# EFFECT OF CHITOSAN AND MORINGA LEAF EXTRACTS ON THE POSTHARVEST QUALITY OF SWEET ORANGE (*Citrus sinensis* L.) FRUIT

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## Abstract

The experiment was conducted on the effect of Moringa leaf extract and Chitosan coating on the shelf life and quality of sweet orange during storage and reduced the post-harvest losses. Study was also showed the interactive effect of Chitosan and Moringa leaf extract on the Sweet orange fruit at the post-harvest laboratory, Department of Horticulture, The University of Agriculture, Peshawar, during 2021-2022. The experiment was laid out in completely randomized design (CRD) with three factors replicated three times. Results showed that in case of Moringa leaf extract coating, maximum appearance (7.50) score, maximum taste (6.67), highest fruit firmness (2.84 kg $cm^{-2}$), maximum total soluble solids (14.41 $brix^{0}$) maximum pH (4.76), maximum titratable acidity (1.70%), maximum ascorbic acid (38.36 mg $100g^{-1}$), minimum weight loss (10.48%) and less decay incidence (2.16%) was noted on fresh day. Similarly, in chitosan coating, maximum appearance (6.83) score, maximum taste (6.69), highest fruit firmness (2.76 kg $cm^{-2}$), maximum total soluble solids (13.73 $brix^{0}$), maximum pH (4.56), maximum titratable acidity (1.70%), maximum ascorbic acid (38.36 mg $100g^{-1}$), minimum weight loss (10.48%) and less decay incidence (2.16%) was noted on 4% coated fruit. In term of storage days, maximum appearance (8.07) score, maximum taste (7.68), highest fruit firmness (4.43 kg $cm^{-2}$), minimum total soluble solids (12.73 $brix^{0}$), minimum pH (4.05), maximum titratable acidity (2.08%), maximum ascorbic acid (59.10 mg $100g^{-1}$), minimum weight loss (0.00%) and less decay incidence (0.00%) was noted on fresh day.

**Keywords:** *Citrus sinensis*, Chitosan, moringa, sweet orange

## Introduction

Sweet orange (*Citrus sinensis* L.) are classified as non-climacteric and belongs to family Rutaceae. Botanically, citrus fruit is a type of berry called hesperidium (Baldwin, 1993). Worldwide oranges were commercially grown in tropical, semi-tropical and in various warm temperate areas (Roy and Schmidt, 1996). In Pakistan, the total area under citrus cultivation is 181.6 thousand hectares with average production of 2468.65 thousand tones. Furthermore, area under citrus cultivation in Khyber Pakhtunkhwa is 4.5 thousand hectares with average production of 31.33 thousand tones. Brazil is the leading yielding country of oranges throughout the world, which produces 19,811,064 metric tons followed by United States, which produces 8,078,480 metric tons followed by China, which produces 6,013,829 metric tons followed by India, which produces 4,571,000 metric tons followed by Mexico, which produces 4,079,678 metric tons. Pakistan ranks 11th in the oranges production in the world and has a world share 2.2 % and produces (1,592.94tonnes) in 2016 and the area of cultivation, was 138.67 hectares (FAOSTAT, 2016). Citrus constitute 85-90% water, 6-9% sugar, less than 2% acids, pectin, essential oils, protein, minerals and fiber (Izquierdo and Sendra, 2003). Citrus family also considered as a best source of vitamin C (Lee and Kader, 2000) that varies with respect to climate, variety, horticultural practices storage conditions and maturity stage. Sweet orange has some medicinal importance. Oranges contain huge amount of citrus limonoids, which fight against cancer (skin, lung, breast, stomach and colon) (Milind et al., 2012). Furthermore, edible coating the aim to inhibit ripening mechanisms and preserve the fruit from water loss and spoiling may be a viable approach to extend product shelf life. Even lately, the incorporation of the additive into these edible coatings to boost their efficacy has been described and patented, such as natural ingredients and their components with antibacterial and antioxidant activity. Certain edible coatings are applied on surface of fruit that have various roles that modify the atmosphere around fruit, provide a barrier thus reducing respiration and transpiration that leads to reduction of water loss, oxidation reaction rates and metabolic activities. Therefore, coating fruits have become more resistance to pathogens and increasing their storage and marketing (Park, 1999). Postharvest decay represents major losses of fruits. The application of fungicides is the most effective method to control postharvest diseases. However, chemical control faces imminent problems of residues; thus, there is a growing need to develop bioactive substances to control the decay. By toxicological studies it is indicated that Chitosan is a by-product from the seafood industry. It is derived from shells of crabs, shrimps and crawfish. It is a safe material and a

carbohydrate polymer that has a wide range of applications in diverse fields used in seed coatings, medical sutures and dietary supplements. Chitosan has been widely used in medicine, agricultural production, and food industry. Chitosan functions as a fungistatic and as a bio stimulant. It interferes directly creation of several defense mechanisms that include the synthesis of protein's inhibitors, induction of callous synthesis and accumulation of chitinases. In general, biotic and a-biotic factors in field induces some disorders in citrus fruits like peel disorder (Grierson, 1998), in the field or during postharvest handling and storage. Many researchers reported the use of Chitosan as a protective safe material against many pathogens. So the information collected from the previous researches the current research was conducted to study the effect of chitosan on banana under different storage conditions. Moringa as a medicinal tree has numerous economic applications and utilizations in human consumption (Kasolo et al., 2010). Moringa leaves can be utilized in the food industry as a natural preservative, that can be used as an alternative to synthetic preservatives in the future, it can also be utilized to market healthier products without synthetic additives (Bukar et al., 2010). The extract of the leaves has a significant antimicrobial activity, and it is effective in preventing growth of fungi (Farooq et al., 2012). Keeping in view the importance and problems related to shelf life and quality of sweet orange fruits. The aim of this experiment was to study the effect of Chitosan on the shelf life of and quality of sweet orange and interactive effect of Chitosan and Moringa leaf extract on the Sweet orange fruit.

## Materials and Methods

The research work on entitled. "Effect of Chitosan and Moringa leaf extract on the postharvest quality of sweet orange fruit". Red blood was conducted at postharvest Horticulture lab, department of Horticulture, The university of Agriculture Peshawar Pakistan during the December 2021- January 2022. The experiment was laid out in completely randomized design (CRD) with two factors replicated three times. Factor A Moringa leaf extract and factor B Chitosan concentration was used in experiment. The data were taken at 7 days' interval and was continued deterioration starts.

### Factor A (Moringa leaf extract)

M1 = Control

M2 = 10%

M3 = 20%

### Factor B (Chitosan concentration)

$C_1$ = Control

$C_2$ = 2%

$C_3$ = 4%

### Moringa leaves collection and preparation of Moringa leaf extract:

Young leaves were collected from moringa tree. Moringa leaf extract was prepared by grinding young leaves (1 ml/10g fresh material) in a conventional juicer blinder. The solid material was separated from the juice by using a cheese cloth. The juice was collected in a separate container in the following two dilutions of moringa leaf extract was made:

M1- Distilled water (was take as control)

M2- 10 ml moringa leaf extract was mixed with 90 ml of distilled water (10% V/V)

M3- 20 ml moringa leaf extract was mixed with 80 ml of distilled water (20% V/V)

**Preparation of chitosan edible coating solution:**

For the preparation of various concentration (2 and 3 % chitosan solution) 2 and 3 grams of chitosan in powder form was weighted respectively with sensitive balance, the powder chitosan was dissolved in 100ml of distilled water. As chitosan cannot be dissolved easily in water so for uniform dissolution few drops of citric acid was added to the solution and placed over magnetic stirrer.

C1- Distilled water (was take as control)

C2- 2gm chitosan powder was dissolved with 100 ml of distilled water (2% W/V)

C3- 3gm chitosan powder was dissolved with 100 ml of distilled water (3% W/V)

**Fruit sample collection**

Mature sweet orange of Red blood of same size was selected from healthy trees of Kaka Saib orchard Nowshera Khyber Pakhtunkhwa Pakistan. The harvested fruits were carefully transported to post-harvest lab, department of Horticulture, the university of Agriculture Peshawar. The fruits with uniform maturity and size without any wounds was washed with water and stored for experiment.

The following parameter was studied.

**Taste and Appearance**

Hedonic scale was used to check the taste and appearance of all the fruits samples. Based on the consistency of judgment, a team of specialists was made. From each sample, fruits of sweet orange was selected randomly and was presented to the specialist. Specialists was asked to make the difference between samples by giving them numbers (0 to 10).

**Fruit firmness ($kgcm^{-2}$)**

Firmness of fruits was determined by penetrometer. A peel was removed from the fruit from the area of analysis. Then the probe of the penetrometer was allowed to penetrate inside the fruit. The reading was displayed on the screen after the release of force. At least three readings was taken from each sample.

**Total soluble solids (°Brix)**

Total soluble solids (TSS) was determined in term of percent or Brix using a standard method of AOAC (2012) using an Abbe refractometer. The juice of each sample was put into separate beaker. A small drop was taken from the juice through a stirrer and then put and spread on the lens of refractometer. The lid of lens was closed slowly and fine reading was taken by adjusting the scale.

**Juice PH**

Juice pH of sweet orange was determined through pH meter. Standardization of pH meter was done by dipping the electrode in the buffer solution. The electrode was dipped in the sample of fruit juice and the reading appears on the solution on the screen was recorded as the pH of the sample.

**Titratable acidity (%)**

The percentage Titratable acidity was determined using the titrametric method as described in AOAC (2012). 5 ml sample was taken in a graduated cylinder. It was then diluted by distilled water up to 50ml. Then from it a 10 ml sample was taken in flat bottom flask. It was titrated against NAOH. The amount of NAOH reduced in the burette was noted and reading was prepared. This procedure was repeated for each sample.

**Ascorbic acid content (mg $100g^{-1}$)**

Content of ascorbic acid of the samples was found by the titrimetric method as described in AOAC (2012). 5ml juice was taken from each sample. Then it was diluted up to 50 ml by the addition of oxalic acid. Then 10 ml sample was taken from this 50 ml for ascorbic acid determination. This was titrated against the dye. The reading on burette was noted and reading was taken.

**Sample Titration (mg $100g^{-1}$)**

To determine the content of Vitamin C, tomato sample extract was taken. It was diluted with 0.4% oxalic acid and the volume was reached up to 100 ml. From this 10ml diluted sample was taken for titration against the dye. After titration with continues shaking light pink color was appeared.

Three consecutive readings were taken from all samples. Ascorbic acid content was determined using the following formula:

$$Ascorbic\ acid\ \left(\frac{mg}{100g}\right) = \frac{L \times F \times 100 \times 100}{S \times P}$$

Where,

F = Dye factor

L = ml of dye used

S = ml of dilute solution taken for titration

P = Sample Volume for titration.

**Weight loss (%)**

The weight loss of samples was determined by using a high-performance balance.

One fruit from each treatment was marked for percentage weight loss. The value of a specific interval was subtracted from the initial value of the sample and was multiplied by 100. The percent weight loss was calculated using the following formula,

$$Weight\ loss\ (\%) = \frac{Weight\ of\ fresh\ fruit - weight\ of\ specific\ storage\ duration}{weight\ of\ fresh\ fruits} \times 100$$

**Decay percentage (%)**

At the end of research, in each treatment rotten fruits quantity was counted and calculated by following formula using the method defined by AOAC (2012).

$$Decay\ percentage = \frac{No.\ of\ rotten\ fruits}{Total\ no.of\ fruits} \times 100$$

**Statistical analysis**

The recorded data was measured through a proper procedure which was suitable for complete randomized design (CRD) with two factors. To analyze the recorded data STATISTIX (version 8.1) software was used with least significant difference at 5 % level of probability.

## Results and Discussions

### Appearance

Data regarding appearance of sweet orange is shown in Table 1a while its ANOVA is shown in Table 1b and original triplicated data are presented in appendix 1a. Mean data shows appearance of sweet orange are significantly affected by different concentration of Moringa Leaf Extract coating and Chitosan coating while interaction between them was recorded non-significant. In term of appearance, maximum score was recorded with 20% coating of Moringa leaf extract (7.50) as followed by 10% coating of sweet orange (6.23) while minimum score was recorded by 0% coating or uncoated sweet orange (5.79). Similarly, maximum score of appearance was recorded with 4% coating of Chitosan (6.83) as followed by 2% coating of sweet orange with Chitosan (6.51) while minimum score was recorded with uncoated sweet orange (6.17). In storage days, maximum score of appearance (8.07) was recorded is fresh day as followed by 7 days of observation (7.14) then 14 day (6.23) and 21 day (5.76) while minimum appearance score (5.33) was recorded on 28 days. In term of appearance, the overall appearance of the skin improved. A group of an experts' judges assessed the appearance of sweet orange. The maximum appearance score was recorded in the coated fruits, which might be related to lowest respiration rate in this fruits, which decrease the loss of colored pigmentation from the fruit surface, resultant in a higher appearance score. During prolonged storage the loss of colour is related to the evaporation of colour pigments from fruits surface (Ribeiro et al., 2007). Fruits' appearance was enhanced by the formation of carotenoids and anthocyanins and the breakdown of chlorophyll during storage (Zhu et al., 2008).

### Taste

Data regarding the taste of sweet orange was showed in Table 1a while its ANOVA is shown in Table 1b. Mean data shows appearance of sweet orange are significantly affected by different concentration of Moringa Leaf Extract coating and Chitosan coating while interaction between them was recorded non-significant. In term of taste, highest score of sweet orange taste (6.67) was recorded when coated with 20% Moringa leaf extract as followed by 10% coated sweet orange (6.47) while lowest score was recorded by 0% or uncoated fruit (6.13). Similarly, high score of sweet orange taste (6.69) was recorded when coated with 4% of Chitosan followed by 2% coating of Chitosan (6.31) while lowest score was recorded by 0% or uncoated sweet orange (6.27). In

term of storage days, maximum taste score (7.68) was recorded on fresh day as followed by 7 day (6.57), 14 day (6.14), 21 day (5.96) while minimum taste was recorded on 28 days of storage (5.78). Taste of fruit is a significant parameter from quality point of view. The optimal sugar to acid ratio, which determines flavor, might be reason why food tastes best on the first day. This ratio increased as a result of ripening, which caused starches to break down into sugars and the existence of converting sugar. Because of the increased sugar concentration, the fruit is sweeter and hence more appealing. The coating reduces respiration, water loss, and suppresses the oxidation reaction by acting as a semi-permeable barrier to the movement of carbon dioxide, oxygen, moisture, and solutes. As a result, the consumer would be satisfied with the fruit's flavor (Baldwin, 1994). The current findings are comparable to those of Wang et al. (2004), who found that fruits of the Jincheng orange type had good eating quality without an unpleasant flavor because of the waxes. Ladaniya (2001) published similar results, showing that the taste score in "Musambi" sweet orange (*Citrus sinensis*) fruits reached its peak after 30 days.

**Fruit Firmness (kg cm$^{-2}$)**

Data regarding fruit firmness (kg cm$^{-2}$) of sweet orange was showed in Table 1a while its ANOVA is presented in Table 1c. Mean data shows fruit firmness (kg cm$^{-2}$) of sweet orange are significantly affected by different concentration of Moringa Leaf Extract coating and Chitosan coating whereas interaction between them was also recorded significant. In term of fruit firmness (kg cm$^{-2}$), maximum score of fruit firmness in sweet orange was noted when coated with 20% moringa leaf extract (2.84) followed by 10% (2.64) while minimum firmness was noted in uncoated fruits (2.60). Similarly, maximum score of fruit firmness was recorded in 4% chitosan coating (2.76) followed by 2% (2.72) while minimum was recorded in uncoated fruit (2.60). In term of storage days, maximum fruit firmness (kg cm$^{-2}$) score was recorded on fresh day (4.43) as followed by day 7 (3.10) then day 14 (2.35) and day 21 (1.86) while minimum fruit firmness (kg cm$^{-2}$) was recorded (1.73) at day 28. Fruit firmness is well-known to be an important component in rotting resistance (Baloch et al., 2011). This led to links between the maintained fruit hardness in treated oranges and a prolonged postharvest period and fruit maturity in various orange varietals (Olmo et al., 2000). Weight and moisture loss are associated with deteriorating fruit firmness (Laurie et al., 1998). According to Summu and Bayindirli (1995), oxygen stimulates the production of de-hydro ascorbic acid from ascorbic acid, which lowers fruit firmness. Similar to this, fruit firmness is impacted by transpiration from the fruit's surface. Fruits soften due to cellular disintegration,

which increases membrane permeability, or the breakdown of insoluble proto-pectins into soluble pectins (Mattoo et al., 1975). According to Asghar et al. (2014), an edible coating of glycerin and gum arabic increased the shelf life of peach fruits by enhancing quality factors including firmness and colour, which support our findings.

**Total soluble solids (TSS) (brix$^{o}$)**

Table 1a showed the data regarding the TSS ($^{o}$Brix) of sweet orange whereas its ANOVA is presented in Table 1d. Mean data shows that TSS of sweet orange as significantly affected by different concentration of Moringa leaf extract coating and Chitosan coating while the interaction between variety and coating was found non-significant. Mean data of TSS is shown in Table 1a, in Moringa leaf extract maximum TSS ($^{o}$Brix) (14.41) was recorded in fruit coated with 20% as followed by 10% coated fruits (13.15) while minimum TSS was recorded with 0% or uncoated fruits (13.02). Similarly, in term of chitosan coating, maximum score was recorded with 4% (13.73) as followed by 2% (13.49) while minimum TSS was recorded with uncoated fruits (13.35). In term of storage days, maximum score was observed on day 28 (14.38) as followed by day 21 (13.84) and day 14 (13.45) and day 7 (13.24) while minimum TSS score was recorded on fresh day (12.73). Oranges are non-climacteric fruits, hence very little ethylene is produced. Fruits' storage time is extended by the conversion of starch to sugar and the hydrolysis of polysaccharides in the cell wall, which raises their TSS (Rojas-Grau et al, 2007). The elevated TSS at room temperature may be attributed to higher metabolic activity (Rab et al., 2010). On the other hand, increased TSS at 2oC occurred prior to the onset of chilling damage (Cohen et al., 1994). According to a study, the rise in total soluble solids, weight loss, and loss of firmness were all significantly decreased in oranges coated with Aloe vera gel (Adetunji, 2012).

**pH**

Data regarding the pH of sweet orang in presented in Table 1a while its ANOVA is showed in Table 1e. Mean data shows that pH of sweet orange significantly affected by different concentration of Moringa leaf extract and Chitosan coating while interaction between them was found non-significant. In term of Moringa leaf extract, the maximum pH of sweet orange juice was

recorded at 20% coating (4.76) as followed by 10% coating (4.32) while minimum pH was recorded on uncoated fruit (4.22). Similarly, in Chitosan coating, significantly maximum pH score was recorded on 4% coating (4.56) as followed by 2% coating of fruits (4.40) whereas minimum score of pH was recorded on uncoated fruit (4.34). In storage days, maximum pH was recorded on 28 day (4.78) as followed by 21 day (4.56), 14 day (4.45) and 7 day (4.32) while minimum pH was recorded on fresh day (4.05). The pH level increased with longer storage times. The breakdown of acids during fruit storage due to respiration may be to blame for the rise in pH. A large increase in catabolic activities brought on by high respiration rates leads to the breakdown of organic acids and an increase in pH level (Sajid et al., 2019). Different treatments impact the biochemical state of fruits, as well as their metabolic processes and rate of respiration, which are the cause pH changes. Due to water vapours in the pack, pH rises throughout the last storage periods, which leads to saturation of the packs environment (Elham et al., 2013).

**Table 1a: Effect of moringa leaf extract coating, chitosan coating and storage duration on Appearance, Taste, Fruit Firmness ($kg.cm^{-2}$), TSS ($^{o}brix$) and pH of Sweet orange**

| Moringa Leaf Extract Coating (%) (MC) | Parameters | | | | |
|---|---|---|---|---|---|
| | Appearance | Taste | Fruit Firmness ($kg\ cm^{-2}$) | TSS ($brix^{o}$) | pH |
| 0 | 5.79 c | 6.13 b | 2.60 b | 13.02 b | 4.22 b |
| 10 | 6.23 b | 6.47 a | 2.64 b | 13.15 b | 4.32 b |
| 20 | 7.50 a | 6.67 a | 2.84 a | 14.41 a | 4.76 a |
| LSD(P≤0.01) | 0.16 | 0.26 | 0.15 | 0.24 | 0.14 |
| **Chitosan Coating (C)** | | | | | |
| 0 | 6.17 c | 6.27 b | 2.60 b | 13.35 b | 4.34 b |
| 2 | 6.51 b | 6.31 b | 2.72 ab | 13.49 ab | 4.40 b |
| 4 | 6.83 a | 6.69 a | 2.76 a | 13.73 a | 4.56 a |
| LSD(P≤0.01 OR 0.05) | 0.16 | 0.26 | 0.15 | 0.24 | 0.14 |
| **Storage Days (SD)** | | | | | |
| Fresh | 8.07 a | 7.68 a | 4.43 a | 12.73 d | 4.05 d |
| 7 | 7.14 b | 6.57 b | 3.10 b | 13.24 c | 4.32 c |
| 14 | 6.23 c | 6.14 c | 2.35 c | 13.45 c | 4.45 bc |
| 21 | 5.76 d | 5.96 cd | 1.86 d | 13.84 b | 4.56 b |
| 28 | 5.33 e | 5.78 d | 1.73 d | 14.38 a | 4.78 a |
| LSD(P≤0.05) | 0.21 | 0.34 | 0.20 | 0.32 | 0.18 |

Mean in columns followed by the same letters are non-significant 5 % level of probability

| | | | | | |
|---|---|---|---|---|---|
| LSD for M x C at 1% levels of significance= | *** | **NS** | *** | **NS** | *** |
| LSD for M x S at 1% levels of significance= | **NS** | **NS** | *** | **NS** | *** |
| LSD for C x S at 1% levels of significance= | **NS** | **NS** | *** | **NS** | **NS** |
| LSD for M x C x S at 1% levels of significance= | **NS** | **NS** | *** | **NS** | **NS** |

**Titrarable Acidity (%)**

Data of Titrarable acidity of sweet orange was presented in Table 2a while its ANOVA is showed in Table 2b. Mean data showed that Titrarable acidity of sweet orange significantly affected by different concentration of Moringa leaf extract coating and Chitosan coating while interaction between them was found non-significant. In term of Moringa leaf extract, maximum titrarable acidity was recorded with uncoated fruit (1.70%) as followed by 10% coated fruit (1.54%) while minimum titrarable acidity was recorded 20% coated fruits (1.38%). Similarly, in Chitosan coating, maximum titrarable acidity was recorded with uncoated fruit (1.61%) as followed by 2% coated fruit (1.56%) whereas minimum titrarable acidity score was recorded with 4% coated fruit (1.44%). In term of storage days, maximum score was recorded on fresh day (2.08%) as followed by 7 day (1.73%), 14 day (1.56%) and 21 day (1.23%) while minimum score was recorded on 28 day (1.09%). The decrease in acidity may be due to postharvest metabolic activity in fruits and pectin being converted to pectic acid during storage. Because the organic acids in the fruits are converted to soluble sugars as storage time increases, the acidity of the fruits decreased (Bhattarai and Gautam, 2006). As a result, acidity decreases, while TSS and sugar increase (Singleton et al., 1999). Our results support the claims presented by Bai et al. (1998) that the use of coating reduces water loss and the respiration process. Coatings prevent gas exchange, which causes fruit to accumulate CO2 and lose acidity while being stored. Fruits' reduced titratable acidity is caused by the Krebs cycle, which oxidises organic acids throughout the ripening process to create energy reserves for fruits (Kays, 1991). According to some investigations, the higher concentration of Aloe vera gel coating suppressed the decline in titratable acidity, which may be related to a reduction in the respiration and catabolism of soluble solids like sugar and organic acid (Ergun and Satici, 2012).

**Ascorbic Acid (mg 100 $g^{-1}$)**

Data of Ascorbic Acid (mg 100 $g^{-1}$) of sweet orange was presented in Table 2a while its ANOVA is showed in Table 2c. Mean data showed that the Ascorbic Acid (mg 100 $g^{-1}$) of sweet orange significantly affected by different concentration of Moringa leaf extract coating and Chitosan coating, interaction between them was also found significant. In term of Moringa leaf extract, maximum ascorbic acid (mg 100 $g^{-1}$) score was recorded on 20% coated fruit (38.36) as followed by 10% coated fruit (38.19) while minimum ascorbic acid score was recorded on uncoated fruit

(37.78). Similarly, in term of Chitosan coating, maximum score of ascorbic acid was recorded on 4% coated fruit (40.87) followed by 2% coated fruit (37.33%) while minimum score was recorded on uncoated fruit (36.13). In term of storage days, maximum score of ascorbic acid was recorded on fresh day (59.10) as followed by 7 day (51.66), 14 day (32.72) and 21 day (24.89) while minimum score was recorded on 28 day (22.18). A less stable vitamin, ascorbic acid loses stability with prolonged storage (Kaul and Saini, 2000). All of the orange samples revealed a decline in ascorbic acid level over the course of storage (Paolo et al., 2001). Ascorbic acid decreases as moisture is lost since it is water soluble. The advantage of coating is that it minimizes ascorbic acid oxidation by preventing oxygen from accessing the fruits (Oluwaseun, 2013). Coating of fruits delay its ripening which allow it to maintained its content of ascorbic acid for a longer period of time (Park, 1999).

**Weight loss (%)**

Data of Weight loss (%) of sweet orange was presented in Table 2a while its ANOVA is showed in Table 2d. Mean data showed that the Weight loss (%) of sweet orange significantly affected by different concentration of Moringa leaf extract coating and Chitosan coating, interaction between them was also found significant. In term of Moringa leaf extract, maximum weight loss (%) was recorded on uncoated fruit (11.00%) as followed by 10% coated fruit (10.82%) while minimum weight loss (%) was recorded on 20% coated fruit (10.48%). Similarly, in term of Chitosan coating, maximum weight loss (%) was recorded on uncoated fruit (11.82%) as followed by 2% coated fruit (10.50%) whereas minimum weight loss was recorded on 4% coated fruits (9.97%). In term of storage day, maximum score was recorded on 28 day (13.89%) followed by 21 day (13.13%), 14 day (11.58%) and 7 day (9.67%) while minimum weight losses was recorded on fresh day (0.00%). Loss in weight is important parameter and significantly impact the appearance (Mohebbi et al., 2012). Fruits with coatings may have served as a barrier, preventing moisture from fruit surfaces from evaporating. Transpiration, respiration, and other metabolic processes are the key factors that lead to weight loss in fruits and other horticulture products (Veravrbeke et al, 2003). This may be because during ripening, evaporation from the fruit surface was caused by cell wall disintegration and membrane permeability. Additionally, the process of transpiration, in which water vapor is moved from inside cells to the outside atmosphere. Our results support Baldwin's

(1994) assertion that edible coatings can easily preserve fruit weight and minimize water loss (Bisen et al., 2012).

**Decay incidence (%)**

Data of Decay incidence (%) of sweet orange was presented in Table 2a while its ANOVA is showed in Table 2e. Mean data showed that the Decay incidence (%) of sweet orange significantly affected by different concentration of Moringa leaf extract coating and Chitosan coating while interaction between them was found non-significant. In term of Moringa leaf extract coating, maximum score was recorded on 0% coated fruit (2.38%) followed by 10% coated fruit (2.33%) while minimum score in decay incidence was recorded on 20% coated fruit (2.16%). Similarly, in Chitosan coating, maximum score was recorded on uncoated fruit (2.32%) followed by 2% coated fruit (2.31%) while minimum score was recorded on 4% coated fruit (2.24%). In term of storage day, maximum decay incidence (%) score was recorded on 28 day (3.95%) followed by 21 day (3.63%), 14 day (3.27%) and 7 day (0.59%) while minimum weight losses was recorded on fresh day (0.00%). Decay is one of the most important postharvest factors in reduction of quality horticultural Crops. El Ghaouth *et al*., (1992) studied how pathogens infected strawberry fruits was affected by the coating of chitosan. Chitosan was fatal to mould cells, stopped the polygalacturonases from secreting, and stimulated enzymes involved in defensive mechanisms. Fruits damage less quickly during storage time in the early days of fresh commodities, when respiration is higher and sugar loss is greater, antifungal appearance were less (Hernandez *et al*., 2007) and antimicrobial activities was increase (Gil *et al*., 2004). Anti-decay effects of chitosan edible coating were observing on table grapes (Xu *et al.*, 2007), strawberry (Kazemini 2012) and jujube fruit (Wang *et al*., 2014).

**Table 2A: Effect of moringa leaf extract coating, chitosan coating and storage duration on Titratable Acidity (%), Ascorbic Acid (mg. 100g$^{-1}$), weight loss (%) and Decay incidence (%) of Sweet orange.**

| Moringa Leaf Extract Coating (%) (MC) | Parameters | | | |
|---|---|---|---|---|
| | Titratable Acidity (%) | Ascorbic Acid (mg. 100g$^{-1}$) | Weight loss (%) | Decay incidence(%) |
| 0 | 1.70 a | 37.78 a | 11.00 a | 2.38 a |
| 10 | 1.54 b | 38.19 a | 10.82 a | 2.33 ab |
| 20 | 1.38 c | 38.36 a | 10.48 a | 2.16 b |
| LSD(P≤0.01) | 0.06 | 2.27 | 0.81 | 0.17 |
| **Chitosan Coating (C)** | | | | |
| 0 | 1.61 a | 36.13 b | 11.82 a | 2.32 a |
| 2 | 1.56 a | 37.33 b | 10.50 b | 2.31 a |
| 4 | 1.44 b | 40.87 a | 9.97 b | 2.24 a |
| LSD(P≤0.01) | 0.06 | 2.27 | 0.81 | 0.17 |
| **Storage Days (SD)** | | | | |
| Fresh | 2.08 a | 59.10 a | 0.00 d | 0.00 e |
| 7 | 1.73 b | 51.66 b | 9.67 c | 0.59 d |
| 14 | 1.56 c | 32.72 c | 11.58 b | 3.27 c |
| 21 | 1.23 d | 24.89 d | 13.13 a | 3.63 b |
| 28 | 1.09 e | 22.18 d | 13.89 | 3.95 a |
| LSD(P≤0.01) | 0.08 | 2.93 | 0.80 | 0.23 |

Mean in columns followed by the same letters are non-significant 5 % level of probability

| | | | | |
|---|---|---|---|---|
| LSD for M x C at 1% levels of significance= | NS | *** | *** | *** |
| LSD for M x S at 1% levels of significance= | *** | *** | *** | NS |
| LSD for C x S at 1% levels of significance= | NS | *** | *** | NS |
| LSD for M x C x S at 1% levels of significance= | NS | *** | *** | NS |

## Conclusions

On the basis of the current study it is concluded that sweet orange coated with 20% moringa leaf extract were found with minimum weight loss, maximum fruit firmness (kg $cm^{-2}$), maximum total soluble solids ($Brix^{o}$), maximum juice pH, maximum ascorbic acid (mg $100^{-1}$), minimum Titratable acidity (%), less Decay percentage (%), good taste and appearance of sweet orange. Sweet orange coated with 4% chitosan were found with minimum weight loss, maximum fruit firmness (kg $cm^{-2}$), maximum total soluble solids ($Brix^{o}$), maximum juice pH, maximum ascorbic acid (mg $100^{-1}$), minimum titratable acidity (%), good taste and appearance of sweet orange . Sweet orange at fresh days were found with man weight loss, maximum fruit firmness (kg $cm^{-2}$), maximum ascorbic acid (mg $100^{-1}$), minimum titratable acidity (%), good taste and appearance of sweet orange. It is recommended, based on the obtained conclusions that sweet orange should be coated with 20% moringa leaf extract and 4% chitosan for better postharvest quality and shelf life of sweet orange up to 21 days of storage.

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