

Effects of Controlled Atmosphere Storage and Temperature on Quality Attributes of Mango

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Abstract

This study was conducted to analyze the effects of Controlled Atmosphere Storage (CAS) and low temperatures on quality attributes of cv. Keitt mango. Mango is one of the choicest fruits in the world and popular due to its delicious taste, pleasant aroma and nutritional value. To date, only 3

Index terms— keitt, controlled atmosphere storage (CAS), temperature, list significance difference.

1 I. Introduction

ango (*Mangifera indica* L.) is native to south Asia and known as king of the fruits due to its excellent flavor, delicious taste and high nutritive values. There are over thousands varieties around the world, the most common are Keitt, Kent and Tommy Atkins and they are also grow in Ethiopia. Mango is produced mainly in-west and east of Oromia, SNNPR, Benishangul and Amhara (Desta, 2005), which are specific areas of Ethiopia and they have a potential to produce wide variety of mango fruit. According to Ethiopian central statistical agency report in 2011/12 report about 12-14 % of total fruit production is mango. But, it is exported less than 2 % (Joosten, 2007). This is due to perishable nature of the product, lack of proper handling and lack of proper storage (Leon et. al, 1997). Besides, the post-harvest loss of mango is 26.3 %. (Tadesse 1991) Thus, Maintenance of fruit quality for a specific period of time before its consumption is important factor in the post-harvest life of the fruit. The physiological changes may occur in harvested fruit due to unfavorable atmospheric conditions especially fluctuation in temperature and humidity. Fresh mango fruits have a short storage life of 4 to 12 days at room temperature and can also suffer low temperature injury (chilling injury) during refrigerated storage (Lakshminarayana, 1973). Therefore, it is necessary to develop improved methods of mango storage in fresh state that can enhance its shelf life without any detrimental effect on the quality. Various methods of extending the storage life of mangoes have been tested but little research has been conducted on controlled atmosphere (CA) techniques. Controlled atmosphere Storage (CAS) has been shown to be beneficial technique in reducing the rate of physiological and biochemical changes, ethylene sensitivity and incidence of decay development of perishable fruit products (Medlicott & Jeger, 1987) and as a result of it senescence is delayed. The response of mangoes to CA condition reported in the literature has been shown to vary. Nakamura et al., (2004) reported that CA storage having 5-10% CO₂ is effective to suppress the respiration rate of ripe mango. Aale et al., (2003) found that CA comprised of 2% O₂ and 2% CO₂ is better for maintaining the aromatic compounds of ripen fruit. Similarly Mitra & Baldwin (2005) stated that low temperature, hypobaric and CA storage can keep the mango fruit for about two to four weeks however, they suggested further research in this area. Aale et al., (2005) reported that CA treatments reduced respiration rate, de-greening of the skin and fruit softening of mangoes but yellowness of the skin, total soluble solids (TSS), total sugars content and taste of the ripe fruit were maintained. In another research Alding and Reeder (1977) recommended that shelf life of keitt mangoes can be increased up to 35 days without any significant quality effect by storing them at 13 °C in 5% CO₂ and 5% O₂. Different varieties of mangoes showed different responses to CA storage (Rattanapanone, 2001). Therefore, the study focused with effects of controlled atmosphere storage and temperature on quality attributes of Ethiopian mango to reduce the post-harvest loss and maintain desired quality. The experiment was carried out to evaluate

3 III. RESULTS AND DISCUSSION

the effects of CAS and temperature, determine sensory evaluation and optimum storage condition of cv. Keitt mango.

2 II. Materials and Methods

The mango cv. Keitt sample used in this experiment was collected in plastic bags from Addis Ababa Et-fruit. The fruits were sorted according to their size, weight and color. Then the sorted fruits were washed by tape water, and dry through blowing dried air stored in CA storage, and ambient storage condition. To determine the effects of temperature and CAS, Completely Randomized Design (CRD) was used with below treatments: Storing fruits at constant temperature of 7°C under CAS conditions of A-(6% O₂ + 10%CO₂), B-(6%O₂ + 8% CO₂), C-(5%O₂ + 5% CO₂) and D-Control(21% O₂ + 0.03% CO₂). Besides, the effect of temperatures without considering CAS effect was also studied fruits stored at different storage temperature of 7°C, 10°C, 13°C and Control (21-24°C) respectively. About 112 uniform cv. Keitt mango fruits samples were used for studying out of which 42 samples were stored at CAS, with gas tight plastic bag in order to control the atmosphere by using closed system, 14 samples were stored in ambient atmosphere, while the remaining 56 samples were investigated for temperature effects. Each Sample was randomly taken within five day intervals to evaluate the effect of Controlled Atmosphere Storage (CAS). CAS chambers were calibrated to establish the specified gas composition by a gas blending flow system. The gas blending system generated CA conditions using external supplies of gases from, pressurized gas cylinders fitted with doublestage regulators and outlet controlling devices. These outlets were connected to the inlet flexible pipes that were inserted into the gas tight plastic containers in which the mangoes were stored.

Fruits were then stored at specified temperature with different controlled atmosphere which were evaluated every 5 days for total soluble solids (TSS), Titratable acidity (TA), pH, weight loss, firmness, and skin color. To investigate effects of different temperatures, sample was taken within 7 days interval using I Button. The One-Wire Viewer a Java?based software package is used to explore Maxim's 1-Wire and I Button devices with a personal computer. The 1-Wire and I Button devices communicate over a single data line plus ground reference, using the 1-Wire protocol. The skin color was measured by using skin indicator chart 1-deep green 2-light yellow-green, 3yellow-light green, 4-yellow-orange5-golden orange. Flash firmness was measured (kg/mm²) using FACCHINI-48011-Model (Italy) penetrometer with 8mm probe diameter. Total soluble solid (TSS) was measured by using Model-RF18 (India) handheld sugar refractometer. Titrable Acidity of the fruit was measured by means of an acid base titration method using a juice sample (10 ml juice + 10 ml distilled water) and 0.1N Sodium hydroxide (NaOH) with phenolphthalein color indicator and pH was measured using digital pH meter. Weight loss also measured using digital weight balance. For the sensory evaluation tests, ten panelists were selected from the university and the tests involved individuals in isolated tasting conditions. Five of panelists were asked to give their individual ratings on all quality attributes of stored fruits including color, aroma, taste, flavor, firmness and overall acceptability of the stored fruits with different conditions while the other five panelists were asked to evaluate quality of the effects of temperatures with a 9-point structured hedonic scale to conduct the preference test: 1-dislike extremely and 9-like extremely. The scores marked by panelists were collected and an average was calculated for each parameter. One way Analysis of variance (ANOVA) was performed on the data collected using Microsoft excel and Origin Pro 8 soft ware's. Comparison between treatment means at 5% level of significance was calculated.

3 III. Results and Discussion

The effects of controlled atmosphere storage (CAS) and low temperatures analysis for quality attributes of cv. Keitt mango and the optimum conditions for long storage were studied. In addition, sensory analysis for the final product using nine hedonic scale also carried out. The results of samples analyzed in this work are presented in tabular and graphical form.

a) The Effect of CAS on Quality Attributes of cv. Keitt Mango Skin color: as the skin indicator chart showed that(1deep green, 2-light yellow-green, 3-yellow-light green, 4yellow orange, 5-golden orange), Skin color of fruits stored at ambient atmosphere changed their color from deep green to yellow orange after 15 days and to golden-orange after 30 days of storage (see on appendix Table 4.2B), whereas the skin color of fruits stored at controlled changed their color after 25 days from deep green to yellow orange and to golden orange colors after 40 days of storage (see on appendix Table 4.1A).The loss of green color was the most obvious change in mango which was probably due to the physiochemical change by degradation of the chlorophyll structure and increased in carotenoids pigments during storage. The principal agents responsible for this degradation might be oxidative system, pH change, and enzymes like chlorophyllase ??wills et.al. 1982).The experimental result observed, showed in significant of CAS on skin color (new LSD at 0.05=1.36) between fruits stored in CAS and ambient atmosphere as presented in (Fig 4 ??1) and the effect of CAS and ambient atmosphere had similar mean result(5-golden orange) after 40 days storage. 2). The current investigations confirmed the view that CAS conditions delay fruit ripening and softening (Kader, 1986).Ripening and senescence rates in many climacteric fruits like mangoes, can be affected by control of the availability of O₂ and CO₂ to the fruit during respiration and that these two compounds can have a significant inhibitory effect on ability of ethylene to initiate ripening (Ben-Yehoshua et al., 2005). Thus, flash firmness of fruits kept in air significantly decreased very rapidly

from 14.1 kg/mm² to 0.099 kg/mm² after 35 days of storage (see on appendix Table 4.2B) and new LSD at 0.05=1.708. The flesh firmness of fruits which were kept under (CAS) with treatment of (10% CO₂ + 6% O₂) had high firmness than the other treatments after 6 weeks storage with mean firmness result being 5.541 kg/mm² (Fig 4 Total Soluble Solid (TSS): it was observed that, TSS of fruits stored in ambient atmosphere were increased from 4.1 to 18.86 °Brix after 30 days and decreased to 14.8 °Brix after 35 days storage (see on appendix Table 4.2B). The increase in TSS might be due to alteration in cell wall structure and break down of complex carbohydrates into simple sugars. As showed the graph below fig 4.3 the total soluble solid of fruits stored at ambient atmosphere sharply decreased in between 30 to 35 storage time, this is due to metabolic process as the temperature become high microbial and respiration activities become increased, conversion of sugar into alcohol (ethanol) become exist. The acidity of the fruit also becomes high. This increase and decrease in TSS are directly correlated with hydrolytic changes in starch and conversion of starch to sugar being important index of ripening process in mango fruits and other climacteric fruits and further hydrolysis decreased the TSS during storage (Kittur et al. 2001). Beside, fruits stored at controlled atmosphere storage also increased the TSS content from 4.1 to 18.25 °Brix after 45 days of storage (see on appendix Table 4.1A). As the result showed, it would stay in CAS further days without significant quality effects. From the CAS treatments; treatment-A (10% CO₂ + 6% O₂) had less TSS content with average (13. Weight loss (%): The reduction in weight is attributed to the physiological loss in weight (PLW) due to respiration, transpiration of water through peel tissue and other biological changes taking place in the fruit. The effect of CAS was highly significant on weight loss of stored fruit (new LSD at 0.05=3.12). The mean weight loss percentage of fruits stored with treatment A (10% CO₂ + 6% O₂) was less (0.75%), whereas fruits stored at ambient atmosphere was high (5.87%) after 4-6 weeks of storage (Fig 4.6). According to the result, the effect of temperatures on skin color of the stored fruits was not significant changes fruits which was exposed to 7, 10, and 13 °C, whereas fruits stored in between 7 °C and ambient temperature (21-24 °C) was significant (new LSD at 0.05=2.41). Flash Firmness: Effect of storage temperatures on firmness of cv. Keitt showed significant difference between fruits stored at temperature of 7 °C and ambient (21-24 °C) temperature (see on appendix Table 4.3C) with new LSD at 0.05=6.50. Weight loss (%): Maximum average weight loss percentage loss observed for fruits stored at ambient temperature (4.44%) after three weeks storage (new LSD at 0.05=4.148). As temperature of storage increased the average weight loss also increased (Table 4.3C).

It was observed that Mangoes stored at low temperature leads to certain physiological disorder observed such as Chilling Injuries (CI). The primary cause of CI is thought to be the damage of cell membrane that initiates a cascade of secondary reaction. CI is a time and temperature problem. Mango fruits are subjected to CI when stored below 10°C. The symptoms include grayish scald-like discoloration of the skin, skin pitting, uneven ripening, and reduction in the level of carotenoids, aroma and flavor during ripening (Thomas, P et al. 1983). Most of mangoes cultivars shows injury below 10°C (50 °F), especially if fruit have just reached maturity. Tolerance to chilling injuries increases during ripening (Medlicott et al. 1990). Chilling injury (CI) has been reported to occurs in mango fruit at temperatures below about 10-13°C, although some cultivars (Dasheri, Langara) were reported to be safely stored at 7-8°C for up to 25 days. Storage at 10 to 13°C (50 to 55°F) with 85 to 90% relative humidity should give a shelf-life of 14 to 28 days for mature green fruit, depending upon variety (Jobin Decor 1988). The result of the experiment showed that fruits stored at temperature of 7 °C after three weeks storage time, were exposed to CI starting from 7 days storage, for the fruit stored at 7 °C with symptoms of un ripening, skin pitting, discoloration, poor aroma and flavor during ripening and is in agreement with Jobin Decor result (Fig 4.9). Color changes in mango fruit are due to the disappearance of chlorophyll and appearance of other pigments (Lakshminarayana et al. 1980). The observed results of skin color of fruits stored with treatment (10% CO₂ + 6% O₂) showed maximum preference with its mean and standard deviation result was 8.4±0.89 (Table 4.4). Fruit flavor depends upon taste (balance between sweetness and sourness or acidity, and low to no astringency) and aroma (concentrations of odoractive volatile compounds). Taste development is due to a general increase in sweetness, which is the result of increased gluconeogenesis, hydrolysis of polysaccharides, especially starch, decreased acidity, and accumulation of sugars and organic acids resulting in an excellent sugar/acid blend (Grierson et al., 1981). Sourness or acidity is determined by the concentrations of the predominant organic acids, which are citric acid, malic acid, and tartaric acid. Some amino acids, such as aspartic and glutamic acid may also contribute to sourness. Several factors affect sugar and acid contents in mango, including cultivar (Kapse et al., 1989). The flavor of Mangoes stored under treatment conditions of A (10% CO₂ + 6% O₂) and B (8% CO₂ + 6% O₂) with average values of 7.4 was preferred by panelists.

But, the overall acceptance was high for fruits stored with treatment A (10% CO₂ + 6% O₂) mean result of 8.0 (see on appendix Table 4.4). Similarly, the effects of temperatures on quality of stored fruits was evaluated by sensory panelists, the color of the fruits stored at temperature of 13 and ambient (21-24 °C) had high preferences with their mean values got 7.6 (see on appendix Table 4.5E). Fruit samples stored at temperature of 13 °C got maximum overall acceptance, while fruits stored at temperature of 7 °C got minimum overall acceptance (Table 4.5E).

4 IV. Conclusions

Mangoes are highly nutritious and favorable fruits. However, post-harvest losses and quality deterioration due to exposure to temperature and improper handling management challenged the productivity and wider usage of the fruit. In Ethiopia, the post-harvest loss (transporting, handling and storage) of mango is estimated as to be about 23.6% from this total loss about 7-10% is storage loss. The major storage loss factors are atmospheric conditions and temperature. Thus, study was carried out by using CAS technology which is constantly monitor and adjust the CO₂ and O₂ levels within gas tight stores or containers to reduce storage loss and extending the storage life of mangoes for better duration without loss of its quality.

The Controlled Atmosphere Storage (CAS) positively affected the quality parameters and significantly improved the shelf life of mangoes. It extends storage life of cv. Keitt mangoes for up to 6 weeks without significant quality loss with treatment at 7°C under 10%CO₂ + 6%O₂ +84%N₂. This condition is better to store the mango for long time without significance loss relative the other conditions and quality of the fruit after storage also confirmed by sensory analysis, thus the above condition is best. On the other hand, the effects of storage temperature on quality attributes of mangoes were significant. The cv. Keitt mangoes stored at 13 °C had better quality after 3 weeks storage time as confirmed by sensory analysis than of fruits stored with other treatments. In general, extending storage duration more than 6 weeks is extending marketing period and maintained fruits availability.

5 Declaration

This work was our original work; there is no conflict interest among authors. wish to express my deepest appreciation to my advisors, Mr. Teshome Worku for his endless help in correcting, commenting, and encouraging accomplishing this work. I also like to appreciate their patience in following up this work from the very beginning to the end. I am very grateful to Mr. Mekidim Asefa, for his assistance, invaluable comments and excellent supervision throughout my research work. I also extend my appreciation to Addis Ababa Institute of Technology, School of Chemical and Bio Engineering Laboratory staff members for their technical assistance during experimental work. Finally, I would like to express my sincere gratitude to my families and friends who have been providing their support and encouragement. And also all others who directly and indirectly contributed to this manuscript are highly acknowledged for their voluntary participation.

6 Appendixes

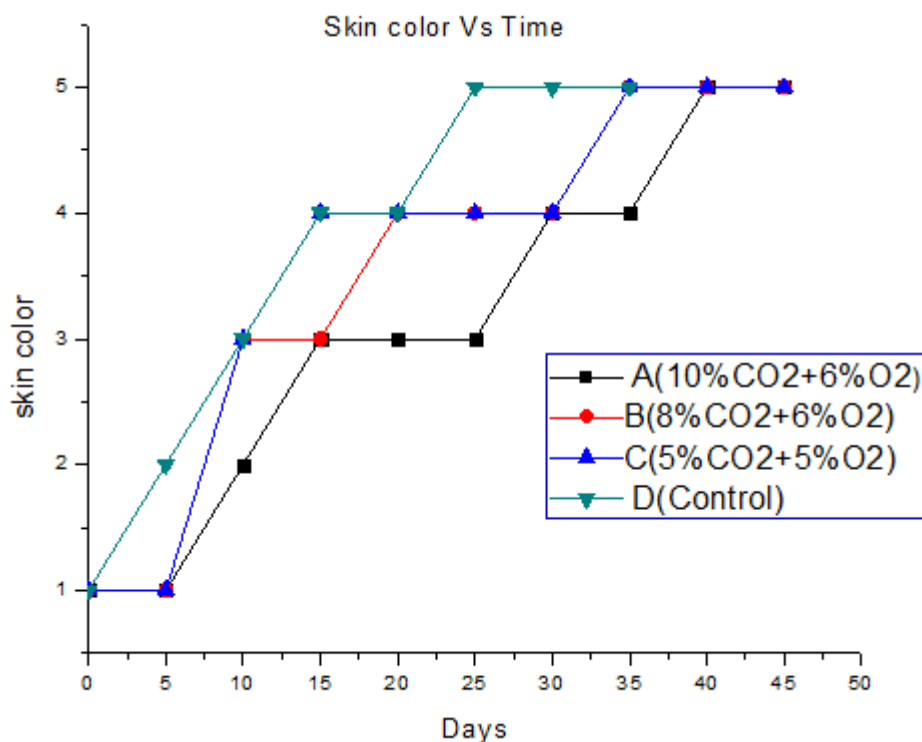
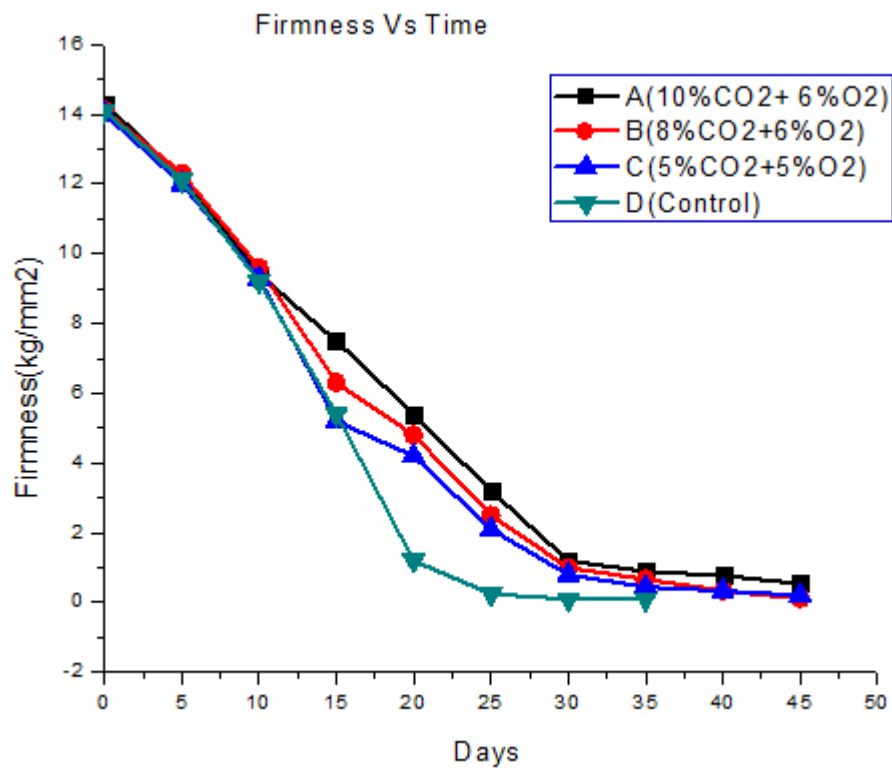


Figure 1: Fig 4 . 1 :



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Figure 2: 7)Fig 4 . 2 :

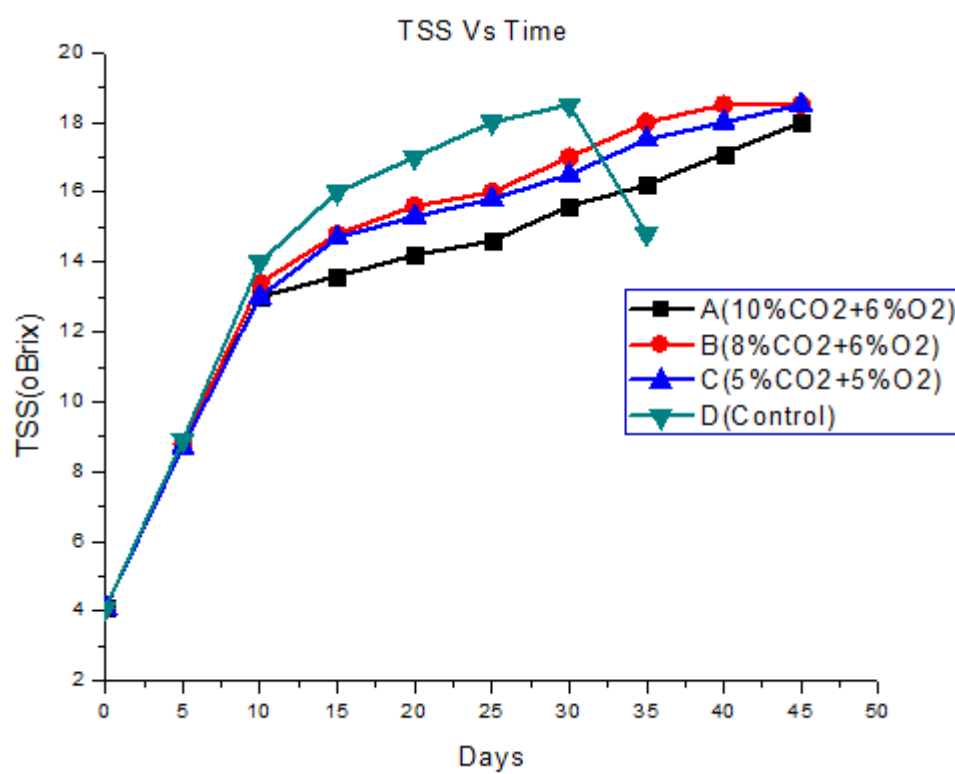
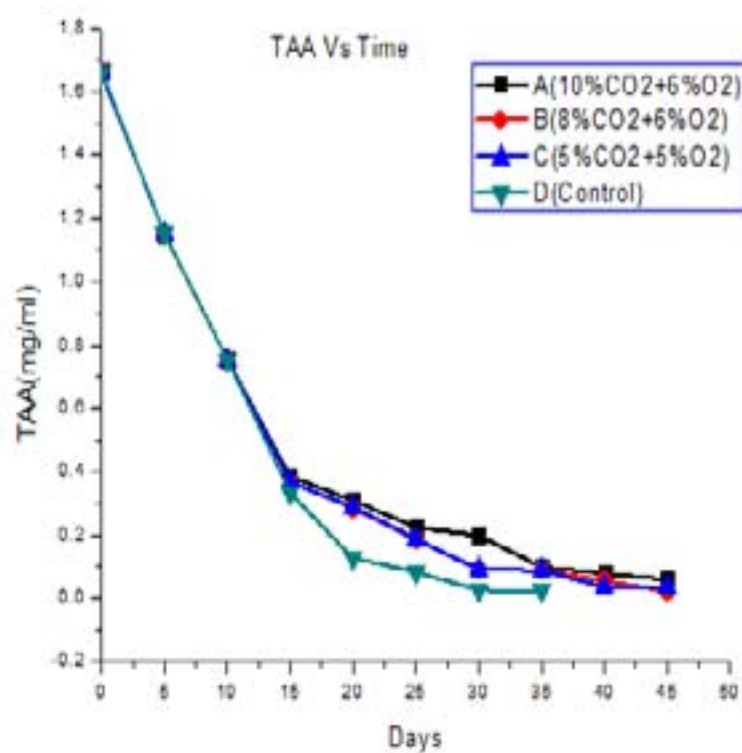
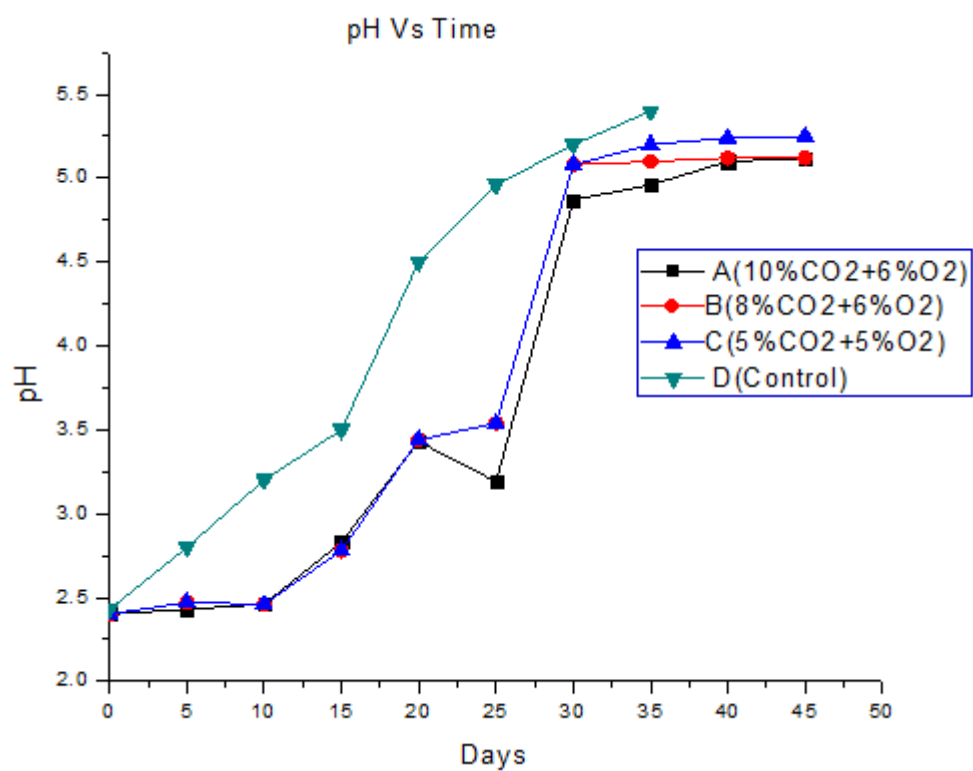


Figure 3:



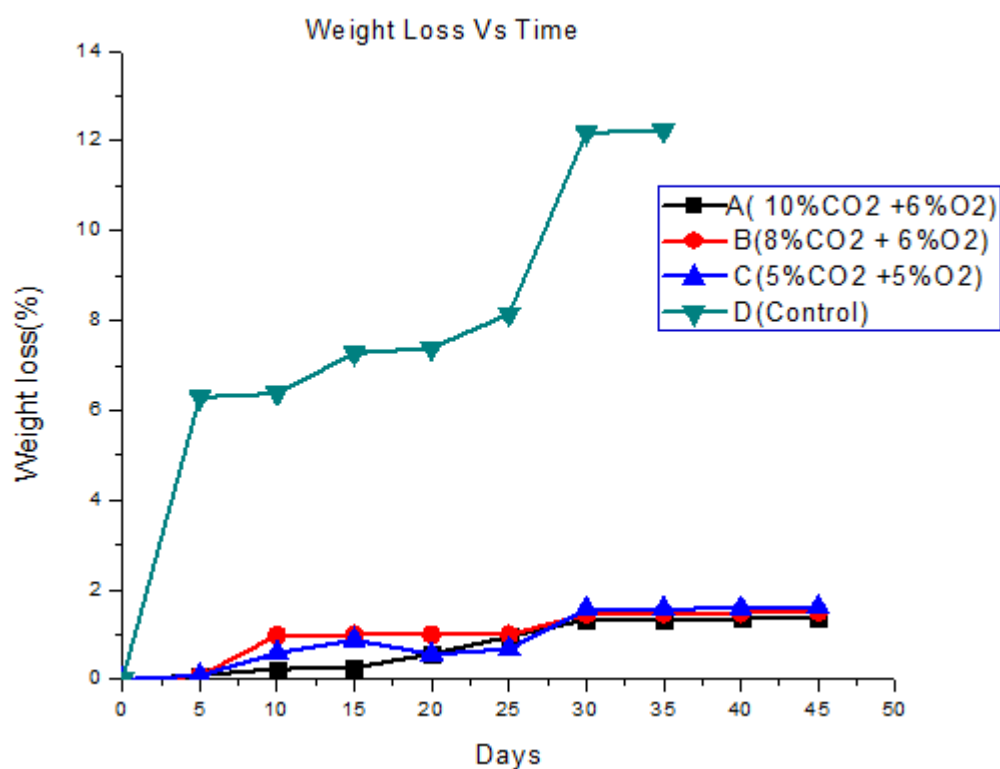
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Figure 4: Fig 4 . 3 :CFig 4 . 4 :



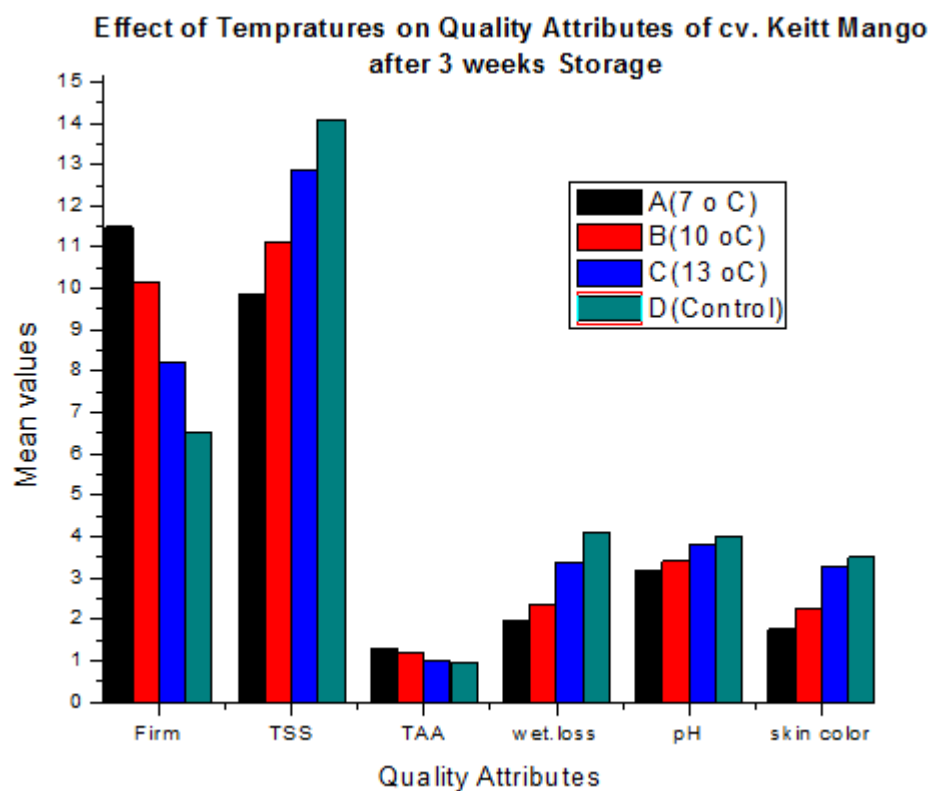
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Figure 5: Fig 4 . 6 :



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Figure 6: Fig 4 . 7 :



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Figure 7: Fig 4 . 8 :Fig 4 . 9 :

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14.

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XVII Issue I Days

Version I

Firmness (kg/mm²)
 TSS (Brix)
 TAA (%)
 pH
 Weight loss (%)
 Skin color

Journal of 0 5 10 15 20 25 30 35 40 45 NB: 1-deep green, 2-light yellow-green, 3-yellow-light green, 4-yellow
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Figure 8: Table 4 .

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Days	Firmness (kg/mm ²)	TSS(Brix)	o TAA (%)	pH	Weight loss (%)	Skin Color
0	14.1	4.1	1.665	2.40	0	1
5	12.1	8.9	1.152	2.83	6.289	2
10	9.2	14	0.7541	3.24	5.370	3
15	5.4	16	0.3328	3.54	3.272	4
20	1.2	17	0.128	4.56	4.384	4
25	0.25	18	0.0828	4.96	3.144	5
30	0.1	18.5	0.0256	5.27	12.182	5
35	0.099	14.8	0.0234	5.48	12.234	5

[Note: NB: 1-deep green, 2-light yellow-green, 3-yellow-light green, 4-yellow orange, 5-golden-orange]

Figure 9: Table 4 .

4

Temperatures	Firm(kg/mm 2)	TAA (%)	TSS(o Brix)	Wet loss (%)	pH	S
7 o C	11.5	1.2865	9.875	2.6	3.18	1
10 o C	10.125	1.202	11.125	2.9	3.3975	2
13 o C	8.2	0.98975	12.875	4.25	3.81	3
Control	6.255	0.9374	14.075	4.44	4.015	4
SQA	A	B	C		D	
Color	8.4 + 0.89	7.8 + 0.83	7.6 + 1.14		7.8 +1.09	
Flavor	7.4 + 1.14	7.4 + 0.89	6.8 + 1.30		7 + 2.00	
Taste	8 + 0.70	8.6 + 0.54	6 + 1.58		5.8 + 2.38	
Firmness	7.4 +1.14	7.4 + 0.54	7.4 + 0.54		8 + 0.00	
Over acceptance	all 8 + 0.70	7.8 + 0.44	7.2 + 0.83		6.8 + 1.78	

NB: A (10%CO₂ +6%O₂), B (8%CO₂ +6%O₂), C (5%CO₂ +5%O₂) & D (Control)

[Note: NB]

Figure 10: Table 4 .

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SQA	7 o C	10 o C	13 o C	Control(21-24 o C)
Color	4 + 1.58	6.4 + 1.51	7.6 + 1.14	7.6 + 1.14
Flavor	3.2 + 1.48	5.8 + 0.83	8 + 0.70	7.2 + 0.83
Taste	3.4 + 0.89	5.2 + 0.83	7.6 + 1.14	5.8 + 0.83
Firmness	3.8 + 3.8	6 + 1.22	7.2 + 0.83	5.6 + 1.14
Over acceptance	all 3.6 + 3.6	6.4 + 0.54	8 + 0.70	6.4 + 0.54

Figure 11: Table 4 .

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