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INFLUENCE OF HARVESTING DATES ON FRUIT QUALITY AND STORAGE PERFORMANCE OF SWEET ORANGE (BLOOD RED) FRUIT

A. Rab[1], J. Rahman[2], M. Sajid[1], N. Ahmad[1], M. Ahmad[1], K. Nawab[3] and K. Ali[4]

[1]Department of Horticulture, The University of Agriculture, Peshawar, 25130 Pakistan
[2]Agriculture Research Institute (North) Mingora, Swat, Pakistan
[3]Department of Extension Education, The University of Agriculture, Peshawar, Pakistan
[4]Department of Agriculture, Abdul Wali Khan University, Mardan, Pakistan
Corresponding Author: E-Mail: abdurrabaup@gmail.com

ABSTRACT

The influence of harvesting dates on storage performance of sweet orange fruits was investigated by harvesting the sweet orange fruit from November 15th to February 15th and storing for 30 days at room temperature. The means total soluble solids (TSS) content (8.383%), TSS/Acid ratio (6.51) and reducing sugars (2.76%) in fruit harvested on November 15th increased to the maximum of 14.15%, 43.13 and 11.19% accordingly when the fruits were harvested on February 15th. By contrast, the acidity (1.39%) and non-reducing sugars (4.88%) in fruits harvested on Nov.15th, declined to the minimum of 0.51, and 4.11%, respectively in fruits harvested on February 15th. The juice content (37.90%) and ascorbic acid (41.03 mg/ 100 ml) in fruits harvested on November 15th increased to the highest of 53.05% and 56.40 mg/ 100 ml for January 15th harvest but thereafter declined to 35.99% and 40.90 mg/ 100 ml, respectively in fruits harvested on February 15th. The storage of sweet orange fruits increased the mean TSS from 11.23 to 12.24% and reducing sugars from 6.62 to 8.12% but decreased the acidity from 1.17 to 0.75% and ascorbic acid from 65.02 to 55.40 mg/ 100 ml. The interaction of harvesting date and storage revealed a significant influence on the TSS/ acid ratio, reducing sugars, juice percentage and ascorbic acid content of sweet orange fruits. The TSS/Acid ratio was not significantly affected by storage in fruits harvested from November 15th to January 15th but was significantly higher in fruits harvested from January 30th to February 15th. The reducing sugars of sweet orange fruit increased from 3.32% in fruits harvested on November 15th to the maximum of 12.32% with delaying the harvesting to February 15th. However, at each harvesting date, the difference in reducing sugars content of fresh and stored sweet orange was not significant. The ascorbic acid content of fresh fruits was the least (54.59 mg/100ml) in fruit harvested on November 15th and increased to the maximum (76.21 mg/100ml) in fruit harvested on January 15th, but declined significantly in fruit harvested on January 30th or February 15th. Storage decreased the ascorbic acid content non-significantly in fruits harvested from November 15th to December 15th. However, delaying harvesting to December 30th and February 15th resulted in significantly lower ascorbic acid content of stored fruits as compared to fresh fruits. The juice content of fresh fruits harvested on November 15th (41.03%) increased to the maximum (56.40%) in fruit harvested on January 15th but thereafter decreased significantly in fruit harvested on January 30th or February 15th. The juice content decreased the significantly with storage so that it was lower than the fresh fruits irrespective of the harvesting dates. The weight loss after 30 days storage was the highest (7.27%) of fruits harvested on November 15th, declined to the least (4.17%) in November 15th harvest but increased to 5.91% in fruits harvested on February 15th. By contrast, oleocellosis incidence was the least (3.33%) of fruit harvested on November 15th and increased significantly with incremental delay in harvesting and was the highest (26.67%) in fruit harvested on February 15th.

Key words: Ascorbic acid, Citrus, Harvesting Date, pH, Sugars, storage, TSS, TSS/ Acid ratio.

INTRODUCTION

The citrus fruits are grown over an area of 194.5 thousand hectares in Pakistan with a total production of 1982.2 thousand tons (Anonymous, 2013). Pakistan exported 0.215 million tons of citrus fruits (Anonymous, 2013). The citrus fruits are also important in global fruit production (Kirda *et al*., 2007). The share of Punjab province to the total citrus production is 1912 thousand tons production from 184.2 thousand hectares, that are predominantly grown with Kinnow mandarin. Citriculture is, therefore, regarded as a major crop husbandry (Chatervedi *et al*., 2001). In the KP province, sweet orange is the predominant citrus fruit grown over 4000 hectares that produces 32.3 thousand tons of sweet orange (Anonymous, 2013).

The sweet orange fruit is an important member of the citrus group of fruits. The sweet orange fruit is harvested during the months of December – January. The excess supply during the peak production results in low prices and decreased income. Thus, storage is required to extend availability and capture good price. According to Kader and Arpaia (2002), citrus fruits have low rates of

respiration and ethylene production, therefore, can be stored for a relatively longer time.

Storage losses increases when the fruits are stored in undesirable conditions that result in altered metabolism (Holland *et al*., 2005) causing undesirable physiological changes (Argudo *et al*., 2005). An alternative to storage is harvesting the fruit early or late in the season to extend marketing season (Anwar *et al*., 1999). However, the fruit quality and storability may be adversely affected by early or late harvesting (Liu *et al*., 1998: Holland *et al*., 2002). Thus, an optimum pre-harvest management is required for superior quality in citrus fruits (Din *et al*., 2012). In citrus fruits, the optimum harvesting time is when the fruit has the maximum carbohydrates, which prolong the storage life (Purvis and Grierson, 1982). It is, therefore, required that the sweet orange fruit is harvested with maximum quality attributes and storage life (Pekmezci *et al*., 1995). The present study aimed to determine the optimum date for bio-chemical quality attributes and the influence of harvesting date on the storage performance of sweet orange fruit.

MATERIALS AND METHODS

The compositional changes in sweet orange fruit during harvesting season and storage at room temperature were investigated by harvesting the sweet orange fruits cv. Blood Red, with about similar size and maturity from November 15th to February 15th, 2006-07 in an orchard in Rustum, District Mardan, Pakistan. The harvested fruits were analyzed for physico-chemical quality attributes either immediately after harvest (S-0) or after storage for 30-days (S-30).

Experimental Design and Statistical Analysis: The experiment was laid out in two factorial randomized complete (CRD) design. The experiment consisted of 16 treatments with two storage durations e.g. Fresh Fruits (S-0) and room storage for 30 days (S-30) as the main blocks and harvesting dates November 15th, December 1st, December 15th, January 1st, January 15th, January 30th , February 1st and February 15th in sub- blocks. Each treatment containing 10 fruits was replicated three times. Data was recorded on various postharvest quality parameters of citrus fruits within 3 hours either after harvest (S-0) or after 30 days storage (S-30) at room temperature.

Chemical analysis: From each treatment and replications, 10 fruits were taken randomly. The juice was extracted from the fruit with locally made pressure extractor. The juice from each treatment and corresponding replications were used for chemical analysis.

Total soluble solids and acidity (%): The total soluble solids of the fruit were determined with a hand refractometer (Kernco Instruments Co. Texas) by placing a drop from thoroughly mixed juice on the slab of brix refractometer and covering with the transparent lid. Acidity, reducing and non-reducing sugars and ascorbic acid content were determined as described earlier (AOAC, 1995).

Total, reducing and non-reducing sugars (%): Total and reducing sugars in the orange fruit juice were estimated by titration as described in AOAC (1995). The juice of orange fruit was filtered through whattman-4 filter paper and 25 grams of filtered juice was transferred to 250 ml volumetric flask. The juice was diluted by adding 100 ml of distilled water. The solution was neutralized with 1N NaOH with 2 ml of lead acetate solution. The solution was shaken and allowed to stand for 10 minutes. The excess lead was removed by adding the required quantity of potassium oxalate and the volume made with water.

The concentrations of reducing and non-reducing sugars were calculated as:

Reducing sugars (%) = 6.25 (X/Y)

where

X = ml of standard sugar solution used against 10 ml Fehling's solution

Y = ml of sample aliquot used against 10 ml Fehling's solution

The total sugars were determined by taking 25 ml of the aliquot in a 100 ml volumetric flask. It was added with 20 ml distilled water and 5 ml concentrated HCl. The solution was kept overnight for converting the non-reducing sugars into reducing sugars. The solution was neutralized with 50% concentrated NaOH solution and volume was made to 100 ml with distilled water. The solution was transferred to a burette and titrated against 10 ml Fehling's solution to get brick red using Methylene blue as an indicator. Total sugars were calculated by the following formula:

% Total sugars = 25 x (X/Z)

Where:

X = ml of standard sugar solution used against 10 ml Fehling's solution

Z = ml of sample aliquot used against 10 ml Fehling's solution

Non- reducing sugars **(%**) = (Total sugars% - Reducing sugars %) x 0.95

Ascorbic acid: The ascorbic acid content of the juice was determined by diluting one ml of juice in 0.4% oxalic acid solution and the volume was made to 10 ml. The diluted sample solution was titrated against the standard dye solution until light pink color appeared, which persisted for about 15 seconds. The ascorbic acid content was estimated by the following formula (AOAC, 1990)

Ascorbic acid = F x T x 10 D x S x 100

F = Factor for standardization = Where, (ml of ascorbic acid) Ml of dye
T = ml of dye used for sample – ml of dye used for blank
D = ml of sample taken for dilution
S = ml of dilute sample taken for titration

The juice was extracted from a known weight of fruit pulp and converted to percent of juice content by the following formula.

$$Juice\,Content\,(\%) = \frac{Weight\,of\,Pulp - Weight\,of\,Juice}{Weight\,of\,Pullp}\ x100$$

Since the weight loss was zero in fresh fruit, it was analyzed, using CRD with harvesting stages and storage after 30 days only. Weight loss is presented as percent of weight loss. For this purpose, initial and final weight of the fruits was determined at time zero and after one-month storage period at room temperature, with the help of an electronic balance measuring weight in gm to the third decimal.

$$Percent\ weight\ loss = \frac{Weight\ of\ fresh\ fruit - Final\ fruit\ Weight}{Weight\ of\ fresh\ fruit}\ x100$$

Similarly, the oleocellosis incidence being zero was determined only after 30 storage by the following formula.

$$Oleocellosis\ (\%) = \frac{Number\ of\ fruits\ with\ oleocellosis}{Total\ number\ of\ fruits}\ x100$$

RESULTS

Total soluble solids (TSS): The total soluble solids content of fruits harvested on November 15th (8.38%), increased significantly to 10.32 and 11.05% with harvesting on November 30th and December 15th. The TSS content of the sweet orange fruits increased further to 12.18, 12.40, 13.56 and 14.15% with harvesting on December 30th, January 15th, January 30th and February 15th, respectively (Table 1). Storage also increased the TSS content of sweet orange fruit significantly from 11.23% in fresh fruits to 12.24% in fruits stored for 30 days at room temperature. The influence of interaction between harvesting date and storage was not significant (Table 1).

Percent acidity: The percent acidity of sweet orange fruit increased significantly with delaying the harvesting date. The percent acidity reduced from the maximum of 1.39 in fruit harvested on November 15th to the minimum of 0.51% for February 15th harvest. The storage of fruit for 30 days at room temperature also decreased the acidity of the sweet orange fruit. The percent acidity of fresh fruits (1.17%) decreased to 0.75% with storage for 30 days (Table 1).

TSS acid ratio: The TSS acid ratio increased significantly from 6.51 in fruits harvested on November 15th to 9.09 and 11.28 in fruits harvested on November 30th and December 15th respectively. Extension in harvesting date to January 30th increased TSS/Acid ratio to 18.94 and finally to the maximum of (31.61) in fruits harvested on February 15th. Storage of sweet orange fruits also significantly increased the TSS/Acid ratio from 10.95 in fresh fruits to 19.36 in fruits stored for one month at room temperature. The interaction of harvesting date and storage revealed that the TSS/Acid ratio was higher after 30 days storage across all harvesting dates (Table 1).

Reducing sugars: There was a significant increase in reducing sugars of sweet orange fruits with a delay of harvesting. Reducing sugars increased from the minimum of 2.76, in fruit harvested on November 15th to the maximum of 11.19% in fruits harvested on February 15th that was statistically at par with January 30th (10.27%). The mean reducing sugars increased significantly during storage from the 6.62 in fresh fruits to 8.12% in fruits stored for 30 days. The interaction of harvesting dates and storage also significantly affected the reducing sugars content of sweet orange fruit. The reducing sugars content of sweet orange fruit increased significantly with 30 days storage. However, at each harvesting date, the increase in reducing sugars content was not significant (Table 2).

Non-reducing sugars: The difference in non-reducing sugars was not significantly different in fruits harvested from November 15th (4.98) to January 30th (4.71%) but declined significantly to the minimum of 4.41% in fruits harvested on February 15th. The storage of sweet orange fruit at room temperature for 30 days as well as the interaction of harvesting dates and storage had no significant effect on non-reducing sugars content of sweet orange fruits (Table 3).

Ascorbic acid content (mg/100ml): The ascorbic acid content of the fruit decreased significantly with delaying harvesting date or one-month storage at room temperature. The mean ascorbic acid content of the fruit harvested on November 15th was 41.03 mg/100ml harvest, which increased to the maximum of 56.40 mg/100ml for January 15th harvest but, thereafter, declined to 48.09 and 40.90 mg/100ml in fruits harvested on January 30th and February 15th respectively. The storage of sweet orange fruits at room temperature for 30 days also resulted in significant decreased in mean ascorbic acid content from 48.30 in fresh fruits to 41.15 mg/100ml (Table 3). The impact of harvesting date and storage period interaction was also significant. Whereas, the ascorbic acid increased from 54.59 to 57.23, from 60.19 to 62.70 and 66.30 to 67.27 mg/100ml during storage in fruits harvested on November 15th, November 30th, and December 15th, but it declined significantly in fruit harvested later than December 15th (Table 3).

Juice content (%): The juice content steadily increased with advancement in harvesting season but then declined.

The initial juice content of fruits harvested on November 15th (37.90%) increased to the maximum of 53.03% for January 15th harvest but then declined to 44.21 and 35.99% in fruits harvested on December 30th and January 15th. Storage also resulted in significant decrease in juice content of the fruits from 48.30 in fresh fruits to 41.15% in fruits stored for 30 days for 30 at room temperature (Table 1). The harvesting date and storage interaction revealed significantly higher juice content in fresh fruits (S-0) that decreased during 30 days storage at room temperature. Thus, the juice content was lower in fruit stored for 30 days at room temperature (S-30) at all the corresponding harvesting dates (Table 3).

Weight loss (%): The percent weight loss in fruits harvested at different dates and stored for one month at room temperature was the maximum weight loss (7.27%) in fruits harvested on November 15th, which decreased non-significantly to 7.14%, with harvesting delayed to November 30th. The weight loss in fruit harvested on December 15th was 5.03%, remained non-significant with later (December 15th to February 15th) harvesting dates (Table 3).

Oleocellosis incidence (%): The incidence of oleocellosis was not observed in fresh fruits irrespective of the harvesting date (Data not shown), but its symptoms appeared during 30 days storage at room temperature. The oleocellosis incidence was 3.33% in fruits harvested on November 15th that increased significantly to 20.00, 26.67 and 30% when harvesting was delayed to January 15th, January 30th, and February 15th, accordingly (Table 3).

Table 1. The influence of harvesting time and 30 days storage at room temperature on TSS and acidity of the sweet orange fruit.

Harvesting Time	TSS (%)			Acidity		
	S-0	S-30	Means	S-0	S-30	Means
15-November	7.80	8.97	8.38 d	1.72	1.07	1.39 a
30-November	9.90	10.73	10.32 c	1.44	0.95	1.20 b
15-Decemebr	10.60	11.50	11.05 c	1.28	0.81	1.04 c
30-December	11.73	12.63	12.18 bc	1.15	0.78	0.97 c
15-January	11.83	12.97	12.40 b	1.01	0.68	0.85 d
30-January	13.23	14.07	13.65 a	0.89	0.61	0.75 e
15-February	13.50	14.80	14.15 a	0.68	0.35	0.51 f
Means	11.23 b	12.24 a		1.17 a	0.75 b	0.065

Means in column in the stated category followed by the same letter are not significant at $p \leq 0.05$. Interactions with no letters allocation are not significant at $p \leq 0.05$.

Table 2. Changes in TSS/Acid ratio and reducing sugars of the sweet orange fruit with harvesting time at 0 and 30 days storage at room temperature

Harvesting Time	TSS/Acid Ratio			Reducing Sugars		
	S-0	S-30	Means	S-0	S-30	Means
15-November	4.56 d	8.45 d	6.51 e	3.32c	2.76 dc	2.76 c
30-November	6.86 d	11.31cd	9.09 d	5.55 c	4.94 c	4.94 bc
15-December	8.31 d	14.26 cd	11.28 cd	6.67 bc	6.17 bc	6.17 b
30-December	10.21cd	16.20 c	13.20 c	8.71 b	7.82 bc	7.82 b
15-January	11.68 cd	19.18 bc	15.43 bc	9.22 ab	8.43 bc	8.43 ab
30-January	14.91c	22.97 b	18.94 b	11.06 ab	10.27 ab	10.27 ab
15-February	20.09 b	43.13 a	31.61 a	12.32 a	11.19 ab	11.19 a
Means	10.95 b	19.36 a		6.62 b	8.12 a	

Means in column in the stated category followed by the same letter are not significant at $p \leq 0.05$. Interactions with no letters allocation are not significant at $p \leq 0.05$.

Table 3. The influence of harvesting time on non- reducing sugars and ascorbic acid content of the sweet orange fruit at harvest and after 30 days storage at room temperature

Harvesting Time	Non-reducing Sugars			Ascorbic Acid (mg/100ml)		
	S-0	S-30	Means	S-0	S-30	Mean
15-November	5.00	4.97	4.98 a	54.59 d	57.23 d	41.03 d
30-November	5.00	5.00	5.00 a	60.19 cd	62.70 c	45.43 c
15-December	5.22	4.79	5.01 a	66.30 b	67.27 b	50.53 b
30-December	4.95	4.35	4.65 a	73.25 a	57.50 d	55.73 a
15-January	4.86	4.90	4.88 ab	76.21 a	57.77 d	56.40 a
30-January	4.68	4.75	4.71 ab	66.23 b	48.40 e	48.09 b
15-February	4.66	4.15	4.41 b	58.37d	36.93 f	40.90
Means	4.91	4.70		65.02 a	55.40 b	

Means in column in the stated category followed by the same letter are not significant at $p \leq 0.05$. Interactions with no letters allocation are not significant at $p \leq 0.05$.

Table 4. The influence of harvesting time and storage on juice content (%), weight loss (%) ascorbic acid and oleocellosis incidence of the sweet orange fruit after 30- days storage at room temperature

Harvesting Time	Juice Content (%)			Weight Loss (%)	Oleocellosis (%)
	S-0	S-30	Means	S-30	S-30
15-November	41.03 cd	34.77 e	37.90 d	7.27 a	3.33 d
30-November	45.43 c	37.59 de	41.51 cd	7.14 ab	6.67 cd
15-December	50.53 b	45.19	47.86 b	5.03 b	11.67 c
30-December	55.73 a	49.38 bc	52.56 a	4.17 b	16.67 bc
15-January	56.40 a	49.70 bc	53.05 a	5.01 b	20.00 b
30-January	48.09 bc	40.33 d	44.21 c	4.89 b	26.67 a
15-February	40.90 c	31.07 e	35.99 e	5.91 ab	30.00 a
Means	48.30 a	41.15 b			

Means in column in the stated category followed by the same letter are not significant at $p \leq 0.05$. Interactions with no letters allocation are not significant at $p \leq 0.05$.

DISCUSSION

The harvesting dates as well as storage for 30 days at room temperature, significantly affected the quality and storage performance of sweet orange fruit. The Total soluble solids increased by 40.78% during the harvesting season and 8.24% during 30 days storage (Table 1). The TSS is an important parameter of citrus fruits quality (Peter *et al*., 1978). The initial increase in TSS with a delay in harvesting may be due to increased conversion of sucrose to monomeric sugars (Song *et al*., 1997) and subsequent accumulation of free sugars (Rab *et al*., 2010). The increase at later stages of harvest or during storage could be due to cell wall hydrolysis that increases the sugar content of the juice (Tariq *et al*., 2001). Since, the TSS percentage depends on total dissolved solids and moisture content of the fruit, the increase in TSS during storage might, in part, be due to decreased moisture content of the fruit. By contrast, the acidity of sweet orange fruit decreased by 63.11% with delaying the harvesting to Feb 15th and by 35.90% during storage (Mahajan *et al*., 2010). The acidity of citrus fruit is due to various organic acids e.g. citric acid, malic acid, benzoic acid, tartaric acid and oxalic acid (Albertini *et al*., 2006), that are consumed during the respiration (Ito, *et al*., 1998) and, thus, decrease as the fruit advances in maturation and during storage (Rapisarda *et al*., 2001; Prasanna *et al*., 2007). Since, the TSS increased and acidity decreased with a delay in harvesting and during storage, both conditions resulted in increased TSS/Acid ratio (Tariq *et al*., 2001, Mahajan *et al*., 2010).

The reducing sugars content of the sweet orange fruit increased by 75.34% during the harvesting season and 22.66% during storage. The reducing sugars, generally, increase with maturation (Ladaniya, 2008). The increased in reducing sugars during one-month storage can be attributed to moisture loss (Jan *et al*., 2012) and hydrolysis of starch (Prasanna *et al*., 2007) and other complex carbohydrates (Ladaniya, 2008). By contrast, the non-reducing sugars declined gradually with delaying harvesting and the difference across harvesting dates was not significant between November 15th and January 30th but significantly lower non-reducing sugars were recorded in fruit harvested on Feb 15th (Table 1). It indicates that the non-reducing sugars are relatively stable during the harvesting season and storage for one month. The pool of free sugars depends on hydrolysis of sucrose (Prasanna *et al*., 2007) and activities cell wall-

hydrolyzing enzymes (Echeverria *et al*., 1989). Thus, the non-reducing sugars decreased slowly with maturation or storage.

The ascorbic acid content increased by 11.08% with delaying harvesting to January 15th but, thereafter, declined by 28.87% with harvesting on February 15th. Similarly, a significant decline (14.80%) in ascorbic acid was recorded during one-month storage at room temperature. The ascorbic acid is an important constituent of citrus and other fruits (Gupta *et al*., 2000) and is rapidly lost during storage (Kaul and Saini, 2000). Thus, the citrus fruits should be harvested at optimum maturity (December 15th to January 15th) because both early or late harvested fruits have low ascorbic acid and, thus, poor quality.

The juice content of the fruit depends on the moisture content of the fruit. The juice content increased with delaying harvesting to January 15th but then declined. It also decreased during storage (Table 3). The juice content was the maximum on January 15th, indicating that January 15th may offer the maximum delay in harvesting sweet orange fruits and further delay may cause a decrease in juice content (Olivier *et al*., 2004). Moisture loss and subsequent decrease in juice content, during storage, is common in different fruits (Akram *et al*., 2001; Al-Obeed and Horhash, 2006). The loss of moisture may be the major reason for decreased juice content in sweet orange fruit during storage. Similarly, delaying harvesting may decrease the moisture uptake by the fruit that decreasing the juice content (Olivier *et al*., 2004).

The weight loss was the least in fruits harvested on December 15th but increased with later harvests (Table 4). The weight loss is due to moisture loss (Jan *et al*., 2012.) that may promote physiological dysfunctions in citrus (Porat, 2004). Natural waxes are developed on fruits to retard the loss of water (Sala *et al*., 1992). The greater weight loss, initially, followed by a decline indicates that natural waxy layer is fully developed by December 15th, that might be weakened with an extended delay in harvesting beyond e.g. January 1st (Erkan *et al*., 2005).

Oleocellosis is a physiological disorder of citrus fruit, caused by rind oils released from oil glands located in the rind (Knight *et al*., 2001). The oil glands are formed by the time the fruit reaches the yellow mature stage (Knight *et al*., 2001). Thus, it is likely to observe comparatively low oleocellosis at early stages of harvesting. Oleocellosis may be caused by abiotic stresses (Whiteside *et al*., 1988), loss of membrane integrity and cell wall hydrolysis (Echeverria *et al*., 1989) during senescence. Thus, the increased oleocellosis incidence may be due to increased polyphenol oxidase (PPO) and peroxidase activities triggered by senescence with delaying harvesting beyond a critical optimum time (Wild, 1998).

Conclusion: The TSS, fruit juice pH, reducing sugars and TSS/Acid ratio increased with delaying the harvesting of sweet orange fruit. Contrastingly, the juice content and ascorbic acid content increased reached a climax and then declined with a delay in harvesting, while the acidity continued to decline through out the harvesting season. On the basis of physo-chemical changes in sweet orange fruit, December 15th to January 15th may be regarded as the optimum time of harvesting the fruits. Storage of sweet orange for one-month at room temperature resulted in significant decline in various quality attributes. Thus, low temperature storage may be adopted for prolong storage of sweet orange fruit.

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