

# **EFFECT OF MATURITY STAGE AND STORAGE DURATION ON PHYSICO-CHEMICAL PROPERTIES OF CITRUS (*CITRUS SINENSIS* VAR. *LATE VALENCIA*)**

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## **Abstract**

This study investigated the effect of maturity stage and duration of storage on physico-chemical properties of citrus fruits (*Citrus sinensis* var. late Valencia) in the Ashanti region of Ghana. A total of 450 mature fruits were harvested from the same farm for three different months, harvesting 150 fruits each month. Each harvest was categorised into three base on stage of maturity namely; mature green (MG), half ripe (HR) and full ripe (FR) fruits. A random sample of 50 fruits from the three categories were analysed on day one of harvest for their physico-chemical properties while the remaining 100 fruits were stored at ambient temperature (between 25C<sup>0</sup> to 30C<sup>0</sup>) for 5 and 10 days before their physico-chemical properties were analysed. The physico-chemical properties measured were weight, juice yield, firmness, pH, vitamin C, TSS, sugar, TDS, TTA and EC. Some of the major findings of the study were that TTA in FR fruits were lower than that of MG and HR fruits at day five and ten of storage. Vitamin C content in MG, HR and FR fruits increased as storage duration increases to day five and ten under ambient temperature. Holding of MG and HR fruits for up to ten days increased the juice yield during processing compared to holding FR fruits. The study recommended that processors of natural orange juice should monitor closely the maturity stage of fruits they procure and the length of time fruits are stored before processing as product quality could be compromised or enhanced by these factors.

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**Keywords:** Physico-chemical properties, citrus, vitamin C, maturity stage

and processing quality

## Introduction

Citrus is one of the most important fruit crops known by human since antiquity. From South East Asia, citrus has become immensely popular worldwide and is now grown in the sub-tropical belt from latitude 40<sup>0</sup> North to 40<sup>0</sup> South in both humid and arid regions. Citrus has two harvesting 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 a fruit crop grown almost throughout the world in the tropics and sub-tropics. Its growth conditions require areas where there is sufficient rainfall or irrigation to sustain growth and freezing conditions are moderate enough not to kill the trees (Gorinstein *et al.*, 2001 and Whiteside, *et al.*, 1993). Important citrus growing nations in the world are Brazil which is the largest citrus grower followed by USA and China. Among the citrus varieties grown throughout the world, sweet orange constitutes the most important proportion accounting for more than two-thirds of total global production. The overall world orange production stood at 51.8 million metric tons in 2013/14 with Brazil and China leading (USDA, 2014). It is estimated that about 104 million tons of sweet oranges are harvested in the world annually (FAO, 2004, 2000). 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 reported to be the most preferred by consumers in the USA and in many parts of the world to other citrus products like 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 of fruit production. Several factors such as changes in physico-chemical properties especial the volatile ones, physical injuries during harvest, chilling injuries during storage as well as harsh climatic weather conditions which affect fruit and nutritonal quality, especially vitamin C in citrus, have been reported (Ladaniya, 2011; Kimball, 1999 and Waks *et al.*, 1985). Among these factors changes in physico-chemical properties is of industrial and commercial importance probably due to its impact on nutritional quality of citrus fruits. The changes in physico-chemical properties could affect 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). The changes in physico-chemical properties have been attributed to factors such as poor fruit handling during transit to market, indiscriminate timing of harvest as well as the effect of temperature and storage conditions. At the time of this research most works sighted in literature (Anwar *et al.* 1999; Ladaniya, 2011; Igbal *et al.* 2012) on factors affecting changes in

physico-chemical properties were limited to date of harvesting or picking time, storage duration, storage temperature or conditions and chilling injuries. No empirical study was sighted on effect of maturity stage and storage duration of citrus fruits especially in Ghana where this research was conducted. The aim of this paper therefore is to investigate the effect of maturity stage and storage duration on the physico-chemical properties of citrus fruits, specifically sweet orange (*Citrus sinensis var late Valencia*) which is widely cultivated in Ghana. This will assist citrus farmers and processors to have a good idea of the possible fruit quality to expect depending on the maturity stage at which fruits are harvested and the duration of storage before processing or consumption.

### **Data Sources and Methodology**

The oranges used for the study were collected from a private farm (Adjei Farms) at Adumasa in the Ejisu-Juaben District of Ashanti Region of Ghana. In all, a total of 450 citrus fruits were harvested from selected citrus trees at three different periods of time (December, 2011 and January and February, 2012). A sub-total of 150 fruits were harvested for each period to form the total sample size. However, because citrus is non-climateric, in practice farmers usually harvest fruits once majority of fruits on the tree are considered mature and taste good regardless of the age and stage of ripening, hence all the fruits harvested to form the sample size were assumed to be of equal age for purposes of this analysis. The orange fruits were purposively grouped according to maturity stage as matured green (MG), half ripped (HR) and full ripe (FR) fruits to test the hypothesis that orange fruits at different stages of maturity have effect on physico-chemical properties of the fruit.

The first batch of 50 fruits were randomly sampled from the three groups and their physico-chemical properties analysed on day 1 of harvest and the remaining 100 fruits stored at room or ambient temperature. Again by farmers' practices in Ghana orange fruits are usually not stored under modified temperature hence this study did not take storage temperature into consideration and only assumed a normal room temperature of between 25C<sup>0</sup> to 30C<sup>0</sup>. The second batch of 50 fruits were randomly sampled and their properties analysed at 5 days of storage. While the last batch of 50 fruits were analysed at 10 days of storage. The same procedure was followed for all the three harvests periods. Even though citrus is non-climateric and therefore are not expected to undergo any significant ripening changes in storage, notwithstanding, some changes could occur in physico-chemical properties that are peculiar to non-climateric fruits. This informed the decision to vary the duration of storage to help assess its effect on changes of physico-chemical properties of fruit in holding.

The study used (3×3) factorial experimental design method with three replications. A one-way ANOVA set at (p<0.01 and p<0.05) was used to analyse the data and the mean values of the parametres analysed with their LSD and CV values presented in line graphs. The summary of physico-chemical properties assessed by this study is as shown in Table 1.

Table1. List of physic-chemical properties assessed

Physico-chemical Property	Measurement Unit
Fruit Weight,	Grams (g)
Fruits Firmness	Millimeters (mm)
Juice Yield	Milliliters (ml)
pH	Number
Vitamin C	mg100ml <sup>-1</sup> juice
Total soluble solids (TSS)	g100ml <sup>-1</sup> juice
Total Dissolve Solids (TDS)	mgL <sup>-1</sup> juice
Total Titratable Acidity (TTA)	g100ml <sup>-1</sup> acid
Electrical Conductivity (EC)	Number

## Results

### Effect of maturity stage and storage duration on TTA content of citrus fruits

The results (Figure 1) showed that fruits harvested at full ripe stage have higher TTA content than half ripe and mature green at day 1 and 5 of storage. Whereas TTA content in the full ripe fruits decreased from 10.25 to 7.51g/100ml acid and that of half ripe and mature green fruits declined from 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 acid level in the stages of ripening on day 10 were not significant.

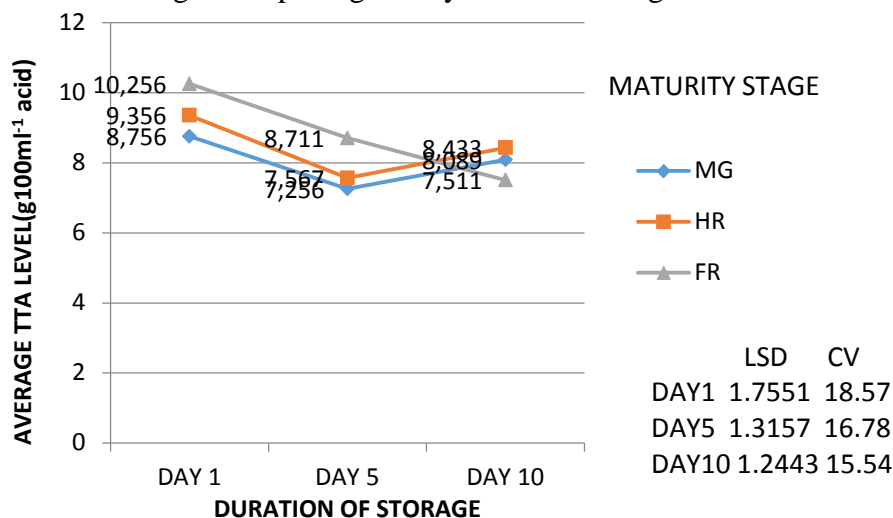


Fig. 1 Effect of maturity stage and duration of storage on TTA

**Effect of maturity stage and storage duration on TSS content of citrus**

The results in (Figure 2) also showed a steady decline in TSS content of half ripe fruits and mature green fruits at 5 and 10 days of storage. However, fruits harvested at the full ripe stage showed slightly higher TSS content, fluctuating between 9.7 and 8.58 g/100ml in storage, than that of half ripe and mature green. The TSS of half ripe and mature green fruits generally decreased from 9.08 to 8.27g/100ml and 8.7 to 7.84 g/100ml in storage, respectively. The differences in the TSS levels in all the stages of ripening in day 1, day 5 and day 10 were significant (p<0.05).

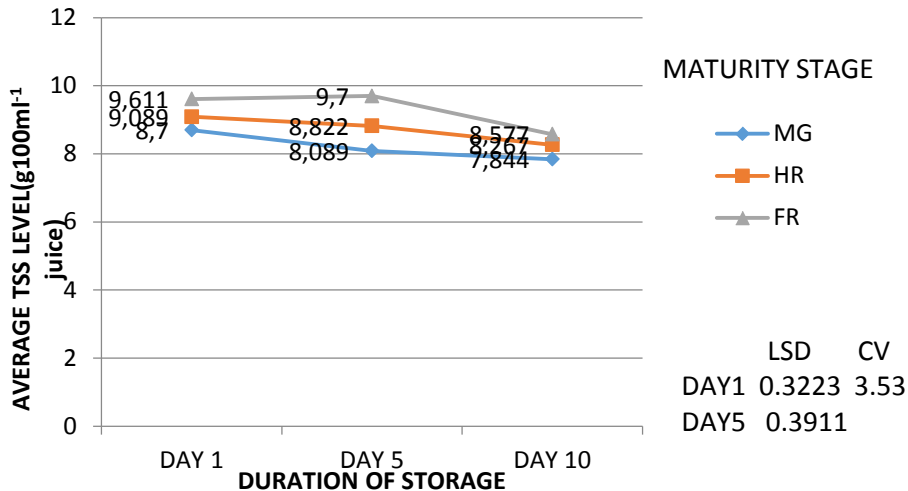


Fig. 2 Effect of maturity stage and duration of storage on TSS

**Effect of maturity stage and storage duration on TDS content of citrus fruits**

The analysis (Figure 3) showed that TDS of fruits harvested at the full ripe stage in storage was fairly constant as compared to that in mature green and half ripe fruits. The TDS content of fully ripe increased from 1687.7mg/l to 1702.9mg/l, while that of mature green fruits decreased sharply from 1757.6mg/l to 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 in the day 10 of storage. However, the differences in the level of TDS for all stages of ripening on all the days of storage were not significant (p>0.05).

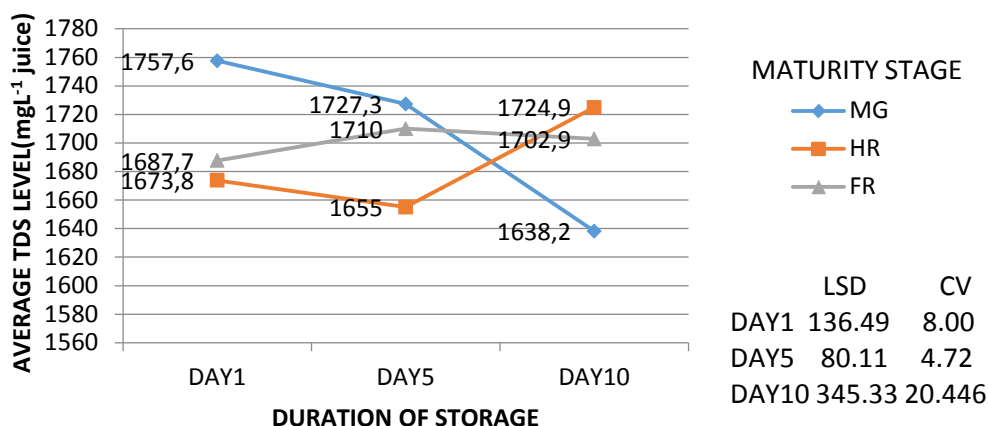


Fig 3. Effect of maturity stage and duration of storage on TDS

### Effect of maturity stage and storage duration on juice yield

The results (Figure 4) further showed a general increase in juice yield of fruits with increase in storage duration. Whereas in half ripe fruits, the juice yield initially decreased from 80ml to 76ml at 5 days of storage and then increased again to 89.89ml at 10 days of storage, the full ripe and mature green fruits increased from 80ml to 82.44ml and 80ml to 87.78ml respectively at both 5 and 10 days of storage. However, the differences in the juice yield of fruits at the various stages of ripening on all the days of storage were not significant ( $p > 0.05$ ).

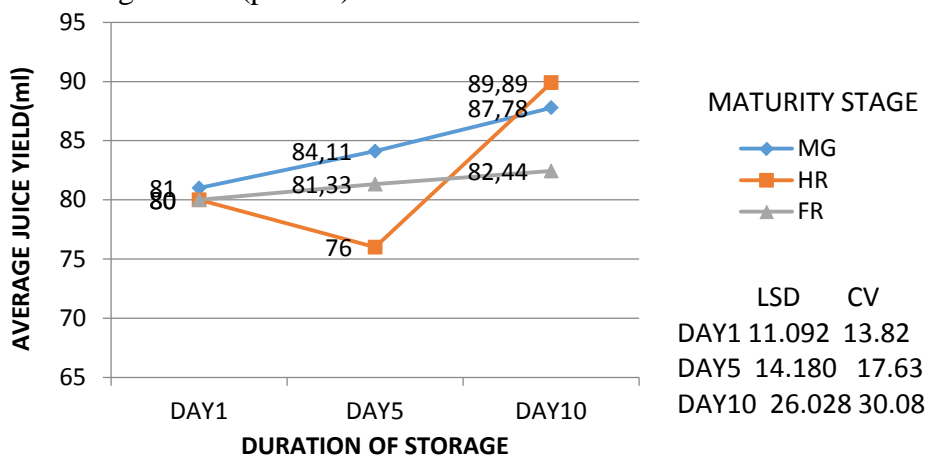


Fig. 4 Effect of maturity stage and duration of storage on Juice Yield

### Effect of maturity stage and storage duration on pH level of citrus fruit juice

The results (Figure 5) showed a general increase in the level of pH of mature green and half ripe fruits at 5 and 10 days of storage. Whereas in the full ripe, the pH level dropped from 3.75 to 4.09, the pH level of half ripe and mature green increased from 4.03 to 3.84 and 4.03 to 3.88 respectively with increased in duration of storage. 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 ( $P > 0.05$ ).

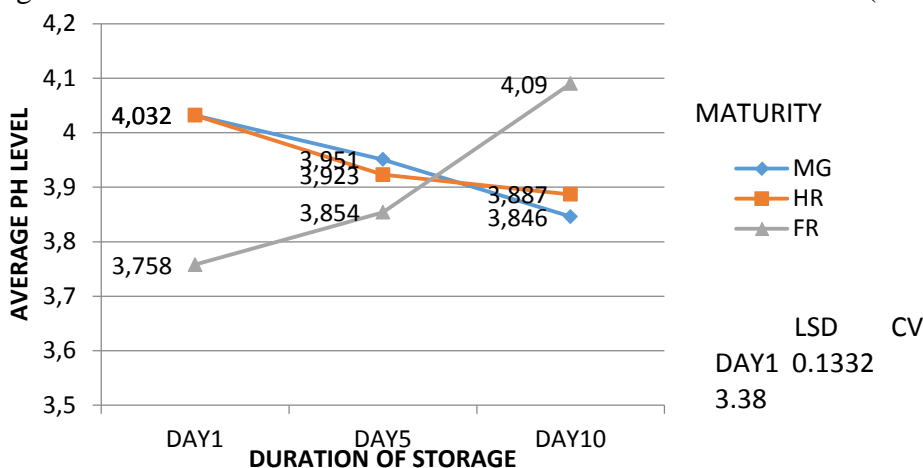


Fig. 5 Effect of maturity stage and duration of storage on pH

### Effect of maturity stage and storage duration on citrus fruit weight

The results (Figure 6) also showed that fruits harvested at the full ripe stage consistently recorded higher weights at day 5 and 10 of storage than half ripe and mature green fruits over the same storage duration. Weight of the full ripe fruits increased from 173.78g to 183.00g in storage, whereas, the half ripe and mature green decreased from 210.89g to 163.00g and 189.56g to 183.00g respectively during prolonged storage. 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 ( $p > 0.05$ ).

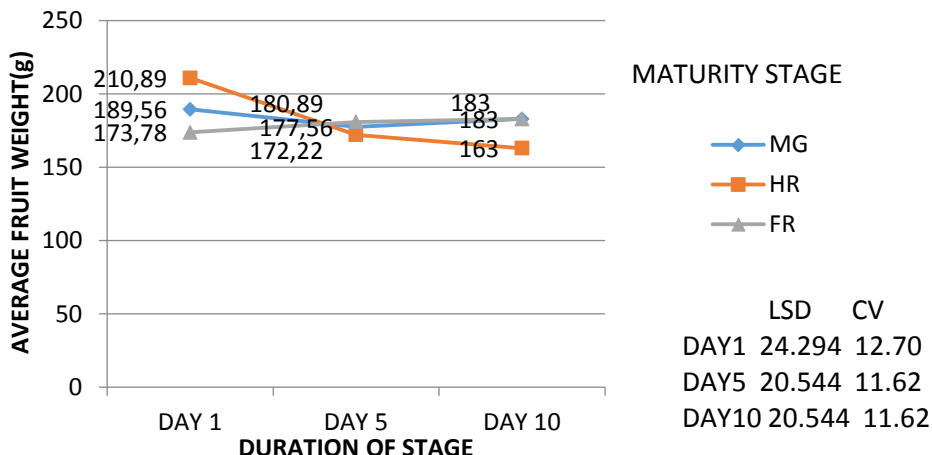


Fig. 6 Effect of maturity stage and duration of storage on fruit Weight

**Effect of maturity stage and storage duration on fruit firmness**

The results (Figure 7) again showed a general increase in fruit firmness at day 5 and 10 of storage. Whereas in mature green fruits firmness increased from 4.01mm to 4.91mm, half ripe and full ripe increased from 3.24mm to 5.12mm and from 3.58mm to 5.42mm respectively. The differences in firmness of fruits observed at all stages of ripening were significant ( $P < 0.01$ ) in day 10 of storage. However, the differences in the various stages of maturity on days 1 and 5 were not significant ( $P > 0.05$ ).

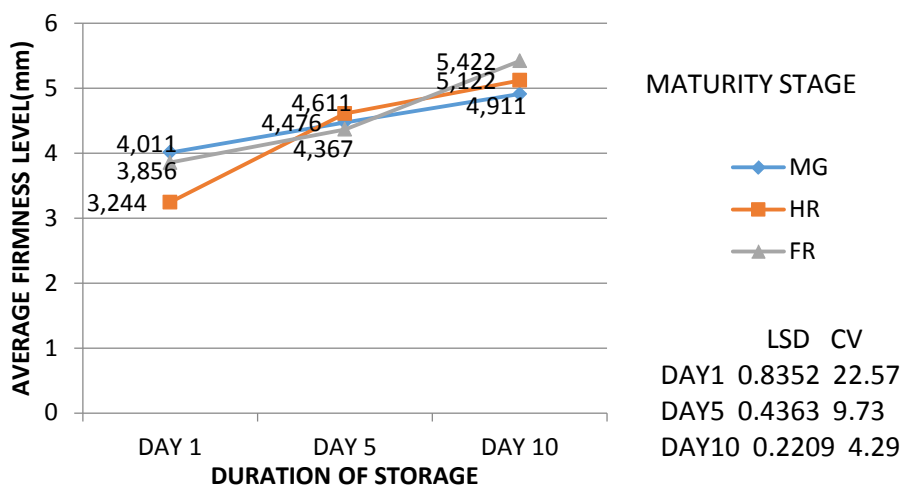


Fig. 7 Effect of maturity stage and duration of storage on fruit firmness

**Effect of maturity stage and storage duration on EC**

The results (Figure 8) showed a general decline in the EC level of mature green and half rip fruits at 5 days of storage, while full rip fruits recorded increment (3339.2 to 3409.3) in EC level at the same days of



storage. However, at 10 days of storage, whereas EC level rose from 3457.3 to 3551.3 and 3409.3 to 3463.1 in mature green and half ripe fruits respectively, the EC level in full ripe fruits declined from 3339.2 and 3032.7. The differences in the EC level of all the stages of ripening on all the days of storage were however not significant ( $p>0.05$ ).

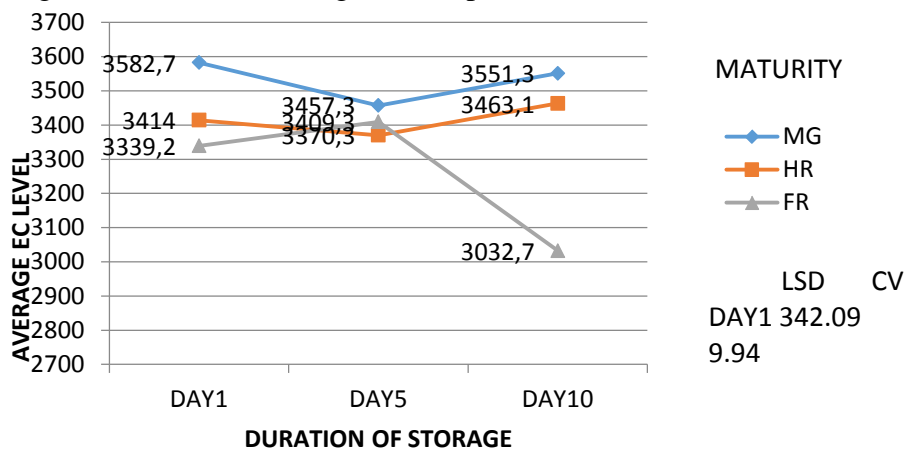


Fig. 8 Effect of maturity stage and duration of storage on EC

### Effect of maturity stage and storage duration on Vitamin C content of citrus

The results (Figure 9) further revealed a general increase in the level of vitamin C content of fruits at day 5 and 10 of storage. Fruits harvested at full ripe increased from 1.97mg/100ml juice to 2.24mg/100ml juice, whereas, half ripe and mature green fruits' vitamin C content consistently increased in storage from 1.95mg/100ml juice to 2.39mg/100ml juice and 1.9mg/100ml juice to 2.22mg/100ml juice respectively. However, the differences in vitamin C content of fruits observed for all the stages of maturity for all the days of storage were not significant ( $p>0.05$ ).

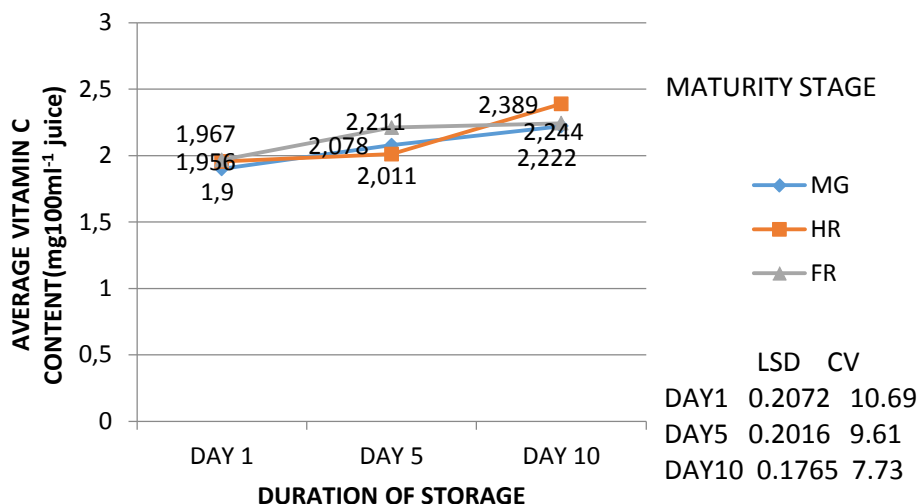


Fig. 9 Effect of maturity stage and duration of storage on Vitamin C

## Discussion of Results

### Total Titratable Acidity (TTA)

The TTA level in full ripe fruits are generally lower than that of mature green and half ripe fruits at 5 and 10 days of storage. However, it is unusual for mature green fruits to have lower TTA level than full ripe as observed in this study because according to Samson (1986) during storage, ripening changes occur in citrus resulting in reduction of TTA. The general decline in TTA levels across all stages of maturity during prolonged storage could be attributed to increase sugar substrates in the fruits which Ladaniya (2011) suspects to increase respiratory activity in citrus fruits in storage. This reduction in acidity with storage makes the fruits less acidic and therefore more acceptable in taste for consumption. Lower acid content is also known to improve fruit flavour suggesting that depending on condition of storage, holding of orange for up to 10 days could reduce acidity and improve the flavor of the citrus fruit juice.

### Total Soluble Solids (TSS)

There was steady decline in TSS content of half ripe and mature green fruits in storage. This observation seemed to agree with similar findings made by Bakshi *et al.* (1967) and Samson (1986) that as fruits mature, the TSS content increase at an increasing rate during early stages of ripening and increase at a decreasing rate as the fruits progress towards full ripe stage. It is unusual for full ripe fruits to record higher TSS level in storage than half ripe and mature green fruits as observed in this study. Probably this observation could be due to the increase in sugar content as acidity level in the fruit decrease in holding. Consequently, fruits palatability will increase because according to Harding and Fisher (1945) high TSS to

acidity ratio in the fruit is a good indicator of palatability.

### **Total Dissolved Solids (TDS)**

The higher TDS content of full ripe orange fruits observed in this study was to be expected. According to World Health Organization (1996), TDS is made up of inorganic salts (e.g. soluble hydrogen carbonate ions, chloride salts, sulphates, calcium, magnesium, sodium, potassium) found in water as well as volatile solids and non-volatile solids absorbed and accumulated or synthesized by plants. This implies fruit at full ripe may have synthesized or absorbed and accumulated higher amount of TDS than half ripe and mature green fruits. The increase in TDS level of fruits in storage could also be due to loss of water in the fruit leading to concentration of TDS substrates during holding. This suggests that holding of orange fruits for about 5 to 10 days could increase the TDS content of the fruit and could be a good source of mineral supplements to consumers of fruit juice and other citrus products.

### **Juice Yield**

An increase in juice yield of full ripe fruits was at a decreasing rate while the increase in both mature green and half ripe fruits were at an increasing rate during storage. The rapid increase in juice yield of mature green and half ripe fruits could be attributed to juice sac cells synthesizing more juice during storage until the fruits fully ripe and begin to deteriorate or senescences under poor storage conditions. This postulation is based on the report of Spiegel-Roy and Goldschmidt (1996) that juice sacs of orange fruits mostly elongate as the fruit mature to contain more juice until the fruit is fully matured and ripped. This analysis suggests that holding of mature green and half ripe oranges for up to 10 days could increase the juice yield during processing than holding full ripe fruit.

### **Level of pH**

The pH level of mature green and half ripe fruits increased in holding over the period of storage. This finding is in contravention with Sasson and Monselise, (1977), Sinha *et al*, (1962) and Cepeda *et al*, (1993) observation that pH level turns to decrease as sweet orange fruits are kept in storage over a period of time. This could be due to the fact that continuously developing cells of mature green and half ripe fruits could be synthesizing acids (malic and ascorbic acids which are major determinants of pH) which may be responsible for the increment of the pH levels observed. The pH level of full ripe fruits, however, reduced in storage as expected and could enhance sweetness as the acidity level of fruits decrease due to increase in sugar content.

### **Fruit Weight**

The study witnessed a general reduction in weights of half ripe and mature green orange fruits in storage. This observation is not in consonance with Iqbal *et al.* (2012) who reported increase in fruit weight, even though they studied effect of harvest date on fruit weight. This reduction could be attributed to the relative humidity of the environment (ambient temperature) under which the fruits were stored because during storage fruits loose some amount of moisture which might result in weight loss. The reduction in weight could make the fruits wrinkle and less firm and therefore may be less attractive to consumers if storage conditions are not modified or prolonged .

### **Fruit Firmness**

It was observed that fruit firmness was high, though not significant, in day 1 and 5 across all the stages of maturity and declined significantly at day 10 of storage. This observation supports Sinha *et al.* (1962) finding that fruit firmness reduce in late valencia oranges as the fruit matures or ripens, which Gussman *et al.* (1993) attributed to ethylene production associated with increased maturity in fruits. The decreased in the firmness of fruits in prolonged storage could also be attributed to fruit senescence due to poor storage condition. It therefore suggests that orange fruits firmness quality may be lost in holding for up to 10 days under ambient temperature or unmodified condition of storage. This reduces fruits quality and may make the fruits unattractive to consumers.

### **Electrical Conductivity (EC)**

The analysis also showed that EC level of full ripe fruits drastically declined in storage as against the EC level in mature green and half ripe fruits which delined at 5 days of storage and increased marginally at 10 days of storage. This observation seemed to partly disagree with Feng *et al.* (2005) report that electrical conductivity increase with ripening and that increasing electrical conductivity in storage is an effective physical maturity index as well as suitable index of storage quality. The observation could probably be due to fruit senescence which hardened the fruit rind. This therefore suggests that the EC level of fruits may not increase no matter the level of fruit maturity in prolonged storage under ambient condition.

### **Vitamin C Content**

There was a general increase in vitamin C content in mature green, half ripe and full ripe fruits in all the storage durations. This implies vitamin C content of citrus fruits may always increase in holding no matter the stage of maturity and duration of storage. The observation is invariance with

Cepeda *et al.* (1993) finding that vitamin C (ascorbic acid) content in citrus fruits (late Valencia variety) decreased with maturity and prolong storage. The increase in vitamin C content observed could be due to residual effect of precursors needed for vitamin C synthesis carried over by developing fruits into storage. The observation therefore suggests that holding orange fruits at ambient temperature up to 5 or 10 days before processing could increase their vitamin C content and therefore make the orange juice nutritious for consumption.

### **Conclusion**

The study concludes that the level of physico-chemical properties such as TTA in full ripe citrus fruits are lower than that of mature green and half ripe fruits at day five and ten of storage. Also while TSS content of half ripe and mature green fruits at five and ten of storage steadily decline that of TDS content increases over the same storage duration. The study also concludes that holding of mature green and half ripe oranges for up to ten days increase their juice yield during processing as compared to full ripe fruits. Whereas fruit weights of mature green and half ripe fruits reduce at day five and ten of storage that of full ripe fruits increases in weight over the same storage duration. The study again concludes that fruit firmness is high at day one and five of storage in all stages of maturity and reduce significantly at ten days of storage. The study further concludes that the EC level of citrus fruits may not increase no matter the stage of fruit maturity and storage duration under ambient temperature. Also, the vitamin C content in mature green, half ripe and full ripe fruits increase as storage duration increases to day five and ten under ambient temperature.

### **Recommendations**

The study therefore recommends that processors of natural orange fruit juice should monitor closely the stage of maturity of the fruits they procure for processing as well as the duration at which fruits are stored before being processed. Since product quality may be compromised or enhanced due to inadvertent changes in physico-chemical properties of the citrus fruits being processed.

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