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Effects of Storage Conditions, Storage Duration and Post-Harvest Treatments on Nutritional and Sensory Quality of Orange (*Citrus sinensis* (L) Osbeck) Fruits

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ABSTRACT
The fruits of Msasa and Jaffa orange varieties were harvested and subjected to post-harvest treatments namely; dipping in hexanal, dipping in calcium chloride and compared with untreated control; and they were stored at ambient (28 ± 2°C) and reduced temperatures (18 ± 2°C) conditions. Data were collected on the 0, 4th, 8th, and 12th days from the date of fruit harvest. Chemical analyses were conducted to determine vitamin C content, total sugars, reducing sugars and total flavonoids. Post-harvest treatments had a significant effect on vitamin C and total flavonoids of Jaffa orange fruit. Hexanal treated fruit had higher values of total flavonoids, vitamin C, and total sugars compared to calcium chloride treated and control fruit. The storage durations showed significant effects on the vitamin C content of Jaffa, total flavonoids, the total and reducing sugars of both fruit varieties. Vitamin C and total flavonoids decreased with increasing storage duration of fruit. The significant interactions of factors were observed on total sugar which was increasing with increasing storage duration, but higher in hexanal treated and ambient stored fruit. Based on consumer acceptance test, the hexanal treated fruits were the most liked followed by calcium chloride treated and untreated fruits based on the appearance, taste, texture and overall acceptability.

KEYWORDS
Vitamin C; flavonoids; reducing sugar; total sugar; consumer acceptability; attributes

Introduction

Nutritional value differ among species, cultivars and maturity stages of fruits (Florkowski et al., 2009). Fruits contain many essential vitamins (A, D, E, K, B, and C), minerals, fiber and phytochemicals such as phenolic compounds and carotonoids, many of which are antioxidants (Yahia and Barrera, 2009). Vitamin C is necessary for growth, development, and repair of body tissues. Citrus fruits also contain flavonoids (hesperidin and naringenin predominantly as

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glycosides) and limonoids (Boeing et al., 2012; Florkowski et al., 2009; Franke et al., 2005; Ladaniya, 2008). Glucose, fructose, and mannose are the major reducing sugars in sweet orange (Ladaniya, 2008). Reducing sugars are the main soluble carbohydrate of most fruits and account for 70% of seedless raisins (Johnson and Conforti, 2003). Various epidemiological studies have demonstrated a strong correlation between adequate consumption of fruits and vegetables with reduced risk of some major diseases such as cardiovascular, diabetes, hypertension, certain types of cancer and some of the degenerative diseases (Garcia-Salas et al., 2010).

The accumulation and degradation of antioxidant compounds in fruits are influenced by both genetic factors such as species and cultivars and other factors such as radiation, cultural practices, maturity at harvest, storage condition and processing (Florkowski et al., 2009). The goal of post-harvest research is to maintain safety and quality while minimizing losses of horticultural crops (Kader, 2003; Kitinoja and Kader, 2002). Post-harvest losses and quality deterioration contribute to physiological losses of nutrients in stored fruits. Nutritional quality parameters of fresh produce change with storage time, and quantification is necessary to determine shelf life (Barrett et al., 2010; Idah et al., 2010). Most fruits and vegetables are composed of 70% to 90% water and once separated from their source of nutrients, they undergo higher rates of respiration, resulting in moisture loss, quality and nutrient degradation, and potential microbial spoilage (Barrett, 2007).

Appearance, texture, color, aroma, freshness, and flavor are important traits used by consumers to select fruits. Consumers have preferences for different combinations of texture, taste, and flavor (Harker, 2001). The acceptance of any food depends on whether it responds to consumer needs and on the degree of satisfaction (Costell et al., 2010).

The loss of nutritional quality during processing and storage of food commodities has become a major issue in the production chain (Rico et al., 2007). The aim of the current study was to determine the nutritional quality of Tanzanian orange fruits as influenced by different post-harvest treatments, storage time and storage conditions.

Materials and Methods

Msasa and Jaffa, the commonly grown orange fruit varieties were harvested from Bwembera and Semngano villages in the Muheza district, Tanga region in Tanzania from June 2016 and July 2017. Fruit were harvested when fully mature and ripe. The results from two seasons were pooled together, and the seasons were treated as replicates. A factorial experiment with three factors was used for each variety and replicated six times. Thirty fruits of each variety were exposed to each treatment which was replicated six times making a total of 360 fruits per treatment. The two varieties of oranges were sorted, cleaned and tested by two post-harvest treatments, namely, hexanal (0.02 % v/v) and in calcium chloride (2 % w/v) where they were dipped for 5 min in each solution, and they were compared to untreated control fruits. Treated and untreated samples were stored under ambient (28 ± 2°C) and cold (18 ± 2°C) conditions. Data were collected on the 0, 4th, 8th, and 12th days after fruit harvest (DAH).

During sample collection, three fruits were randomly selected from each treatment. They were cut, squeezed, filtered to remove pulp and seeds and then centrifuged for 10 min. The supernatant was then used for measuring the nutritional parameters namely; vitamin C (ascorbic acid), total flavonoids, reducing sugars and total sugars of orange fruits as described below.

Vitamin C was determined by using 2, 6-dichlorophenol-indophenol titrimetric method followed methods by Rajwana et al. (2010) and Hughes (1983). 5 mls of orange juice was measured and mixed with 50 mls of 4% oxalic acid as extractant. The juice was then filtered, and the filtrate made up to 100 mls with distilled water. 5 mls was taken out and put in the conical flask, then 10 mls of 4% oxalic acid was added and titrated against 2, 6-dichlorophenolindophol till light pink end point which persisted for 10–15 s. The amount of 2, 6-dichlorophenolindophenol consumed is equivalent to the amount of ascorbic acid. Standard ascorbic acid solution was prepared by adding 1 ml of 0.1% ascorbic acid and 1.5 mls of 0.4% oxalic acid. The amount of vitamin C present in the sample was then calculated using the formula:

$$Vitamin\ C = \frac{R1 \times V \times 100}{R \times T \times W1}$$

Where: R1 = volume of dye used in titration of aliquot, R = volume of dye used in titration of standard ascorbic acid solution, W1 = weight of sample used, V = volume of aliquot made by addition of 0.4% oxalic acid, T = volume of aliquot used for titration.

Total flavonoid was determined by Aluminum Chloride ($AlCl_3$) colorimetric assay followed method by John et al. (2013). 5 mls of orange juice was added into 100 mls of 80% methanol in the flask. An aliquot (1 ml) of extracts or standard solutions of quercetin (20, 40, 60, 80 and 100μg/ml) was added to 10 mls volumetric flask containing 4 mls of distilled water. To the flask was added 0.30 ml of 5% Sodium nitrite ($NaNO_2$) and after five minutes 0.3 ml 10% ($AlCl_3$) was added. 5 minutes later, 2 mls of 1 M Sodium hydroxide (NaOH) was added and the volume was made up to 10 mls with distilled water. The solution was mixed and absorbance was measured against blank at 510 nm. The amount of total flavonoid present in the sample was calculated from the graph and it was expressed as mg quercetin equivalents (QE)/100 mg.

Total sugar was determined by Anthrone method as described by Lal et al. (2018). 0.1 ml of orange juice sample was poured into a tube containing 5 mls of 2.5 N Hydrochloric acid (HCl). The sample was hydrolyzed by keeping it in a boiling water bath for 3 h and then cooled to room temperature. The sample was neutralized with solid sodium carbonate until effervescence ceased. The volume was made up to 100 mls with distilled water and then centrifuged. The supernatant was collected and 1 ml aliquot was taken for analysis. The standards were prepared by taking 0, 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard. The volume was made up to 2 mls in all the tubes including the sample tubes by adding distilled water. 4 mls of Anthrone reagent was added and then heated in a boiling water bath for 8 min. The boiled mixture was cooled rapidly and absorbance was read at 630 nm. From the graph, the amount of total sugar present in the sample tube was calculated as:

$$\text{Total sugar} = \left(\frac{\text{Quantity of sugar obtained}}{\text{Weight of sample}}\right) \times 100$$

Reducing sugar was estimated by Nelson-Somogy method (Maddu and Ravuri, 2015). 2 mls of orange juice sample was measured and the sugar extracted using 5 mls hot 80% ethanol. The extract was filtered by using two layers cheese cloth. The supernatant was collected and evaporated by keeping it on a water bath at 80°C. 10 mls water was added to dissolve the sugars. The aliquots of 0.1 ml were pipetted out to separate test tubes. The standard glucose solution was pipetted out of into a series of test tubes (0.2, 0.4, 0.6, 0.8 and 1 ml). The volume in both sample and standard tubes was made up to 2 mls with distilled water. 2 mls distilled water was pipetted out in a separate tube and set as blank. 1 ml of alkaline copper tartrate reagent was added to each tube. The tubes were placed in boiling water bath for 10 min. They were cooled and 1 ml of arsenomolybolic acid reagent was added. The volume in each tube was made up to 10 mls with water. The absorbance was read at 620 nm after 10 min. The amount of reducing sugars present in the sample was calculated from the graph. Absorbance corresponds to 0.1 ml of test = x mg of glucose

$$\text{Reducing sugars}(\%) = \left(\left(\frac{x}{0.1} \times 10\,\text{mg of glucose}\right) \times 100\right)$$

All parameters were measured in triplicates. Data were analyzed using R software and where significant means were separated using Tukey's Honestly Significant Differences (HSD) ($p \leq 0.05$).

The consumer acceptance test was carried out in the Department of Crop Science and Horticulture (DCSH) of Sokoine University of Agriculture (SUA) by 80 untrained consumers who arrived in groups of 10, using a 5-point Likert type scale (Albert and Tullis, 2013; Krabbe, 2017). (where 1 = dislike extremely, 2 = dislike moderately, 3 = Neither like nor dislike/Uncertain, 4 = like moderately and 5 = like extremely). A Likert scale is an ordered scale from which respondents choose one option that best aligns with their view. The Msasa orange fruit samples were prepared and coded with 3-digit random number and served to the consumers/judges. The panel individuals aged 21–40 years among which 52.5% were males and 47.5 were females. Water was provided for rinsing the mouth after assessing any sample. The consumer judges were instructed to rate each fruit sample for appearance, taste, aroma, texture and overall acceptability indicating their degree of liking or disliking by putting a number as provided in the Likert scale according to their preference. Testing was complete in one session and each consumer evaluated all three samples. Chi square test statistic was used to assess the relationship between quality attributes and post-harvest treatments on sensory of fruits (Lawless and Heymann, 2010).

Results

Vitamin C (Ascorbic Acid)

Vitamin C content of Msasa and Jaffa orange fruits decreased significantly ($p < .001$) with storage duration (Tables 1 and 2 respectively). However, the effects of post-harvest treatments, storage condition, and all interactions were not significant ($p > .05$) on both varieties. Orange fruits had highest vitamin Ccontent at harvest (before storage), then decreased to the lowest level at 12th day of storage. Post-harvest treatments and storage conditions had no influence on vitamin Ccontent of the two orange fruits.

Total Flavonoids

Total flavonoids of Msasa and Jaffa orange fruits varied significantly ($p = .046$ and $p = .003$, respectively) with post-harvest treatments (Tables 1 and 2). Likewise, the effects of storage duration were significant ($p = .003$ for Msasa and $p < .001$ for Jaffa). However, the effects of storage condition and all the interactions were not significant ($p > .05$). The hexanal treated fruits had highest total flavonoids at 8 and 4 days for Msasa and Jaffa variety respectively, regardless of storage condition. Total flavonoid content of both fruit varieties was highest at harvest but decreased with time in storage.

Total Sugars

Our results showed significant ($p < .001$) effects of storage duration × post-harvest treatments on total sugars of fruits of Msasa and Jaffa varieties (Tables 1 and 2). We also observed significant effects ($p = .003$ and $p < .001$) of storage duration on total sugars of fruits of Msasa and Jaffa varieties, respectively (Tables 1 and 2). On the contrary, the effects of post-harvest treatment, storage condition, and all other interactions were non-significant ($p > .05$). We observed increased total sugars content of these fruits over time in storage. Hexanal treated fruits had highest total sugar content throughout the storage time.

Table 1. Effects of storage conditions, post-harvest techniques and storage duration on vitamin C, total flavonoids, total sugars and reducing sugar content of Msasa orange variety.

Parameter	Storage condition	Post-harvest treatments	Storage duration At Harvest	04DAH	08DAH	12DAH	Significance level
Vitamin C (mg/100 mls)	28 ± 2°C	$CaCl_2$	76.81a	58.99c	61.01c	53.74d	SD***
		Control	79.71a	54.48d	61.30c	51.91e	SC^{ns}
		Hexanal	82.61a	63.45c	52.61e	54.17d	PT^{ns}
	18 ± 2°C	$CaCl_2$	75.36a	67.99b	54.49d	51.01e	$SC \times SD^{ns}$
		Control	78.26a	58.68c	64.64c	54.06d	$SD \times PT^{ns}$
		Hexanal	79.71a	68.26b	54.64	55.22d	$SC \times PT^{ns}$
							$SC \times SD \times PT^{ns}$
Total flavonoids (mg CE/ 100 mls)	28 ± 2°C	$CaCl_2$	38.30a	36.50b	25.47d	16.46f	SD**
		Control	40.70a	28.77c	26.49d	13.31g	SC^{ns}
		Hexanal	41.20a	36.12b	27.53c	15.35f	PT*
	18 ± 2°C	$CaCl_2$	40.30a	37.94b	28.17c	16.56f	$SC \times SD^{ns}$
		Control	40.50a	28.12c	29.34c	15.00f	$SD \times PT^{ns}$
		Hexanal	41.80a	38.74b	30.63c	20.00e	$SC \times PT^{ns}$
							$SC \times SD \times PT^{ns}$
Total sugars (%)	28 ± 2°C	$CaCl_2$	22.00e	25.11d	34.63c	42.01a	SD**
		Control	21.19e	28.74d	32.75c	40.98a	SC^{ns}
		Hexanal	22.02e	25.71d	37.95b	44.36a	PT^{ns}
	18 ± 2°C	$CaCl_2$	22.85e	23.15d	34.73c	39.28b	$SC \times SD^{ns}$
		Control	21.53e	25.58d	33.72c	37.76b	SD × PT***
		Hexanal	21.67e	24.21d	37.33b	41.53a	$SC \times PT^{ns}$
							$SC \times SD \times PT^{ns}$
Reducing sugars (%)	28 ± 2°C	$CaCl_2$	16.05g	33.10d	35.43c	40.38b	SD***
		Control	14.56g	28.35e	36.83c	41.33a	SC***
		Hexanal	15.67g	31.75e	38.54b	43.73a	PT^{ns}
	18 ± 2°C	$CaCl_2$	14.65g	20.47f	33.13d	35.68c	SC × SD***
		Control	14.01g	23.92f	28.05e	35.80c	$SD \times PT^{ns}$
		Hexanal	13.78g	29.01e	35.98c	39.11b	$SC \times PT^{ns}$
							$SC \times SD \times PT^{ns}$

Note: Means in the same column bearing the same letter(s) are not significantly different (Tukey HSD at $p \geq 0.05$). SD = Storage Duration (Day), SC = Storage Conditions, PT = Post-harvest treatment, DAH = Days After Harvest of fruit, $CaCl_2$ = Calcium Chloride. *; **; ***; = significant at $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$, respectively, ns = non-significant ($p > 0.05$).

Reducing Sugars

Content of reducing sugars of Msasa and Jaffa fruits was significantly (p <.001 and p = .034, respectively) affected by storage duration (Tables 1 and 2). Furthermore, storage condition and storage duration × storage condition had significant (p < .001) effects on Msasa variety only while post – harvest treatments had significant (p =.022) effects on Jaffa variety only (Tables 1 and 2). All the interactions had non – significant (p > .05) effects. Reducing sugar content of both fruit varieties increased with storage duration regardless of post-harvest treatments and storage condition. Fruits had lowest reducing sugar contents at harvest and highest at 12 days of storage. Hexanal treated Jaffa fruits had highest reducing sugar contents than the calcium chloride treated and the untreated fruits.

Table 2. Effects of storage conditions, postharvest techniques and storage duration on vitamin C, total flavonoids, total sugars and reducing sugar content of Jaffa orange variety.

Parameter	Storage condition	Post-harvest treatments	Storage duration: At Harvest	04DAH	08DAH	12DAH	Significance level
Vitamin C (mg/100 mls)	28 ± 2°C	$CaCl_2$	75.36a	57.97c	53.77d	42.32	SD***
		Control	72.46a	59.42c	49.13e	39.13g	SC^{ns}
		Hexanal	73.91a	65.22b	57.39c	47.39f	PT^{ns}
	18 ± 2°C	$CaCl_2$	76.81a	45.94f	51.30e	53.77d	$SC \times SD^{ns}$
		Control	76.81a	52.61d	51.74e	46.67f	$SD \times PT^{ns}$
		Hexanal	78.26a	66.67b	60.87c	51.16e	$SC \times PT^{ns}$
							$SC \times SD \times PT^{ns}$
Total flavonoids (mg CE/100 mls)	28 ± 2°C	$CaCl_2$	44.45a	30.04c	25.16d	19.79e	SD***
		Control	45.62a	34.31c	32.14c	27.87d	SC^{ns}
		Hexanal	43.18a	38.85b	30.099c	25.78d	PT **
	18 ± 2°C	$CaCl_2$	43.37a	28.46d	22.81e	27.01d	$SC \times SD^{ns}$
		Control	45.35a	34.15c	30.58c	19.34e	$SD \times PT^{ns}$
		Hexanal	44.34a	40.25b	37.14b	27.00d	$SC \times PT^{ns}$
							$SC \times SD \times PT^{ns}$
Total sugars (%)	28 ± 2°C	$CaCl_2$	30.22d	36.62b	38.70b	51.53a	SD***
		Control	28.94d	35.84b	39.93b	43.68b	SC^{ns}
		Hexanal	30.72d	38.71b	46.27a	52.55a	PT^{ns}
	18 ± 2°C	$CaCl_2$	29.73d	33.94c	37.13b	46.14a	$SC \times SD^{ns}$
		Control	28.10d	33.37c	34.20c	38.29b	SD × PT***
		Hexanal	28.42d	35.64b	40.10b	48.34a	$SC \times PT^{ns}$
							$SC \times SD \times PT^{ns}$
Reducing sugars (%)	28 ± 2°C	$CaCl_2$	18.74f	26.20d	36.55b	47.13a	SD *
		Control	16.51f	27.43d	34.04c	44.73a	SC^{ns}
		Hexanal	17.40f	29.60c	42.69a	48.80a	PT *
	18 ± 2°C	$CaCl_2$	17.49f	20.82e	37.73b	39.83a	$SC \times SD^{ns}$
		Control	20.46f	20.57e	34.83c	37.67b	$SD \times PT^{ns}$
		Hexanal	19.95f	24.63d	40.08a	45.66a	$SC \times PT^{ns}$
							$SC \times SD \times PT^{ns}$

Note: Means in the same column bearing the same letter(s) are not significantly different (Tukey HSD at $p \geq 0.05$). SD = Storage Duration (Day), SC = Storage Conditions, PT = Post-harvest treatment, DAH = Days After Harvest of fruit, $CaCl_2$ = Calcium Chloride. *; **; ***; = significant at $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$, respectively, ns = non-significant ($p > 0.05$).

Consumer Acceptance

The panelists' acceptance score for appearance, taste, aroma, texture and overall acceptance attributes are shown in Table 3. Chi square test results showed that appearance of fruits was significantly (χ^2 = 19.156, $p < 0.001$) associated with post-harvest treatment methods (Table 3). The appearance of hexanal-treated fruits was ranked the highest by the majority of panelists. We also found significant (χ^2 = 36.510, $p < 0.001$) association between post-harvest treatment method and taste of fruits (Table 3), in this case panelists' scores for hexanal treated fruits were the highest. Likewise, scores for aroma were highest for hexanal treated fruits. The association between aroma and post-harvest treatment method was also significant (χ^2 = 29.764, p = .013) (Table 3). Our results further showed that texture of fruits was significantly (χ^2 = 147.905, p = .001) associated with post-harvest treatment method

Table 3. The likert scores for Msasa orange fruits treated with Calcium Chloride, Hexanal and untreated control using 5-points scale.

Attributes	Post-harvest treatments	Dislike extremely (1)	Dislike moderately (2)	Neither like nor dislike (3)	Like moderately (4)	Like extremely (5)
Appearance	Calcium Chloride	1	8	3	80	240
	Hexanal	2	4	6	48	340
	Control	14	24	27	88	100
Taste	Calcium Chloride	3	4	12	48	120
	Hexanal	1	6	12	96	165
	Control	3	4	9	120	5
Aroma	Calcium Chloride	1	2	12	108	5
	Hexanal	3	10	18	96	140
	Control	3	4	9	116	5
Texture	Calcium Chloride	2	6	12	40	105
	Hexanal	3	4	12	44	100
	Control	2	4	48	76	10
Overall acceptability	Calcium Chloride	3	6	21	24	130
	Hexanal	2	2	15	50	144
	Control	6	4	9	104	5

Note: The values in the brackets in each column represent respective value of the scale in that column.

(Table 3). The calcium chloride treated fruits had the highest texture scores while the untreated fruits scored the least. Finally, hexanal treated fruits were considered most acceptable while untreated fruits were the least accepted. The association between post-harvest treatment method and the overall acceptability of fruits was significant (χ^2 = 59.462, p = < 0.001) (Table 3). According to panelists, appearance and taste scored higher points in the ranking than aroma and texture.

Discussion

Post-harvest treatments used in this study affected the ascorbic acid content of orange fruits. The high ascorbic acid content in hexanal and calcium chloride treated fruits can be linked to improved firmness. Calcium and its salts have been used to slow softening of different varieties of minimally processed fruits (Soliva-Fortuny and Martín-Belloso, 2003). Turmanidze et al., (2016) reported raspberry and strawberry fruits retained high levels of ascorbic acid when treated with calcium chloride. Turmanidze et al. (2016) also associated use of calcium chloride treatment with reduced respiration rate, ascorbic acid degradation and membrane lipid peroxidation which enhanced the total antioxidant capacity in the treated fruits. The current study therefore associated the high ascorbic acid content to improved firmness of fruits.

Vitamin C of orange fruits decreased with storage time. The decrease in vitamin C during storage is caused by reduction of antioxidant potential in fruits. Ascorbic acid is the most prone vitamin to loss and changes to a less active form as the result of time and temperature in storage (Kramer, 1977). The degradation reactions of vitamin C are often responsible for significant quality changes that occur during storage of foods (Touati et al., 2016). Smoot and Nagy (1980) reported that storage temperature and time could affect the percent of vitamin C content of orange fruits. The degradation of vitamin C is initially slow but later increase due to endogenous metabolism (Zee et al., 1991). Several other studies reported the decreased stability of vitamin C with increased storage temperature (Davey et al., 2000; Emese and Nagymate, 2008; Oyetade et al., 2012).

Post-harvest treatments had significant effects on total flavonoids. Hexanal and calcium chloride treated fruits had higher total flavonoids content than untreated fruits. We attributed total flavonoids to delayed ripening as previously reported by El Kayal et al. (2017). The hexanal treated fruits maintained firm and fresh appearance throughout storage time. A study by Sharma et al. (2010) revealed that hexanal treated sweet cherry maintained post harvest firmness for up to 30 days. This study showed that the tested post-harvest treatments had significant effects on maintaining the total flavonoids of orange fruits stored for 4 days under ambient storage conditions only; while 8 days stored were significant in both storage conditions. The current study showed a decrease in total flavonoids with storage duration further confirming a report by Saci et al. (2015).

Oranges treated with hexanal had high total sugars content than calcium chloride treated and untreated fruits. Changes in sugars during fruit maturation usually depend on the fruit species and variety. Generally, fruits have high glucose, fructose and sucrose levels at more advanced stages of maturation (Mahmood et al., 2012). Total sugars increased with storage time, though it was highest on the 11th day of storage. This might be due to the fact that oranges, as other non-climacteric fruits are harvested when fully ripe.

Storage duration had a significant effect on the reducing sugars content of orange fruits of both varieties. Fruits stored for 8 days had higher contents of reducing sugar than fruits stored for 4 and 12 days. The reducing sugars content increased with storage time. Fructose and sucrose are the major components of soluble sugars in cultivated fruits (Cordenunsi et al., 2002). Our results were similar to those reported by Zhang and Ge (2016) who found that the sucrose content of watermelon increased substantially after 20 days after anthesis and it was the main soluble sugar in mature fruit. The current study showed that fruits stored under ambient condition had higher contents of reducing sugars than those stored under lower temperatures. According to Bhardwaj and Nandal (2014) high temperature accelerate hydrolysis of acids and polysaccharides into simple sugars. Sarmah et al. (1981) observed considerable increase in reducing sugar content in Kinnow mandarin juice stored at room temperature as compared to those kept at low temperature.

The consumer acceptance results showed that hexanal treated fruits were the more liked than the calcium chloride treated and untreated fruits. The acceptance of the food product usually indicates actual use value of the product (Watts et al., 1989). The primary consideration for selecting and eating a food commodity is the product's palatability or eating quality, while other quality parameters, such as nutrition and wholesomeness are secondary (Lawless and Heymann, 2010). The hedonic scale assumes consumer preferences exist on a continuum and that preferences can be categorized by responses based on like and dislike. The visual appearance of fresh fruit is one of the first quality determinants used by buyers (Mitcham et al., 1996). Flavor, nutritional quality, and appearance are recommended for increased consumption and healthier diets for consumers (Kader, 2003). Sensory inputs interact to drive overall impressions, for example, ratings of flavor may be driven by appearance and texture inputs, as well as by pure flavor inputs (Moskowitz and Krieger, 1995).

It can be concluded that post-harvest treatments had a significant effects on total flavonoids of Msasa and Jaffa orange varieties and reducing sugars of Jaffa variety only. Hexanal treated fruits had higher values of total flavonoids, vitamin C, and total sugars compared to calcium chloride treated and the untreated fruits. Storage condition had significantly reducing sugars of Msasa variety only. Storage durations showed significant effects on the vitamin C, total flavonoids, the total sugars and reducing sugars of both Msasa and Jaffa orange fruits. Vitamin C and total flavonoids decreased storage duration of fruits. Total sugars and reducing sugars of Msasa and orange varieties increased with storage duration regardless of storage conditions and post-harvest treatment used. Therefore, it is recommended that hexanal can be used for maintaining both internal and external qualities of orange fruits.

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