.

### 3.5.4 Determination of Vitamin C content

Vitamin C content was determined by High Performance Liquid Chromatography (HPLC) method (Vikram *et al.*, 2005). Five grams of the sample was weighed and extracted with 0.8% metaphosphoric acid. The extract was then made to 20 mL and centrifuged at 10000 rpm for 10 minutes. The supernatant was filtered and diluted with 10 mL of 0.8% metaphosphoric acid. This was then filtered using cotton wool and micro-filtered through 0.45 μ filter and 20μL injected into the HPLC. HPLC analysis was done using Shimadzu (10A model; Tokyo, Japan) and a UV-Vis detector. The mobile phase was 0.8%metaphosphoric acid, at 1.1mL/min flow rate and wavelength of 266.0 nm.

### 3.5.5 Plant Extracts

Five grams of samples were weighed into amber-colored bottles containing 50 mL of analytical grade methanol and vortexed for 3 hr. The solution was incubated in darkness for 48–72 hr at room temperature. The extracts were centrifuged for10 min at

13,000×*g*/relative centrifugal force (RCF) and supernatants used to determine the total phenolic and flavonoid content and antioxidant capacity.

#### 3.5.5.1 Determination of total phenolic content

Total phenolic content was determined by the Folin–Ciocalteu colorimetric method (Wojdylo *et al.*, 2007) with gallic acid as the standard. Two milliliters of 10% (v/v) Folin Ciocalteu reagent and 4 mL of 0.7 mol/L sodium carbonate were added onto 1 mL of prepared sample extract. The mixture was vortexed and allowed to stand at room temperature for 2 hrs. The absorbance was measured at 765 nm using UV-Vis spectrophotometer (Shimadzu UV–1240), and results were expressed as gallic acid equivalent (GAE), milligrams/100 g of dry matter.

#### 3.5.5.2 Determination of total flavonoid content

Colorimetric method was used for determination of flavonoids as described by Jagadish *et al.*, (2009) with slight modification. To a 10 ml volumetric flask, 1 ml of plant extract was taken and 3mL of 5% sodium nitrite solution was added. After 3 minutes, 3 mL of 10% aluminum chloride was added to the mixture, which was kept at room temperature for 5 more minutes, followed by the addition of 2ml of 1M sodium hydroxide. The mixture was vigorously shaken for 5 min and the volume made up to 10ml with water. Absorbance was measured at 415nm using UV-Vis spectrophotometer (Shimadzu model UV-1601 PC, Kyoto, Japan). The total flavonoid was quantified using quercetin standard and results presented as quercetin equivalent (qe).

#### 3.5.5.3 Determination of antioxidant activity

The free radical-scavenging activity was determined using diphenyl picrylhydrazyl radical (DPPH) according to Ayoola *et al.*, (2008). One milliliter of the extract was placed in a test tube; 3 mL of methanol was added followed by 0.5 mL of 1 mM DPPH in methanol. The mixture was shaken vigorously and left to stand for 5 min. Vitamin C was used as the antioxidant standard at the same concentrations as the extract. The

absorbance of the resulting solution was measured at 517 nm with a UV-vis spectrophotometer. All tests were run in triplicate and the radical scavenging activity was then calculated using the following formula;

$$\%\ Inhibition\ of\ DPPH = \frac{(A_B - A_A)}{A_B} \times 100$$

Where:

$A_B$ = absorption of the blank sample;

$A_A$ = absorption of the extract.

### 3.5.6 Color determination

Color for processed ALVs leaf samples was determined by use of Dadali, Kilic Apar, and Ozbek (2007) method with some slight modifications using a hunter lab color difference meter (Minolta, Tokyo, Japan). Before use, the instrument was standardized with a black and white ceramic plate. L* value was used as an indicator of lightness/ brightness in the leaf samples.

### 3.5.7 Mineral determination

Minerals were determined after dry ashing and atomic absorption spectrophotometer (AAS) according to the method described by the AOAC (2000). The minerals determined were zinc, iron, calcium and magnesium. About 5g of the leaf sample were weighed and placed into a weighed dry crucible. The crucibles were placed on a hot plate under fume hood and increasing the temperature slowly until smoking cease and the samples were thoroughly charred. There after placed in a muffle furnace and temperature gradually increased to 250C and heated for 1 hour. The temperature was increased gradually to 550C and incinerated to complete ashing. The temperature was

then decreased to 3000, the crucibles removed and cooled to room temperature. The ash was transferred quantitatively to 100 mL beaker using 20 mL of 1N HCL, then heated at 80-900C on a hot plate for 5 minutes. This was then transferred to 100 mL volumetric flask and filled to the mark using 1N HCL. Insoluble matter was filtered and the filtrate kept in a labeled polyethylene bottle. The absorbance of the solutions was read by Atomic Absorption Spectrophotometer (AAS). The various mineral standards were also prepared to make the calibration curve.

### 3.6 Statistical analysis

Data were subjected to analysis of ANOVA using Stata version 12 software (Stata Corp.) while Duncan test at 0.05 significance level were used to perform mean variation.

# CHAPTER FOUR

## RESULTS AND DISCUSSION

**Objective 1;** To determine the effect of harvest maturity and minimal processing (slicing, blanching and drying techniques) on the nutritional quality and anti-oxidant constituents of the selected ALVs

### 4.1 Proximate composition

#### 4.1.1 Moisture content

The results of moisture content (M.C) of young and mature leaves are presented in Table 1 and 2, respectively. From the results, fresh sample of black nightshade that were sliced and blanched had the highest M.C of 89.34% compared to the other AlVs at young stage. After drying, the sliced treatments of solar dried stinging nettle retained the highest M.C of 7.14%. compared to the freeze-dried samples.

**Table 1: Effect of processing (slicing, blanching, solar and freeze-drying methods) on percentage moisture content of young stinging nettle, amaranth and black nightshade**

| Treatments | Percentage moisture content<br>**stinging nettle** | | | **Amaranth** | | | **Black nightshade** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Fresh** | **Solar Dried** | **Freeze Dried** | **Fresh** | **Solar Dried** | **Freeze Dried** | **Fresh** | **Solar Dried** | **Freeze Dried** |
| **Fresh** | $76.60\pm0.27^{b}{}_{A}$ | | | $80.44\pm0.71^{b}{}_{B}$ | | | $87.28\pm0.79^{b}{}_{C}$ | | |
| **UU** | $76.60\pm0.27^{b}{}_{F}$ | $6.76\pm0.31^{aE}$ | $5.50\pm0.13^{aD}$ | $80.44\pm0.71^{b}{}_{G}$ | $4.7\pm0.19^{bC}$ | $3.49\pm0.02^{bB}$ | $87.28\pm0.79^{b}{}_{H}$ | $3.3\pm0.08^{bB}$ | $1.35\pm0.03^{aA}$ |
| **UB** | $80.25\pm0.01^{d}{}_{F}$ | $6.96\pm0.01^{aE}$ | $5.27\pm1.03^{aD}$ | $83.43\pm0.33^{d}{}_{G}$ | $4.73\pm0.21^{bC}$ | $3.62\pm0.10^{bB}$ | $89.34\pm0.68^{c}{}_{H}$ | $3.83\pm0.16^{bB}$ | $1.62\pm0.19^{aA}$ |
| **SU** | $75.39\pm0.19^{a}{}_{E}$ | $7.04\pm0.17^{bD}$ | $5.26\pm0.07^{aC}$ | $79.04\pm0.13^{a}{}_{F}$ | $5.82\pm0.05^{cC}$ | $3.34\pm0.37^{bB}$ | $86.64\pm0.07^{a}{}_{G}$ | $2.99\pm1.05^{aB}$ | $1.26\pm0.11^{aA}$ |
| **SB** | $78.68\pm0.23^{c}{}_{E}$ | $7.14\pm0.21^{bD}$ | $5.10\pm0.27^{aC}$ | $82.53\pm0.89^{c}{}_{F}$ | $2.26\pm0.42^{aA}$ | $2.76\pm0.92^{aA}$ | $88.00\pm0.05^{c}{}_{G}$ | $3.18\pm0.17^{bB}$ | $2.04\pm0.09^{bA}$ |

Values are given as percentage moisture means of three replicates ± SD. Means with different superscript upper-case letters across the row and lower case within the column are significantly different ($P < 0.05$). Fresh - no processing, UU - unsliced unblanched, UB - unsliced blanched, SU - sliced unblanched, SB -sliced blanched.

**Table 2: Effect of processing (slicing, blanching ,solar and freeze drying methods) on percentage moisture content of mature stinging nettle, amaranth and black nightshade**

| Treatments | Percentage moisture content<br>**stinging nettle** | | | **Amaranth** | | | **Black nightshade** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **fresh** | **Solar Dried** | **Freeze Dried** | **fresh** | **Solar Dried** | **Freeze Dried** | **Fresh** | **Solar Dried** | **Freeze Dried** |
| **Fresh** | $74.95\pm0.97^{b}{}_{A}$ | | | $78.22\pm0.66^{b}{}_{B}$ | | | $85.78\pm0.27^{b}{}_{C}$ | | |
| **UU** | $74.95\pm0.97^{b}{}_{F}$ | $7.08\pm1.29^{aE}$ | $4.32\pm0.17^{aC}$ | $78.22\pm0.66^{b}{}_{G}$ | $6.09\pm0.47^{b}{}_{D}$ | $2.31\pm0.51^{bB}$ | $85.78\pm0.27^{b}{}_{H}$ | $2.74\pm0.41^{a}{}_{A}$ | $1.05\pm0.02^{bB}$ |
| **UB** | $75.88\pm0.27^{c}{}_{E}$ | $7.14\pm0.61^{a}{}_{D}$ | $5.66\pm0.03^{bC}$ | $81.2\pm0.39^{dF}$ | $2.37\pm0.37^{aB}$ | $1.53\pm0.01^{aA}$ | $87.22\pm0.31^{d}{}_{G}$ | $2.2\pm0.09^{bB}$ | $1.97\pm0.03^{aA}$ |
| **SU** | $71.66\pm1.01^{a}{}_{E}$ | $7.57\pm0.91^{a}{}_{D}$ | $4.76\pm0.19^{aC}$ | $75.01\pm0.07^{a}{}_{F}$ | $2.03\pm0.99^{aB}$ | $1.31\pm0.09^{aA}$ | $82.97\pm0.89^{a}{}_{G}$ | $4.6\pm0.23^{dC}$ | $1.5\pm0.29^{aA}$ |
| **SB** | $76.31\pm0.87^{d}{}_{F}$ | $7.06\pm0.11^{aE}$ | $4.59\pm0.31^{aD}$ | $80.05\pm1.03^{c}{}_{G}$ | $2.52\pm0.77^{aB}$ | $1.42\pm0.11^{aA}$ | $86.31\pm0.07^{c}{}_{H}$ | $3.01\pm1.03^{cC}$ | $1.54\pm0.81^{aA}$ |

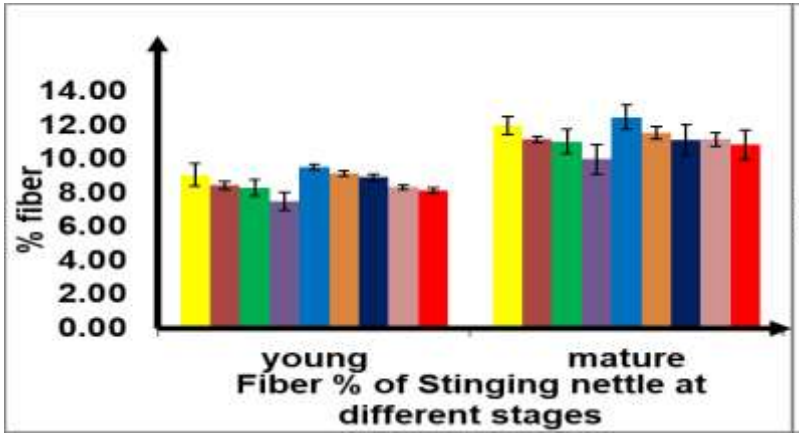
Values are given as percentage moisture content means of three replicates ± SD. Means with different superscript upper-case letters across the row and lower case within the column are significantly different ($P < 0.05$). Fresh - no processing, UU - unsliced unblanched, UB - unsliced blanched, SU - sliced unblanched, SB -sliced blanched.

In this study the moisture content of freeze-dried samples were lower, while solar dried samples had slightly higher moisture content suggesting that freeze drying led to removal of more water as compared to solar drying. In addition, moisture content of the vegetables declined with the maturation of the leaves. Similar findings have been observed by Florkowski *et al.*, (2009) who reported that *Cleome gynandra (*African Spider Flower) had a decrease in M.C with maturation. This may be due to structural changes as leaf grows older probably due to transpiration and starch hydrolysis. The blanched samples had higher moisture content as compared to the unblanched samples, possibly due to disruption of the leaf tissue cells, facilitating degradation and solubilization of water-soluble components (Yardfon *et al.*, 2013). This therefore leads to softening of leaf tissues hence higher rates in removal of water.

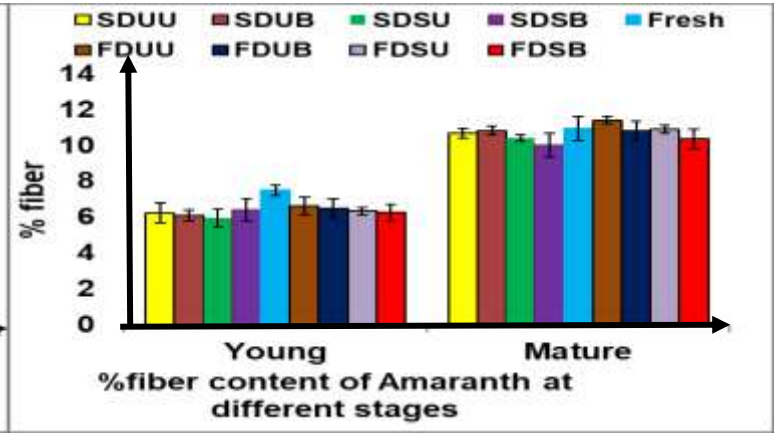
### 4.1.2 Fiber content

Result for fiber content of the three AIVs (figure 4.1) shows that there was no significant difference ($P > 0.05$) between the treatments. Results show that, fresh black nightshade had the highest fiber content of 12.89% and 9.53% for mature stage and young stage, respectively. On the other hand, the lowest percentage of fiber content (6.4 %.) was observed in sliced blanched solar dried samples of amaranth.

a)




b)




c)

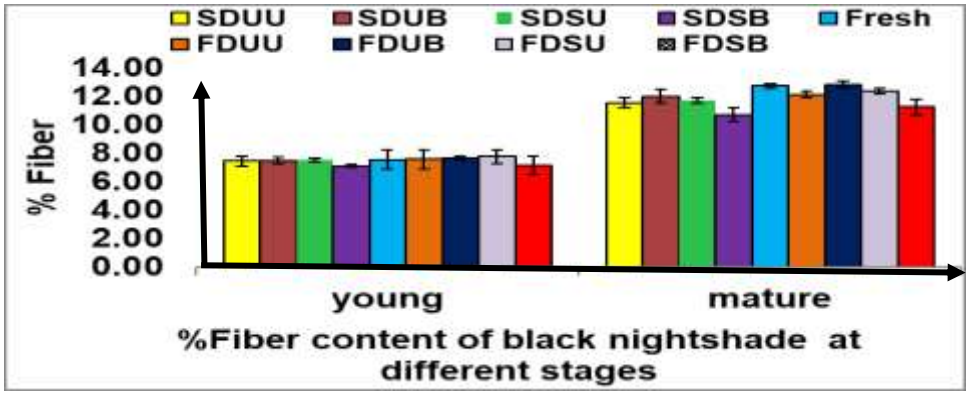
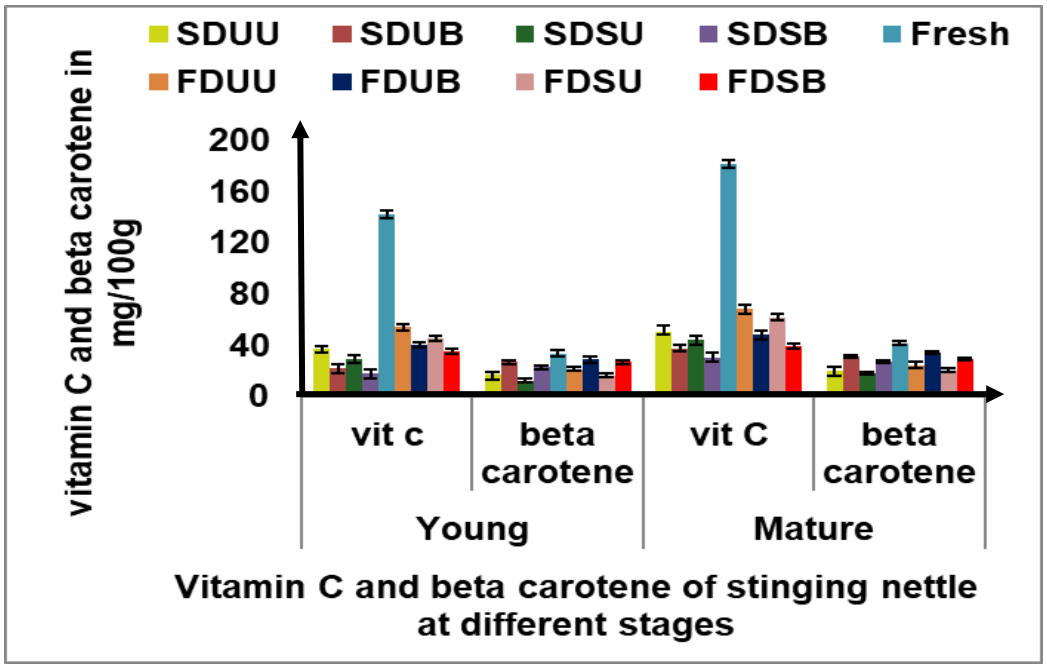



**Figure 4.1: Effect of harvest maturity and processing (slicing, blanching, solar and freeze-drying methods) on crude fiber, of young and mature (a) stinging nettle, (b) Amaranth and (c) Black nightshade (in dry weight basis)**

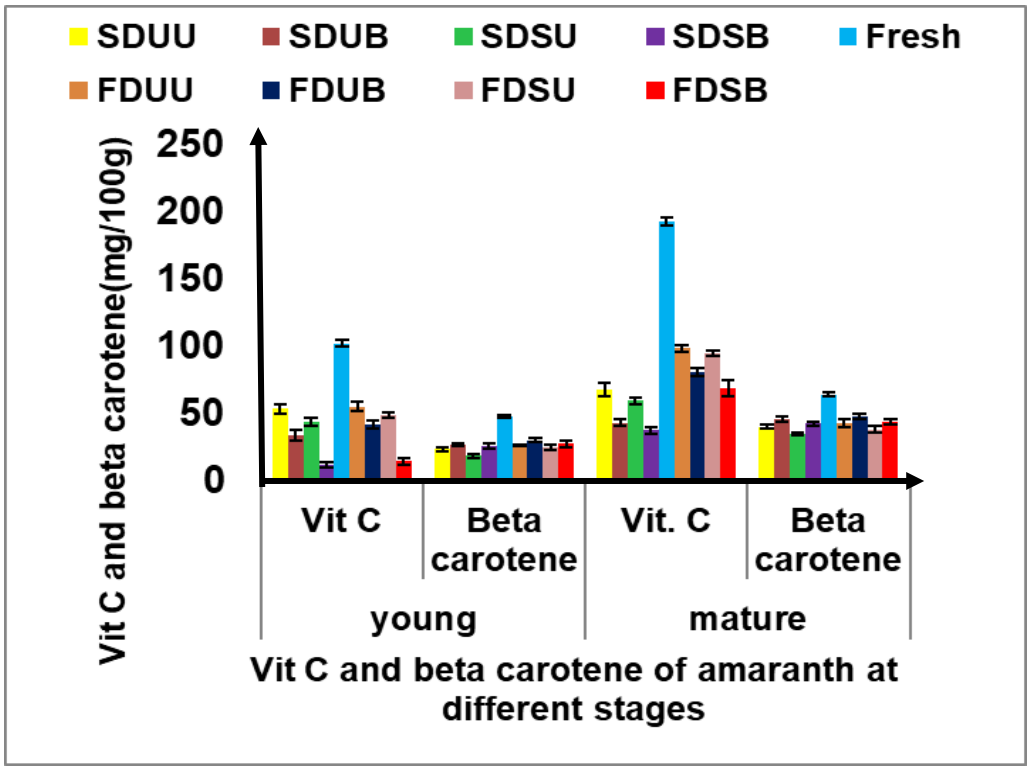
There was a significance difference (P≤0.05) between the fiber content of the leaves at the two stages of harvest. The fresh mature black nightshade had significantly higher values (12.77%) as compared to fresh young stinging nettle (9.53%). This may be due to fiber material being more elaborate in mature leaf organs than in young leaf (Foulk *et al.*, 2011). For the blanched samples, there was no significance difference (P≥0.05) in fiber content for both solar dried and freeze-dried samples. This could be due to the stability of fiber component found in the vegetables. In addition, no significance difference (P≥0.05) was observed in fiber content between the sliced and unsliced samples, blanched and unblanched samples and between the solar and freeze-dried samples.

### 4.2 Vitamin C and β-carotene content of the minimal processed ALVs

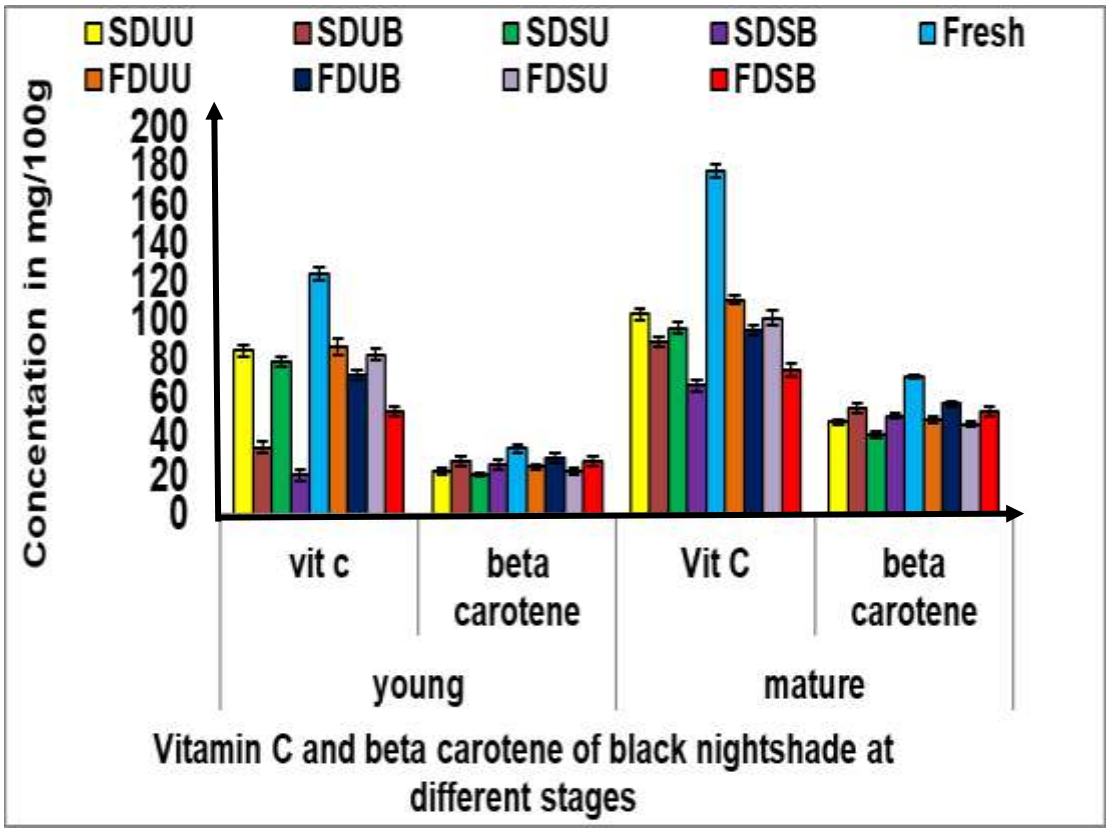
The vitamin C and β-carotene results for young and mature stage AIV samples are presented in figure 4.2. From the results, the fresh samples of amaranth had a higher β-carotene content of 47.82mg/100g at young stage, while the black nightshade had the highest β-carotene content at mature stage (71.22mg/100g). On the other hand, the lowest content was observed in the young and mature stage of stinging nettle in solar dried sliced unblanched with β-carotene content of 12.33mg/100g and 18.29mg/100gdw respectively.


SDUU
SDUB
SDSU
SDSB
Fresh
FDUU
FDUB
FDSU
FDSB
vitamin C and beta carotene in mg/100g
200
160
120
80
40
0
vit c
beta carotene
vit C
beta carotene
Young
Mature
Vitamin C and beta carotene of stinging nettle at different stages

a)


SDUU
SDUB
SDSU
SDSB
Fresh
FDUU
FDUB
FDSU
FDSB
Vit C and beta carotene(mg/100g)
250
200
150
100
50
0
Vit C
Beta carotene
Vit. C
Beta carotene
young
mature
Vit C and beta carotene of amaranth at different stages

b)




c)

**Figure 4.2: Effect of harvest maturity and processing (slicing, blanching, solar and freeze-drying methods) on vitamin C and Beta-carotene of (a)Stinging nettle, (b)amaranth and (c)black nightshade respectively**

In this study mature leaves were found to have significantly higher ($P < 0.05$) β-carotene content compared to the young leaves, suggesting that β-carotene increases with the maturation of the leaves. The highest β-carotene of the three AIVs on solar drying was reported in unsliced blanched leaves, followed by sliced blanched, unsliced unblanched and the lowest was observed in sliced unblanched leaves. On the other hand, solar dried samples had significantly lower β-carotene in all the vegetables ($P<0.05$) as compared to freeze dried samples, probably due to degradation of some of the compounds by solar radiation (Lim and murtijaya, 2007). The blanched solar and

freeze-dried samples had higher beta carotene content as compared to the unblanched samples. In this case, there was a significance difference ($p \leq 0.05$) between the unsliced unblanched and sliced unblanched samples of solar and freeze-dried treatments. On the other hand, both solar and freeze-dried samples of unblanched treatments were significantly lower as compared to the blanched treatments. Slicing of the samples significantly affected the β-carotene content whereby lower amount was observed in sliced treatments as compared to unsliced samples. The reduction of the β-carotene during slicing may be due to increase in surface area which could have promoted the oxidation of β-carotene (Schonfeldt and Pretorius, 2011). Oxidation of β-carotene can be prevented by avoiding light to the vegetables/samples.

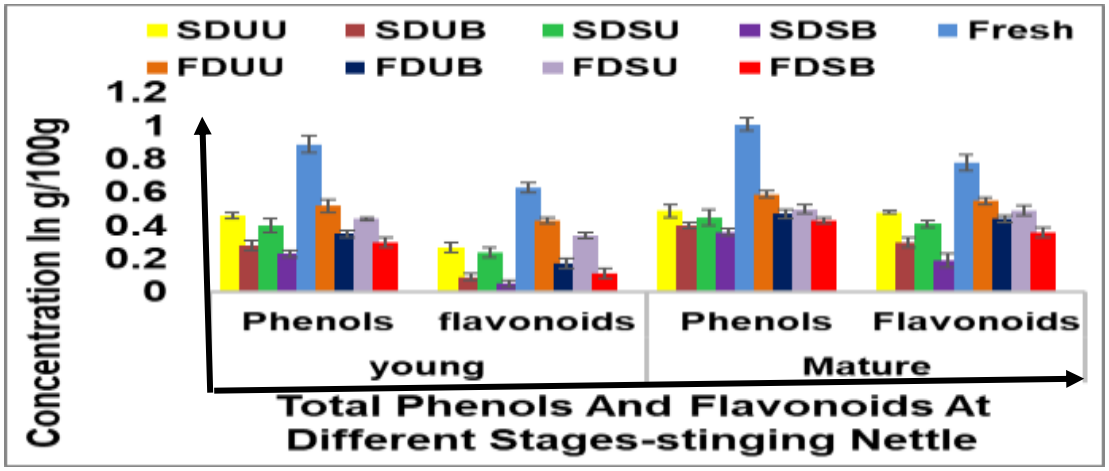
On the other hand, the fresh samples of stinging nettle had higher vitamin C content (142.06mg/100g), at young stage, whereas amaranth had the highest vitamin C content at mature stage (193.52 mg/100g). Lowest vitamin C content on the other hand, was observed in sliced blanched solar dried samples of young stage amaranth and mature stage stinging nettle with values of 11.87 mg/100g and 30.66 mg/100g, respectively. Vitamin C was shown to increase with the maturation of the leaves. These findings concur with other studies in broccoli leaves (Omary *et al.*, 2003) and spinach leaves (Yamada *et al.*, 2003). Blanching was observed to significantly affect the vitamin C content ($P < 0.05$). Blanched samples had lower vitamin C as compared to the unblanched samples. On the other hand, there was a significant difference on the vitamin C content in solar and freeze-dried samples. The results of blanching agree with the findings of a study by Nobose *et al.*, 2017, which showed that blanching affects the vitamin C content. Study on effect of Moringa leaves revealed that, fresh Moringa leaves reduced its content of Vitamin C from 691mg/100g to 439mg/100g (36.5% loss). Since vitamin C is heat liable, much of it was lost during blanching and heat treatment (Volden *et al.*, 2009). In addition, Liu *et al.*, (2002) observed that the blanching temperature inactivates most of vitamin C enzymes thus inhibiting their accumulation. Slicing of the samples also affected the vitamin C content whereby, the unsliced

blanched had significantly higher content as compared to sliced blanched samples. Besides, the sliced unblanched samples showed significantly higher content as compared to sliced blanched. It has been reported that slicing of the vegetables increases the surface area, therefore altering the availability of vitamin C (Dos Reis *et al.*, 2015). Processing have led to losses of Vitamin C and β-carotene, to avoid such losses, reduced time of blanching to be considered.

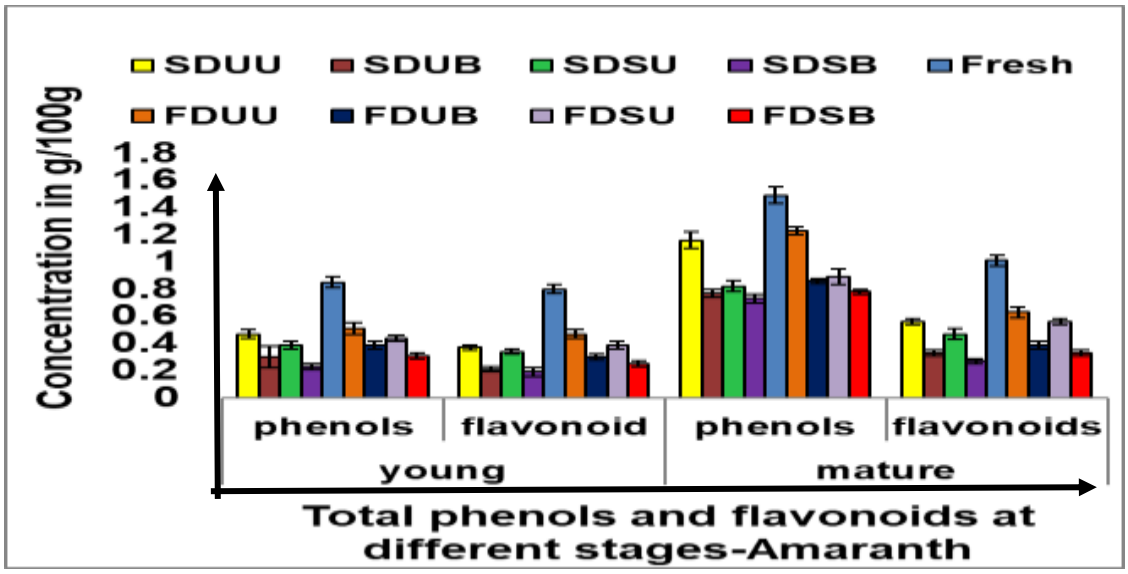
### 4.3 Phytochemical content of processed ALVs

#### 4.3.1 Total flavonoid content

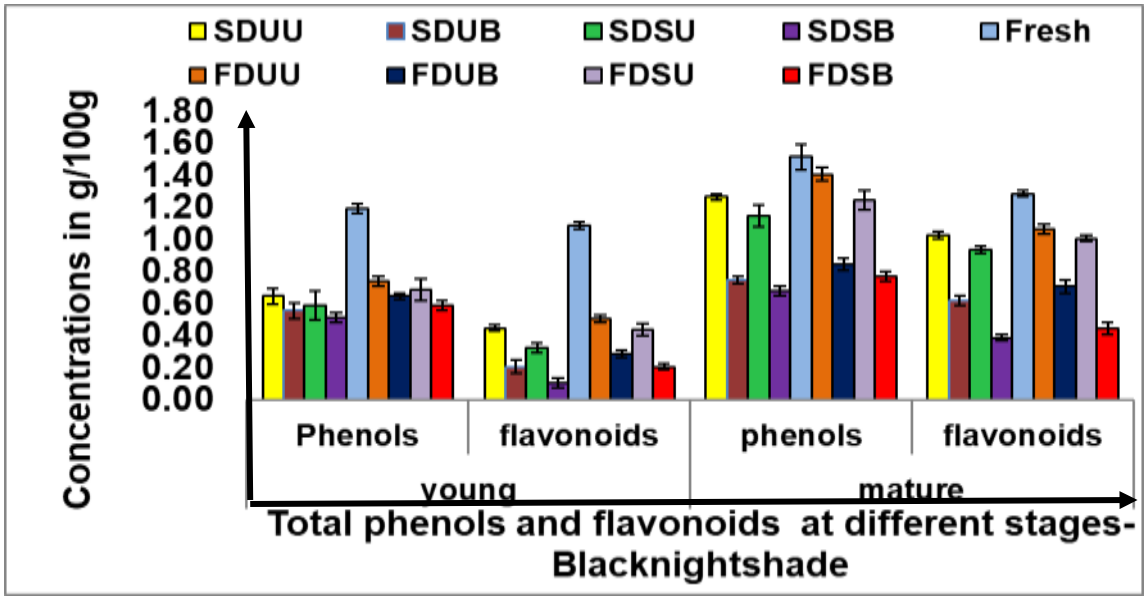
The total flavonoid results for AIV samples are shown in figure 4.3. These results indicate that black nightshade at young and mature stage had higher flavonoid content of 1.09g/100g and 1.29g/100g (qe), respectively as compared to the dried samples. This was followed by unsliced unblanched freeze dried samples of black nightshade which had the highest flavonoid content of 0.51 g/100g and 1.07 g/100g (qe) in young and mature stage, respectively. The lowest flavonoids were observed in sliced blanched solar dried samples of both young and mature stage stinging nettle with values of 0.05 g/100g and 0.19 g/100g, respectively.




**a)**




b)




c)

**Figure 4.3: Effect of harvest maturity and processing on total flavonoid and phenol content of young and mature (a) stinging nettle, (b) amaranth and (c) black nightshade (dry weight basis) (g/100g)**

All mature AIV leaves had significantly higher ($P < 0.05$) flavonoid as compared to the young leaves, therefore, suggesting that total flavonoid content increases with plant maturity. These results concur with the findings of Pandjaitan *et al.*, (2005) who observed increased flavonoid content in mature spinach leaves compared to immature leaves. Blanching affected the flavonoid content whereby the blanched samples had significantly ($P < 0.05$) lower content of flavonoids in the three AILs as compared to the unblanched samples. This suggests that blanching affected the chemical components especially the flavonoid, which likely leached into the blanching water. Drying on the other hand showed some effect on the flavonoid content. Drying reduced the content of flavonoid in both stages. Freeze dried samples had a higher content of Flavonoid as compared to the solar dried leaves samples. Slicing of the samples significantly ($P < 0.05$) affected the flavonoids. Unsliced samples had significantly higher flavonoid as compared to the sliced samples. Sliced unblanched samples had significantly higher flavonoids as compared to sliced blanched but significantly lower as compared to unsliced unblanched. According to Dos Reis *et al.*, (2015), slicing of vegetables alters the bioavailability of bioactive compounds such as flavonoids.

### 4.3.2 Total phenol content

The total phenol contents had the same trend as the flavonoids with fresh samples of young and mature stage black nightshade reporting higher contents of 1.2 g/100g and 1.52 g/100g, respectively. Unsliced unblanched freeze dried samples of black nightshade on the other hand reported a higher value of 0.74g/100g and 1.41g/100g in young and mature stage, respectively. Sliced blanched solar dried samples had the lowest value of total phenols with stinging nettle being the highly affected at both stages.

The total phenols in the study AIVs ranged between 0.23 -1.52 g/100g. However, the values were significantly lower than the ranges of 3.23 g/100g - 11.7 g/100g reported by Zainol *et al.*, (2003) in broccoli leaves. Phenol content was seen to increase with maturity as higher concentration was observed in mature leaves than the young leaves.

Similar results were observed by Igbal and Bhanger, (2006) who reported increase in polyphenols concentration as leaf matures. Total phenols were affected by blanching and the drying methods. Blanched samples had significantly lower phenols than the unblanched samples. On the other hand, fresh and freeze-dried samples had significantly higher phenols than the solar dried samples. Sliced samples reported low levels of phenols as compared to the unsliced. Dos Reis *et al.*, (2015) reported that chopping alters the bioavailability of bioactive compounds such as carotenoids, polyphenols and flavonoids. Aditha *et al.*, (2012) also found out that raw amaranth extract had higher total phenolic content as compared to blanched counterpart. Similarly, Amin *et al.*, (2006) reported a loss of 71% of total phenolic content in blanched Amaranthus. According to Aditha *et al.*, (2012), blanching of vegetables leads to oxidation of the compounds specifically, phenolics thus affecting their concentration. In addition, since phenolic compounds are known to occur in soluble forms and in combination with cell wall components in plants (Francisco *et al.*, 2010), the high temperature of the blanching may also lead to the disruption of the cell walls and the breakdown of the phenolics. This leads to leaching of these compounds into the blanching water.

### 4.3.3 Total antioxidant capacity

The antioxidant activity results for AIVs are shown in Table 3. A significant increase in antioxidant activity was observed with leaf maturation. The $IC_{50}$ values (the concentration which scavenges 50% of the DPPH radicals) were high in fresh black nightshade at 2.4mg/ml and 1.11mg/mL in amaranth at mature stage. On the other hand, the $IC_{50}$ values of the blanched samples were significantly higher ($p \leq 0.05$) as compared to the unblanched samples. The $IC_{50}$ values of stinging nettle and amaranth for unsliced blanched solar dried similarly to unsliced blanched freeze-dried samples were significantly lower (2.48mg/ml and 2.4mg/ml fw respectively) as compared to amaranth of sliced blanched solar dried (2.5mg/ml) but significantly higher as compared to sliced unblanched solar dried (2.35mg/ml) of amaranth.

**Table 3: Effect of harvest maturity and processing (slicing, blanching and drying methods) on antioxidant activity of stinging nettle, amaranth and black nightshade**

| | **Young** | | | **Mature** | | |
|---|---|---|---|---|---|---|
| | Stinging Nettle | Amaranth | Black nightshade | Stinging Nettle | Amaranth | Black nightshade |
| SDUU | $2.01\pm0.00^{dD}$ | 2.1±0.00bE | $1.42\pm0.01^{bC}$ | $0.07\pm0.01^{bA}$ | $2.18\pm0.02^{dF}$ | $1.39\pm0.09^{dB}$ |
| SDUB | $2.48\pm0.22^{gD}$ | $2.48\pm0.00^{fD}$ | $2.38\pm0.00^{fA}$ | $2.15\pm0.00^{gB}$ | $2.48\pm0.01^{gD}$ | $2.4\pm0.00^{hC}$ |
| SDSU | $2.3\pm0.01^{eD}$ | $2.35\pm0.01^{dE}$ | $2.23\pm0.00^{eC}$ | $0.34\pm0.04^{dA}$ | $2.3\pm0.01^{eD}$ | $1.53\pm0.01^{eB}$ |
| SDSB | $2.5\pm0.09^{hC}$ | $2.5\pm0.00^{gC}$ | $2.5\pm0.04^{hC}$ | $2.48\pm0.02^{hB}$ | $2.4\pm0.00^{fA}$ | $2.49\pm0.16^{hB}$ |
| Fresh | $2.34\pm0.07^{fE}$ | $2.17\pm0.04^{cD}$ | $2.4\pm0.00^{gF}$ | $0.78\pm0.00^{eB}$ | $1.11\pm0.23^{aC}$ | $0.12\pm0.00^{aA}$ |
| FDUU | $0.02\pm0.07^{aA}$ | $1.91\pm0.00^{aF}$ | $0.88\pm0.01^{aC}$ | $0.98\pm0.03^{fD}$ | $1.38\pm0.97^{bE}$ | $0.29\pm0.00^{bB}$ |
| FDUB | $2.32\pm0.04^{eD}$ | $2.4\pm0.21^{eE}$ | $2\pm0.11^{dC}$ | $0.08\pm0.00c^{A}$ | $2.4\pm0.12^{fE}$ | $1.98\pm0.00^{fB}$ |
| FDSU | $0.99\pm0.00^{cB}$ | $2.11\pm0.10^{bF}$ | $1.51\pm0.01^{cD}$ | $0.04\pm0.09^{aA}$ | $1.72\pm0.00^{cE}$ | $1.11\pm0.01^{cC}$ |
| FDSB | $2.44\pm0.01^{eC}$ | $2.5\pm0.03^{gE}$ | $2.49\pm0.00^{hD}$ | $0.09\pm0.01^{cA}$ | $2.48\pm0.01^{eD}$ | $2.29\pm0.03^{gB}$ |

Values are given as means $IC_{50}$ (mg/ml) ± SD. Means with different superscript upper-case letters across the row and lower-case letters within the column are significantly different ($P < 0.05$). $IC_{50}$ values (the concentration which scavenges 50% of the DPPH radicals). SDUU-solar dried unsliced unblanched, SDUB-solar dried unsliced blanched, SDSU-solar dried sliced unblanched, SDSB-solar dried sliced blanched. FDUU-freeze dried unsliced unblanched, FDUB-freeze dried unsliced blanched, FDSU-freeze dried sliced unblanched, FDSB-freeze dried sliced blanched and fresh-fresh sample (no processing).

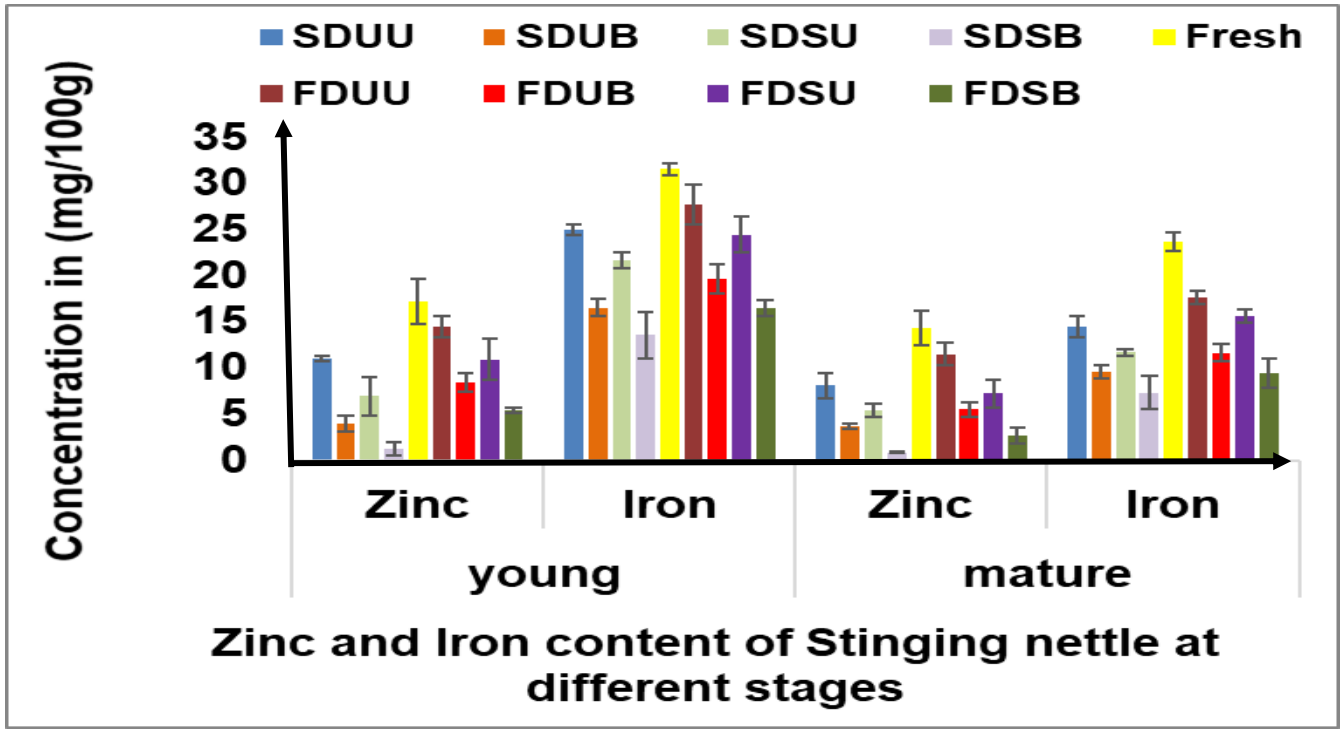
Significant changes in antioxidant activity were observed for the different growth stages, treatments and drying methods. The $IC_{50}$ values are inversely proportion to the antioxidant activity where the higher the $IC_{50}$ the lower the antioxidant activity and vice versa. Therefore, from the results, it shows that there is a significant increase in antioxidant activity as the AIVs leaves matures. For the blanched samples, there was a significant difference ($P < 0.05$) on the $IC_{50}$ values of both solar and freeze-dried treatments. The antioxidant activity of the blanched samples was significantly lower (2.5mg/ml fw) ($P < 0.05$) as compared to the unblanched samples (2.01 mg/ml fw). Similarly, for the solar and freeze-dried samples, the antioxidant activity of unsliced blanched (2.48 mg/ml fw) was significantly higher as compared to sliced blanched (2.5

mg/ml) but significantly lower as compared to sliced unblanched (2.3 mg/ml). On the other hand, there was a significant difference ($P < 0.05$) on the unblanched samples. Higher antioxidant activity was observed in freeze and solar dried unsliced unblanched (0.02 mg/ml) and lowest in sliced unblanched (2.35 mg/ml). Lower antioxidant activity on the blanched samples might have been due to leaching of soluble antioxidants into the blanching water (Hunter & Fletcher, 2002). Besides, slicing also had significant effect on the antioxidant activity since lower antioxidant activity was reported for the sliced samples as compared to the unsliced samples. The results of study concur with findings by Sreelatha, (2009) and Pandjaitan *et al.*, (2005) which found out that antioxidants are affected by stage of maturity in Moringa Oleifera and spinach leaves respectively.

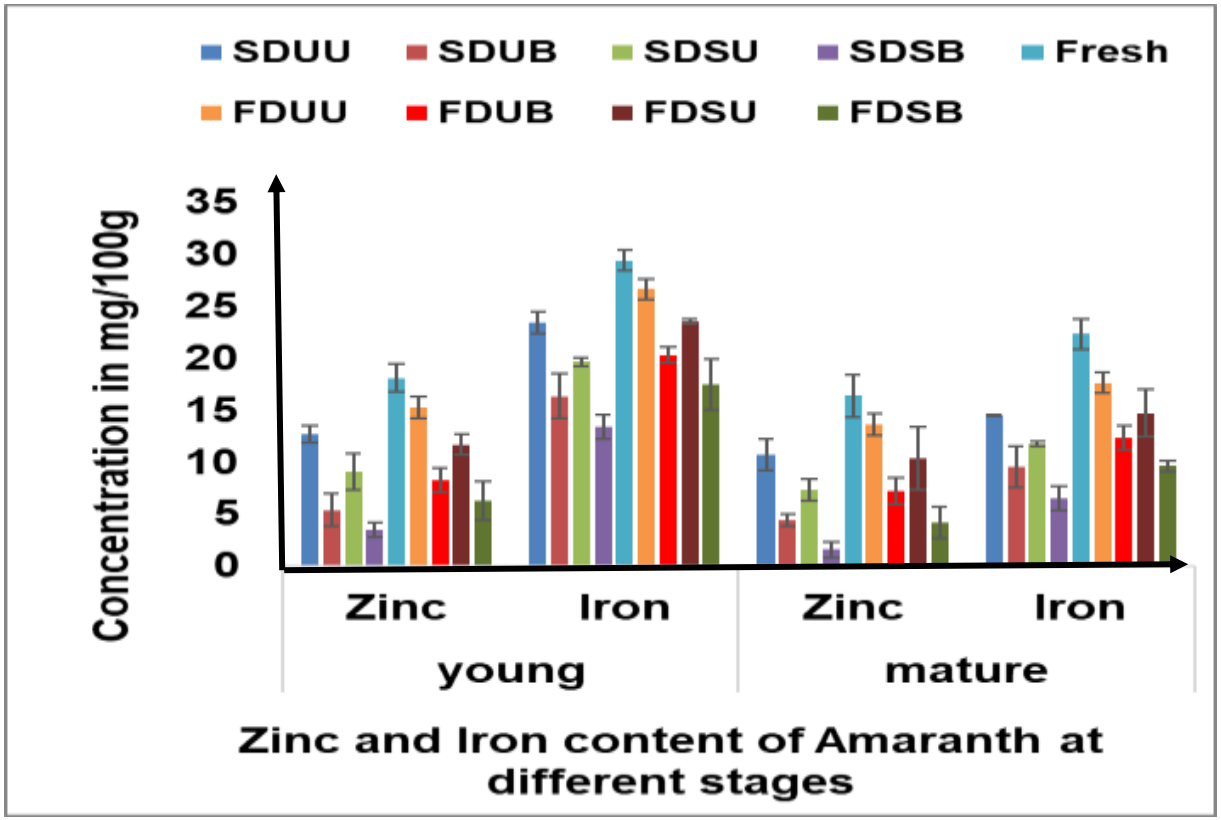
## 4.4 Mineral content

### 4.4.1 Zinc content

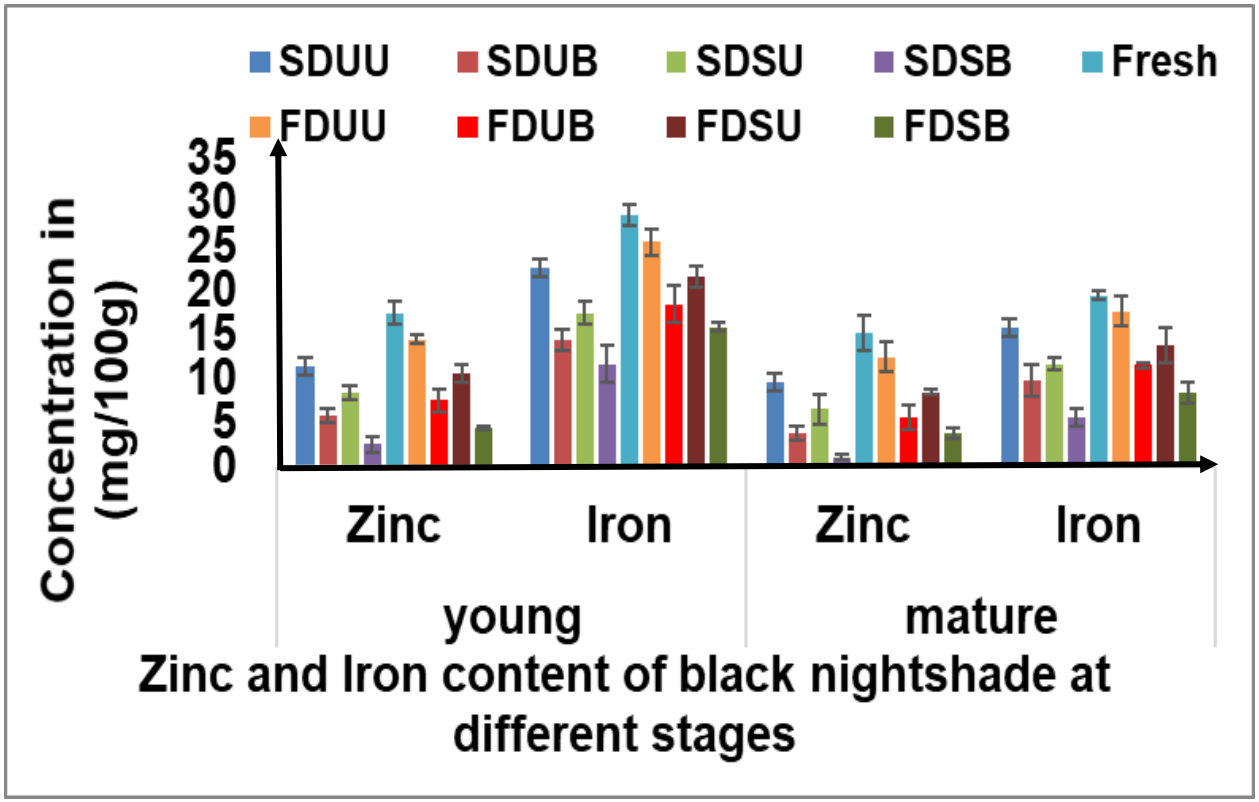
Results for mineral content of young and mature stinging nettle, amaranth and black nightshade is shown in figure 4.4. From the results, fresh leaves have reported a higher Zinc content of all minerals studied. Fresh amaranth at young and mature stage had the highest content of Zinc content of 18.18mg/100g and 16.45mg/100g respectively compared to the other ALVs. On the other hand, least zinc content was reported in solar dried sliced blanched of stinging nettle (1.30mg/100g and 0.87mg/100g) and at young stage and mature stage respectively. Amount of zinc content at young stage ranged between 1.3-18.18mg/100g while at mature stage it ranged from 0.87-15.17mg/100g.


SDUU
SDUB
SDSU
SDSB
Fresh
FDUU
FDUB
FDSU
FDSB
Concentration in (mg/100g)
35
30
25
20
15
10
5
0
Zinc
Iron
Zinc
Iron
young
mature
Zinc and Iron content of Stinging nettle at different stages

a)


SDUU
SDUB
SDSU
SDSB
Fresh
FDUU
FDUB
FDSU
FDSB
Concentration in mg/100g
35
30
25
20
15
10
5
0
Zinc
Iron
Zinc
Iron
young
mature
Zinc and Iron content of Amaranth at different stages

b)



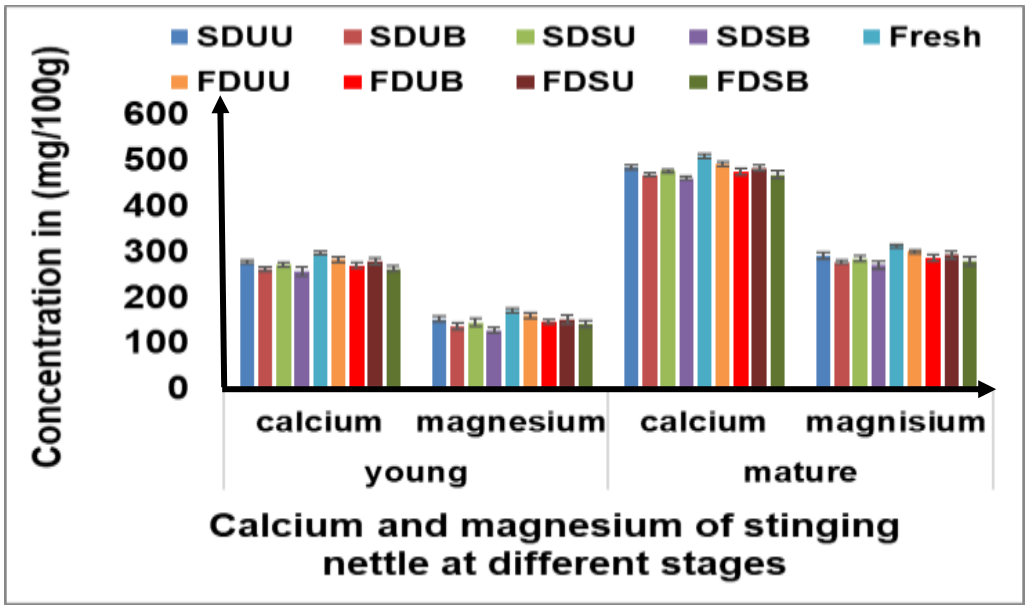

c)

**Figure 4.4: Effect of harvest maturity and processing (slicing, blanching, solar and freeze-drying methods) on mineral content (Zinc and Iron) of (a)stinging nettle, (b)amaranth and (c)black nightshade.**

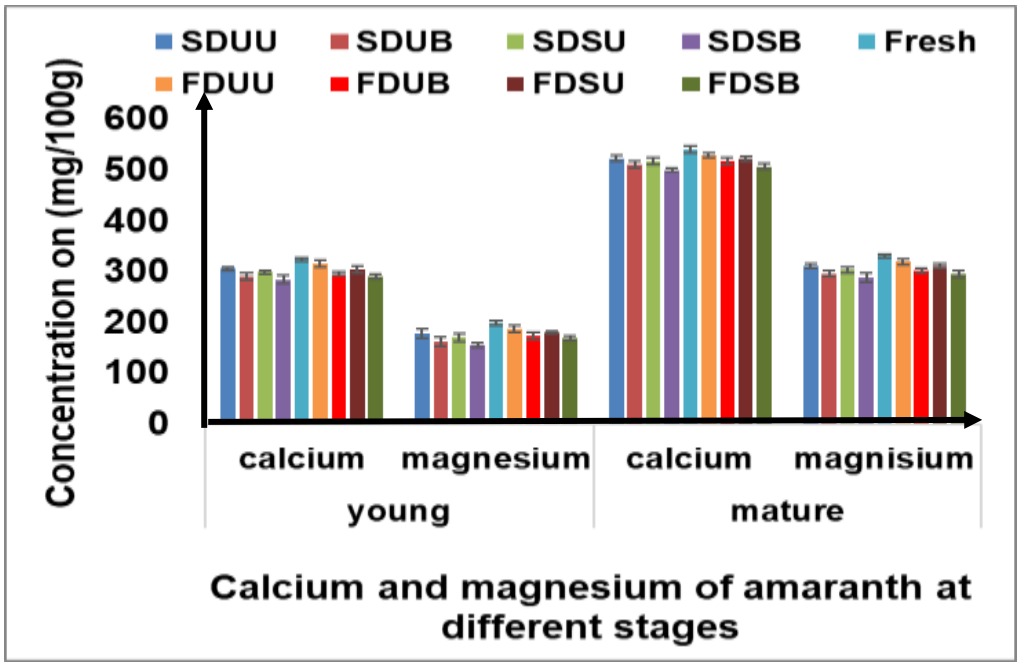
There was a significance difference (P≤0.05) on the zinc content as the leaves mature. A significant decrease was observed as the leaves ages. Similar trend was observed by Manabí *et al.,* (2011) on *A. cruentus* and found a decrease from 0.08 ± 0.01 mg/100 g (vegetative) stage to 0.05 ± 0.01 mg/100 g at heading (reproductive) stage. According to Khader and Rama, (2003), decrease in zinc content maybe during fruit initiation and development, some metabolites responsible for cellular synthesis and growth are translocated from the leaves, stems and roots to the developing fruits. However, the values of zinc content in leaf vegetable reported by Manabí are slightly lower as compared to the current study and this may be attributed to their genetic variations, soil, harvest maturity among other factors (Marls, 2017). There was a significant reduction (P≤0.05) on zinc content of amaranth, stinging nettle and black nightshade during drying. Oladele and Aborticide found similar results on Indian dried spinach and its zinc content reduced from 2.30-1.41µg/100g. Blanching had a significant difference (P≤0.05) on zinc content. Blanched leaf samples had significantly lower content of zinc as compared to unblanched samples. Sofia *et al.,* (2009), found blanched Kale reduced its zinc content from 0.51mg/100g -0.46mg/100g FW. In addition, Ghadames *et al.*,2018, found a reduction of blanched pumpkin leaf and relate the decrease to conditions of plants, food handling processing and leaching. These may be due to leaching of the minerals into the blanching water. Slicing as well had a significant different on content of zinc on the ALVs. Lower concentration was reported on sliced than on unsliced. These findings concur with Renard Landry *et al.,* (2016) who found unsliced *A. cruentus (Amaranthus)* to have a higher content of zinc (48mg/kg) as compared to sliced leaf samples (38.22mg/kg). Slicing of the vegetables increases the surface area, damaging the cell structure therefore altering the availability of minerals.

### 4.4.2 Iron content

For Iron, fresh stinging nettle at both stages (figure 4.5), reported the highest content of iron as 31.66mg/100g and 23.70mg/100g for young and mature stage respectively while the least was observed on black nightshade solar dried sliced blanched as 11.63mg/100g and 5.55mg/100g at young and mature stage respectively. Similar values were reported by Abukutsa (2010), on Amaranthus grown at different sites as 16.0 mg/100 g and 20.1 mg/100 g of their iron content. Higher concentration of iron was significantly higher ($P \leq 0.05$) in young leaves than mature leaves. Similar trend was reported by Khader and Rama, (2003), where they reported a decrease of iron content in green leafy vegetables as they mature. The reason for the decrease may be, during fruit formation and maturation as explained by Noggle and Fritz, (2006), there may be possible translocation of some of its contents and a decline in chlorophyll activity and associated light absorbing pigments following senescence of the leaf. Drying showed a significant difference ($P \leq 0.05$) on the iron content of the leafy vegetables. Freeze dried samples were significantly higher as compared to solar dried samples. However, there was a decline in iron content when the leaf samples were either solar or freeze dried. Sheetal *et al.*, (2011) found as well a sharp decline on iron content of green leafy vegetables when dried. According to Sheetal *et al.*, (2011) during the process of dehydration, iron could have been bound to other constituents of the vegetables thus reducing the solubility in turn influencing mineral composition. In addition, ascorbic acid (promoter of iron bioavailability) is also destroyed during dehydration resulting to lower iron content. Blanching of the vegetables reported significantly lower content ($P \leq 0.05$) of iron than unblanched. According to study by schnfeld 2011, he found a reduction on iron content of amaranthus tricolor leaves from 16.2-8.5mg/100g and cow peas leaves from 3.9-3.0mg/100g. Reduction of iron content can be attributed to leaching of the mineral during blanching. Slicing on the other hand had significantly lower iron content as compared to the unsliced samples. Reason for lower content in sliced samples may be an increase in surface area affecting iron content.


SDUU
SDUB
SDSU
SDSB
Fresh
FDUU
FDUB
FDSU
FDSB
Concentration in (mg/100g)
600
500
400
300
200
100
0
calcium
magnesium
calcium
magnisium
young
mature
Calcium and magnesium of stinging nettle at different stages

a)


SDUU
SDUB
SDSU
SDSB
Fresh
FDUU
FDUB
FDSU
FDSB
Concentration on (mg/100g)
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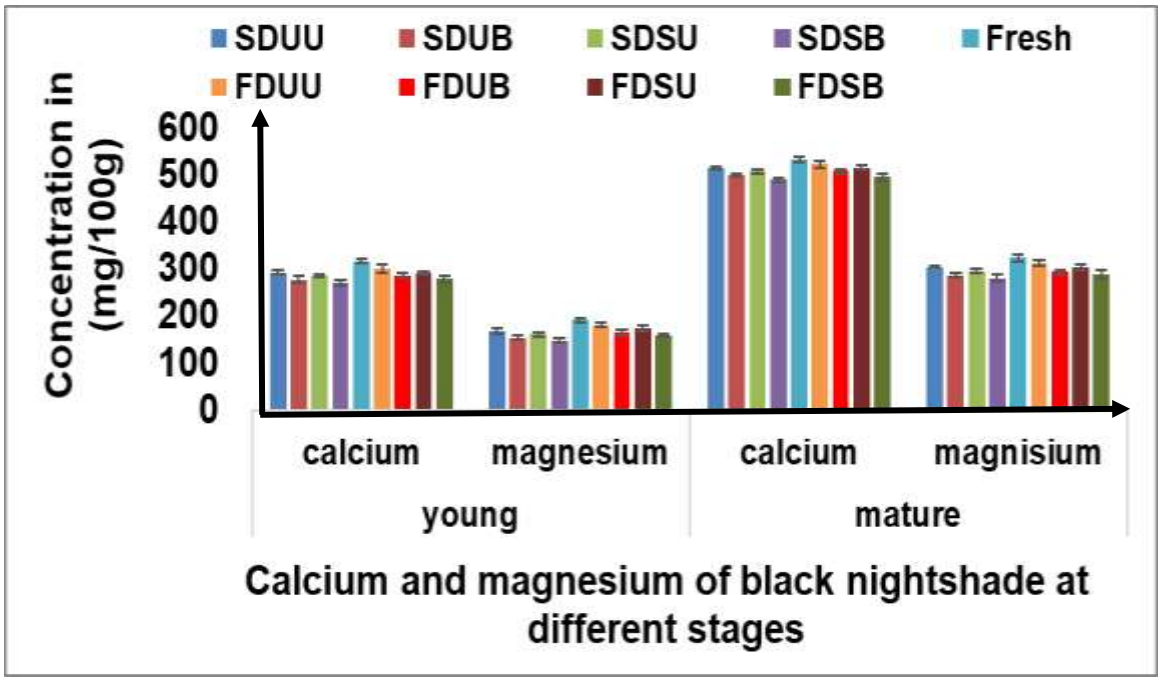
500
400
300
200
100
0
calcium
magnesium
calcium
magnisium
young
mature
Calcium and magnesium of amaranth at different stages

b)




c)

**Figure 4.5: Effect of harvest maturity and processing on mineral content (Calcium and magnesium) of (a)stinging nettle, (b)amaranth and (c)black nightshade.**

### 4.4.3 Calcium content

Fresh leaves sample had higher content as compared to processed leaf samples (figure 4.5). Fresh amaranth at both stages of maturity had the highest calcium content as 325.38mg/100g and 541.79mg/100g at young and mature stage respectively. On the other hand, the least content was reported on black nightshade at young and mature stage as 271.03mg/100g and 491.44mg/100g respectively. These values are within the range reported by Uusiku *et al.* 2010, where they reported a range of ALVs to be 15mg/100g in some species of Chenopodium and 888mg/100g in U. urens. Schnfeld 2011 reported calcium content of South Africa GLVs from a range of 151-586mg/100g. There was a significant increase ($P \leq 0.05$) on calcium content as leaf ages in all ALVs studied. Increase in calcium content may be due to accumulation with advancing maturity because of its immobile nature. Similar increase was observed by Yang and

Keding (2009) where they reported an increase in calcium content. Drying had a significant difference (P≤0.05) on the calcium content on the ALVs studied. Freeze drying was significantly higher as compared to solar drying. However, drying caused a significant decrease (P≤0.05) in calcium content. Sheetal *et al.,* (2011) reported a decrease in *Chenopodium album* leaf reduced to more than half of its calcium content from 27.88 mg/100 g of fresh greens to 6.94 mg/100 g of dried greens. Decrease in calcium availability maybe influenced by dietary fiber components and organic acids. Blanching on the content of calcium of the ALVs, reported significantly lower (P≤0.05) as compared to the unblanched leave samples. Schnfeld 2011, found similar results on South Africa GLVs where there was a decrease in calcium content of cooked cowpeas leaves from 221-151mg/100g and cat whiskers from 393-265mg/100g. Reduction in calcium content in blanched may be due to leaching out into the blanching water (Vorster *et al.,* 2002). Slicing as well showed a significant difference (P≤0.05) on the content of calcium in the ALV. Sliced samples were significantly lower as compared to unsliced leave samples. Slicing of the vegetables increases the surface area, damaging the cell structure therefore altering the availability of minerals.

### 4.4.4 Magnesium content

Magnesium content in the ALVs studied (figure 4.5) was similarly higher in fresh as compared to processed leaf samples. Fresh amaranth at both maturity stages was the highest with magnesium content of 199.15mg/100g and 331.95mg/100g at young and mature stage respectively. While the least was reported in stinging nettle solar dried sliced blanched at young and mature stage as 129.27mg/100g and 271.62mg/100g respectively. The values are within the range reported by Gupta *et al.,* (2004) which they gave magnesium levels in *Cocculus Hirsutus* (Broom Creeper) and *amaranthus tricolor* (Amaranth) range from 35 and 253mg/100g respectively. Magnesium content increased significantly (P≤0.05) following maturation of the leaves. Similar increase was reported by Michael and Anthony, (2007), where they studied effect of plant maturity on mineral

content of leaves of *Memordica balsamia*. According to Khader and Rama (2003), the increase may probably be caused by its ion being in an unfixed or dissociable form that accumulates with age.

Drying as well showed a significant difference ($P \leq 0.05$) in the magnesium content. Freeze dried samples retained better than solar dried samples. Drying caused a significance reduction in magnesium content. Blanching had a significant difference ($P \leq 0.05$) as compare to unblanched leaf samples. Magnesium content of blanched samples was significantly lower as compared to fresh and unblanched samples. Similar observation was reported by Slupski *et al.*, (2005) who found greater loss in blanched dill leaf as compared to raw leaf. Losses of these mineral during cooking/blanching/boiling can be due to leaching of the cell content including mineral into the blanching water (G. Oboh, 2005). Slicing as well showed a significant difference ($P \leq 0.05$) on the magnesium content. Lower values were reported on sliced than unsliced. Arnard Landry *et al.*, 2016 reported similar findings on the content of magnesium where magnesium content was lower on the sliced than on unsliced leaves of *A. cruentus* (red/purple Amaranth) and *A. hybridus (green Amaranth)*. According to various food processing techniques, like cutting, it causes a decrease in the mineral content of the vegetables (Shahnaz *et al.*, 2003).

### 4.5 Color changes during processing

Color of the food is the first quality parameter evaluated by consumers and is critical in product acceptance, even before it is tasted. From the table 4, L* value (brightness/darkness) was used to characterize the coloration of both fresh and processed leaves samples of stinging nettle, amaranth and black nightshade at different stages of growth. At young stage, stinging nettle and black nightshade solar dried sliced blanched were darker (L* 35.46 and 35.43) respectively as compared to amaranth and at mature stage stinging nettle solar dried sliced blanched was darker (L* 37.55) as compared to amaranth and black nightshade.

**Table 4: Effect of harvest maturity and processing (slicing, blanching, solar and freeze-drying methods) on color of young and mature stinging nettle, Amaranth and Black nightshade**

| | Stinging nettle | | Amaranth | | Black nightshade | |
|---|---|---|---|---|---|---|
| **L*value** | **Young** | **mature** | **Young** | **Mature** | **Young** | **Mature** |
| **SDUU** | $44.67\pm2.95^{fA}$ | $47.49^{\pm}0.95^{gD}$ | $46.55\pm2.76^{fC}$ | $49.25\pm0.44^{hF}$ | $45.46\pm0.10^{gB}$ | $48.48\pm0.21^{gE}$ |
| **SDUB** | $37.40\pm2.25^{cA}$ | $39.47\pm1.01^{cB}$ | $39.49\pm1.77^{cB}$ | $42.44\pm0.85^{cD}$ | $37.37\pm2.68^{cA}$ | $41.51\pm0.12^{cC}$ |
| **SDSU** | $41.72\pm1.26^{eA}$ | $43.51\pm2.56^{fC}$ | $43.51\pm0.81^{eC}$ | $45.55\pm0.35^{eD}$ | $42.70\pm1.51^{fB}$ | $45.65\pm0.67^{fD}$ |
| **SDSB** | $35.46\pm1.50^{bA}$ | $37.55\pm1.10^{bB}$ | $37.63\pm1.04^{bB}$ | $39.53\pm0.51^{bC}$ | $35.43\pm2.69^{bA}$ | $39.57\pm0.56^{bC}$ |
| **Fresh** | $31.68\pm2.07^{aA}$ | $33.67\pm1.97^{aC}$ | $33.64\pm0.77^{aC}$ | $35.65\pm0.89^{aD}$ | $32.37\pm1.27^{aB}$ | $35.62\pm0.61^{aD}$ |
| **FDUU** | $47.60\pm1.25^{gA}$ | $50.13\pm0.40^{hD}$ | $49.31\pm0.40^{gC}$ | $52.43\pm1.04^{iE}$ | $48.59\pm1.21^{hB}$ | $52.56\pm0.55^{iE}$ |
| **FDUB** | $39.44\pm1.60^{dA}$ | $41.38\pm2.54^{eB}$ | $43.52\pm0.95^{eC}$ | $46.35\pm0.17^{fE}$ | $41.65\pm0.90^{eB}$ | $44.70\pm0.72^{eD}$ |
| **FDSU** | $44.69\pm1.25^{fA}$ | $47.46\pm0.64^{gC}$ | $46.45\pm1.16^{fC}$ | $48.47\pm0.47^{gD}$ | $45.47\pm0.62^{gB}$ | $49.67\pm0.93^{hE}$ |
| **FDSB** | $37.64\pm0.44^{cA}$ | $40.35\pm1.21^{dB}$ | $40.43\pm1.00^{dB}$ | $43.44\pm0.38^{dC}$ | $39.62\pm1.53^{dA}$ | $43.41\pm0.35^{dC}$ |

Values are given as means of three replicates ± SD. Means with different superscript upper-case letters across the row and lower case within the column are significantly different ($P < 0.05$). SDUU-solar dried unsliced unblanched, SDUB-solar dried unsliced blanched, SDSU-solar dried sliced unblanched, SDSB-solar dried sliced blanched. FDUU-freeze dried unsliced unblanched, FDUB-freeze dried unsliced blanched, FDSU-freeze dried sliced unblanched, FDSB-freeze dried sliced blanched and fresh-fresh sample (no processing).

The ALVs studied showed a significant difference ($P\leq0.05$) on the maturity of L* value. Young leaves were darker than mature leaves. This was in line with Nashiela *et al.*, 2015, where they found young leaves of C. *caudatus (*tassel flower) to be darker than mature leaves. Marete *et al.*, 2009 attributed this dark color with higher total phenolic content in the sample.

There was a significance difference ($P\leq0.05$) on effects of drying methods on the color of the samples. There was increased brightness (L*) on the dried leave samples as compared to fresh samples. These indicated that the dried samples were much brighter

as compared to fresh samples. Similar results were reported by Khaled *et al.,* 2014, where after studying effect of drying methods on color of Portulaca oleracea L. leaves, they found the dried leaves significantly increased brightness as compared to fresh leaves. Whereas freeze dried presented brighter colors as compared to solar dried samples (darker). Darkening of the leaf samples on solar dried samples may be due to solar radiation effects and high temperature unlike to freeze dried samples (Shitanda and Wanjala, 2006). In addition, Rahimmalek and Goli, (2013) added that long drying time and high temperature is the most effective factors in color damage.

Blanching on the other hand showed a significant difference ($P \leq 0.05$) on the L* value of the studied ALVs. Blanched leaves were significantly darker as compared to the unblanched leaves which were brighter as shown in the table 7. Raja *et al.*, (2017), found higher brightness (53.8) in non-blanched Carica papaya L. leaf than blanched samples (50.2) and Puree *et al.,* (2016), found lighter color on fresh cocoyam leaf and dark color on water blanched leaf sample. Dark color in blanched samples could be due to inactivation by endogenous enzyme during blanching responsible for color degradation causing the leaf tissue to be succulent, resulting to mass compactness finally limits the lightness (Ankita and Parasad, 2015; Haile *et al.*,2015). Slicing as well showed a significant difference ($P \leq 0.05$) on the L* value. Sliced blanched showed lower L* value as compared to sliced unblanched.

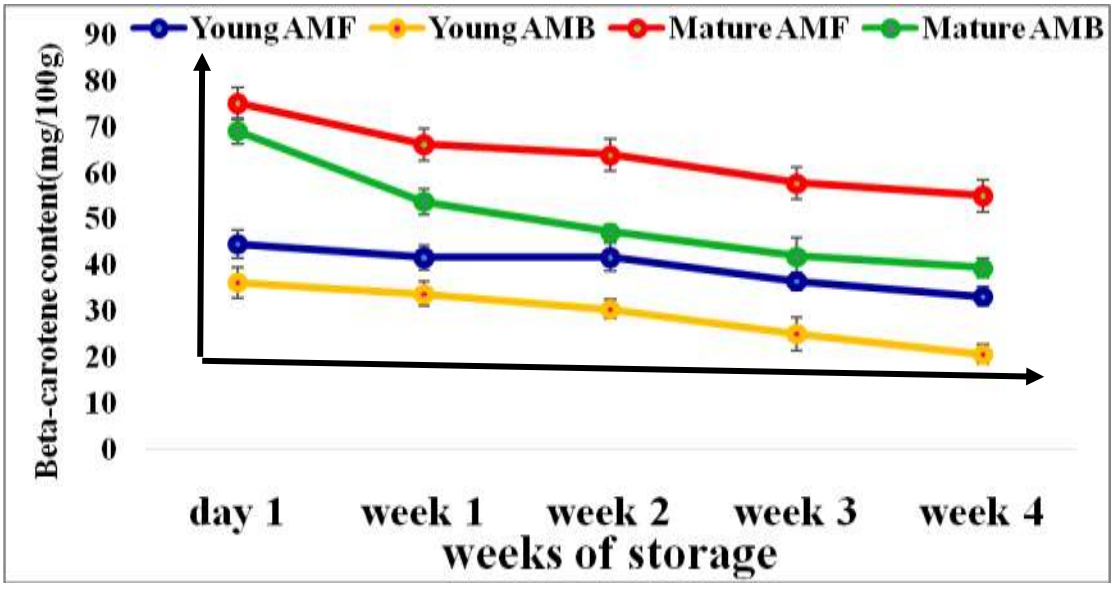
**Objective 2; to assess the effect of different packaging materials on the nutritional stability of the minimally processed ALVs**

### 4.6 Effect of storage (Ziploc bag packaging) on β-carotene content (mg/100g) of ALVs

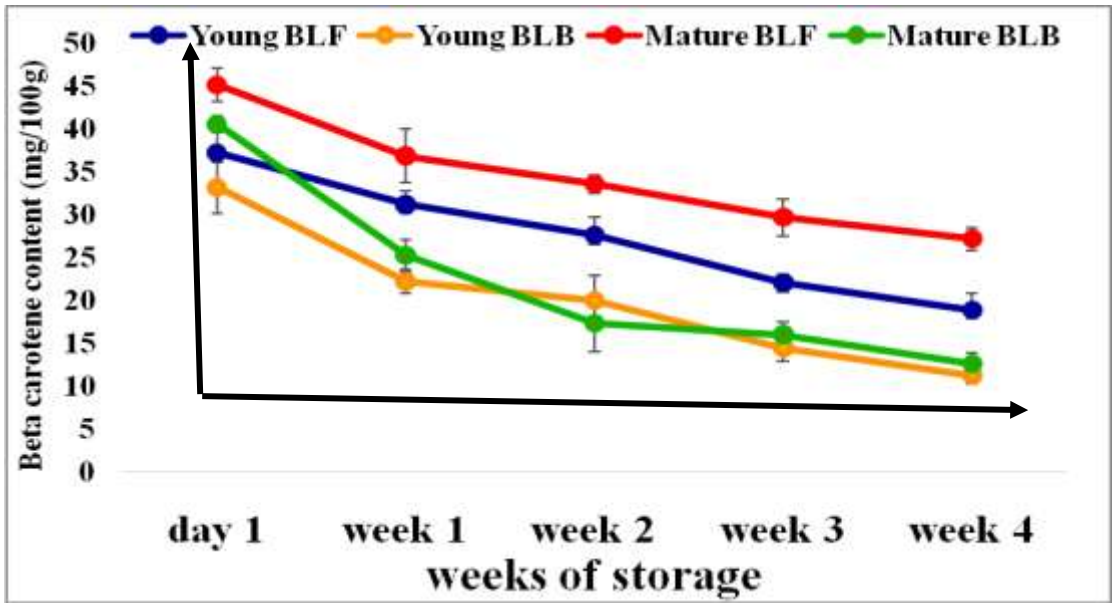
The results of beta carotene content of frozen Amaranth, Black nightshade and Stinging nettle before and after packaging for the four weeks, of amaranth, blacknightshade and stinging nettle are shown in figure 4.6. The highest beta carotene content was reported on amaranth (44.53mg/100g and 75.08mg/100g) before packaging at young and mature stage respectively. On the other hand, lowest beta carotene content before packaging,

was observed in blacknighshade (37.13mg/100g and 45.05mg/100g) at young stage and mature stage respectively. For the processed ALVs, blanched amaranth reported higher beta carotene content of 36.22mg/100g and 75.08mg/100g at young stage and mature stage before packaging. On the other hand the lowest beta carotene content before packaging, was reported in blanched black nightshade at both stages of maturity, young and mature as 33.10mg/100g and 40.51mg/100g respectively. After packaging, as from week 1 to week 4, fresh samples reported a higher beta carotene content as compared to blanched samples from both maturity stages. At young stage from week 1, 2,3 and 4 for fresh samples, the highest beta carotene content was similar reported in amaranth as 41.66/100g, 41.67mg/100g,36.57mg/100g and 33.24mg/100g. Between point 0-day 1 there was a decrease in the beta carotene content.

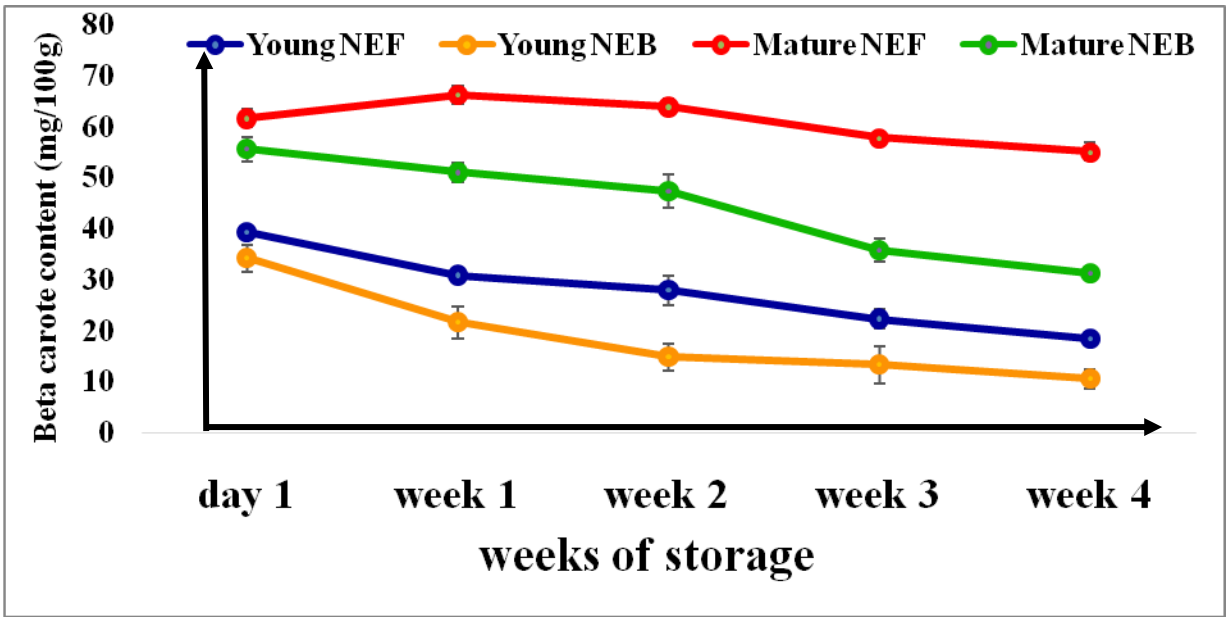
respectively. On the other hand , the lowest beta carotene content was observed in both blacknightshade and stinging nettle where there was no significance difference between them at young stage. For the processed ALVs after packaging, blanched amaranth at young stage, had the highest from week 1, 2 , 3 and 4 as 33.82mg/100g, 30.40mg/100g, 25.13mg/100g and 20.64mg/100g respectively. Blanched blacknightshade and stinginging nettle had the least beta carotene content for the four weeks of packaging.



a)


Young BLF
Young BLB
Mature BLF
Mature BLB
Beta carotene content (mg/100g)
50
45
40
35
30
25
20
15
10
5
0
day 1
week 1
week 2
week 3
week 4
weeks of storage

b)


Young NEF
Young NEB
Mature NEF
Mature NEB
Beta carote content (mg/100g)
80
70
60
50
40
30
20
10
0
day 1
week 1
week 2
week 3
week 4
weeks of storage

c)

**Figure 4.6: Effect of storage (Ziploc bag packaging) on β-carotene content (mg/100g) of frozen (a) amaranth, (b) black nightshade and (c) stinging nettle.**

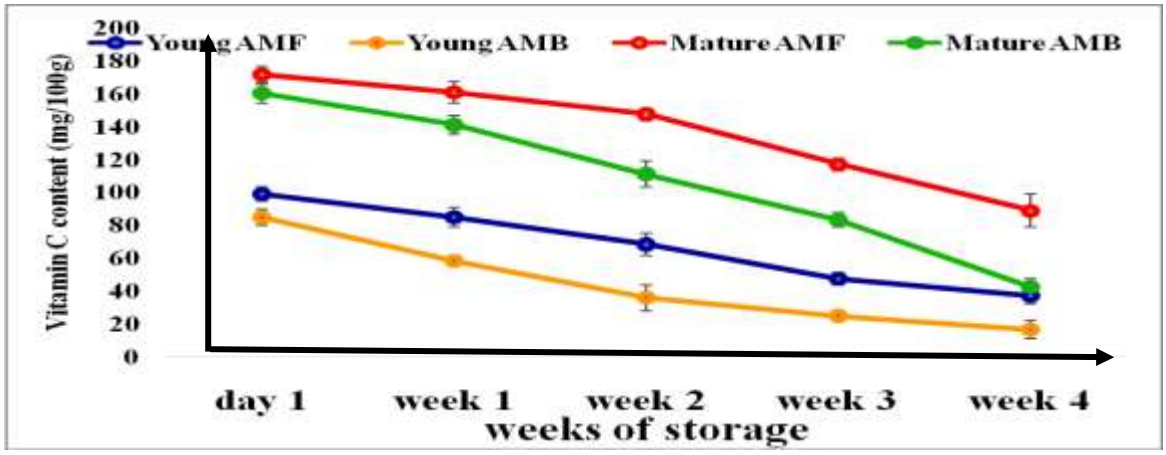
Values are given as means (mg/100g) of three replicates ± SD). **AMF-**Amaranth fresh**, AMB-**Amarath blanched**, BLF-**Black nightshade fresh**, BLB-**Black nightshde blanched**, NEF-**Stinging nettle fresh, **NEB-**Stinging nettle blanched

Beta carotene was significantly higher in mature leaves than young leaves. Suggesting that beta carotene content increases with maturation. Some researchers reported that vitamin C concentration is highest in mature leaves with fully developed chloroplasts (Khan *et al.*, 2011) and regardless of fertilizers used, vitamin C content increased with maturity in spider plant and black nightshade grown in Kenya (Ayua *et al.,* 2016). Blanching had a significant difference ($P \leq 0.05$) on the content of beta carotene when Amaranth, stinging nettle and black nightshade leaves were frozen for four weeks. Fresh samples had a higher beta carotene content than blanched samples. As reported by Bédouet *et al.*, (2015), during blanching, leaf tissue cells are disrupted making the organelles containing carotenoids more accessible accounting for the carotenoid extraction hence lesser beta carotene content than fresh. Similar results were reported by bouzari *et al.*, (2014) where after blanching and freezing peas, green beans and broccoli found a 30% loss in beta carotene content. There was a significance difference ($p \leq 0.05$) in beta carotene when ALVs leaves were frozen for 4 weeks. From the above fig 1,2 and 3, beta carotene content over time from week 1-4 beta carotene content reduced in all the leave samples.

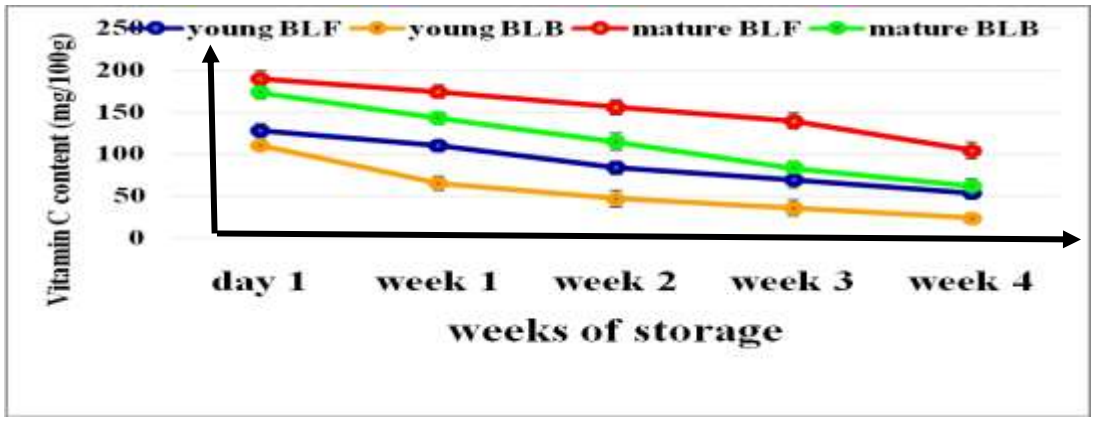
### 4.7 Effect of storage (Ziploc bag packaging) on Vitamin C content

Results for vitamin C of frozen amaranth, blacknightshade and stinging nettle before and after packaging for the two stages of maturity are shown in figures 4.7. Fresh stinging nettle at young stage and mature stage had the highest content of vitamin C of 149.71mg/100g and 197.75mg/100g while the least was reported in amaranth

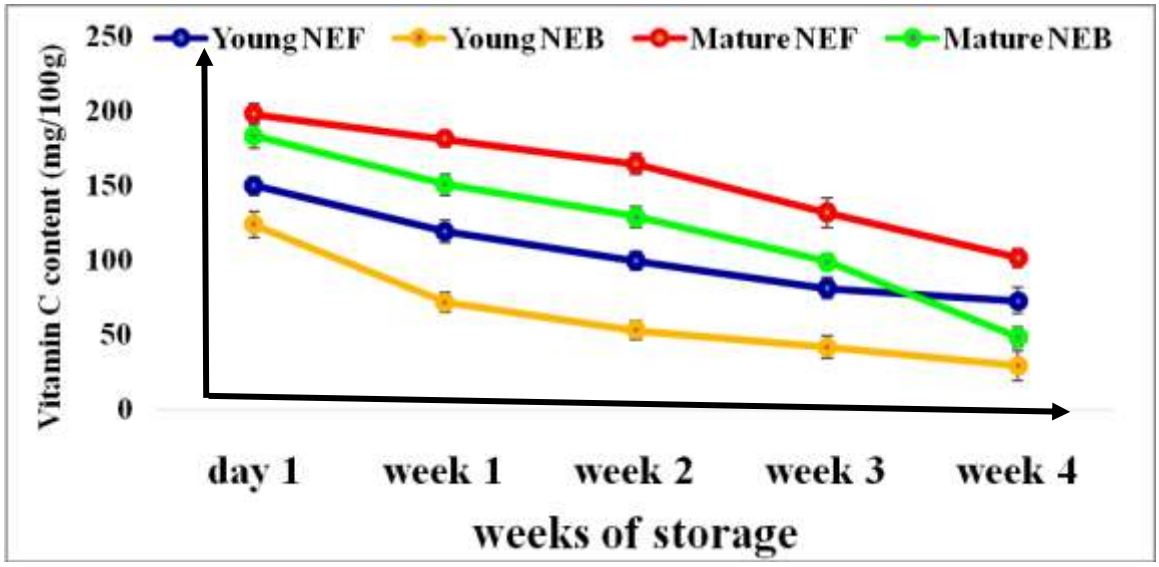
(99.11mg/100g and 171.69mg/100g) before packaging both at young and mature stage respectively. Blanched stinging nettle had the highest vitamin C content of (123.65mg/100g and 183.12mg/100g) at young stage and mature stage respectively. After packaging, fresh stinging nettle had the highest content of vitamin C in week 1, 2, 3 and 4 as 119.25mg/100g, 99.54mg/100g, 81.27mg/100g and 72.85mg/100g respectively at young stage. On the other hand, least vitamin C content was reported in amaranth for week 1, 2, 3 and 4 as 85.08mg/100g,68.55mg/100g, 47.57mg/100g and 37.41mg/100g respectively. For the blanched samples, stinging nettle had the highest content of vitamin C at young stage for the week 1, 2, 3 and 4 as 71.65mg/100g, 53.26mg/100g, 41.87mg/100g and 29.54mg/100g respectively. Least vitamin C content was reported in blanched fresh amaranth for week 1, 2, 3 and 4 as 58.50mg/100g, 36.15mg/100g, 25.18mg/100g and 16.86mg/100g respectively.




a)




b)




c)

**Figure 4.7: Effect of storage (Ziploc bag packaging) on Vitamin C content (mg/100g) of frozen(a) amaranth, (b) black nightshade and (c) stinging nettle**

Values are given as means (mg/100g) of three replicates ± SD). **AMF**-Amaranth fresh**, AMB**-Amarath blanched**, BLF**-Black nightshade fresh**, BLB**-Black nightshde blanched**, NEF**-Stinging nettle fresh, **NEB**-Stinging nettle blanched

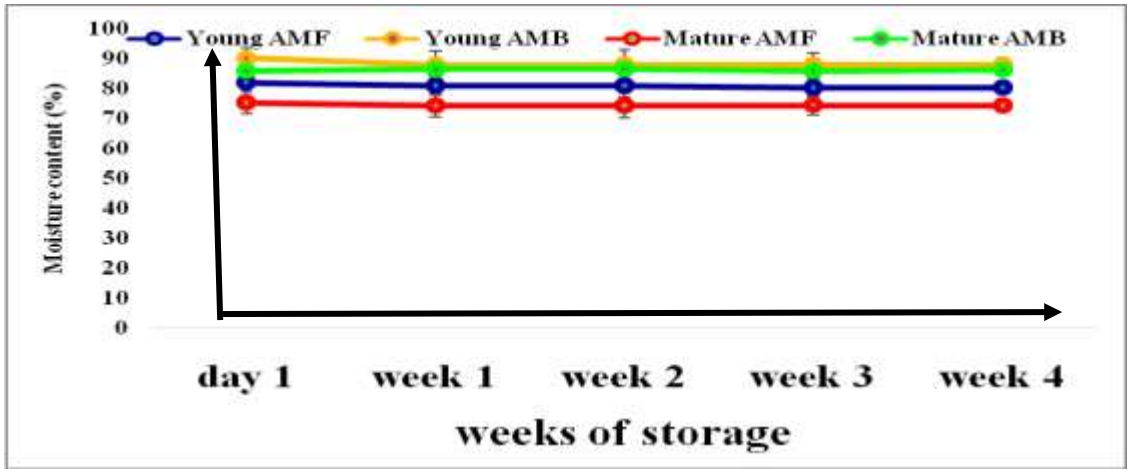
Mature leaves had a significant difference (P≤0.05) on the content of vitamin C as compared to young stage. Yamada *et al.* 2003, reported similar findings where spinach had a higher content of vitamin C at mature stage than young stage. Blanching had a significance difference (P≤0.05) on the ALVs where vitamin C content was lower as compared to fresh leaves. Jaworski, (2005b) reported a loss of 70% of blanched spinach in comparison with raw spinach. In addition, Rita puppies, (2003), reported average loss during blanching/freezing of approximately 30% for peas, 10% for green beans, 30% for broccoli, and 40% for spinach. The losses of vitamin C, as explained by Franke *et al.*, (2004), is that vitamin C is highly sensitive to oxidation and it is the least stable nutrient during processing which may leach into blanching medium.

There was a significance difference (P≤0.05) on the ALVs leaves frozen for 4 weeks. Significant reduction in vitamin C content at each week of storage was observed. Similar findings were reported by Prabhu and Barrett, (2009) where they found a loss of 31% and 72 % of *cassia tora* leaves and 59% and 60% of *C. tridens* loss of their initial ascorbic acid during freeze storage for 14 days.In addition, Hunter and Fletcher, (2002) noted poor retention of vitamin C of spinach after freezing at -18°c storage. This may be due to instability of vitamin C during storage which is easily oxidized gradually reducing during storage (Yahia *et al.*, 2001). However, irrespective of vitamin C losses, the AIVs were within the recommended daily intake range of 65mg/day to 90mg/day in adults. For children and adolescents, it ranges between 75.6-100mg/day.

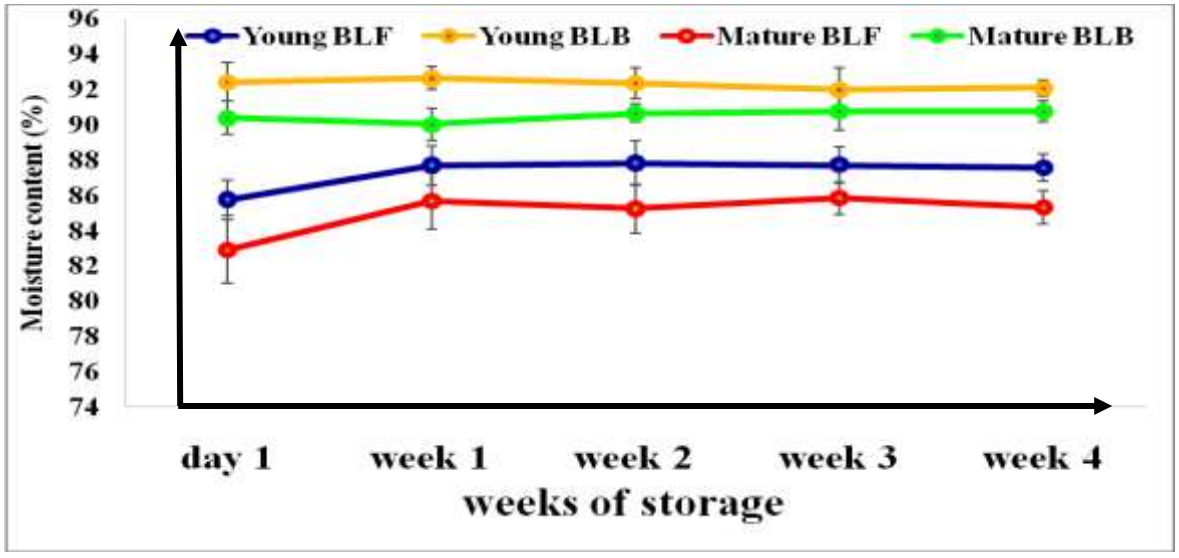
### 4.8 Effect of storage (Ziploc bag packaging) on% moisture content (mg/100g) of ALVs

Moisture content results of amaranth; black nightshade and stinging nettle before and after packaging for 4 weeks at different harvest maturity are presented in figure 4.8. Blanched samples reported to have a higher moisture % than the fresh samples both before and after packaging. Where blanched black nightshade had 92.43% higher than the fresh black nightshade which had 85.77% among the ALVs studied. After packaging from week 1, 2, 3 and 4, fresh black nightshade similarly was shown to have

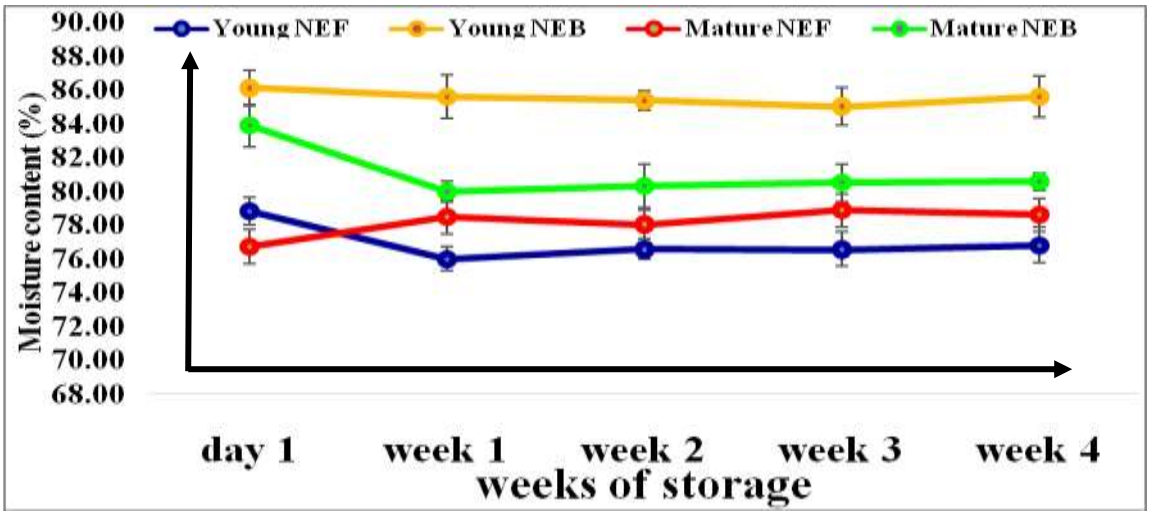
the highest % of moisture as compared to the other ALVs at young stage as 87.69%, 87.84%, 87.72% and 87.57% respectively. Least moisture % was reported in stinging nettle as 76.02%, 76.60%, 76.59% and 76.83% respectively for the 4 weeks. Similar trend was observed in fresh mature where black nightshade had the highest moisture% and stinging nettle having the least moisture % for the 4 weeks of packaging. It has been noted that, fresh amaranth can be stored for 7days under room temperature.




a)




b)




c)

**Figure 4.8: Effect of storage (Ziploc bag packaging) on% moisture content (mg/100g) of(a) amaranth, (b) black nightshade and (c) stinging nettle .**

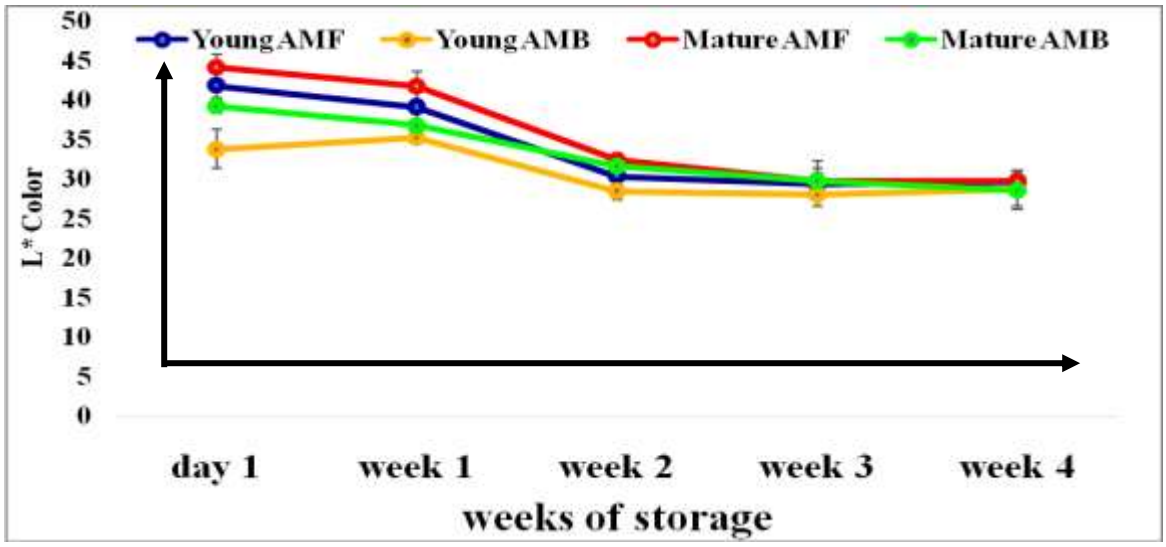
Values are given as means (mg/100g) of three replicates ± SD). **AMF**-Amaranth fresh**, AMB**-Amarath blanched**, BLF**-Black nightshade fresh**, BLB**-Black nightshde blanched**, NEF**-Stinging nettle fresh, **NEB**-Stinging nettle blanched

Moisture content % decrease as the leaves ages. Young leaves had a higher moisture content % .as compared with mature stage. Findings concur with Florkowski *et al.*, (2009), who observed a decrease in moisture content of *Cleome gynandra (African spider flower)* upon maturation. This may be due to structural changes as leaf grows older probably due to transpiration and starch hydrolysis. In addition, the fresh leaf sample reported significantly lower content ($P \leq 0.05$) of moisture % as compared to the blanched. The higher content of moisture content in blanched may be probably due to adsorption of water into damaged cells and water clinging to vegetable leaf surfaces. There was no significance difference ($P \geq 0.05$) on the % of moisture content during storage, though there was a slight increase which was not significant. Small fluctuation

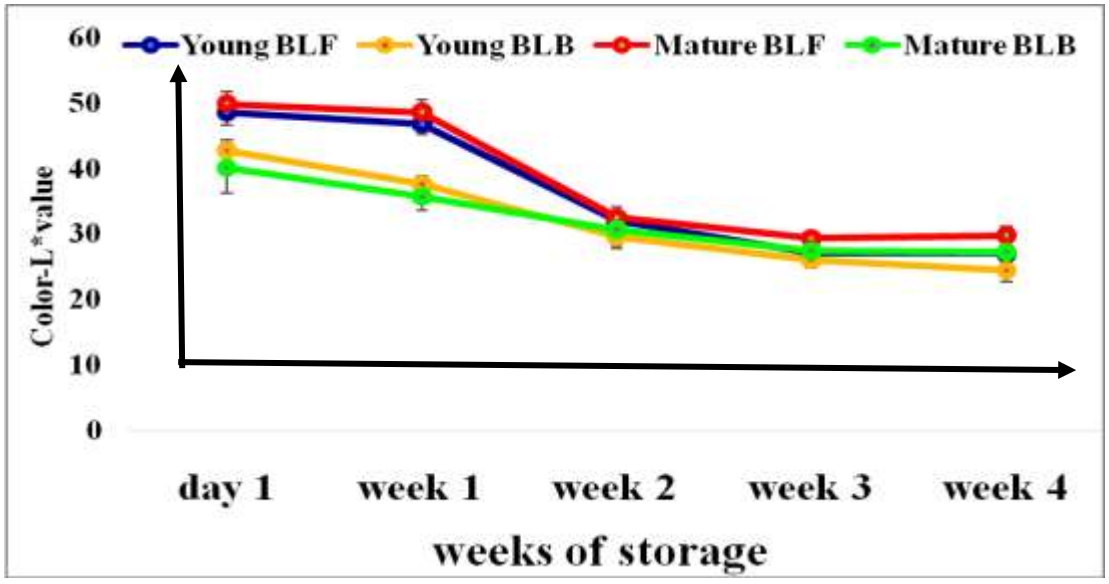
on moisture content noted during storage was mostly due to the respiration and other enzymatic processes (Jacxsens *et al.*, 2002). Similar findings were reported by Yoko *et al.*, (2000) where he studied spinach, komatsuna and kaiware frozen for 14 days and observed non-significant changes in moisture content.

**4.9 Effect of storage (Ziploc bag packaging) on Color (L*) % (mg/100g)**

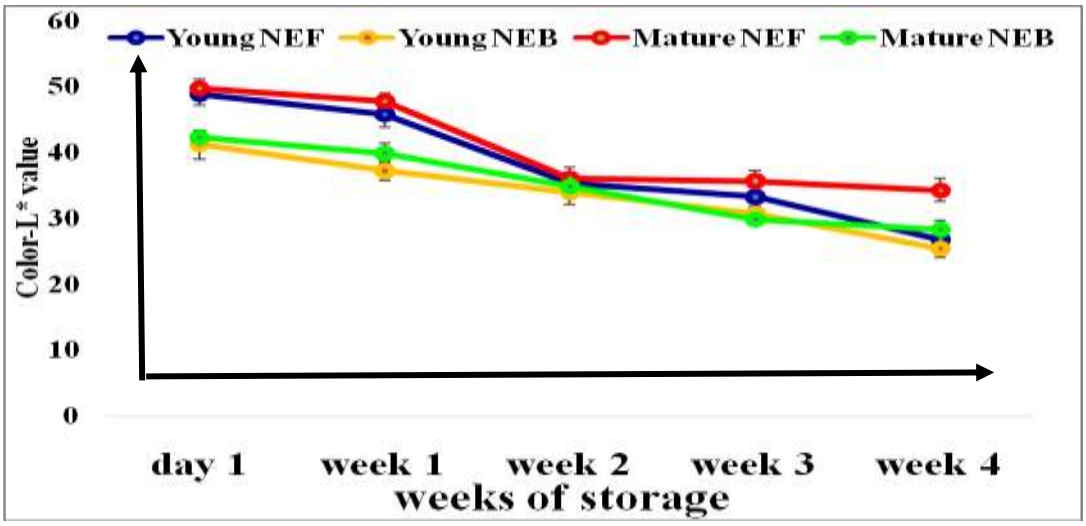
L* value is used as a parameter to indicate lightness/brightness. Results for color L* value are presented in figure 4.9. Changes in L* value on the frozen leaf samples indicated a decrease in L* value during the four weeks of storage. However fresh samples has reported a higher L* value while blanched samples had lower L* values. On the ALVs studied, the fresh black nightshade and stinging nettle had a higher L* value (48.57 and 48.83) respectively as compared to amaranth(41.83). Maturity on the other hand, showed a significant difference ($P \leq 0.05$) on the L* value of amaranth, black nightshade and stinging nettle. L* value for mature leaves were significantly higher than the young leaf samples. Similar findings were reported by Nashiela *et al.*, (2016) who found young leaves of *C. caudatus* (ulam raja) to be significantly darker than mature leaves. Blanched as well showed significant difference on the L* value ($P \leq 0.05$) where the L* value were darker as compared to fresh leaf samples as shown in the fig 10,11 and 12. Raja *et al.*,(2017) reported similar observation on blanched *Carica papaya* L.(papaya) leaf on reduced lightness on blanched. These might be due to thermal oxidation or light degradation. L* value on storage was found to significantly decreasing on the first and second week while on the third and fourth week did not change significantly.


Young AMF
Young AMB
Mature AMF
Mature AMB
L* Color
50
45
40
35
30
25
20
15
10
5
0
day 1
week 1
week 2
week 3
week 4
weeks of storage

a)


Young BLF
Young BLB
Mature BLF
Mature BLB
Color-L*value
60
50
40
30
20
10
0
day 1
week 1
week 2
week 3
week 4
weeks of storage

b)




**c)**

**Figure 4.9: Effect of storage (Ziploc bag packaging) on color) of (a) amaranth, (b) black nightshade and (c) stinging nettle.**

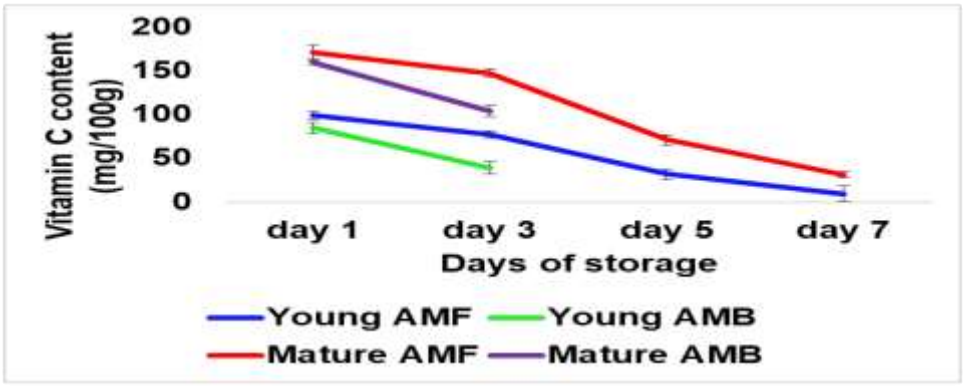
Values are given as means (mg/100g) of three replicates ± SD). **AMF**-Amaranth fresh**, AMB**-Amarath blanched**, BLF**-Black nightshade fresh**, BLB**-Black nightshde blanched**, NEF**-Stinging nettle fresh, **NEB**-Stinging nettle blanched

### 4.10 Effect of storage (Xtend bag packaging) on Vitamin C(mg/100g) of ALVs

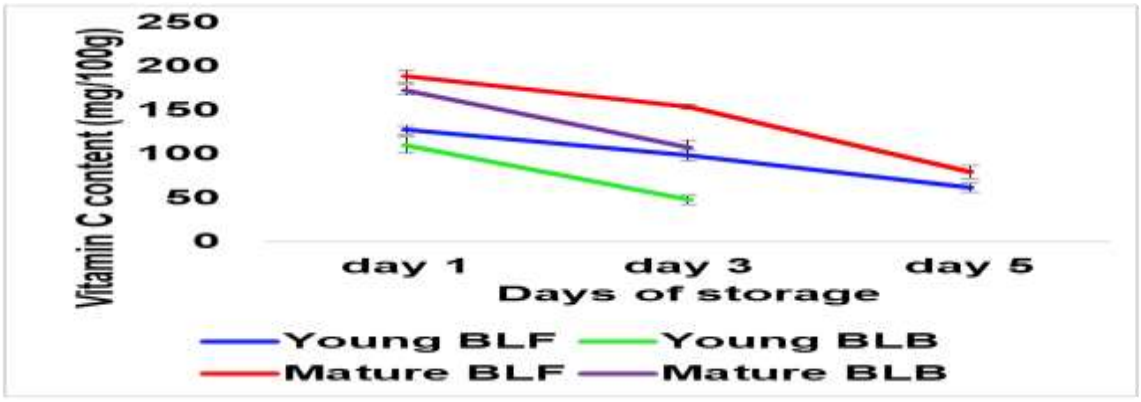
Packaging under Ziploc bag on the nutrition stability; vitamin C of processed are shown in figure 4.10. Fresh samples have shown to be significantly higher in vitamin C content than the blanched samples both before and after packaging. Among the different 'xtend' bags used, there was no significance difference ($P \geq 0.05$) between them. Before packaging, fresh stinging nettle had the highest vitamin C content of 149.71mg/100g and 197.71mg/100g at young and mature stage respectively. Similarly, blanched stinging nettle had the highest content (123.65mg/100g and 183.12mg/100g) at both

stages of maturity. Least was blanched amaranth (85.05mg/100g and 160.14mg/100g) at young and mature stage. After 2 days of packaging, there was a decline in vitamin C

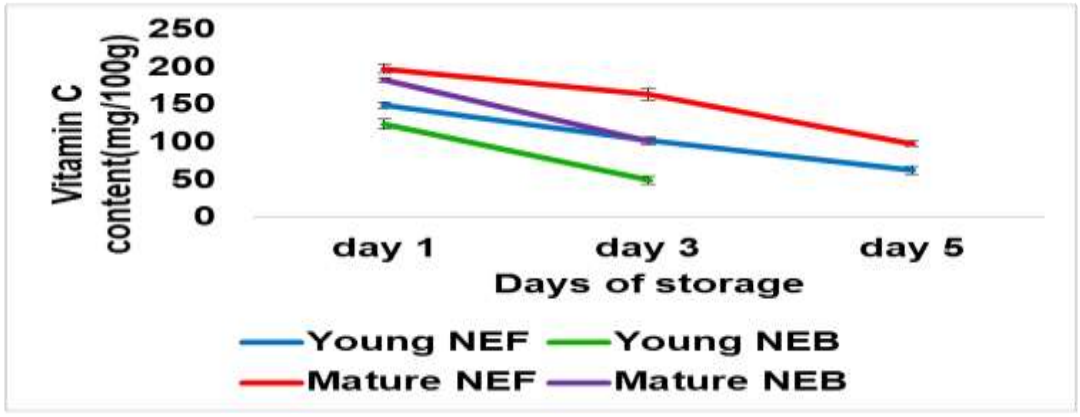
and fresh stinging nettle retained the highest content of vitamin C of 103.37mg/100g at young stage. While the least vitamin C content was in fresh amaranth having 76.67mg/100g. On day 5, fresh stinging nettle had retained the highest vitamin C content of 63.48mg/100g and the least was amaranth (30.75mg/100g) at young stage. Blanched samples on day 5 had already gone bad. On day 7, all ALVs had gone bad except amaranth, which had finally retained vitamin C content of 9.44mg/100g and 31.54mg/100g at young and mature stage respectively.


Vitamin C content (mg/100g)
200
150
100
50
0
day 1
day 3
day 5
day 7
Days of storage
Young AMF
Young AMB
Mature AMF
Mature AMB

a)


Vitamin C content (mg/100g)
250
200
150
100
50
0
day 1
day 3
day 5
Days of storage
Young BLF
Young BLB
Mature BLF
Mature BLB

b)


Vitamin C content(mg/100g)
250
200
150
100
50
0
day 1
day 3
day 5
Days of storage
Young NEF
Young NEB
Mature NEF
Mature NEB

c)

**Figure 4.10: Effect of storage ('xtend' bag) on vitamin C content of (a)amaranth, (b)black nightshade and (c)stinging nettle stored at room temperature (dry weight basis)**

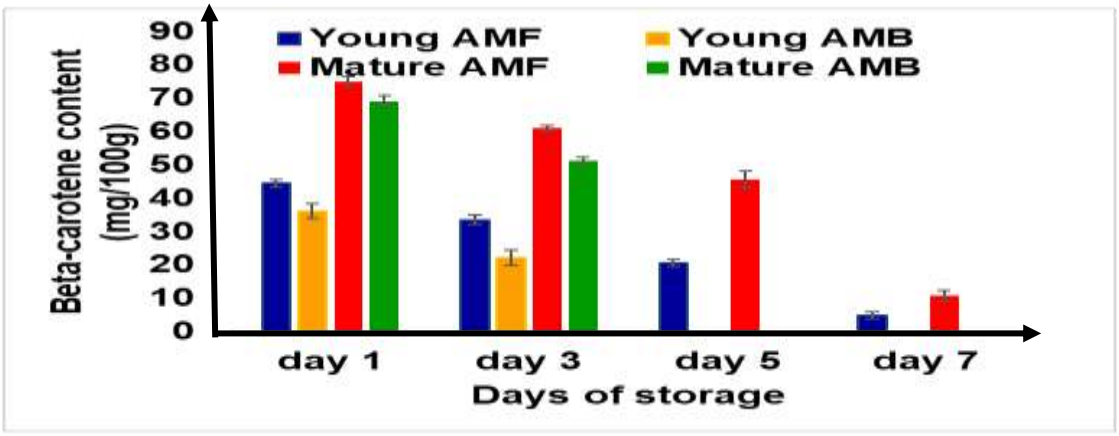
Values are given as means (mg/100g) of three replicates ± SD). **AMF**-Amaranth fresh**, AMB**-Amarath blanched**, BLF**-Black nightshade fresh**, BLB**-Black nightshde blanched**, NEF**-Stinging nettle fresh, **NEB**-Stinging nettle blanched

There was a significant difference of vitamin C ($P \leq 0.05$) as the leaves ages. At young stage, the content of vitamin C in xtend bags during the stored periods, were lower than mature stage. Similar findings were observed by Omary *et al.,* (2003), who found higher content of vitamin C during period of maturation of broccoli leaf. Processing of vegetable leaves, had an effect of Vitamin C content. Fresh samples were significantly higher ($P \leq 0.05$) compared to blanched samples. Results agree with the study by Volden *et al.,* (2009) where there was a loss of 41% of vitamin C content in blanched cauliflower compared to the unblanched. This may be due to, vitamin C being heat labile and much of it was lost during blanching and heat treatment. There was a significance difference ($P \leq 0.05$) on content of vitamin C in the ALVs leaves stored for 3, 5 and 7 days at room temperature. Higher rate of vitamin C loss were noted during each stored day. changes can result from alterations in expression of genes and activity of enzymes in the pathway of Vitamin C metabolism during storage (Galani *et al.,* 2017). Vitamin C might be synthesized as a response to the stress caused by the storage temperature and then Similar findings were reported by Nyaura *et al.,* (2014), after investigating effect of amaranth leaves packed in modified atmospheric packaging at room temperature for several days. Loss of vitamin C during the stored period may be due to the effect of residual oxygen retained in the active bag packaging (Nyaura *et al.,* 2014). Reduction of beta-carotene can be prevented by using of ziploc bag storage. Which it retained nutrients to 4weeks.

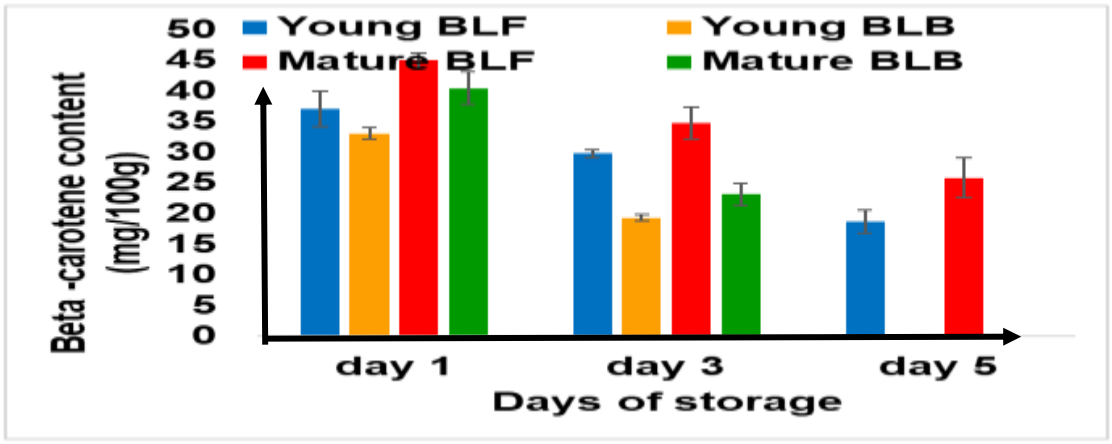
### 4.11 Effect of storage (Xtend bag packaging) on β-carotene (mg/100g) of ALVs

Beta carotene content results of amaranth, black nightshade and stinging nettle with different 'xtend' active bags packaging at room temperature are shown in figure 4.11. Before and after packaging, fresh samples had shown to have higher beta carotene content than the blanched samples. In addition, mature stage had higher content of beta carotene than young stage. Before packaging, fresh amaranth at both stages had the highest beta carotene of 44.53mg/100g and 75.08mg/100g at young and mature stage respectively. Fresh black nightshade had the least beta carotene content of 37.13mg/100g and 45.05mg/100g at young and mature stage respectively. Lower level

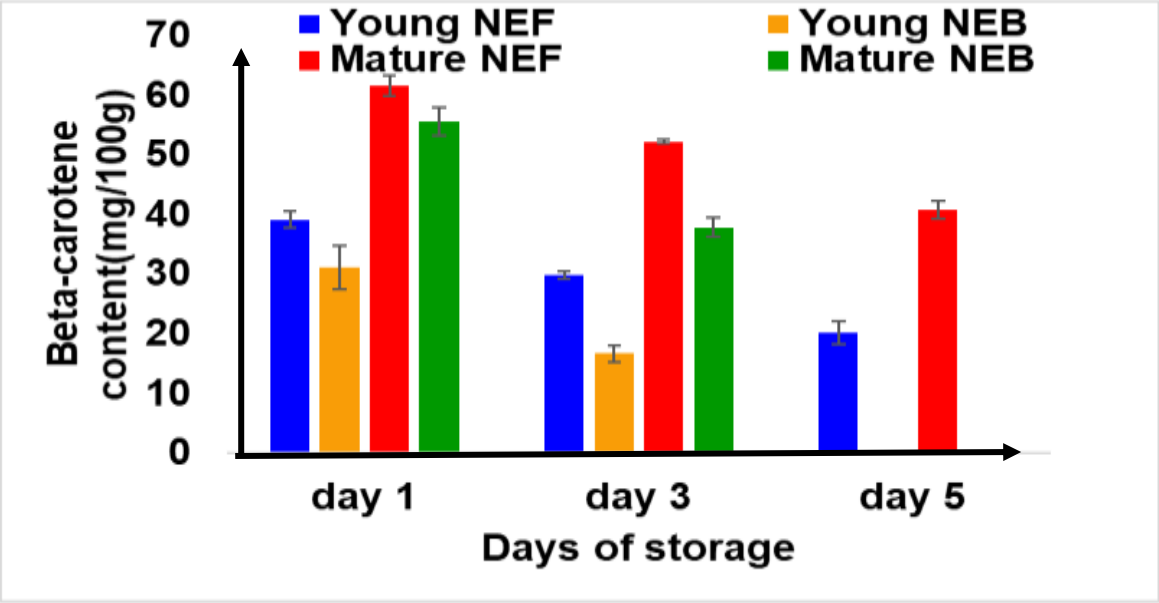
of beta-carotene was in blanched black nightshade were; 33.10mg/100g and 40.51mg/100 at both young and mature stage respectively. After 2days of packaging, beta carotene content had declined and the highest had retained 33.62mg/100g in amaranth at young stage while the least was observed in black nightshade and stinging nettle as 27.85mg/100g and 28.66mg/100g respectively. On the $5^{th}$ day, fresh stinging nettle had the highest beta carotene content of 20.26mg/100g and 20.63mg/100g at young stage. On the $7^{th}$ day, only amaranth had not gone bad. At young stage, beta carotene content had decline to 4.95mg/100g and 10.85mg/100g at mature stage.


Beta-carotene content
(mg/100g)
90
80
70
60
50
40
30
20
10
0
Young AMF
Mature AMF
Young AMB
Mature AMB
day 1
day 3
day 5
day 7
Days of storage

a)


Beta -carotene content
(mg/100g)
50
45
40
35
30
25
20
15
10
5
0
Young BLF
Mature BLF
Young BLB
Mature BLB
day 1
day 3
day 5
Days of storage

b)




c)

**Figure 4.11: Effect of storage ('xtend' bag) on beta carotene of (a)amaranth, (b)black nightshade and (c)stinging nettle kept at room temperature**

Values are given as means (mg/100g) of three replicates ± SD). **AMF**-Amaranth fresh**, AMB**-Amarath blanched**, BLF**-Black nightshade fresh**, BLB**-Black nightshde blanched**, NEF**-Stinging nettle fresh, **NEB**-Stinging nettle

There was a significance difference (P≤0.05) on the beta carotene content as the leaves ages. Higher content was reported on mature leaves as compared to young leaves. Suggesting, beta carotene content increases with maturation. Fresh samples were significantly higher (P≤0.05) on the content of beta carotene as compared to blanched samples. Bouzari *et al.*, (2014) found similar findings on study of broccoli leaves that were blanched which may be due to disruption of leaf tissue cells making the organelles containing carotenoids more accessible accounting for the carotenoid extraction hence lesser beta carotene content than fresh. Storage of the ALVs leaves at room temperature in an active bag, reported a significance difference (P≤0.05) on the beta carotene content where there was a reduction of beta carotene as from 3$^{rd}$ day, 5$^{th}$ day and 7$^{th}$ day of storage as compared to the 1$^{st}$ day before packaging. Similar results were reported by Anjum *et al.,* (2008), where he found a reduction in lettuce and spinach to be 59.5% and 23.3%, in beta carotene content stored at room temperature. Reduction in beta carotene may be attributed to the oxidation in the package and catalyst by light.

### 4.12 Effect of storage (Ziploc bag packaging) on %moisture content (mg/100g) of ALVs.

Results for the % of moisture content of the 'xtend' bag packaging for the 4 weeks stored at room temperature are shown in table 5. Percentage of moisture content in young stage was reported to be higher than at mature stage. Among different 'xtend' bags used, there was no significance (P≥0.05) difference observed before and after packaging. Before packaging, fresh black nightshade both young and mature, had the highest % of moisture content of 85.77% and 82.94% respectively and the least was in stinging nettle (78.85% and 75.33%) at young and mature stage respectively. For the blanched samples before packaging, blanched black nightshade had the highest moisture content of 92.43% and 90.41% at young and mature stage respectively and the least was observed in stinging nettle as 86.14 % and 83.90 % at young and mature stage respectively. After packaging on day 3, % of moisture content had slightly decreased and the highest still was fresh black nightshade with 84.80 % (young) and 81.05 %

(mature) and the least % moisture content was reported in stinging nettle as 76.65 % and 73.35 % at young and mature stage respectively. Blanched samples on the 5th day had gone bad. On the 7th day, only amaranth had deterioration and the moisture % was shown to be 75.56% and 70.15 % at young and mature stage respectively.

**Table 5; Effect of storage ('xtend' bag packaging) on moisture content (%) of amaranth, black nightshade and stinging nettle kept at room temperature**

| | Before packaging | | Day 3 | | Day 5 | | Day 7 | |
|---|---|---|---|---|---|---|---|---|
| | young | mature | young | mature | young | mature | young | mature |
| AGF | $82.00\pm1.37^{bG}$ | $78.71\pm0.93^{bD}$ | $81.50\pm1.06^{cF}$ | $77.29\pm0.45^{bC}$ | $79.23\pm4.13^{bE}$ | $75.02\pm0.03^{bB}$ | $75.56\pm0.49^{aB}$ | $71.57\pm1.97^{aA}$ |
| AWF | $82.00\pm1.37^{bG}$ | $78.71\pm0.93^{bD}$ | $81.28\pm0.33^{cF}$ | $76.77\pm1.10^{bC}$ | $80.13\pm3.25^{bE}$ | $74.06\pm0.34^{bB}$ | $74.40\pm0.24^{aB}$ | $71.38\pm1.01^{aA}$ |
| ABF | $82.00\pm1.37^{bG}$ | $78.71\pm0.93^{bD}$ | $81.31\pm0.73^{cF}$ | $77.83\pm0.45^{bC}$ | $79.72\pm1.82^{bE}$ | $74.87\pm0.33^{bB}$ | $74.75\pm1.07^{aB}$ | $70.15\pm0.99^{aA}$ |
| BGF | $85.77\pm3.12^{cE}$ | $82.94\pm0.82^{cC}$ | $83.53\pm0.90^{dD}$ | $80.86\pm1.49^{cB}$ | $82.03\pm0.15^{cC}$ | $78.33\pm1.03^{cA}$ | sp | sp |
| BWF | $85.77\pm3.12^{cE}$ | $82.94\pm0.82^{cC}$ | $83.33\pm0.72^{dD}$ | $80.70\pm1.35^{cB}$ | $82.10\pm0.82^{cC}$ | $77.40\pm1.36^{cA}$ | sp | sp |
| BBF | $85.77\pm3.12^{cE}$ | $82.94\pm0.82^{cC}$ | $84.80\pm1.84^{dD}$ | $81.05\pm1.62^{cB}$ | $82.43\pm0.26^{cC}$ | $78.48\pm0.50^{cA}$ | sp | sp |
| NGF | $78.85\pm2.22^{aF}$ | $75.33\pm1.07^{aD}$ | $76.20\pm1.61^{aE}$ | $73.35\pm3.36^{aB}$ | $74.48\pm2.67^{aC}$ | $71.57\pm0.54^{aA}$ | sp | sp |
| NWF | $78.85\pm2.22^{aF}$ | $75.33\pm1.07^{aD}$ | $76.65\pm1.24^{aE}$ | $73.64\pm1.0^{7aB}$ | $74.94\pm0.49^{aC}$ | $70.25\pm0.79^{aA}$ | sp | sp |
| NBF | $78.85\pm2.22^{aF}$ | $75.33\pm1.07^{aD}$ | $76.65\pm1.02^{aE}$ | $73.58\pm1.71^{aB}$ | $74.36\pm0.86^{aC}$ | $71.04\pm3.24^{aA}$ | sp | sp |
| AGB | $90.07\pm1.46^{dD}$ | $86.00\pm1.54^{cC}$ | $84.22\pm0.46^{dB}$ | $79.02\pm2.54^{cA}$ | sp | sp | sp | sp |
| AWB | $90.07\pm1.46^{dD}$ | $86.00\pm1.54^{cC}$ | $83.03\pm1.32^{dB}$ | $80.06\pm0.31^{cA}$ | sp | sp | sp | sp |
| ABB | $90.07\pm1.46^{dD}$ | $86.00\pm1.54^{cC}$ | $83.84\pm0.65^{dB}$ | $79.05\pm1.40^{cA}$ | sp | sp | sp | sp |
| BGB | $92.43\pm1.49^{dD}$ | $90.41\pm0.96^{dC}$ | $89.14\pm0.37^{eB}$ | $85.21\pm0.73^{dA}$ | sp | sp | sp | sp |
| BWB | $92.43\pm1.49^{dD}$ | $90.41\pm0.96^{dC}$ | $88.69\pm0.58^{eB}$ | $86.47\pm0.41^{dA}$ | sp | sp | sp | sp |
| BBB | $92.43\pm1.49^{dD}$ | $90.41\pm0.96^{dC}$ | $89.87\pm0.18^{eB}$ | $85.17\pm0.22^{dA}$ | sp | sp | sp | sp |
| NGB | $86.14\pm1.05^{cD}$ | $83.90\pm1.34^{cC}$ | $78.46\pm0.45^{bB}$ | $77.81\pm1.34^{bA}$ | sp | sp | sp | sp |
| NWB | $86.14\pm1.05^{cD}$ | $83.90\pm1.34^{cC}$ | $77.01\pm1.54^{bB}$ | $75.26\pm0.77^{bA}$ | sp | sp | sp | sp |
| NBB | $86.14\pm1.05^{cD}$ | $83.90\pm1.34^{cC}$ | $78.60\pm2.31^{bB}$ | $76.46\pm3.43^{bA}$ | sp | sp | sp | sp |

Values are given as means (%) of three replicates ± SD. Means with different superscript upper-case letters across the row and lower case within the column are significantly different ($P < 0.05$). **AGF**-amaranth green line strip fresh, **AWF**-amaranth white line strip fresh, **ABF**-amaranth black line strip fresh, **BGF**-black nightshade green line fresh, **BWF**-black nightshade white line fresh, **BBF**-black nightshade black line fresh, **NGF**-stinging nettle green line fresh, **NWF**-stinging nettle white line fresh, **NBF**-stinging nettle black line fresh, **AGB**-amaranth green line strip blanch, **AWB**-amaranth white line strip blanch,

**ABB**-amaranth black line strip blanch, **BGB**-black nightshade green line blanch, **BWB**-black nightshade white line blanch, B**BB**-black nightshade black line blanch, **NGB**-stinging nettle green line blanch, **NWB**-stinging nettle white line blanch, **NBB**-stinging nettle black line blanch

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Percentage on moisture content showed significance difference ($P \leq 0.05$) as the leaves matures. Young leaves had significantly higher moisture content as compared to the mature leaves. Reduction in moisture content as the leaf matures may be probably due to transpiration and starch hydrolysis. There was a significance difference ($P \leq 0.05$) on the % of moisture content when the ALVs were blanched. A higher % was noted on the blanched leaves as compared to the fresh samples probably due to adsorption of water into damaged cells and water clinging to vegetable leaf surfaces (Yardfon *at al*., 2013). In addition, there was a significance difference ($P \leq 0.05$) on the % of moisture content as the leave samples were stored for 7days. There was a decrease in moisture % for the entire period of storage These was in line with work by Koraddi (2005) who found similar results on fenugreek, coriander and cucumber after storing in a paper bag. Decrease in % of moisture content may be due to a higher permeability which influenced respiration and transpiration rate (Jyothi *et al.*, 2013).

### 4.13 Effect of storage (Ziploc bag packaging) on Color (L*)

L* value of the 'xtend' bag packaging of processed amaranth, black nightshade and stinging at young and mature stages are shown in table 6. L* value for fresh leaf samples was higher at both stages as compared to blanch leaf samples. These showed that, fresh leaf samples were lighter as compared to blanch leaf samples. Fresh black nightshade and stinging nettle were the lightest with the L* value of 48.57 and 48.83 respectively while amaranth had less L* value of 41.83 at young stage. Color changes were observed when leaf samples were stored in 'xtend' bags at room temperature. There was an increase in L* value at both stages of maturity during the storage period. However, blanched samples on the third day had already gone bad.

**Table 6; Effect of storage ('xtend' bag) on color (L*) of amaranth, black nightshade and stinging nettle kept at room temperature**

| | Before packaging | | day 3 | | day 5 | | day 7 | |
|---|---|---|---|---|---|---|---|---|
| | young | mature | young | mature | young | mature | young | mature |
| AGF | 41.83±3.18 cA | 44.17±1.67[c] B | 46.30±1.52 dC | 49.30±1.87[d] E | 47.27±1.65 aD | 51.27±0.46[a] F | 49.10±2.81 aE | 52.73±0.67 aG |
| AWF | 41.83±3.18 cA | 44.17±1.67[c] B | 45.43±2.01 dC | 48.64±3.01d E | 48.90±2.81 aD | 50.40±1.55[a] F | 49.77±3.45 aE | 51.53±1.03 aG |
| ABF | 41.83±3.18 cA | 44.17±1.67[c] B | 45.13±0.97 dC | 48.90±1.91[d] E | 47.07±1.79 aD | 51.86±2.03[a] F | 48.27±1.99 aE | 52.23±1.79 aG |
| BGF | 48.57±2.66 dA | 50.83±2.22[d] B | 51.93±1.57 fC | 53.93±0.77[f] D | 54.87±3.01 bE | 56.93±0.61[b] F | sp | sp |
| BWF | 48.57±2.66 dA | 50.83±2.22[d] B | 51.43±0.33 fC | 53.30±1.73[f] D | 54.90±2.99 bE | 56.70±0.23[b] F | sp | sp |
| BBF | 48.57±2.66 dA | 50.83±2.22 B | 51.70±0.41 fC | 53.80±0.57[f] D | 55.47±1.05 bE | 57.17±1.89[b] cF | sp | sp |
| NGF | 48.83±0.79 dA | 50.77±3.03[d] C | 49.40±0.67 eB | 52.53±0.93[e] D | 53.80±2.33 bE | 55.70±0.56[b] F | sp | sp |
| NWF | 48.83±0.79 dB | 50.77±3.03[d] C | 48.07±1.09 eB | 52.20±1.18[e] D | 54.70±2.09 bE | 55.30±0.79[b] F | sp | sp |
| NBF | 48.83±0.79 dB | 50.77±3.03[d] C | 48.43±2.07 eB | 51.43±2.29[e] D | 53.33±0.37 bE | 55.56±1.25[b] F | sp | sp |
| AGB | 33.80±0.39 aA | 39.27±1.91[a] C | 36.50±1.41 aB | 42.83±2.06[a] D | sp | sp | sp | sp |
| AWB | 33.80±0.39 aA | 39.27±1.91[a] C | 37.53±1.91 aB | 41.27±0.99[a] D | sp | sp | sp | sp |
| ABB | 33.80±0.39 aA | 39.27±1.91[a] C | 37.20±3.02 aB | 41.03±2.57[a] D | sp | sp | sp | sp |
| BGB | 37.67±1.71 bA | 42.03±1.23[b] C | 38.13±1.14 bB | 43.53±1.43[b] D | sp | sp | sp | sp |
| BWB | 37.67±1.71 bA | 42.03±1.23 b[C] | 39.77±0.81 bB | 44.93±0.88[b] D | sp | sp | sp | sp |
| BBB | 37.67±1.71 bA | 42.03±1.23[b] C | 38.43±1.77 bB | 44.03±0.69[b] D | sp | sp | sp | sp |
| NGB | 41.17±2.62 cA | 42.27±4.51[b] B | 43.60±2.97 cC | 45.10±0.55[c] D | sp | sp | sp | sp |
| NWB | 41.17±2.62 cA | 42.27±4.51[b] B | 43.43±1.07 cC | 45.97±2.39[c] D | sp | sp | sp | sp |
| NBB | 41.17±2.62 cA | 42.27±4.51[b] B | 45.07±2.01 cC | 46.80±2.88[c] D | sp | sp | sp | sp |
| Sp- | | | | | | | | |

spoilt

Values are given as means (%) of three replicates ± SD. Means with different superscript upper case letters across the row and lower case within the column are significantly different ($P < 0.05$). **AGF**-amaranth green line strip fresh, **AWF**-amaranth white line strip fresh, **ABF**-amaranth black line strip fresh, **BGF**-black nightshade green line fresh, **BWF**-black nightshade white line fresh, **BBF**-black nightshade black line fresh, **NGF**-stinging nettle green line fresh, **NWF**-stinging nettle white line fresh, **NBF**-stinging nettle black line fresh, **AGB**-amaranth green line strip blanch, **AWB**-amaranth white line strip blanch, **ABB**-amaranth black line strip blanch, **BGB**-black nightshade green line blanch, **BWB**-black nightshade white line blanch, B**BB**-black nightshade black line blanch, **NGB**-stinging nettle green line blanch, **NWB**-stinging nettle white line blanch, **NBB**-stinging nettle black line blanch

There was a significance difference on the L* value ($P \leq 0.05$) at different stages of maturity on amaranth, black nightshade and stinging nettle. L* value was lighter at mature stage as compared to young stage during the storage period. Blanching as well caused significant color change on the stored ALVs. Significant decrease ($P \leq 0.05$) in L* value was reported in blanched relative to fresh leaf samples. Rui *et al.*, 2009, reported similar observation on frozen watercress leaf. Blanched frozen watercress had lower L* value as compared to fresh. Bowers, (2000) verified that color changes after blanching could be attributed to the replacement of the gases inside the intracellular spaces due to blanching medium, altering light refraction from the cell surface. In addition, Dueik *et al.*, (2010) linked decrease in L value during blanching with non-enzymatic browning reaction which accelerates at high temperature. Storage on the other hand showed a significance difference ($P \leq 0.05$) on the L* value of the Alvs studied. On storage, L* value increased significantly indicating lightning on the leaf sample. The results in this work agree with Prabhu and Barrett, (2009), where they

found an increase in L* value of cassia tora (Sickle Senna) and corchorus tridens (Jew's Mallow) stored at room temperature (20$^{o}$C) for four days. The increase in L* value is a sign of reduction of the intensity of green color due to appearance of yellow pigments.

# CHAPTER FIVE

# CONCLUSION AND RECCOMENDATIONS

## 5.1 Conclusion

From the study, it is evident that the AIV maturity as well as the different processing techniques affects their nutritional, minerals and phytochemical composition. The fiber, vitamin C, β-carotene, phenols, flavonoids and antioxidant activity increased with the maturity of the leaves. Freeze drying retained vitamins C, β-carotene, phenols, flavonoids and antioxidant activity better than solar dried. The fiber content of AIV leaves were not affected by the drying method or even processing like slicing and blanching. On the other hand, blanching of the three ALVs was shown to affect the nutritional and phytochemical quality. Their nutritional and phytochemical quality in all the parameters decreased during blanching unlike β-carotene where its content was higher as compared to unblanched samples. For the sliced samples, all the parameters were affected, resulting to lower content on the AlVs. On minerals, Zinc and Iron content were lower at mature leaves and higher at young leaves. Thus, Zinc and Iron needs to be harvested at young stage if the target as to increase intake of this minerals.

Storage of vegetables to increase shelf life is important, AIVs stored at frozen condition retains nutrients for up to 4weeks. Zip lock packaging samples that were frozen for a month, reported significance difference. Stability of the vitamins (β-carotene and vitamin C) during storage was affected where its content declined. However, the loss was not much as compared to fresh. Blanching on the other hand lead to a decrease in lightness of the ALVs studied. Active bag as well showed a significance decrease on the vitamins. There was no significance different on the types of active bags used. In general, frozen samples retained better nutrition quality than active bag stored at room temperature.

## 5.2 Recommendations

Maturity of ALVs is important during harvesting. There is need to plan for the right time of harvesting since most of the nutrient except zinc and iron mineral are high at mature stage than young stage.

Blanching has shown to affect nutrition quality, phytochemical and antioxidant activity. Lower temperature and shorter period for blanching should be used to retain nutrients better.

Recommend this study to vegetable farmers so that they can adopt this processing method. This will help increase vegetable shelf life by maintaining their nutritional quality and improving safety.

Recommendation goes to the Agricultural policy makers, will help them to use appropriate storage methods and processing. This will help in preventing postharvest food loss and waste especially during in seasons of AIVs.

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