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DEPARTMENT OF HORTICULTURE

EFFECT OF STAGE OF RIPENING AND MONTH OF HARVEST ON THE PHYSICO – CHEMICAL PROPERTIES OF *CITRUS SINENSIS VAR.* LATE VALENCIA STORED AT AMBIENT CONDITIONS.

BY

ABDUL-FATAWU ALHASSAN

MAY, 2013

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY IN SCIENCE (M.Phil. POSTHARVEST TECHNOLOGY) DEGREE

MAY, 2013

DECLARATION

I Abdul-Fatawu Alassan do hereby declare that the thesis titled "Effect of Stage of ripening and month of harvest on the Physico – Chemical Properties of Citrus Fruits (Citrus sinensis v*ar. Late Valencia*)" is result of my own research conducted in the Department of Horticulture, Kwame Nkrumah University of Science and Technology, KNUST, except references to other people's work which have been duly cited.

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(Head of Department)

DEDICATION

This project work is dedicated to the Almighty Allah. This work is also dedicated to my parents and siblings, to my wife Radiya and my children: Abdul-Fatawu Abdul-Haqq Wunpini, Abdul-Fatawu Faidullahi Tipagya and Abdul-Fatawu Fayaadatu Tunteeya who in diverse ways helped me to go through this course successfully.

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ABSTRACT

The study was undertaken to determine effect of stage of ripening and month of harvest on the physico-chemical properties of citrus fruits (*Citrus sinensis var*. late Valencia). A total of four hundred and fifty (450) citrus fruits with the same maturity periods were harvested from the same farm for three different months, harvesting one hundred and fifty (150) fruits each month. Some fruits were analyzed for their physico-chemical properties in their fresh state on day one of harvest while the others were stored for five and ten days before their physico-chemical properties were analyzed. The experiment was repeated for each month starting from December to January and then February in the laboratory of the Department of Horticulture, KNUST. The physico-chemical parameters measured were weight, pH, vitamin C, TSS, sugar, TDS, juice yield, firmness, TTA and EC. Some of the major findings of the study were that Vitamin C content of citrus fruits increased with duration of storage, early harvested citrus fruits contained high TSS and TTA. The level of TTA and TSS in citrus generally did not depend on storage duration. The study also found that citrus fruits use acids for respiration during prolong period of holding which may reduce sourness and improve flavour. Also, TSS content in full ripe orange increase as sugar content increases and acid content decreases. The study also revealed that time of harvest influences TSS content. Vitamin c content in matured green and half ripe fruits increase with duration of storage. The study recommended that citrus fruits should be stored between five to ten days interval before processing to obtain maximum amount of vitamin C. Also fruits meant for juice extraction should be harvested midway in the season or the duration of storage should be increased to obtain high juice yield.

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LIST OF ACRONYMS

AOAC	Association of Official Analytical Chemist
EC	Electrical Conductivity
FAO	Food and Agriculture Organization
KNUST	Kwame Nkrumah University of Science Technology
pH	Hydrogen Potential or Power
TDS	Total Dissolved Solids
TSS	Total Soluble Solids
TTA	Total Titratable Acidity

CHAPTER ONE

INTRODUCTION

The orange is the world most popular fruit juice constituting a major portion of the food industry (Tetra Pak 2004, Kimball 1999). In 2005, about 59 million tons of oranges were produced worldwide (FAO 2006). This represents a 45 % increase in orange production since 1970 (FAO 2006). As of 2005, 21.8 million tons of orange fruits were processed into orange juice with Brazil (11.9 million tons) and the United States (6 million tons). In the United States orange juice is also the most popular fruit juice accounting for 60% of all fruit juice sales (Graumlich 1986, Jia 1999).

Almost all the oranges produced from the United States come from Florida and California with the former accounting for about 75% of the total oranges (USDA 2007). In Florida about 92 % of all oranges produced are processed into single strength orange juice while 72% of all the oranges are sold as fresh fruit in California (USDA 2007).

Citrus fruits belong to the *Rutaceae* family. Citrus are ever green plants that give fruits of different forms and sizes (round to oblong). The fruits are fragrant and has good flavour and juice. The exact center of origin of citrus is unknown. It is however, generally believed that all commercially important citrus varieties originated from South Asia specifically the Philippines and the Himalayas, south of Indonesia or Australia (Janick *et al.,* 1981), where there is greater diversity in varieties than anywhere else in the world (Mcphee, 1967). Recent evidence also suggests that Yunnan province in South-Central China may be as important as any other place due to the diversity of species found and the system of rivers that could have provided means of dispersal to the South (Gimmtter and Hu, 1990). Currently, ten species of edible citrus are known of which eight are commercially cultivated and five are considered to be of great economic importance (Salunkhe and Desani, 1984).

Citrus is one of the most important fruit crops known by human since antiquity (Gorinstein, 2001). From South East Asia, citrus has become immensely popular worldwide and is now grown in the sub-tropical belt from 40 ^{0}C latitude north to 40 ^{0}C latitude south in both humid and arid regions. Citrus has two growing seasons; the major season which starts from October to February and the minor season which also starts from March to August in the tropics, south of the Sahara. Citrus is currently grown throughout the world. It grows particularly well in areas where there is sufficient rainfall and irrigation to sustain growth and where freezing conditions are not severe enough to kill the trees (Whiteside *et al*., 1988).

Currently, Brazil is the largest citrus grower followed by the United States of America (USA) and China (FAO, 2000). Total world citrus production rose to 39 million tons in 1989/90, of which 50% came from Brazil and the USA (Fox, 1991). Of this, sweet orange constitute the most important proportion accounting for more than two-thirds of the global total production (FAO,2004). Annually, more than 104 million tons of sweet oranges are harvested worldwide (FAO, 2004).

Sweet oranges are usually consumed as fresh fruits or juice and are a good source of vitamin C with high antioxidant potential (Codd *et al.*, 1972). The frozen concentrated orange juice (FCOJ) is most preferred by consumers than any other citrus product (Fox, 1991).

Other products of citrus that have received much attention globally, locally and commercially include fresh pasteurized juice, pulp for cattle feed, pectin, essential oils and flavonoid from the peels (Samson, 1986). These have given citrus an important place in the world fruit production (Copper and Chapter, 1977).

Several factors which affect the fruits and the nutrients, especially vitamin C quality of citrus, have been reported. One of such factors is the changes in the physico-chemical properties, especially the volatile ones in the citrus fruits (Kimball, 1999). The changes in the physico -chemical properties have been attributed to indiscriminate timing of harvest and the duration of storage of citrus fruits particularly in the tropical countries such as Ghana (Waks *et al.,* 1983). These changes may affect consumption as well as industrial processing quality (nutrients) of the citrus fruits which is a source of livelihood to many smallholder farmers in the country, as may have possible repercussions on the industrial processing quality and the nutrients derived by those who depend on the citrus fruits and juice for their food and nutritional supplements (Hatch, 1995).Transit periods to markets and handling practices of fruits vary from place to place. The effect of varying storage period should be investigated to help consumers including processors plan to minimize their effects, so that they could produce products of consistent quality. Many citrus fruit producers, processors and consumers are often not aware that the time at which the fruits are harvested and the duration of storage could have effects on the physico- chemical properties of the citrus fruits and the likely impact on the nutritional quality and consumption of the fruits (Ortega *et al,* 1997).Thus there is the need to conduct research to establish the possible effects of the stage of ripening and time of harvest on the physic-chemical properties of citrus fruits, specifically sweet orange(Citrus sinensis var late Valencia)which is widely cultivated in Ghana. This will assist citrus farmers/producers and processors to have a good idea of the possible fruit quality to expect depending on the time of harvest and duration for storage. It would also help in selecting the most appropriate duration for storage of the fruits to ensure processing quality, since it will increase consumption and create the opportunity for increased production by the smallholder farmers in the country.

The main objective of this research therefore, was to determine the effect of time of harvest and duration of storage on the physico -chemical properties of citrus fruits (*Citrus sinesis var*. late Valencia).

The research specifically sought to:

1. Assess the effect of time of harvest on physico -chemical properties of citrus fruits
2. Assess the effect of storage duration on physico-chemical properties of citrus fruits
3. Determine the effect of duration of storage on vitamin C of citrus fruits.

The health and nutritional benefits associated with citrus consumption are clear and cannot be over emphasized. Citrus fruits are nutrient-dense foods that can be a good source of carbohydrates, vitamins, dietry fibre and minerals. In other to derive the full benefits of citrus fruits, producers, processors and consumers need information on the right time to harvest and the appropriate duration of storage of citrus fruits, especially (*Citrus sinesis var*. late Valencia) which is most popular in Ghana in order to preserve its qualities and increase citrus fruits consumption.

CHAPTER TWO

LITERATURE REVIEW

2.1 Sweet Orange (*Citrus sinensis var*. late Valencia)

2.1.1 Origin, Varieties, Cultivation and Uses

The sweet orange, *Citrus sinensis*, is one of the most popular citrus fruit crops cultivated in the world today (Hui, 1999). Sweet orange is believed to have originated from Southern China and possibly as far south as Indonesia (Webber *et al*., 1967). The commonest sweet orange varieties cultivated are Late Valencia, Washington Narvels, Valencia (Codd *et al.*, 1972). Sweet orange may be grouped into four, based on fruit morphological characteristics, chemical composition, and conveniences (Albrigo, 1977). These are;

Round oranges, pigmented (blood) oranges, narval oranges and less oranges.

Sweet orange is further broken down into three sub-groups of colour and shape, narvel and red colured oranges such as blood oranges (Codd *et al.,* 1972). The sweet orange fruits are in general low to moderate acids and moderate to high soluble solids contents (Suling, 1967).

Sweet oranges are usually consumed as fresh fruit or juice (Codd *et al.,* 1972). Other citrus products from sweet oranges include pasteurized juice, pulp for cattle feed, pectin, essential oils and flavonoids from peels (Samson, 1986).

Among the numerous varieties of sweet orange the late Valencia is the most preferred, both by farmers and consumers probably due to its taste and the wide range of climatic tolerance it has.

The taste of the late Valencia fruits is principally governed by the levels of sugar and acids in the juice sacks and the relative ratios among them. The overall taste of Valencia depends on the ripening stage; early-season fruits are sour than late-season fruits, which often lack appropriate acidity content (Cohen, 1999). The variety late Valencia has two growing seasons, the major and the minor seasons.

2.1.2 Diseases and Control of Citrus

Although there has been a strong growth in orange juice production worldwide over the past thirty years, the United States has been experiencing a steady decline in demand for orange juice with annual per capita consumption dropping to its lowest point of 4 gallons in the past 11 years.

A part of the decline has been attributed to the rise of low carbohydrates diet packages such as the Atkins and South Beach diets which categorize orange juice as high Carbohydrate food and may have affected consumer demand. Other cause of the decline includes adverse weather conditions and impacts of diseases which reduced overall juice production.

Oranges subjected to freezing conditions are frequently unsuitable for consumption due to the off -flavors generated the formation of white spots on the fruit surface and the dehydration of fruit. Ice crystals grow within the fruit damaging the cells and creating pathways for moisture loss and fruit dehydration. Since 1835, Florida has periodically experienced severe freezes, which negatively affected the total citrus yield (FCM 2007, Reuters 2010).

In addition to freezes, Florida has also experience hurricane (most recently hurricane Charley, Frances and Jeanene) which have not only damaged crops and trees but also aided the spread of citrus diseases such as citrus canker. Xanthomonas citri subsp is the plant pathogenic bacterium that causes citrus canker and spreads primarily by wind and rain.

Citrus canker manifests as nacrotic lesions on the fruit, leaves and stems of citrus plants with severe infection causing premature fruit drop, blemished fruit and twig dieback (Schubert 2001,Bock 2005).

While citrus canker has long plaqued Florida since 1912 with periodic eradications (in 1930 and 1992) and subsequent returns (in 1986 and 1995), it has been usurped in severity and importance by citrus greening (Gottwald, 2007). Citrus greening also known as huanglongbing, is a bacterial disease that is widely regarded as the most severe and devastating disease of citrus (Gottwald, 2007).

As with other fruits, citrus is attacked by several pre-and/ or postharvest pathogens that affect fruit quality, green and blue mould infections caused by *Penicllium spp* (Drobi *et al.*, 1989) and Sout rot caused by *Geotrichum candidum* (Chalutz and Wilson, 1990). In developing countries, where protection and proper handling of fresh fruits is inadequate, losses during transit and storage are even greater amounting up to about 50% of the harvested crop (Wisniewski and Wilson, 1992).

Citrus fruit diseases are currently being managed with synthetic fungicide applied pre-or postharvestly. However, concerns over the real or perceived negative effects of synthetic pesticides on both man and his environment (Norman, 1988), has led to the implementation of more restrictive legislations regarding the maximum residue levels (MRL) of pesticides, particularly to fruit exported to European markets. Black spot disease of citrus which makes black spot lesions on citrus fruits has led to the rejection of whole export consignments in international markets (Kotze, 1981).

1.2 Medicinal and Nutritional Importance of Citrus

The high demand for oranges and their extracted juice is due to their high nutritional value and desirable flavor (Jordan 2003, Polydera 2004). Orange juice is an excellent source of ascorbic acid (Vitamin C), sugars(sucrose, fructose and glucose) minerals(potassium ,magnesium, calcium), bioactive compounds such as carotenoids (b-carotene, a-carotene, b-cryptoxanthin) and flavanones (hesperidin, narirutin), which have antioxidant properties.

The daily recommended intake of ascorbic acid is 75 mg for adult women and 90mg for adult men with insufficient uptake of ascorbic acid leading to scurvy, a disease characterize by bleeding gums, impaired wound healing, anemia, fatigue and depression. Regular consumption of orange juice, which contains about 40 mg of ascorbic acid per 100 ml helps to reduce the risk of the occurrence of scurvy (Norman and Clein 1956).

Some research has also shown that bioactive antioxidants found in orange juice have been implicated in the reduction of degenerative human disease such as caner (Steinmetz 1993, In addition to the nutritional benefits, orange juice has a unique, delicate and desirable taste with over 200 flavor compounds in proper concentration (Jia 1999).

While sugars and Citric acid are major contributors to the sweetness of arrange juice, a combination of other compounds such as acetaldehyde, citral, ethyl butyrate, d-limonene, linalool and octanal, also contribute to the unique flavor of orange juice (Ahmed 1978, Jia 1999).

Much of the increase in orange juice consumption is linked to the potential health related benefits contained in the juice (Nagy and Attaway, 1980). Citrus fruits and juices have several health benefits and nutritive properties.

They are rich in vitamin C (ascorbic acid) and folic acid, as well as good source of fibre. They are fat free, sodium free and Cholesterol free. They however, contain potassium, calcium, folate, thiamin, niacin and vitamin B (Carpenter, 1986).

The citrus contains folate which is associated with the prevention of natural tube defects, which is a severe birth defect. A 225 ml glass of orange juice provides 75 mg of folic acid (Whitney *et al.*, 1992). Fruit juice helps in the production of DNA and RNA as well as matured red blood cells, which ultimately prevent anemia (Rolfes, 1999).

The fruits also contain potassium which is an essential mineral that work to maintain the body's water and acid balance. Phyto – chemicals, which occurs naturally from plants including citrus have a wide range of physiological effects and may help to protect humans against various chronic diseases, including cancer and heart diseases (Steinmetz and potter, 1999).

Recently, epidemiological studies suggest that consumption of citrus fruits is associated with a reduced risk of cardiovascular diseases, stroke and certain form of cancer. These protective effects have partly been ascribed to the antioxidant properties especially of flavonoids (Hollman and Kahan, 1997).

Flavonoids are found in many citrus plants. Flavonoids can specifically guard against cancer because they have shown to protect DNA from damage, inhibit glycolysis and prevent invasive action of rapidly growing cells (Benevelete *et al.,* 1987). In cell metabolism, flavonoids primarily have an effect at the cell membrane on the intercellular enzymes Yu *et al.,* 2005).

The flavonoids also inhibit the excretion of molecules such as lactate and certain ATP aces that cancerous cells frequently excrete and have free radical reducing properties Gracia, 1997 and Yu *et al.,* 2005). Insufficient levels of citrate in the urine of some people can result to kidney stone diseases, and it has been suggested that eating citrus fruits and drinking orange juice may help prevent kidney stone by increasing urinary citrate (New *et al.,* 1997).

Currently, ascorbic acid is the most widely used, vitamin supplement worldwide. Based on available biochemical, clinical and epidemiological studies, the current recommended daily acceptance (RDA) for ascorbic acid is suggested to be 100 to 120 mg/l daily to achieve cellular saturation and optimum risk reduction of heart disease, stroke and cancer in healthy individuals.

The vitamin content in orange juices range from 150 to 450 mg/l; one glass of orange juice (200 ml) can deliver about 30-80% of recommended daily intake of vitamin C (Gliszozynska-suliglo *et al*., 2004). Despite the nutritional and health benefits of citrus fruits, consumption is very low due to lack of knowledge (Nestle *et al*., 1998).

2.3. Physio-chemical Properties of Citrus Fruits

The composition of citrus fruits varies with cultivars, climate, rootstock, maturity and cultural practice. Most citrus, like other fruits are sources of primary water (juice), but also contain moderate levels of carbohydrates, organic acids, amino acids, ascorbic acids and mineral salts and small quantities of flavonoids, carotenoids, volatiles and lipids. It has been reported that fruit size, weight and juice contents of sweet oranges increased with maturity (Cepeda *et al*., 1993), while that of the rind thickness reduced with maturity (Sinha *et al*., 19 62).

Also important is sugars contained in citrus fruits. Sugars in sweet oranges consist mostly of glucose, fructose and sucrose in approximately a ratio of 1:1:2. Closely associated with sugars is the amount of total soluble solids (TSS) content of the fruit. Citrus fruits contain high amounts of both total soluble solids (TSS) and total Titratable acids (TTA) which levels increase during fruit maturation (Goff and Klee, 2006).

Total soluble solids (TSS) which include carbohydrate, organic acids, proteins, fats and various minerals composes about 10 to 20% of the fresh weight of the citrus fruit. Bakhishi (1967), reported that total soluble solid (TSS) decrease in Valencia varieties when harvesting is delayed. Linked to TSS, is total Titratable acid (TTA) content of the citrus fruit. The total Titratable acidity (TTA) of citrus juice is an important factor of juice quality and in determining the time of fruits harvest.

In most growing regions the ratio of total soluble solids (TSS) to total Titratable Acid (TTA) content determines whether fruits are harvestable or otherwise. The ratio of TSS and TTA increases during maturation and is a good indicator for palatability

Citrus fruits also contain high amounts of volatiles and pectins. The main volatiles in citrus fruits are esters and aldehydes, followed by alcohols and hydrocarbons, alberdo and flavedo which make up the peel or rind. The peel or rind of citrus fruit contains more pectin than other parts of the fruit (Bruemmer, 1975).

The higher concentration of flavourness, limonin and water soluble pectins are inversely correlated to processed juice flavour and these components are found in higher quantities in juice that contains more peel extract from hard squeezed fruit (Albrigo and Carter, 1977). Pectins are high molecular weight carbohydrates composed of chains of anhydrogalacturonic linkage.

During maturation of citrus fruits, insoluble pectins are converted to water soluble pectins and this change in pectin composition signal fruit softening or over maturity (Nagy *et al.*, 1980).

Orange juice contained a variety of chemicals with sugars or carbohydrates being the most predominant chemicals (Kimball 1999). These carbohydrates represent roughly 80% of the soluble solids in orange juice (Kimball 1999, Kelebek 2009). The main carbohydrates in orange juice are sucrose, glucose and fructose in the ratios of 2:1:1 (Kimball 1999,Kelebek 2009).

The sucrose molecule consist of one molecule of glucose and one molecule of fructose (more specially an a-D-glucopyranosyl unit and a b—D-fructofuranosyl unit) linked head to head (reducing end to reducing end) (Kimball 1999, Bemiller and Whistler 1996). As sucrose consist of one part glucose to one part fructose and one molecule, the density of aqueous solutions of sucrose mixed with equal parts of fructose and glucose are similar densities of 100 % sucrose (Kimball, 1999).

Juice density is a very important quality control parameter in the juice industry (Kimball 1999, Cepeda 1999). Juice densities are used in weight and volume parameter adjustments, standardization laboratory results, managing inventories and marketing (Kimball 1999). Insoluble solids such as cloud and pulp contribute little to the orange juice density (Kimball 1999). As orange juice is a sugar containing solution, its density can be determined by scales that apply to pure sugar solutions (Kimball 1999).

However, soluble solids in orange juice include carbohydrates and non-carbohydrates (Kimball 1999). Orange acids and their salts contribute to about 10 % of soluble solids in oranges fruit.

2.3.1 Firmness

Degradation of insoluble protopectin to the more soluble pectic acid and pectins contributes to a decrease in firmness in many fruit. These changes occur relatively slowly and are less pronounced in citrus fruits as compared to climacteric fruits (Ladaniya, 2004).

However, some softening of the fruit also occurs due to turgor pressure changes and /or respiratory loss of dry matter during growth, development and senescence. Furthermore, environmental conditions, irrigation practices, postharvest water loss, and aging of the fruit also influence the texture changes. For Example, pre-harvest spraying of fruits with GA_3 retarded rind senescence of navel orange, carotenoid accumulation, and softening (Coggins, 1982). Some physiological disorders, such as chilling injury (CI) and watery breakdown, cause softening and 'spongy' fruit during low temperature storage (Murata, 1997). Paul and Jung Chen, (2000) similarly noted that postharvest heat treatments can affect fruit softening and contribute to loss of membrane integrity and flavour changes.

2.4 Time of Harvesting and Physio-chemical Changes of Citrus Fruits

Flowering of sweet oranges usually occurs from February to April and ripening begins between October and June (Codd *et al.,* 1972). Usually sweet oranges are often harvested early by farmers due to lack of information about quality improvement with time.

Early and immature harvest may reduce the quality of the fruits and ultimately the returns of the farmer and a loss to the nation. The value of citrus fruits in the human body depends on the time of maturity and the time of harvest as well as the duration of storage without losing its nutrients value (Waks *et al.*, 1985). It has been reported that, the overall taste of Valencia depends on the ripening stage; early-season fruits are sour than late-season fruits, which often lack appropriate acidity (Cohen, 1999).

The most important determination of fresh citrus fruits quality during harvesting are fruit size, shape, peel colour, peel quality, peel firmness and texture. Generally, seedless fruits are more desirable than seedy fruits, as put by Hensz (1971) that fewer than nine seeds per fruit are desirable.

Colour is not a good indicator of maturity, so percentage soluble solids (Brix of which 70 – 80% composed of sugars) and Titratable acids of the juice are used as maturity index (Salunkhe and Desai, 1986) for harvesting. A brix acid ratio ranging from 8 to 10 is generally accepted as a measure of minimum maturity for harvesting, while a ratio of 10 to 16, considered being of acceptable quality. If the fruits remain on the trees, the brix continues to increase and the acid diminishes, until eventually over ripe. Unpleasant sweet fruit reach a brix acid ratio of 20 or more (Samson, 1986).

Sinha (1962) and Sapeda (1993) also observed that ascorbic acid content of citrus fruits decrease with time of maturity especially in late Valencia. The stability of ascorbic acid in citrus depends markedly on the pH and oxygen levels of the citrus fruit (Sudheer, 2007) during fruit maturation.

2.5 Storage and Physico-chemical Changes of Citrus Fruits

The demand for the fruits increase from January onward but the quality of the fruit cannot be retained because citrus fruit quality does not improve in storage. Fruits can be stored for 8-12 weeks depending on the cultivar, ventilation rate in storage rooms, influence of internal atmosphere and incidence of decay of the orange (Waks *et al*., 1985). During storage there is reduction in sensory quality due to lipid oxidation and non- enzymatic browning.

Citrus fruits when exposed to high temperatures for long period of time often affect internal quality and flavour. On the other hand, exposure of sweet orange to chilling temperatures results in surface pitting, abnormal ripening, increased susceptibility to decay and enhanced senescence (Purvis, 1975). Storing the fruit at too low temperatures can cause adverse effects in the fruits such as chilling injury (CI) (Wills *et al*., 1998). Citrus fruits are susceptible to chilling injury therefore the fruits are usually stored at moderate temperatures. During storage at 9 to 10^{0}C, fruits typically develop undesirable yellow colour after only 3 or 4 weeks and may become fully yellow after 8 weeks (Murata, 1997, Ladaniya, 2004). The gradual reduction of green colour of citrus fruits during storage adversely affect customer's acceptance during marketing.

Fruits quality changes during storage. Citrus fruits undergo internal quality changes during long-term storage after harvest, but these changes depend on the cultivar and storage conditions. For example, the TSS of the late Valencia did not change during nine days of storage at room temperature, but the TSS of blood orange, increased (Echeverria and

Ismail, 1987). Waxed fruits also develop off-flavours if stored for a long time at high temperatures of poor gas exchange.

Acid content of citrus fruits also increase with short period of storage and peel colour changes significantly from light green to yellow (Batchelor and Bittens, 1954). In stored oranges, acids decreased faster than sugars so that the fruit is predicted to be lightly sweeter in holding (Samson, 1986). Malic acid shows decrease in storage in Valencia sweet oranges (Samson and Monselise, 1977).

Storage of fruits in airy conditions with acetaldehyde decrease acidity and accelerate degreening. In citrus fruits matured on the tree, soluble solids (TSS) increases rapidly at first and then at a slower rate, while total acidity (TTA) increases early in development, then steadily decrease (Samson, 1986). The decrease in Titratable acid concentration in most citrus fruits during ripening may be partly due to dilution with increased fruits size and water content (Kimball, 1984).

2.6 Vitamin C Content of Citrus Fruits in Storage

Vitamin C is a water-soluble vitamin that is commonly found in relatively high concentrations in many fruits (Kays and Paull, 2004a) and particularly in citrus species. The term “Vitamin C” refers to both L-ascorbic acid and dehydroascorbic acid, the latter being the first oxidation product of the former.

There are many factors that influence the amount of vitamin C in fruit products, such as differences of genotype, pre-harvest climatic conditions, cultural practices, maturity, harvesting methods and postharvest handling procedures. For example, vitamin C in plant tissues can be increased when the intensity of light is high or less frequent irrigation is applied during the growing season.

High rates of nitrogen fertilizers may decrease the vitamin C content in many fresh commodities and losses of vitamin C in fresh commodities are enhanced by extended storage, higher temperatures, low relative humidity, physical damage and chilling injury (Harris, 1975; Mozafar, 1993; Lee and Kader, 2000).

Currently, ascorbic acid is the most widely used, vitamin C supplement worldwide. It has been known for many years that citrus are a valuable source of ascorbic acid (vitamin C). Ascorbic acid functions as a co-enzyme and is an essential part of the human diet (Nagy and Attaway, 1980). The vitamin content in orange juices range from150 to 450 mg/l; one glass of orange juice (200 ml) can deliver about 30-80% of recommended daily intake of vitamin C (Gliszozynska-Suliglo *et al*., 2004). Stability of ascorbic acid in citrus fruits however depends markedly on pH and oxygen content of the citrus fruit (Sudheer, 2007).

Exposure of sweet oranges to chilling temperatures results in rapid ascorbic acid loss and enhanced senescence of fruits. Sinha *et al*., (1962) and Sapeda *et al.*, (1993) observed that ascorbic acid contents decreased with time of maturity in late Valencia citrus fruits.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Source of Samples and Location of the Study

The study was conducted at the Ejisu-Juaben District of the Ashanti Region of Ghana. The people in this area were mostly farmers. Cash crops cultivated in this area included oil palm, cocoa and citrus. They also cultivated food crops such as maize, cassava and cocoyam. The oranges used for the study were collected from Adjei Farms at Adumasa in the Ejisu-Juaben District of the Ashanti Region of Ghana. However, determination of the physico-chemical properties was done at the horticulture Laboratory of the Department of Horticulture at the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

3.2 Collections of Samples

For the purpose of the study, four hundred and fifty (450) mature citrus fruits at similar stage of maturity and size were harvested from selected citrus trees at three different periods or stages. One hundred and fifty fruits were harvested in December, 2011, followed by another one hundred and fifty fruits in January, 2012, while the third harvest took place in February 2012. The one hundred and fifty (150) oranges were randomly grouped into three. Analysis was done to assess the quality properties of the fruits.

Fifty (50) fruits were randomly picked from the three groups and were analyzed on the same day of harvest. Another fifty (50) fruits were analyzed on the fifty (5^{th}) day of harvest and the last fifty (50) were analysed on the tenth (10^{th}) day of harvest. The same procedure was used for all the harvests (December, January and February).

3.3 Research Design

The study used two by two (2 ×2) factorial design with three replications. Changes in physic-chemical properties due to different time of harvest and storage duration monitored and assessed were; fruit weight, pH, Vitamin C, total soluble solids (TSS), total dissolve solids (TDS), juice yield, fruits firmness, total titratable acidity (TTA) and electrical conductivity (EC).

3.4 Determinations of Physical Properties

3.4.1 Fruit Weight

The weight of the fruits was measured in grams (g) using an electronic scale and each of the fruit sample weight was recorded as such.

3.4.2 Fruit Firmness

The fruit firmness was determined using a penetrometer. The penetromter was used to puncture the peels of the fruits three times at different points and the reading on the penetrometor recorded as fruit firmness.

The penetrometer (QA supplies FT-327) was zeroed and the plunger head placed against the skin on one side of the fruit. Steady downward pressure was applied until the plunger had penetrated the flesh of the fruit up to the depth mark (half way up) on the plunger. Plunger was removed and the reading on the penetrometer dial recorded. The process was repeated on the opposite side of the same fruit. Four readings were taken for this parameter on every fruit per each replication and the average calculated and recorded.

3.4.3Determination of firmness (pulp and skin)

The fruit was firmly held with one hand on a rigid surface (lab working bench). A plunger of size 11 mm (1 cm^2) diameter was used because that is generally suitable for use in testing harder fruit as recommended by OECD standards(OECD, 1999).

3.4.3 Juice Yield

The juice content of fruits was determined by extracting the juice with a blender and the volume measured in a calibrated measuring cylinder in milliliters (ML).

3.5 Determinations of Chemical Properties.

3.5.1 Determination of Total Titratable Acids (TTA)

10ml of fruit juice was diluted with 50ml of distilled water and titrated against 0.1M NaOH. This was done twice for each replication and titre values were recorded. The average titre value recorded for each replication.

Total titrable acidity was calculated using the formula:

$$\text{grams/ litre acid} = \frac{\text{Titre x acid factor x 100 x 10}}{\text{10 (ml juice)}}$$

The acid factor is 0.0064 for citric acid which is the dominant acid in citrus fruits (OECD, 1999).

3.5.2 Determination of total soluble solids (TSS) content.

Whole fruits were diced with a knife and blended with a blender (Binatone, BLG-402) and sieved using a nylon cloth. A drop of juice was placed onto the refractometer (QA supplies-R305846) prism plate. The reading on the prism scale was recorded. After each test the prism plate was cleaned with (distilled) water and wiped dry with a soft tissue. This was done three times for every replication and the average TSS calculated (OECD, 1999).

3.5.3 Determination of pH

Fruit juices from already blended fruits from each replication were poured into beakers. The combo pH and EC meter (HI-98129) was dipped into the juice and pH readings taken. The readings were taken three times for each replication and the average pH for each replication recorded (OECD, 1999).

3.5.6 Determination of Electrical Conductivity (EC) and Total Dissolved Solids (TDS) of the juice.

These tests were conducted using the juice expressed from the fruit as used in determining the TSS. The combo pH and EC meter (HI-98129) used in the determination of the pH was also used to determine the EC as well as the TDS of the juice one after the other. The pH meter was dipped into the juice bulb wise and readings were recorded to four decimal places. In all, three readings were taken for each parameter per a replication and their various averages recorded. The bulb area of the apparatus was washed and wiped clean using distilled water and a clean tissue respectively before dipping it into the juice of another replication.

3.6 Determination of Vitamin C

Fruit juice from the blended fruits from each replications were titrated against 0.1 ml Na OH with indophenothaline dye (2,6 dichlorophenol).

It was determine by titrating 20 ml of juice extracted and 20 ml of distilled water against 2.6 dichlorophenol. The titre values were then recorded as the content changed colour from pink to blue black.

CHAPTER FOUR

RESULTS

4.1 Total Titratable Acidity (TTA)

4.1.1 Effect of stage of maturity on acid content of citrus fruits

Figure 4.1 shows the effect of stage of maturity on total titratable acid content of stored orange fruits. Fruits harvested at the full ripe stage showed consistently higher acid content than both half ripe and mature green for day 1 and 5 of storage. Whereas TTA content in the full ripe fruits decreased from 10.25 to 7.51g/100ml acid, that of half ripe and mature green fruits varied between 9.36 to 8.43g/100ml acid and 8.76 to 8.09g/100ml respectively. Significant differences ($P<0.05$) existed in the TTA content between full ripe and mature green stages of ripening on the Day 1 and 5. However, the differences in the various stages of ripening on 10 were not significant ($p>0.05$).

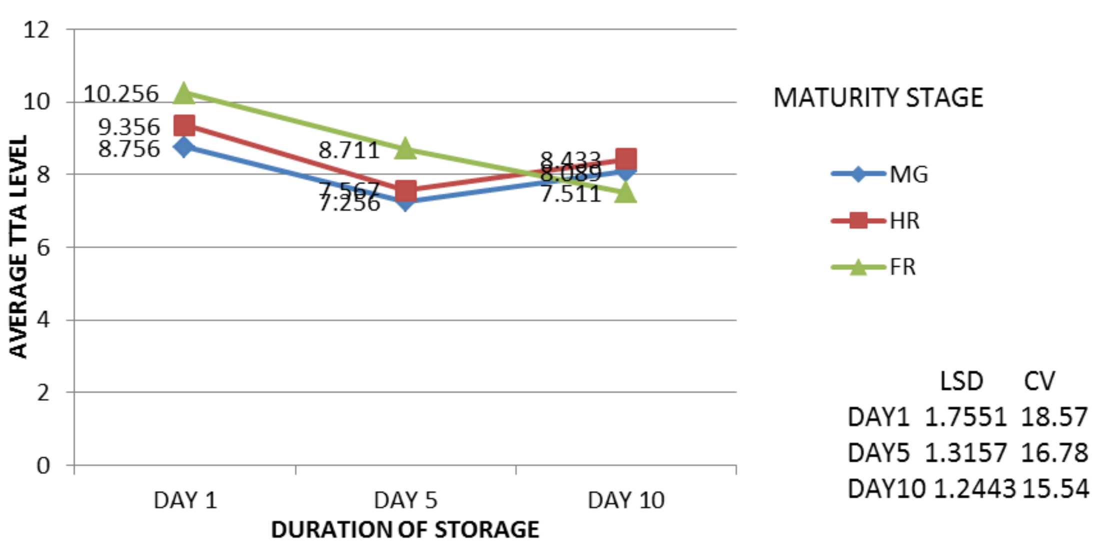


Figure 4.1 Effect of Maturity Stage and Duration of Storage on TTA

4.1.2 Effect of Time of Harvesting on Acid content of Citrus fruits

Figure 4.2 shows the effect of harvest time on total titratable acid content of the stored orange fruits. There was a general decrease in titratable acid content in all the stages of harvest except in January. Fruits harvested in January showed fairly constant acid content than those harvested in December and February. The TTA content of fruits in January remained fairly constant from 9.03 to 9.13 while that in December and February varied between 11.00 to 7.04and 8.33 to7.86 respectively. Significant differences of ($P<0.05$) existed in the TTAcontent among all the stages of harvest for all the days of storage.

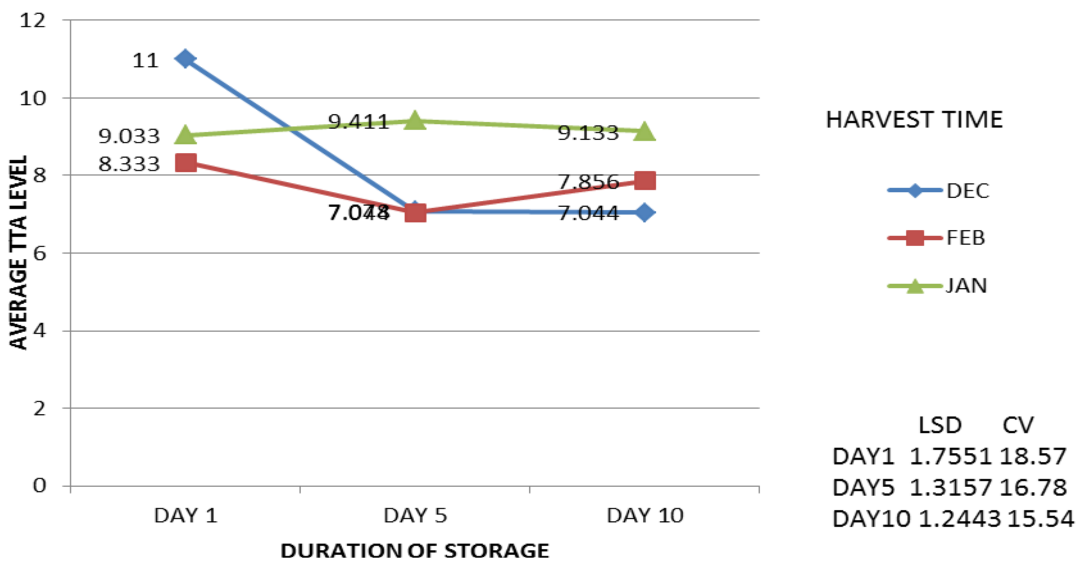


Figure 4.1(b) Effect of Harvest Time and Storage Duration on TTA

The fresh harvest in December showed significantly higher TTA (11.00g/100ml acid). However, the difference between the January and February fresh harvest was not significant (P>0.05). By the 10th day of storage fruits had significantly lower (P<0.05) TTA content.

4.2 Total Soluble Solids (TSS)

4.2.1 Effect of stage of maturity on TSS content of citrus

Figure 4.3 shows the effect of maturity stage on total soluble solids content of the stored orange fruits. There was a steady decline in total soluble solids content of half ripe fruits and mature green fruits in storage. Fruits harvested at the full ripe stage showed slightly higher TSS content than both half ripe and mature green. While in the full ripe the TSS content fluctuated (9.7to8.58). The TSS of half ripe and mature green fruits generally decreased from 9.08g/100ml to 8.27 and 8.7 to 7.84, respectively. However, the differences in the various stages of ripening in Day 1, Day 5 and Day 10 were all significant (p<0.05).

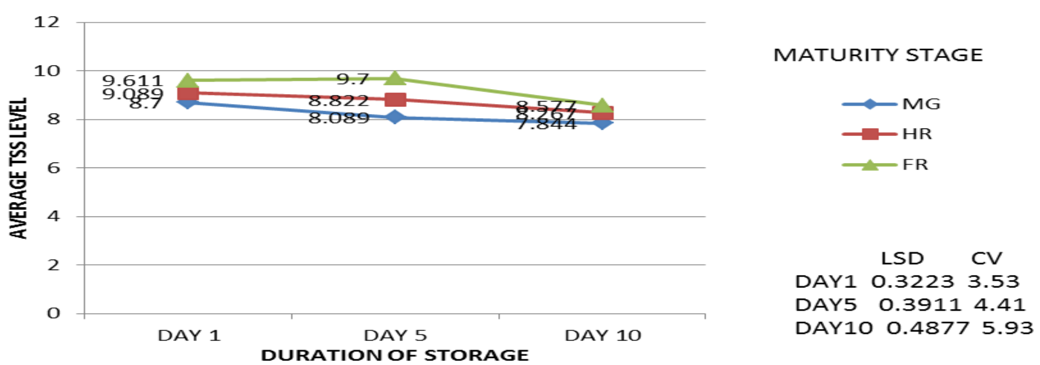


Figure 4.3 Effect of Maturity Stage and Storage Duration on TSS

4.2.2 Effect of time of harvest on TSS of citrus fruits.

Figure 4.4 shows the effect of time of harvest on total soluble solids content of the orange fruits. The TSS of the citrus fruits was higher (P<0.05) in thye February harvest than the rest.This was closely followed by the December and January harvest. Whereas,the TSS content in February increased from 10.53 to 13.22, the December and January harvest varied between 9.26 –10.44 and 7.61 – 7.422 respectively.

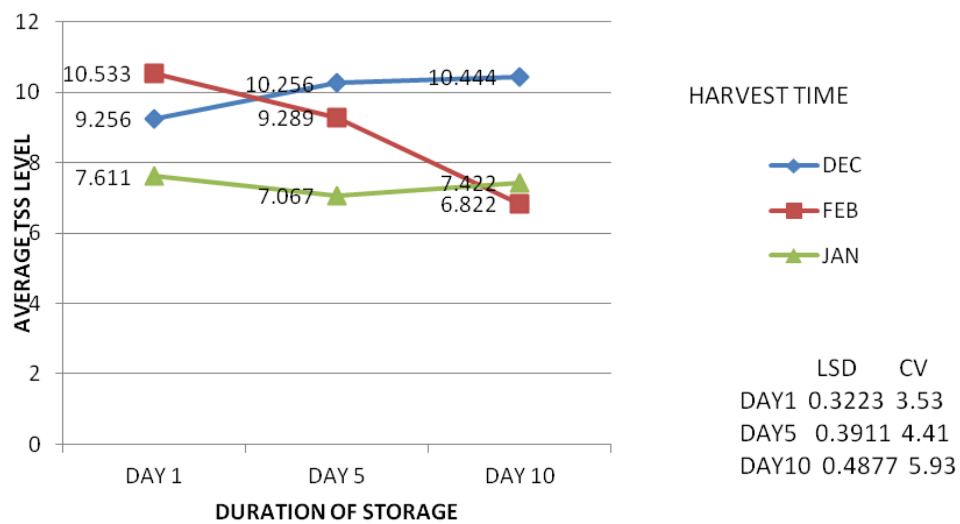


Figure 4.4 Effect of Harvest Time and Storage Duration on TSS

4.3 Total Dissolved Solids (TDS)

4.3.1 Effect of stage of maturity on TDS content of citrus fruits

Figure 4.5 shows the effect of maturity stage and duration of storage on total dissolved solids content of the orange fruits. The TDS of fruits harvested at the full ripe stage instorage was fairly constant in than mature green and half ripe fruits. The TDS content of fully ripe increased from 1687.7mg/l to 1702.9mg/l, while the mature green fruits decreased from 1757.6mg/l – 1638.2mg/l by the 10th day of storage .On the other hand, TDS content of half ripe fruits decreased from 1673.8mg/l to 1655mg/l and again increased to 1724.9mg/l. However, the differences in the various stages of ripening on all the days of storage were not significant (p>0.05).

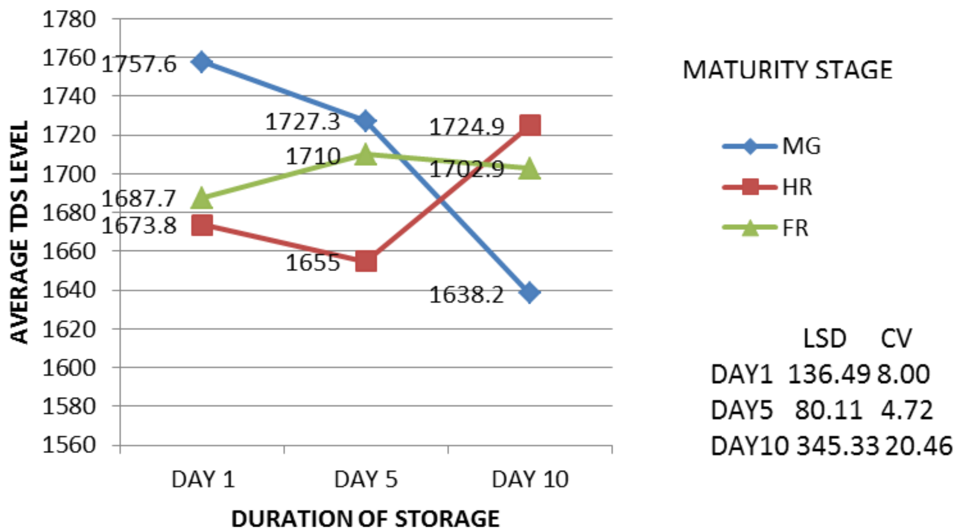


Figure 4.5 Effect of Maturity Stage and Storage Duration on TDS

4.3.2 Effect of stage of maturity on TDS content of citrus fruits

Figure 4.6 shows the effect of stage of harvest and duration of storage on total dissolve soilds content of the orange fruits. There were increases in TDS content of fruits harvested in December and January. Whereas, the TDS content of fruits harvested in December and January increased from 1675.6mg/l to 1698mg/l and 1705.4 to 1740.0mg/l respectively, that of February decreased from 1738mg/l to 1628mg/l. However, the differences in the various harvest time of fruits in all days of storage were not significant (p>0.05).

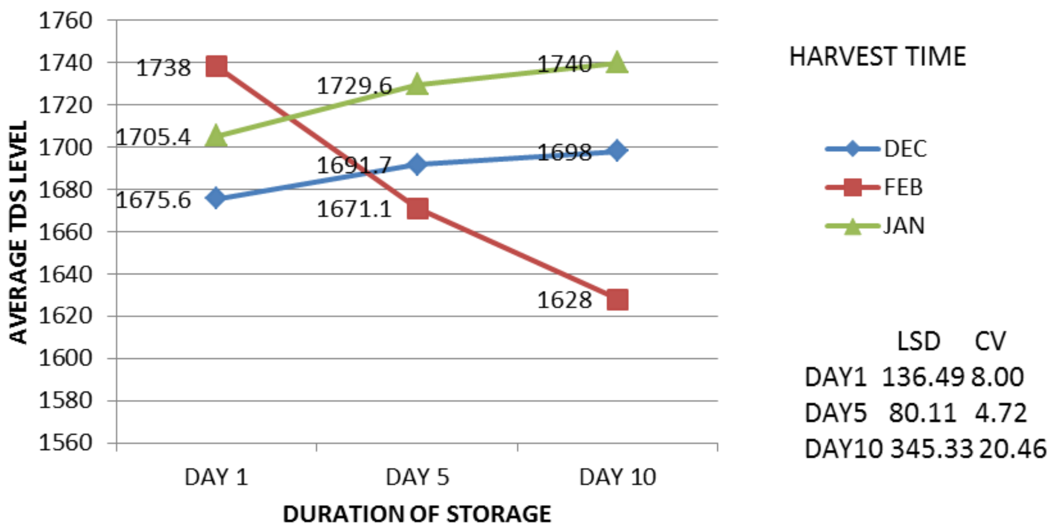


Figure 4.6 Effect of Harvest Time and Storage Duration on TDS

4.4 Juice Yield

4.4.1 Effect of stage of maturity on juice yield

Figure 4.7 shows the effect of maturity stage on juice yield of the orange fruits. There was a general increase in juice yield of fruits with storage. Whereas, in the half ripe the juice yield decreased from 80ml to 76ml and then increased again to 89.89ml, the full ripe and mature green increased from 80ml to 82.44m and87.78ml per fruit respectively. However, the differences in the juice yield of fruits at the various stages of ripening on all the days of storage were not significant ($p>0.05$).

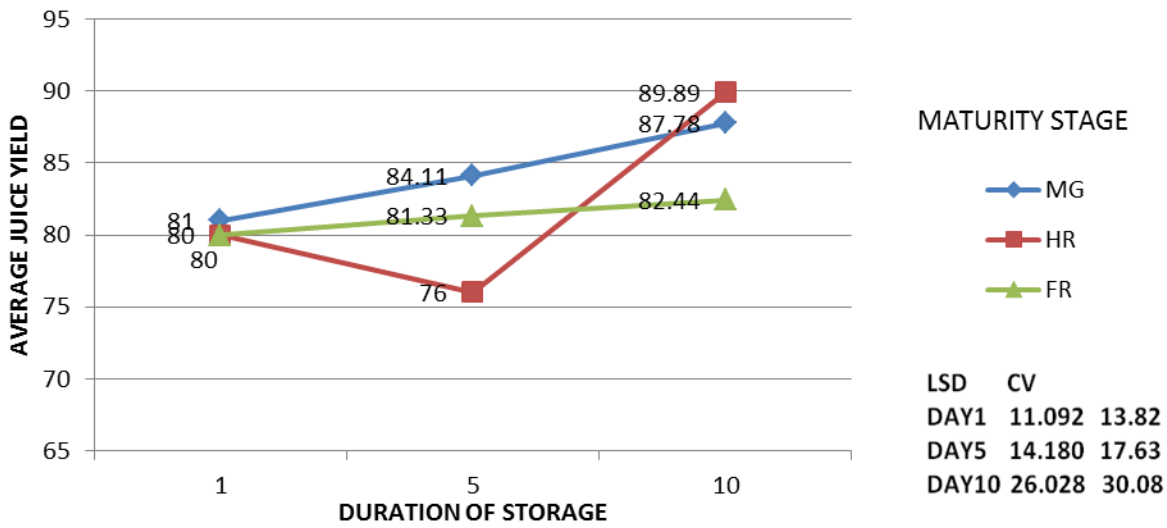


Figure4.7 Effect of Maturity Stage and Storage Duration on Juice Yield

4.4.2 Effect of month of harvest on juice yield of citurs fruits

Figure 4.8 shows the effect of time of harvest on juice yield of the stored orange fruits. There was a general decrease in juice yield in storage for all the months of harvest. Whereas fruits harvested in February steadly decreased fom 67.89ml to 61.78ml, that of January decreased from 84.67ml to 84.25ml. Fruits harvested in December showed a decline in juice yield from 88.44ml to 85.78ml during storage. The differences in the juice yield of fruits in storage in all the months of harvest were not significant ($p>0.05$), irrespective of the days of storage.

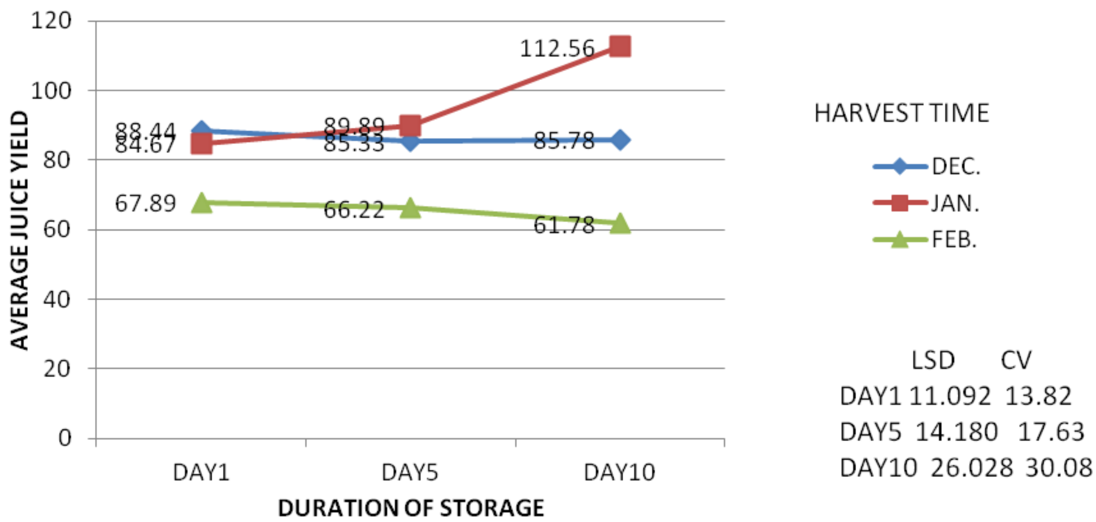


Figure 4.8 Effect of Harvest Time and Storage Duration on TDS

4.5 Level of pH

4.5.1 Effect of month of harvest on pH of citrus fruit juice

Figure 4.9 shows the effect of maturity stage on pH of juice from the orange fruits. There was a general decrease in the level of pH of mature green and half ripe orange fruits in storage. Fruits harvested at the full ripe stage showed lower pH level than both half ripe and mature green at Days 1 and 5 of storage. Whereas, in the full ripe ,the pH increased from 3.75 to 4.09, the half ripe and mature green decreased from 4.03 to 3.84 and 4.03 to 3.88 respectively. Significant differences at ($p<0.01$) existed in the level of pH in various stages of ripening on day 1 and day 10. However, the differences in the various stages of ripening on day 5 was not significant ($P>0.05$).

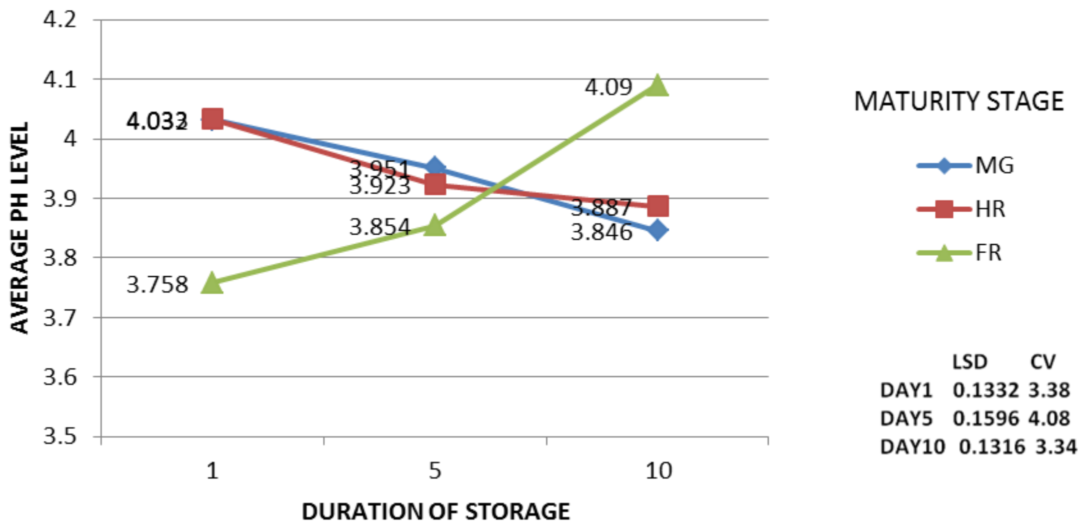


Figure4.9 Effect of Stage of Maturity and Storage Duration on PH

4.5.2 Effect of storage of maturity on pH of citrus fruit juice

Figure 4.10 shows the effect of time harvest on pH of the orange fruit juice. There were flactuations in pH level of orange fruits in storage for all the months of harvest. Fruits harvested in February showed consistently lower pH level than both December and January harvest. February harvest showed pH level of 4.10 to 4.18, whereas December and January varied between 3.92 to3.87 and 3.81 to 3.76 respectively. The differences in the pH levels of oranges for all the days of storage were significant ($P<0.05$) in all the months of harvest.

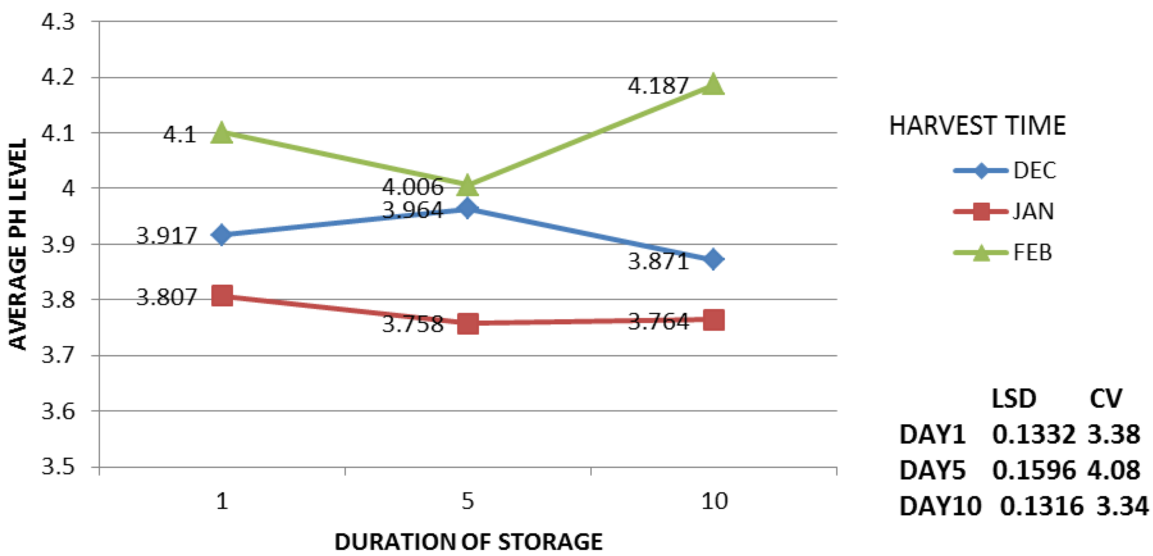


Figure 4.10 Effect of Harvest Time and Storage Duration on pH

4.5.2 Effect of stage of maturity on pH of citrus fruit juice

Figure 4.11 shows the weight of citrus fruits as affected by different stages of maturity. .There were fluactuations in pH level of orange fruits in storage for all the months of harvest. Fruits harvested at the full ripe stage showed consistently higher weight than both half ripe and mature green. Weight of the full ripe fruit weight decreased from 173.78g to 162.00g,whereas, the half ripe and mature green decreased from 210.89g to 163.00g and 189.56g to 183.00g respectively. Significant differences ($P<0.05$) existed in the weight of all the stages of ripening on Day 1. However, the differences in the various stages of ripening on Days 5 and 10 were not significant ($p>0.05$).

4.6 Fruit Weight (g)

4.6.2 the effect of harvest time on the weight

Figure 4.12 shows the effect of month of harvest on the weight of the orange fruits. There was a general decrease in weight level of orange fruits in storage for all the months of harvest. Whereas, in the December harvest the level of fruit weight decreased from 180.22g to 163.56g and then rose again to 180.00g, the January and February harvested fruits weight consistently decreased from 209.56g to 177.00g and 184.44g to 172.00g respectively. Significant differences ($P<0.05$) existed in the weight levels of fruits for all the months of harvest on the Day 1. However, the differences in the weight levels of fruits on days 5 and 10 were not significant ($p>0.05$).

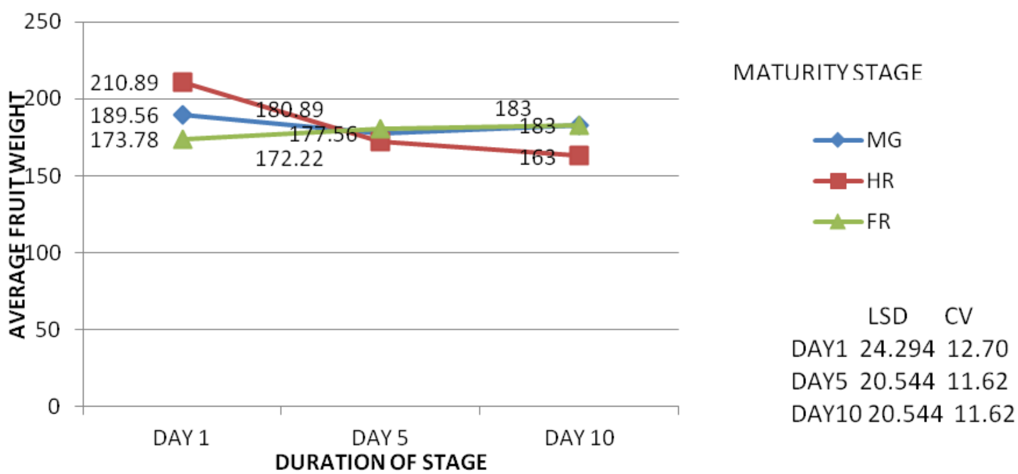


Figure 4.12 Effect of Harvest Time and Storage Duration on fruit Weight

4.7 Fruit Firmness

4.7.1 Effect of stage of ripening on fruit firmness

Figure 4.13 shows the effect of maturity stage on the firmness of the orange fruits. There was a general increase in fruit firmness in storage. Whereas in mature green fruits firmness increased from 4.01 mm to 4.91 mm,and half ripe and full ripe increased from 3.24 mm to 5.12 mm and 3.58 mm to 5.42 mm respectively. The differences in firmness of fruits observed at all stages of rippening were significant at ($P<0.01$) in day 10 of storage. However, the differences in the various stages of ripening on days 1 and 5 were not significant ($P>0.05$).

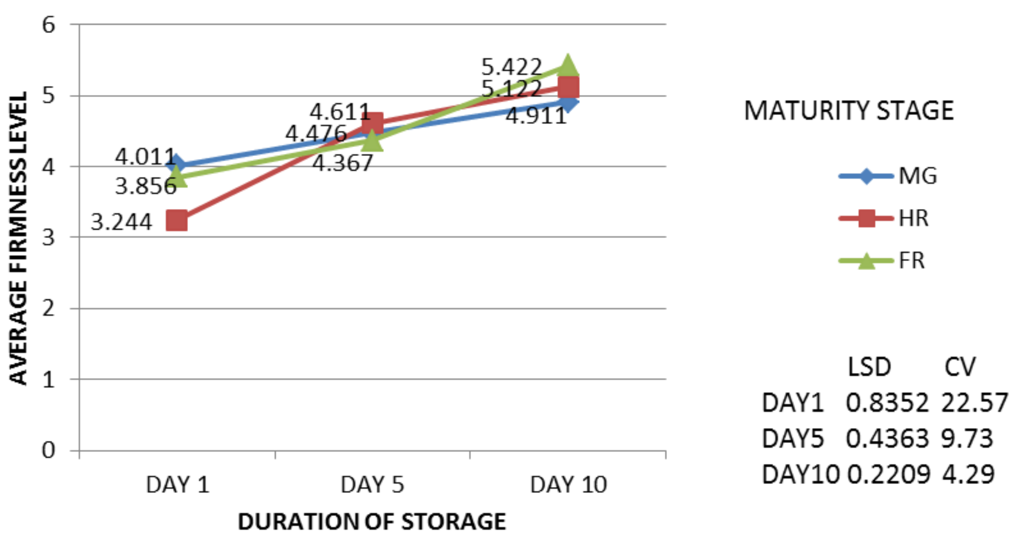


Figure 4.13 Effect of Maturity Stage and Storage Duration on Firmness

4.7.2 Effect of month of harvest of citrus fruits on fruit firmness

Figure 4.14 shows the effect of harvest time and duration of storage on level of firmness of the orange fruits. There was a general increase in the level of fruit firmness in storage for all the months of harvest. Fruits harvested in February showed consistently higher level of firmness than January and Decmber. Whereas February firmness consistently increased from 4.42 mm to 6.04 mm, January and December harvest increased from 3.42 mm to 4.75 mm and 3.44 mm to 4.65 mm respectively. The differences in firmness of the citrus fruits in storage were significant (P<0.05) for Day 5 and 10.However,no differences were found for Day 1 (P>0.05).

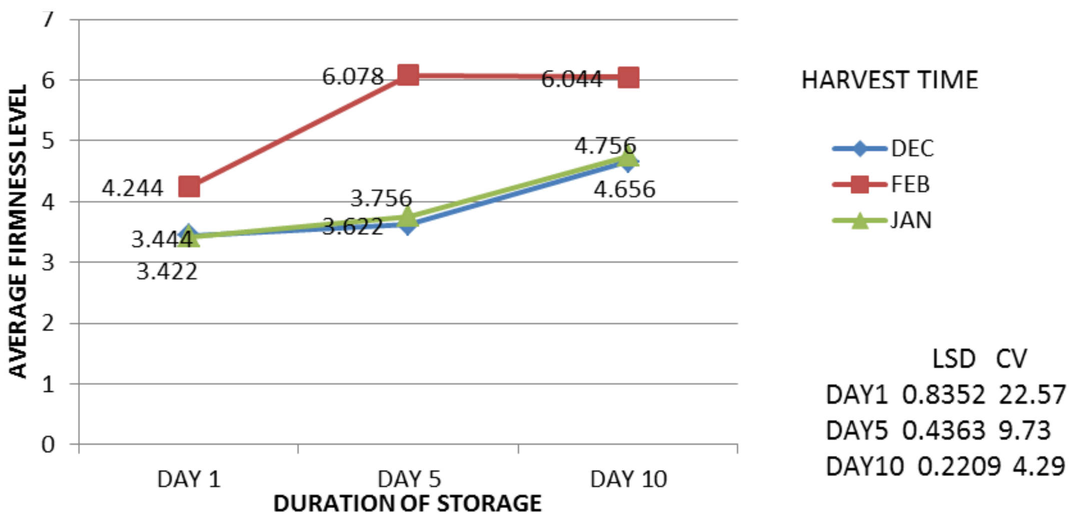


Figure 4.14 Effect of Harvest Time and Storage Duration on Firmness

4.8 Electrical Conductivity (EC)

4.8.1 Effect of stage of maturity of citrus on Electrical conductivity

Figure 4.15 shows the effect of maturity stage on electrical conductivity of the juice orange fruits. The EC of mature green fruits varied from 3582.7 to 3551.3, while the full ripe ranged between 3339.2 and 3032.7 and the half ripe from 3414 and 3463.1. The differences in the EC level of all the stages of ripening on all the days of storage were not significant (p>0.05).

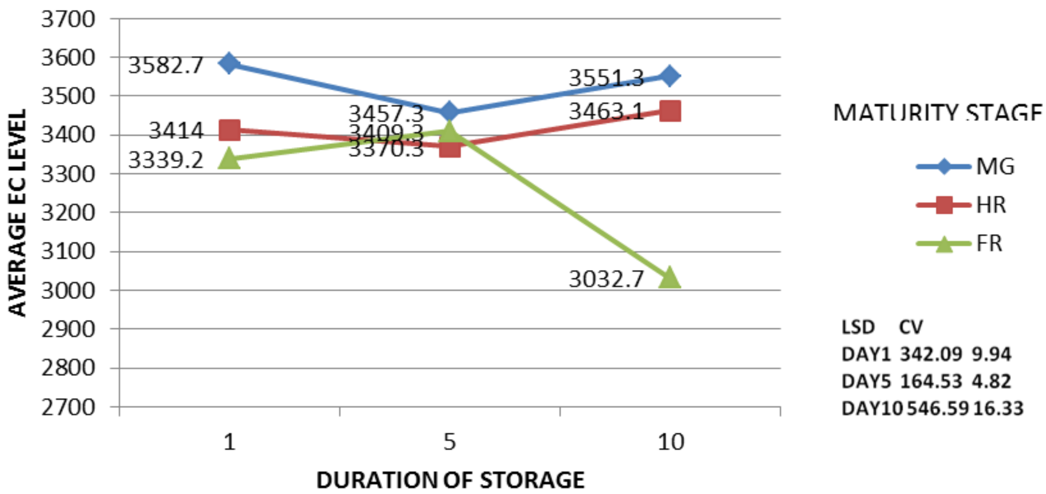


Figure 4.15 Effect of Maturity Stage and Storage Duration on EC

4.8.2 Effect of stage of maturity on EC of citurs fruits

Figure 4.16 shows the effect of harvest time and duration of storage on electrical conductivity of the orange fruits. The EC of January harvest decreased from 3644.3 to 3413, while the December harvest rose from 3234.4 to 3361.1 and then declined to 3042.3.On the other hand, the half ripe varied from 3457.1 to 3591.8. The differences in the EC level of fruits in storage for Days 1 and 10 were significant ($P < 0.05$). The differences in vitamin C level of fruits observed at all stages of rippening for all the days of storage were not significant ($p > 0.05$).

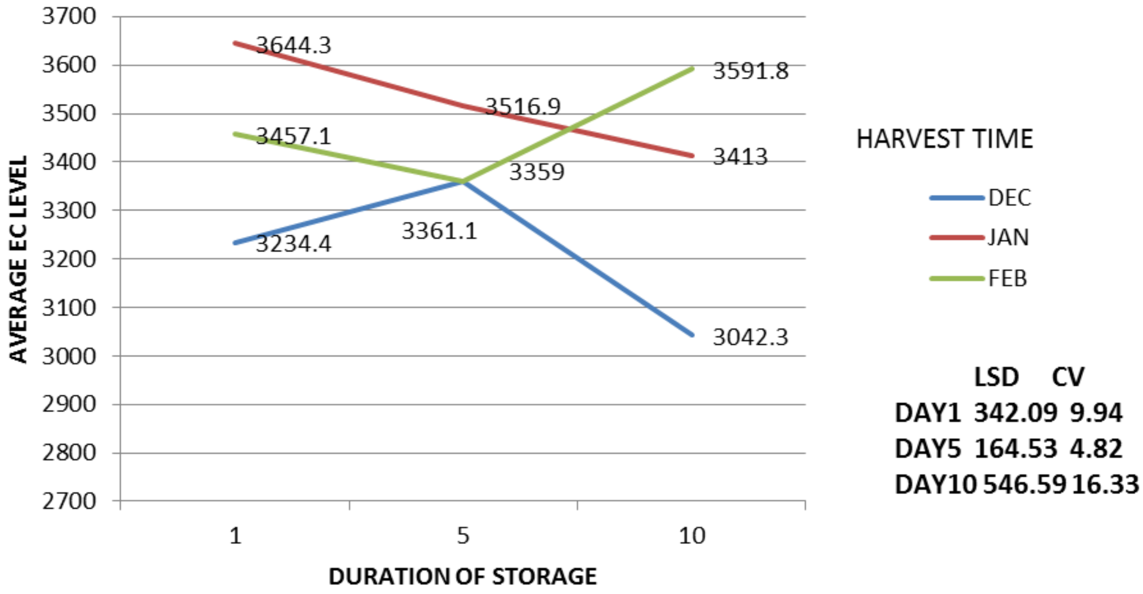
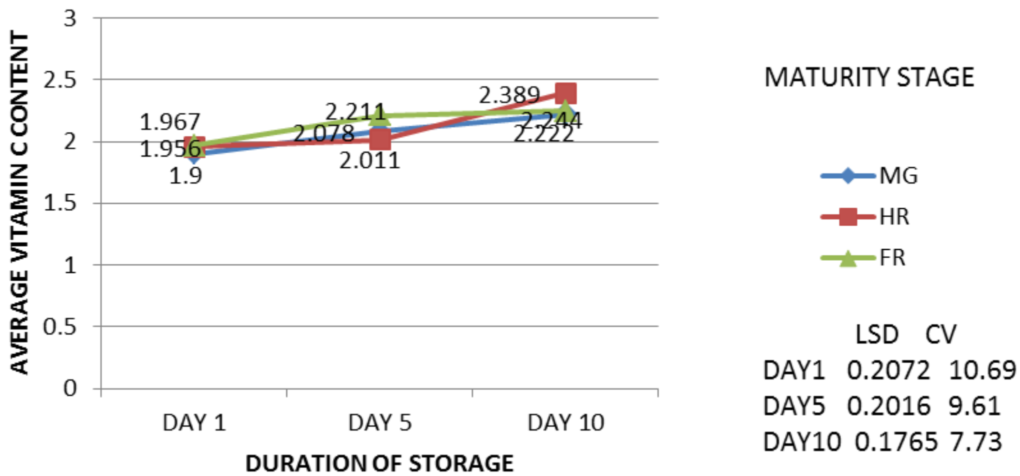


Figure 4.16 Effect of Harvest Time and Storage Duration on EC

4.9 Vitamin C Content

Figure 4.17 shows the effect of maturity stage and duration of storage on vitamin C of the orange fruits. There was a general increase in the level of vitamin C content of fruits in storage. Fruits harvested at full ripe increased from 1.97mg/100ml juice to 2.24mg/100ml juice, whereas, half ripe and mature green vitamin C level in storage consistently increased from 1.95mg/100ml juice to 2.39mg/100ml juice and 1.9mg/100ml juice to 2.22mg/100ml juice respectively.



4.17 Effect of Figure Maturity Stage and Storage Duration on Vitamin C

Figure 4.18 shows the effect of harvest time and duration of storage on vitamin C content of the orange fruits. There was a general increase in the level of vitamin C content of fruits in storage for all the months of harvest. Fruits harvested in the month of December showed consistently higher vitamin C level in storage than January and February fruits. Whereas, December harvested fruits had vitamin C increased from 2.3mg/100ml juice to 2.51mg/100ml juice, January and December increased from 1.74mg/100ml juice to 1.93mg/ml juice and 1.77mg/100ml juice to 2.41mg/100ml juice respectively. The differences in vitamin C level of fruits observed in storage for all the months of harvest were significant at (P<0.01) for all the days of storage.

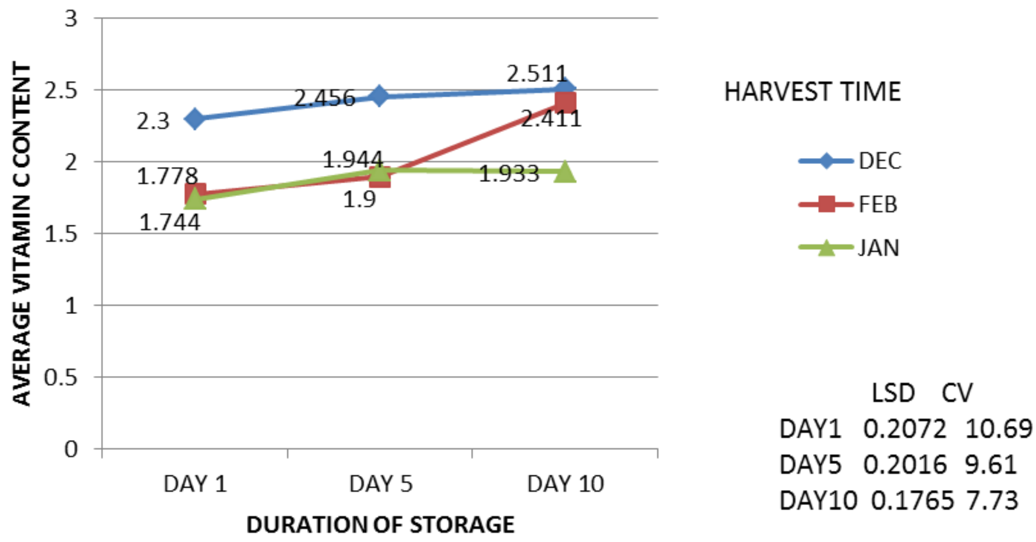


Figure 4.9 Effect of Harvest Time and Storage Duration on Vitamin C

CHAPTER FIVE

DISCUSSION

5.1 Total Titratable Acidity (TTA)

The general decrease in total titratable acidity observed in this study was to be expected. According to Batchelor and Bittens (1954) and Samson (1986) during storage, ripening changes occur in fruits resulting in reduction in total titratable acidity. The decrease could be attributed to prolonged use of fruit acids for respiration during holding. However, it is unusual for mature green fruits to have lower TTA levels than the full ripe. The reduction in acidity with storage is expected to make the fruits less acidic and therefore more accetable in taste. Lower acid content is known to improve flavour resulting from higher sugar – acid ratio. The results suggested that holding of orange for up to 10 days could reduce acidty and improve the flavor of the juice.

According to Samson (1986) if fruits remain unharvested on the tree, the TSS continues to increase while the acidity diminishes, until eventually they over ripe. The decrease in TTA concentration in most citrus fruits during ripening may be partly due to dilution with increased ripening due to increased water content (Kimball, 1984). Since lower acid content is known to improve flavour and sweetness resulting from sugar:acid ratio, the results suggested that oranges harvested late February could be sweeter and more flavoured than early harvested fruits due to low acid content.

5.2 Total Soluble Solids(TSS)

The steady decline in total soluble solids content of half ripe and mature green fruits in storage observed in this study was unexpected. According to Samson (1986) and Bakshi (1967) as fruits mature, the TSS content increases rapidly at first and then at a slower rate when fully riped, while TTA increases early in development, then steadily decreased. It is unusual for full ripe fruits to have increasing TSS levels in storage than half ripe and mature green fruits. Probably this observation could be due to the increase in sugar content as the acid content in the fruit decreases in holding. According to Fisher (1945), the TSS to acidity ratio in the fruit is a good indicator for palatability.

The decrease in total soluble solids in February observed in this study was to be expected. According to Bakshi (1967), the TSS decreases in Valencia varieties when harvesting is delayed. However, it is very usual for fruits harvested early and mid-early (i.e December and January) to have higher TSS levels than late harvest, since TSS increase rapidly in the late development of orange fruits. Probably, this observation may be attributed to high amount of water absorbed by the fruit during early development which increases fruit size and is also likely to carry high amounts of the minerals that constitute the TSS content in orange fruits. It is also known that February months are generally drier than December and January .This probably resulted in lower moisture content of the fruits concentration sugar in the juice of the fruits harvested in February.

5.3 Total Dissolved Solids (TDS)

The higher TDS content of full ripe orange fruits observed in this study was to be expected. According to WHO (1996), TDS is made up of inorganic salts found in water as well as organic salts synthesized by plants. This implies fruit at full maturity may have synthesized or absorbed and accumulated higher amount of TDS than half ripe and mature green orange fruits. The increase in TDS in storage could be attributed to loss of water in the fruits during holding. The results suggested that holding of orange for up to 5 or 10 days could increase TDS.

5.4 Juice Yield

The increase in juice yield of full ripe and mature green orange fruits observed in this study was to be expected. According to Spiegel-Roy and Goldschmidt (1996), the juice sacs of orange fruits mostly elongate to contain more juice when the fruit is fully matured and ripped. The increase could be attributed to juice sac cells synthesizing more juice during storage until the fruit deteriorates or senescences under poor storage conditions.

The results suggested that holding of mature and full ripe oranges for up to 10 days could increase the juice yield during processing.

5.5 Level of pH

According to Samson and Monselise, (1977), Sinha *et al.,* (1962) and Sapeda *et al.,* (1993) malic acid and ascorbic acid which are major determinants of pH in citrus. Decreased pH in storage in late valencia sweet oranges could be attributed to the stage of storage, since less matured cells could be synthesizing more acids. The results suggest that holding unripe orange for 5 to 10 days could increase acidity.

The general fluctuation in pH levels of orange fruits all the months of harvest observed was unexpected. This observation could be attributed to storage conditions and delay in harvest as more acids could be used for respiration either during storage or as the fruits stayed on the tree for longer periods of time. The fluctuations observed in the results suggested that pH level could be unstable in holding notwithstanding the time that the fruits are harvested.

5.6 Fruit Weight

Motlagh and Quantic (1988), reported that during storage fruits loose some amount of moisture which result in weight loss. The reduction in weight with storage could make the fruits wrinkled and therefore less attractive and acceptable to consumers. The results suggested that holding of orange for up to 5 or 10 days could reduce fruit weight and hence its acceptability to some consumers if the storage conditions are not modified.

Cepeda *et al*., (1993) indicated that fruit weight increase with harvesting time. The increase could be attributed to accumulation of photosynthates in the fruit (Khan *et al*., 1992). Also the general decrease in fruit weight in storage was to be expected. According to Motlagh and Quantic (1988), during storage fruits lose some amount of moisture which results in weight loss.

5.7 Fruit Firmness

According to Sinha *et al.* (1992), firmness or rind thickness reduced with maturity and ripening in valencia late oranges. The decrease may be due to ethylene production which is associated with increased maturity Gussman (1993). However, the general increase in fruit firmness in storage observed was unexpected and could be attributed to loss of moisture from the rind of the fruits. Poor firmness level may reduce fruit quality hence making fruits unattractive to consumers.

According to Anwar *et al.,* (1999) peel thickness or firmness increase with delay in harvest time. The increase could be attributed to increase in fruit size as harvesting is delayed which may lead to corresponding increase in fruit firmness. Also, some citrus cultivars have greater firmness retention during storage than others Tu *et al*., (1997) which may be the case of the Valencia late used in this study. The results suggested that good firmness quality of orange fruits is attained when harvesting is delayed.

5.8 Electrical Conductivity (EC)

According to Droby *et al.,* (1989), electrical conductivity increase with ripening and that electrical conductivity is an effective physical maturity index as well as suitable index of storage quality. The decrease could be attributed to delay of ripening which is associated with reduction in fruit softening as an indication of membrane permeability (Hershkovitz et al., 2005). However, the EC was expected to increase with storage because fruits would have softened to enhance membrane permeability in holding for up to 10 days which did not occur. This observation may be attributed to fruit senescence which could have hardened the fruits instead of softening. The low level EC may imply poor storage quality or maturity of fruits. The results suggested that holding of orange fruits for up to 5 or 10 day do not increase EC. The general fluctuation of EC of orange fruits with harvest time was expected.

According to Samson and Monselise (1977) during growth of orange internal conductivities declined sharply and then increased very strongly under different storage conditions. The decline could be attributed to differences of peel electrolytes at the fruit equators and the stylar ends of the orange fruit during prolonged storage. However, the increase in EC level of late harvested fruits (February) was expected since fruits might have softened enough to allow membrane permeability and ion leakage (Ahmed *et al.*, 2010).

5.9 Vitamin C Content

The general increase of vitamin C content with maturity of orange fruits in storage was unexpected. According to Sinha *et al.*, (1962) and Sapeda *et al.,* (1993), vitamin C (ascorbic acid) contents decreased with time of maturity and prolong storage in late Valencia citrus fruits. The content of vitamin C in fruits and vegetables was influenced by various factors such as genotypic differences, pre-harvest climatic conditions and cultural practices, maturity and harvesting methods, and postharvest handling procedures (Lee and Kader, 2000). Probably, the increase could be due to incomplete synthesis of vitamin C by precursors which was carried over in to storage hence the increase observed.

The general increase of vitamin C content of orange fruits with harvest time was to be expected. According to Sinha *et al.*, (1962) vitamin C content of late Valencia fruits increase with increase in harvest time. The increase could be attributed to difference in light intensity during the various harvests time period because the higher the intensity of light during the growing season, the greater the vitamin C content in plant tissues (Lee and Kader, 2000). However, the increase in vitamin C content of orange fruits in storage was unexpected. According to Sinha *et al.*, (1962) and Sapeda *et al.*, (1993) vitamin C contents decreased with storage in late Valencia citrus fruits. The content of vitamin C in fruits and vegetables is influenced by various factors such as genotypic differences, pre-harvest climatic conditions and cultural practices, maturity and harvesting methods, and postharvest handling procedures (Lee and Kader, 2000). Probably, the increase could be due to incomplete synthesis of vitamin C by precursors which was carried over in to storage hence the increase observed.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary of Findings

The study found that TTA content in citrus fruits generally decreased in storage and that keeping orange for up to 10 days could reduce its acidity and increase the fruits acceptability to consumers. The study also found that fruits harvested at mid and late (i.e January and February) had low TTA content and could be sweeter or flavoury than those harvested early (i.e December). It was also found that TSS content of citrus fruits declined in storage, while that of fully ripe fruits increased. Again it was found that TSS content of late harvested fruits decreased, while that of mid and early harvested fruits increased. Furthermore holding of orange for up to 5 or 10 days increased TDS content of the fruits. Again, the study established that orange fruits harvested in mid-late (i.e late January) had high amount of TDS in holding.

It was established that holding of mature and full ripe oranges for up to 10 days increased the juice yield during processing. The study also found that late harvested orange fruits in holding gave maximum juice yield during processing than early harvesting. The pH level of citrus fruits generally fluctuated and could be unstable in holding notwithstanding the time that the fruits are harvested. Also it was established by the study that holding of orange for more than 5 days reduced fruit weight of orange fruits and that good firmness quality of orange fruit is attained when harvesting is delayed.

6.2 Conclusions

Based on the findings of the study, it can be concluded that citrus fruits used acids for respiration during prolonged period of holding, which may reduce its sourness and improve flavor. It can also be concluded that increased in sugar content of full ripe orange fruits as the acid content in the fruit decreases in holding, caused TSS content of full ripe orange fruits in holding to increase. The study also concluded that time of harvest influenced the TSS content in orange fruits. The vitamin C content of citrus, mature green and half ripe fruits, increased with duration of storage. Also, the longer the citrus fruit stayed on the tree the lower the pH level and the higher the fruit firmness. The general conclusions that can therefore be drawn are that most physico-chemical properties of citrus fruits are influenced by the time of harvest and stage of maturity.

6.3 Recommendations

The study recommended that industries that extract vitamin C from fresh citrus fruits should harvest the fruits early enough (December) in the season to obtain maximum yield of vitamin C. However, when harvesting is done midway or lately (January or February) then, the fruits should be stored between five days and ten days interval to obtain maximum yield of vitamin C.

Industries that process fruit juice from citrus fruits should harvest midway (January) in the season or increase the duration of storage to obtain high juiced yield. It also recommended sell their produce on weight should market them when it is fully ripe since high weight of fruits will increase their revenue. Also citrus farmers can delay the time of harvest to obtain fruits with higher weight for more profit from sales.

REFERENCES

Albrigo, L.G, Carter, R.D., (1977)*Structure of Citrus Fruits in Relation to Processing*. In Nagy, S, Shaw, P.E, Veldhuis, M.). K (Eds) Citrus Science and Technology Vol. 1, CT. PP.30 – 73

Anwar B.A and S.J. oniye 2004. Chemical studies of the seed of orange. J. Biology sci. 4:711-715.

Attaway, J.A and Nagy, S., (1980), *Analytical Indicators of Processed Oranges Juice Quality* PP. 76:584-59

Bakhshi, J.C., Singh, G. and K.K Singh., (1967). *Effect of Time of Picking on Fruits Quality and Subsequent Cropping of Valencia Late Variety of Sweat Orange (C. Sinensis).* Indian Journal of Horticulture, 24:63 – 70.

Benavente - Garcia, O., Castillo, J and Del Rio, J.A., (1997). Use and Properties of Citrus Flavonoids. *Journal of Agricultural and Food Chemistry*, 45 (12), 4505 – 4515.

Benevelet, P. and kitahata, B. 1987. Citrus juice modulates bone strength in male senescent rat modele of osteoporosis. Nutrition; 22:559-563.

Carpenter, K. 1986. The history of scurvy and vitamin c. Cambridge UK, Cambridge university press.

Cepeda, J.S, Baez –Sanndo, R, and Angule, M., (1963). Ascorbic Acid And Quality Loses of Valencia Oranges. *Horticulture Science*, 28:581.

Cepeda, J.S, Bringas, E and Balz, M., (1993). Ascobic Acid and Quality Losses of Valencia Oranges Stored on Trees. *Horticulture Science*, 28:581.

Chalutz, E and Wilson, C. L., (1990). Harvest Biological Control of Green and Blue Mold and Sour Rot on Citrus Fruits. *Plant Diseases* 74:134 – 137.

Droby, S and Wilson, C.L 1989 biological control of postharvest diseases of citrus. Pages 60-70

Echeverria, E and Ismail, M. A., (1987). Changes in Sugars and Acids of Citrus Fruits during Storage. *Proc. Fla. State Hort Soc*. 100:50-2

Food and Agriculture Organization (FAO) 2000. Citrus fruits annual statistics

Goff, S.A, and Klee, H. J., (2006). *Volatile Compounds: Sensory Cause for Health and Nutritional Value* PP. 815 – 819

Gorinstein, W., (2001). *Chilling Injury in Tropical and Sub-Tropical Fruits: Effect of Harvest Date, Degreening, Delayed Storage and Peel Colour or CT on Sweet Orange*.

Harris. R.S., (1975). Effect of Agricultural Practices on the Composition of Foods. *Nutritional Evaluation of Food Processing*. AVI, West Port, CT.Pp 33-57.

Hatch, G. 1995. Asthma inhaled oxidants and dietary antioxidants. American journal of clinical nutrition.

Kays, S.J, Paull R.E (2004). *Post Harvest Biology*. Exon Press, Georgia, USA. ISBU 1 – 888186-54-2.

Khan. M.I, Ahmed, M. J, and Kayani, M. Z., (1997). Physical Changes Occurring in Grape Fruit during Maturation and Ripening. *Journal of Agricultural Research*, 30:359 – 363.

Kotze J.M., (1981). Epidemiology and Control of Citrus Black Sport in South Africa. *Plant Diseases.* 65:945 – 950

Ladaniya, M.S., (2004). *Citrus: Postharvest Cold Chain*, Pp.239-276.

Lee, S.K, and Kader A. A., (2000). Pre-Harvest and Post-harvest Factors Influencing Vitamin C Content Of Horticultural Crops. *Postharvest Biology and Technology*, 20, 207 – 220.

Mozafar, A., (1993). Nitrogen Fertilizers and the Amount of Vitamins in Plants. *A Review Journal of Plants Nutrition*, 16:2479-2506

Murata, T., (1997). *Citrus*. In: Mitra, S.K (Ed) Post Harvest Physiology and Storage of Tropical and Sub-tropical Fruits .CAB International, UK, Pp 21-40, 47.

Nagy, S., (1980). Vitamin C Contents of Citrus Fruits and their Products. *A Review Journal of Agriculture and Food Chemistry* 28, 8-18.

Nagy, V, Szabo, Z, Mark, L, Deli, J., (2007). Comparative Study on the Carotenoid Citrus. *Innovative Food Science and Emerging Technologies*, 8:390 – 394.

New, S and Reid, d, 1997. Nutritional influence on bone mineral density. American journal of clinical nutrition 66: 1831-1839

Norman, c 1988. EPA sets new policy on export of fruits, science. 242:366-367

Ortega, R, Requejo, A. and Redondo, M. 1997. Dietary intake and congnitive function in a group of elderly people. American journal of clinical nutrition, 66: 803-809.

Samson, J.A., (1986). Citrus, Tropical Fruits. *Longman Scientific and Technical Essex*, New York Pp 73-138.

Sinha, R.B, Randhawa, G. S, and Jain, W. L., (1962). Seasonal Changes in Late Valencia Oranges. *Indian Journal of Agricultural Science*, 32.14 – 162.

Spiegel-Roy, P. and Goldschmidt, E.E. (1996). Reproductive Physiology: Flowering and Fruiting, Biology of Citrus. Biology of Horticultural Crops. Cambridge University Press, New York, pp 70 - 125

Steimetz, K and Potter, J. 1999. Vegetable fruits and cancer, II mechanisms. Cancer causes and controls 2:427-445

Waks, R, Hicman, H, and Martinek, K.. (1985). *Composition and Physiological Properties of Fruits.* PP. 24

Whitney and Rofles, S. 1992. Understanding nutrition. Belmon, Ca, USA.

Wisniewski, M.E, and Wilson, C.L., (1992). Biological Control of Post-harvest Diseases of Fruits and Vegetables: *Journal of Horticultural science* 27: 94 – 98.

World Health Organization, (1996). Total Dissolved Solids in Drinking-water: Background Document for Development of WHO Guidelines for Drinking-water Quality. http://www.water-research.net/totaldissolvedsolids.htm.

Yu, S.A. and Sacco, V. 2005. Study antimicrobial activity of lemon peel extract. Brit J Pharm Toxicol.,2(3):119-122