Journal of Agricultural and Marine Sciences 2021, 26(1): 13–20
DOI: 10.24200/jams.vol26iss1pp13-20
Reveived 16 Nov 2020
Accepted 22 Nov 2020

RESEARCH PAPER

Effect of Storage Conditions on Postharvest Quality of Tomatoes: A Case Study at Market-Level

Mai Al-Dairi, Pankaj B. Pathare*, Adil Al-Mahdouri

تأثير ظروف التخزين على جودة الطماطم بعد الحصاد: دراسة حالة على مستوى السوق

مي الدايري، بانكاج باثير*، عادل المحذوري

ABSTRACT. Postharvest loss is one of the main obstacles for ensuring food security in Oman as it leads towards reduced fresh produce quantity, quality and market value. The aim of this study was to determine the postharvest losses due to quality reduction in fresh produce of tomato during storage at market level in Oman. This paper consisted of two separate studies. Firstly, a semi-structure survey was conducted to collect the data from the market vendors. Secondly, fresh tomatoes were also purchased from the market and were stored in the laboratory at 10°C and 22°C for 12 days. All data were analyzed using SPSS statistical software. The results of the survey showed that 35% of respondents suggested that the color and texture are the most important quality attributes attracted by the consumers. Two days period was the best duration to store fresh produce in the current market. About 55% of the respondents mentioned that the nature of the produce was the most important factor causing postharvest losses along the supply chain. The results of the experiments showed a significant ($p<0.05$) changes of color attributes such as lightness (L*), redness or greenness (a*), total color change (ΔE), weight loss and firmness during 12 days at both temperature conditions. However, no significant impact of both factors on yellowness or blueness (b*), chroma, hue and total soluble solid (TSS) values was observed. This study indicated high changes in weight loss, lightness, redness, total color change and firmness in tomato stored at 22°C. The lower was the lightness (4.96) and firmness (11.18 N) and the greater was the redness (12.22) and weight loss (16.6%), caused the greater the rejection by the customers of the tomato at market level. Accordingly, storage temperature played a critical role on the improvement and development of tomato and any perishable fresh produce along the supply chain.

KEYWORDS: Color, market, postharvest losses, quality, texture, tomato

المستخلص:تعتبر خسارة ما بعد الحصاد إحدى العقبات الرئيسية أمام ضمان الأمن الغذائي في سلطنة عمان لأنها تؤدي إلى انخفاض كمية المنتجات الطازجة وجودتها وقيمتها السوقية. كان الهدف من هذه الدراسة هو تحديد خسائر ما بعد الحصاد بسبب انخفاض جودة المنتجات الطازجة من الطماطم أثناء التخزين على مستوى السوق في عمان. تتألف هذه الورقة من دراستين منفصلتين. اشتملت الأولى على إجراء مسح ميداني شبه هيكلي لجمع البيانات من بائعي السوق. واشتملت الدراسة الثانية على جمع البيانات المخبرية على نوع من الطماطم الطازجة المحلية، حيث تم تخزينها في المختبر عند ١٠ درجة مئوية و ٢٢ درجة مئوية لمدة ١٢ يومًا. تم تحليل جميع البيانات باستخدام برنامج الحزمة الإحصائية للعلوم الإجتماعية (SPSS). وأظهرت نتائج المسح الميداني أن ٣٥٪ من المستجيبين أشاروا إلى أن اللون والملمس هما أهم سمات الجودة التي تجذب المستهلكين. وقد كانت فترة التخزين المفضلة للمنتجات الطازجة في السوق هي يومان. ذكر حوالي ٥٥٪ من المستجيبين أن طبيعة المنتج كانت العامل الأكثر أهمية في حدوث خسائر ما بعد الحصاد على طول سلسلة التوريد. أظهرت نتائج التجارب تغيرًا مؤثراً (p>٠,٠٥) في سمات اللون مثل الخفة (L*)، الإحمرار أو الإخضرار (a*)، تغير اللون الكلي (ΔE)، فقدان الوزن و الصلابة خلال ١٢ يوم في جميع درجات حرارة التخزين. ومع ذلك ، لم يلاحظ أي تأثير كبير لكلا العاملين على الإصفرار أو الإزرقاق (b*)، صفاء اللون، تشبع اللون وقيم المواد الصلبة الذائبة الكلية (TSS). أشارت هذه الدراسة إلى حدوث تغيرات كبيرة في فقدان الوزن والخفة، والاحمرار، وتغير اللون الكلي وثبات الطماطم المخزنة عند ٢٢ درجة مئوية. كلما قلت الخفة (٤,٩٦) و الصلابة (١١,١٨ نيوتن) و أزداد الاحمرار (١٢,٢٢) وفقدان الوزن (١٦,٦٪) ،حيث زاد رفض الزبائن للطماطم على مستوى السوق. وفقًا لذلك ، تلعب درجة حرارة التخزين دورًا مهمًا في تحسين الطماطم وأي منتجات طازجة قابلة للتلف على طول سلسلة التوريد.

الكلمات المفتاحية: اللون، السوق، خسائر ما بعد الحصاد، الجودة، الصلابة، الطماطم.

Introduction

Globally, One-third of the total fresh food produced is lost during food supply chain before reaching to the consumers (Gautam et al., 2017; Munhuewyi, 2012). Despite all of the benefits derived from any fresh produce, postharvest losses make them unprofitable and useless (Sarma, 2018). Postharvest losses of fresh produce can be encountered during harvesting, storing, handling, packaging, transporting and marketing operations (Sibomana et al., 2016). The nature of fresh produce is one of the main causes of postharvest losses along the whole value chain as they are highly perishable (Parfitt et al., 2010), respire and live even after harvesting (Kader and Rolle, 2004). Improper harvesting method and equipment, inadequate storage and packaging facilities are the factors contributing to the postharvest losses in fresh produce (Chebanga et al.,

Pankaj B. Pathare* (✉) pankaj@squ.edu.om; pbpathare@gmail.com, Department of Soils, Water and Agricultural Engineering, College of Agricultural & Marine Sciences, Sultan Qaboos University, Oman

2018). Cultural practices (Semida et al., 2019), environmental factors (Singh et al., 2014), poor transportation services (Caixeta-Filho and Péra, 2018) and improper market facilities are other important causes of the postharvest losses (Sharma and Singh, 2011). At market level, the incidence of fresh produce quality losses and deterioration can occur due to poor management (Sharma and Singh, 2011) and performance of traders, processors, producers, retailers and other labors in the marketing system. Absence of technical awareness and knowledge on postharvest losses (Sarma, 2018), limited marketing strategies and information (Rolle, 2006), and lack of efficient communication between producers and buyers are other factors leading to postharvest damage on fresh produce at market level (Arah et al., 2015). Moreover, losses during marketing can occur due to non-existence of adequate postharvest infrastructure, technologies (Aujla et al., 2011) and sanitation, packaging, loading, unloading and storage (Kader and Rolle, 2004). Additionally, inappropriate storage facilities can cause high quantitative losses compared to the qualitative losses in fresh produce (Ayomide et al., 2019). Subsequently, negative impacts on several parameters such us nutritional status, consumer acceptance and income are affected (Sarma, 2018; Seyoum and Woldetsadik, 2004). Postharvest losses in fresh produce at market level in Oman are estimated between 3-19 % (Opara, 2003).

Tomato *(Solanum lycopersicum)* is one of the major and popular fresh produce in the world (Costa and Heuvelink, 2018; Guan et al., 2018; Sarma and Ali, 2019). Statistics display that the production of tomatoes in Sultanate of Oman ranked first among other vegetables like onions *(Allium cepa)* (Ona, 2017), cucumbers *(Cucumis sativus)* and potatoes *(Solanum tuberosum)* which reach up to 199,132 tons (886 ha cultivated area) in 2018 after it was 39,586 tons (2532 ha cultivated area) in 2000 **(Figure 1)** (FAOSTAT, 2020). It is a vital source of nutrients (Ayandiji et al., 2011; Erba et al., 2013), minerals (Sarma, 2018; Sibomana et al., 2015) with various benefits to human body (Arab and Steck, 2000; Bhowmik et al., 2012) like vitamins (A, B and C), amino acids, calcium, copper, sodium (Mandal et al., 2018), antioxidants, lycopene and carotenoids that are responsible for reducing the incidence of some chronic and vascular diseases (Arah et al., 2015; Tadesse et al., 2015). Tomato production can be a source of income (Addo et al., 2015) in most of the developing countries (Arah et al., 2015; Sarma, 2018). The quality of tomato can be recognized predominantly by flavor, texture, color and nutritional value (Kader and Rolle, 2004). Due to the current postharvest problems, losses in tomato could reach to 50% worldwide (Addo et al., 2015).

During marketing, temperature is the main factor that impacts tomato quality as it directly influences the rate of losses. Proper control of temperature condition is the most suitable way to retain the quality of fresh produce during the whole supply chain (Arah et al., 2015). Basically, temperature can influence tomato color, firmness and flavor (Tadesse et al., 2015). Storage below 10°C cause poor color development of tomato (Khairi et al., 2015), however, storage at 20°C and 30°C reduce tomato firmness and weight loss (Tadesse et al., 2015). Storing tomato at low temperature can decrease the metabolic activity of tomato. High increase in temperature can elevate transpiration rate, respiration rate and ethylene production rate. However, chilling temperature can reduce tomato quality due to the incidence of chilling injuries (Atanda et al., 2011). Most of the studies reported that storage temperature around 10°C is the most appropriate storage temperature condition for maintaining the quality (Cantwell et al., 2009; Khairi et al., 2015; Ponce-Valadez et al., 2016) and delaying softening of tomato (Ayomide et al., 2019). Relative humidity (RH) is another important factor during storage of tomato (Ramaswamy, 2014), which can influence its texture and weight loss (El-Ramady et al., 2015). The optimal rela-

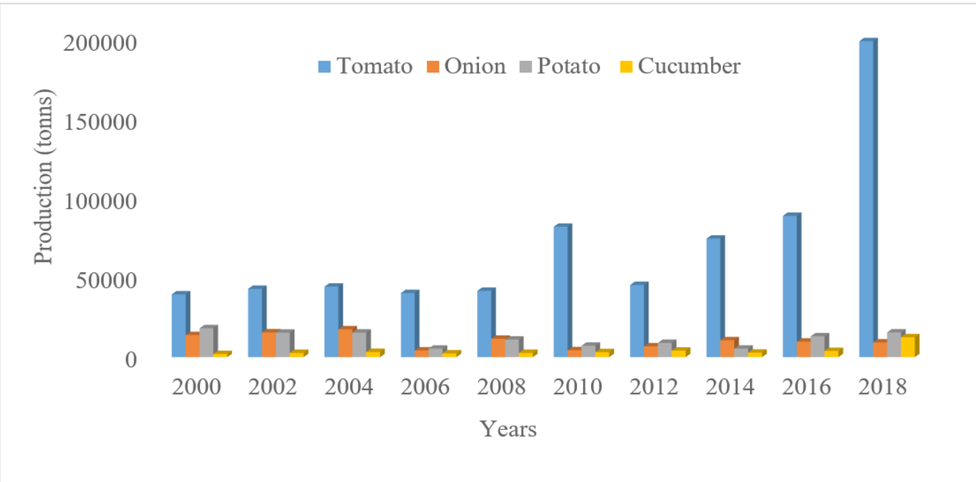

Figure 1. Tomato annual production among other vegetables in Oman. (FAOSTAT, 2020)

tive humidity values for green and firm ripe tomato are 85-95% and 90-95%, respectively (Suslow and Cantwell, 2009). Application of proper temperature and humidity management practices at market level plays a significant role to reduce postharvest food losses at market level. Therefore, the aim of this study was to determine vendor's knowledge on postharvest practices and their related losses at market level and to correlate them with local tomato produce quality losses during storage using laboratory experiments.

Materials and Methods

Market survey

The study was conducted in the Central Market of Fruits and Vegetables, Muscat, Sultanate of Oman. This market was selected due to its large-scale of sales and availability of different fresh produces compared to other markets in Muscat. A semi-structure survey was designed as a tool for data collection by conducting short interviews with the 20 vendors. The questionnaire consists of formal questions and it was pre-reviewed and tested to provide the desired wide-range of responses from the vendors. The purpose of this survey was to determine the vendor's knowledge about postharvest quality and losses in fresh produce.

Laboratory Experiment

About 32 kg of tomatoes were purchased from the market and delivered to Postharvest Laboratory, College of Agriculture and Marine Sciences at Sultan Qaboos University. Tomatoes with no bruising signs, uniform color and shape were selected to be tested for some quality analysis for total period of 12 days at two days intervals. The tomatoes were stored at 10°C with 85±5% RH and 22°C with 45±5% RH (simulate market storage temperature). Each storage condition consisted of seven groups of tomato samples for storage time (temporal) assessment. Each group included five replicates. Temperature/RH prop (Model: TES 13604, TES Electrical Corp., Taiwan) was used to measure temperature and relative humidity.

Tomato Quality Measurements

Electric weight balance (Model: GX.4000, Japan) was used to weigh each tomato group. The percentage of weight loss in tomato was calculated using the equation (Eq. 1) applied by Moneruzzaman et al. (2009):

Color value of each tomato sample was measured using a colorimeter (Model: TES 135A, TES Electrical Corp., Taiwan) which expresses the color values of L* (Lightness), a*(redness, greenness) and b*(yellowness, blueness). The devise was calibrated using a white standard tile (L*=93.90, a*= 3.13, b*= 3.20). Total color differences, (Eq. 2), chroma (Eq.3) and hue angle in (Eq.4) (Pathare et al., 2013) were respectively calculated to show color changes (Bal et al., 2011) during 12 days at 10°C and 22°C.

$$\Delta E^* = \sqrt{\Delta a*^2 + \Delta b*^2 + \Delta L*^2} \qquad \text{(Eq.2)}$$

$$C = \sqrt{a*^2 + b*^2} \qquad \text{(Eq.3)}$$

$$H = \tan^{-1}\left(\frac{b*}{a*}\right) \qquad \text{(Eq.4)}$$

Hand penetrometer (Model: FT 327, EFFEGI, Italy) was used to determine each tomato firmness by using the standard method of OECD (2018) at two days interval. Kleinhenz and Bumgarner (2012) procedure was used to identify total soluble solid by using hand-held refractometer calibrated in ° Brix at 22°C.

Data Analysis

In order to determine, the effect of storage time and temperature on tomato quality parameters, analysis of variance (ANOVA) was performed by using SPSS 20.0 (International Business Machine Crop., USA) software.

Results and Discussions

Survey Analyses

The analysis of the semi-structure survey of the vendors showed that 75% of the participants were (from the age of 31-40) and this age is almost appropriate for people to sell fruits/vegetables products especially for those who are searching for a job. This is an active age of the community who can establish an excellent marketing network. Almost, 50% of the vendors were school graduate, this helped to facilitate good and rapid understanding of the respondents to the survey. This also pays the attention for the vendors to know the most common fresh produce consumed by people and getting more knowledge about postharvest and its related losses. The majority of the respondents were non-Omani (90%) because Omani farms owners let their labors (from other nationalities) to sell their fruits/vegetables on the market.

$$\text{Weight loss (\%)} = \frac{Initial\ weight\ of\ tomato - final\ weight\ of\ tomato}{Initial\ weight\ of\ tomato} \times 100 \qquad \text{(Eq.1)}$$

Vegetables Vendor's Observations on Postharvest Quality, Losses and Practices

Four of these 20 vendors were from closed markets (retail shops), but the other 16 were from an open markets (retail shade). The temperature of the closed markets was between 18ºC to 23ºC. On the other hand, the temperature of the open markets was 32.7ºC in the dates of conducting this survey. For consumer preference on a specific product, color and texture were having the highest attention by the consumers for a specific fresh produce as suggested by 35% of the vendors compared with flavor and money. Generally, color is the most significant quality preference of any fresh produce (Tadesse et al., 2015) as well as texture (Batu, 2004) and the availability of undesirable color and texture in any fresh produce can consider as a serious problem encountered during the supply chain. About 60% of the vendors are more likely to store their products for two days. However, others prefer to store them for three and five days. Vendors are storing their products within time that is not exceeding these specific periods due to the lack of ventilated storage utilities (Negasi et al., 2013). High temperature (Tilahun, 2010) was also one of the reasons that make vendors storing their products for not more than 5 days as it was characterized to reduce the quality of fresh produce as it can reach to 45°C in Oman. Some of the vendors were not storing their products as they were selling the whole amount in the same day. There were several factors causing postharvest losses along the supply chain as stated by the vendors. For example, 55% of the vendors suggested that nature of the product was the most important barrier causing fresh produce losses as they are highly perishable (Nath et al., 2018), sensitive (Parfitt et al., 2010) and required careful storage, transportation and handling facilities (Kader, 2013) before they reach to the market. This is followed by marketing problems, improper harvesting and other causes due to infections with 30%, 10% and 5% respectively. Summary of vendor's respondents on postharvest quality, losses and practices is shown in **Table 1**.

Table 1. Summary of vegetables vendor's responses on questionnaire (%)

Consumer preference on a specific product		Days of storing the products		The main barrier of postharvest losses	
Texture	35%	2	60%	Infection	5%
Color	35%	3	20%	Improper harvesting	10%
Flavor	20%	5	20%	Nature of the product	55%
Money	10%	7	0%	Marketing problems	30%

Tomato Quality Analysis: Experimental Results

Weight Loss: The results showed a significant effect ($p<0.05$) of storage days and temperature on tomato weight loss. In the current study, high weight loss was recorded with 16.6% in tomato stored at 22°C compared to 3.18% losses at 10°C for 12 days storage period. Ambient storage condition showed the ability to increase weight loss of tomato due to high water dehydration (Fagundes et al., 2015), transpiration (Žnidarčič et al., 2010) and respiration rate (Žnidarčič and Požrl, 2006). Furthermore, Ayomide et al. (2019) stated that low relative humidity (45±5%) at 22°C was responsible for the reduction of water content in fresh produce leading to weight loss. Similar findings were recorded by Pinheiro et al. (2013) on the stored fresh tomato. These results were in agreement with different studies in which a progressive increase was also found in weight loss during storage time at 8°C, 12°C, 20°C for 20 days (Park et al., 2018), at 34°C for 10 days (Pila et al., 2010) and at room temperature, 12°C and 5°C for two weeks (Javanmardi and Kubota, 2006). These findings were also in accordance with that of Abiso et al. (2015) who reported high percentage of weight loss in tomato with different maturity stages after 10 days storage at room temperature that could be mainly due to respiration and transpiration with a minimum loss in tomato stored at cold temperature. Overall, low weight loss in tomato at low storage temperature can be resulted from the ability of cold stored tomato to affect vapor pressure and increase water retention.

Color Measurements: Color measurements of this study showed that L* value was significantly ($p<0.05$) affected by storage time and temperature (Table 2). L* value decreased from 14.13±1.68 to reach 11.76±0.63 on day 0 and 12, respectively, at 10°C storage. However, the reduction was three times higher on tomato stored at ambient storage condition as it became 4.96±0.55 in the last day of storage. At 12 day of storage, study showed 64.89% reduction on lightness on tomato stored at 22°C compared to only 16.77% at 10°C. This attributed to tomato darkening resulted from the synthesis of carotenoids (Yahia et al., 2007).

Similarly, storage days and temperature showed a statistical difference ($p<0.05$) with a* value as tomato color altered from bright green (-) to dark red (+) color (Table 2). Storage at 22°C decreased a* values of tomato from -2.19±0.83 on day 0 to 8.02±1.59 and 12.22±0.98 on day 6 and 12 respectively. In contrast, a* value was increased slowly to reach 1.53±0.51and 5.68±0.72 on day 6 and 12 respectively after it was 2.19±0.83 on day 0 at 10°C. The a* value increment at 22°C occurred due to ethylene biosynthesis (Hatami et al., 2012), synthesis of lycopene and degradation of chlorophyll (López and Gómez, 2004) that allowed for the intensification of red color (Weingerl and Unuk, 2015). This can also advocate what has been recorded by Munhuewyi (2012), where tomato kept at ambient condition can provide an ideal environment for tomato ripening that is categorized with increasing redness compared to cold storage condition. Messina et al. (2012) found the same behavior in tomato stored for 7 and 14 days. Regarding storage at cold temperature, Guillén et al. (2006) reported similar results on different variety of tomato cultivars at 10°C for 28 days.

Table 2 presents b* value (mean±sd) at 10°C and 22°C for 12 days storage conditions. There was no significant (p>0.05) change on b* value of fresh tomato at both storage conditions during the whole period of storage. Same results of non-significance on b* value were recorded by López and Gómez (2004) during storage. Total color change ΔE during storage is consider as a result of changes in L*, a* and b* values. Storage days showed a significant impact (p<0.05) on color differences ΔE value of tomato stored at 10°C and 22°C. Overall color differences (ΔE) was mostly higher for ambient stored tomato (20.05±4.56) compared to optimum temperature (7.74±4.07) after 12 days of storage (Table 2). Moreover, no changes (p>0.05) occurred in chroma and hue values during 12 days at both storage temperature conditions (Table 2). However, Tadesse et al. (2015) showed a significant differences in chroma and hue stored for 16 days at 4, 20 and 30°C.

Firmness: The data showed that firmness of stored tomato was significantly (P<0.05) affected by storage time and temperature. In the day last of storage, the highest value (49.64 N) was reported in tomato stored at 10°C while the storage at 22°C reported the lowest value (11.18 N) **(Table 2)**. Moisture losses (Lana et al., 2005), degradation of polysaccharide (Teka, 2013) and degradation of tomato cell wall were due to enzymes activation could be the main reason for decreasing firmness during storage (Hatami et al., 2012). Slow increase of firmness was shown on tomato firmness stored at 10°C due to the increment of relative humidity, which had the ability to slow softening and enhance/retain the firm status of tomato during storage (Ayomide et al., 2019). The findings of firmness reduction were in agreement with Tigist et al. (2013) who stated storage at 22°C reduced the firmness of tomatoes.

Total Soluble Solids (TSS): Tomato total soluble solid (TSS) ranged from (4.04 to 4.48) °Brix in this study (Table 2). The highest value (4.48 °Brix) was recorded on day 10 in tomato stored at 10°C where the lowest value (4.04 °Brix) was shown on day 6 and 10 in tomato stored at 22°C. Therefore, the study revealed no statistical differences (p>0.05) of storage days and temperature on tomato total soluble solid (TSS). Similarly, Wills and Ku (2002) experienced the same finding of non-significance after storing tomato for 10 days at ambient room temperature.

Table 2. Quality parameters data of tomato at two storage conditions during12 days of storage.

Quality parameter	Storage temperature	Storage days						
		0	2	4	6	8	10	12
L*	10°C	14.13±1.68	12.39±1.56	13.25±1.07	13.26±1.13	13.36±1.56	11.87±1.75	11.76±0.63
	22°C	14.13±1.68	12.37±0.55	9.09±0.72	7.81±0.63	6.34±0.71	5.95±0.75	4.96±0.55
a*	10°C	-2.19±0.83	0.45±1.26	1.1±0.15	1.53±0.51	2.7±0.49	3.0±0.63	5.68±0.72
	22°C	-2.19±0.83	2.64±2.58	5.88±0.63	8.02±1.59	9.15±1.33	10.13±0.73	12.22±0.98
b*	10°C	54.36±4.42	52.40±1.23	54.02±3.36	56.95±4.95	54.52±1.83	54.74±6.68	56.90±2.20
	22°C	54.36±4.42	49.22±2.56	44.80±2.68	50.96±1.01	41.72±5.25	41.99±3.10	46.35±6.28
ΔE	10°C	-	5.94±4.02	5.94±3.59	6.12±2.72	6.60±1.03	7.86±2.06	7.74±4.07
	22°C	-	8.42±2.45	13.98±5.33	18.70±10.98	19.14±5.44	19.81±5.65	20.05±4.56
Chroma	10°C	54.41±4.40	52.41±1.24	54.03±3.36	56.97±4.95	54.59±1.85	54.82±6.65	57.18±2.25
	22°C	54.41±4.40	49.34±2.53	45.19±2.60	51.60±0.90	42.74±5.05	43.20±2.99	47.94±6.23
Hue	10°C	-1.53±0.01	0.93±1.38	1.55±0.003	1.54±0.008	1.51±0.007	1.51±0.01	1.47±0.009
	22°C	-1.53±0.01	5.27±18.74	7.72±1.28	6.52±1.11	4.65±1.02	4.16±0.51	3.79±0.40
Firmness (N)	10°C	34.73±3.92	37.08±3.73	41.79±3.83	43.16±2.75	46.89±2.06	48.46±2.55	49.64±2.35
	22°C	34.73±3.92	32.18±5.30	27.27±6.77	21.78±1.45	20.01±1.08	12.16±1.57	11.18±1.08
TSS (%)	10°C	4.12±0.17	4.26±0.23	4.10±0.23	4.42±0.34	4.30±0.18	4.48±0.04	4.34±0.18
	22°C	4.12±0.17	4.08±0.08	4.32±0.44	4.04±0.05	4.16±0.08	4.04±0.05	4.12±0.17

Conclusion

Color and texture of fresh tomato were highly affected by time and storage temperature. This indicated the significance of these two parameters as they greatly affect consumer's acceptance in markets. This agreed what had been responded in the questionnaire as most of the vendors suggested that color and texture were the top consumer's preference for a specific food product. Similarly, weight loss, L*and a*, were influenced by storage days at 10°C and 22°C. Most of these quality parameters were almost retained at low temperature (10°C). No significant changes were observed for b*, chroma, hue and TSS values at both storage conditions for 12 days storage. This study indicated that storage temperature was one of the vital factors, which required high monitoring along postharvest supply chain and marketing.

Acknowledgement

The authors would like to thanks Sultan Qaboos University for funding this study through internal grant (IG/AGR/SWAE/19/03).

References

Abiso E, Satheesh N, Hailu A. (2015). Effect of storage methods and ripening stages on postharvest quality of tomato *(Lycopersicom Esculentum Mill)* cv. Chali. Annals. Food Science and Technology 6(1): 127-137.

Addo J, Osei M, Mochiah M, Bonsu K, Choi H, Kim J. (2015). Assessment of farmer level postharvest losses along the tomato value Chain in three agro-ecological zones of Ghana. International Journal 2(9): 2311-2476.

Arab L, Steck S. (2000). Lycopene and cardiovascular disease. The American Journal of Clinical Nutrition 71(6): 1691S-1695S.

ArahI, Kumah E, Anku E, Amaglo H. (2015). An overview of post-harvest losses in tomato production in Africa: Causes and possible prevention strategies. Journal of Biology, Agriculture and Healthcare 5(16): 78-88.

Atand S, Pessu P, Agoda S, Isong I, Ikotun I. (2011). The concepts and problems of post–harvest food losses in perishable crops. African Journal of Food Science 5(11): 603-613.

Aujla K, Shah N, Ishaq M, Fraooq A. (2011). Postharvest losses and marketing of grapes in Pakistan. Sarhad Journal of Agriculture 27(3): 485-490.

Ayandiji A, Adeniyi O, Omidiji D. (2011). Determinant postharvest losses among tomato farmers in imeko-afon local Government area of Ogun State, Nigeria. Global Journal of Science Frontier Research 11(5): 23-27.

Ayomide O, Ajayi O, Ajayi A. (2019). Advances in the development of a tomato postharvest storage system: Towards eradicating postharvest losses. Journal of Physics: Conference Series. IOP Publishing, p. 022-064.

Bal L, Kar A, Satya S, Naik S.N. (2011). Kinetics of colour change of bamboo shoot slices during microwave drying. International Journal of Food Science & Technology 46(4): 827-833.

Batu A. (2004). Determination of acceptable firmness and Colour Values of Tomatoes. Journal of food engineering. 61(3): 471-475.

Bhowmik D, Kumar K, Paswan S, Srivastava S. (2012). Tomato-A natural medicine and its health benefits. Journal of Pharmacognosy and Phytochemistry 1(1): 33-43.

Caixeta-Filho J, Péra T. (2018). Post-harvest losses during the transportation of grains from farms to aggregation points. International Journal of Logistics Economics and Globalisation 7(3): 209-247.

Cantwell M, Nie X, Hong G. (2009). Impact of storage conditions on grape tomato quality, 6th ISHS postharvest symposium, Antalya, Turkey.

Chebanga F, Mukumbi K, Moses M, Mtaita T. (2018). Postharvest losses to agricultural product traders in Mutare, Zimbabwe. Journal of Scientific Agriculture (2): 26-38.

Costa J, and Heuvelink E. 2018. The Global Tomato Industry. CAB International, Oxfordshire, UK.

El-Ramady H, domokos-szabolcsy E, Abdalla N, Taha H, Fári M. (2015). Postharvest Management of Fruits and Vegetables Storage, Sustainable Agriculture Reviews. Springer International Switzerland, p. 65-152.

Erba D, Casiraghi M, Ribas-Agustí A, Cáceres R, Marfà O, Castellari M. (2013). Nutritional value of tomatoes *(Solanum lycopersicum L.)* grown in greenhouse by different agronomic techniques. Journal of Food Composition and Analysis 31(2): 245-251.

Fagundes C, Moraes K, Pérez-Gago M, Palou L, Maraschin M, Monteiro A. (2015). Effect of active modified atmosphere and cold storage on the postharvest quality of cherry tomatoes. Postharvest Biology and Technology. 109: 73-81.

FAOSTAT. 2020. Food and Agriculture Organization Corporate Statistical Database. FAO, Rome, Italy.

Gautam S, Acedo A, Schreinemachers P, Subedi B. (2017). Volume and value of postharvest losses: The case of tomatoes in Nepal. British Food Journal 119(12): 2547-2558.

Guan Z, Biswas T, Wu F. (2018). The US Tomato Industry: An Overview of Production and Trade, EDIS.

Guillén F, Castillo S, Zapata P, Martínez-Romero D, Valero D, Serrano M. (2006). Efficacy of 1-MCP treatment in tomato fruit: 2. Effect of cultivar and ripening stage at harvest. Postharvest Biology and Technology 42(3): 235-242.

Hatami M, Kalantari S, Delshad M. (2012). Responses of different maturity stages of tomato fruit to different storage conditions, VII International Postharvest Symposium 1012. pp. 857-864.

Javanmardi J, Kubota C. (2006). Variation of lycopene, antioxidant activity, total soluble solids and weight loss of tomato during postharvest storage. Postharvest Biology and Technology. 41(2): 151-155.

Kader A. (2013). Postharvest technology of horticultural crops-An overview from farm to fork. Ethiopian Journal of Applied Science Technology 1: 1-8.

Kader A, Rolle R. (2004). The role of post-harvest management in assuring the quality and safety of horticultural produce (Vol.152). Food and Agriculture Organization, Rome, Italy.

Khairi A, Falah M, Suyantohadi A, Takahashi N, Nishina H. (2015). Effect of Storage Temperatures on Color of Tomato Fruit (Solanum lycopersicum Mill.) Cultivated under Moderate Water Stress Treatment. Agriculture and Agricultural Science Procedia. 3: 178-183.

Kleinhenz D, Bumgarner N. (2012). Using Brix as an indicator of vegetable quality: Instructions for measuring °Brix in cucumber, leafy greens, sweet corn, tomato, and watermelon. Agriculture and Natural Resources, The Ohio State University, Columbus, OH.

Lana M, Tijskens L, Van Kooten O. (2005). Effects of storage temperature and fruit ripening on firmness of fresh cut tomatoes. Postharvest Biology and Technology 35(1): 87-95.

López A, Gómez P. 2004. Comparison of color indexes for tomato ripening. Horticultura Brasileira 22 (3): 534-537.

Mandal D, Lalhmingchawii C, Hazarika T, Shukla A. (2018). Effect of chitosan, wax and particle film coating on shelf life and quality of tomato cv. Samrudhi at ambient storage. Research Journal of Agricultural Science 9: 111-16.

Messina V, Domínguez P, Sancho M, Walsöe N, Carrari F, Grigioni G. (2012). Tomato quality during short-term storage assessed by colour and electronic nose. International Journal of Electrochemistry 2012: 1-7.

Moneruzzaman K, Hossain A, Sani W, Saifuddin M, Alenazi M. (2009). Effect of harvesting and storage conditions on the post-harvest quality of tomato *(Lycopersicon Esculentum Mill)* Cv. Roma Vf. Australian Journal of Crop Science 3(2): 113.

Munhuewyi K. (2012). Postharvest losses and changes in quality of vegetables from retail to consumer: A case study of tomato, cabbage and carrot. Master thesis, Stellenbosch University, Stellenbosch.

Nath A, Meena L, Kumar V, Panwar A. 2018. Postharvest management of horticultural crops for doubling farmer's income. Journal of Pharmacognosy and Phytochemistry. 7(1): 2682-2690.

Negasi T, Nigussie D, Kebede W, Lemma D, Abuhay T. (2013). Characterization of soil nutrient management and post-harvest handling practices for onion production in the central rift valley region of Ethiopia. Agriculture, Forestry and Fisheries. 2(5): 184-95.

OECD. (2018). (Organization for Economic Co-operation and Development). Guidelines on Objective Tests to Determine Quality of Fruit and Vegetables, Dry and Dried Produce, https://www.oecd.org. Accessed date September 12, 2020

Ona. (2017). Oman Produced More than 1.77 Million Tonnes of Agricultural Commodities in 2015. Times of Oman, Muscat.

Opara L. (2003). Postharvest losses at the fresh produce retail Chain in the Sultanate of Oman, Australian-postharvest-horticulture-conference, Brisbane, Australia. p. 1-3.

Parfitt J, Barthel M, Macnaughton S. (2010). Food waste within food supply chains: Quantification and potential for change to 2050. Philosophical Transactions of the Royal Society B: Biological Sciences 365(1554): 3065-3081.

Park M, Sangwanangkul P, Baek D. (2018). Changes in carotenoid and chlorophyll content of black tomatoes *(Lycopersicone sculentum L.)* during storage at various temperatures. Saudi Journal of Biological Sciences 25(1): 57-65.

Pathare P, Opara U, Al-Said, F. (2013). Colour measurement and analysis in fresh and processed foods: A review. Food and Bioprocess Technology 6(1): 36-60.

Pila N, Gol N, Rao T. (2010). Effect of Postharvest treatments on physicochemical characteristics and shelf life of tomato *(Lycopersicon Esculentum Mill.)* fruits during storage. Agriculture and Environmental Science 9(5): 470-479.

Pinheiro J, Alegria C, Abreu M, Gonçalves E, Silva C. (2013). Kinetics of changes in the physical quality parameters of fresh tomato fruits (*Solanum lycopersicum*, cv.'Zinac') during storage. Journal of Food Engineering 114(3): 338-345.

Ponce-Valadez M, Escalona-Buendía H, Villa-Hernández J, de León-Sánchez F, Rivera-Cabrera F, Alia-Tejacal I, Pérez-Flores L. (2016). Effect of refrigerated storage (12.5 C) on tomato *(Solanum lycopersicum)* fruit flavor: A biochemical and sensory analysis. Postharvest Biology and Technology 111: 6-14.

Ramaswamy H. (2014). Post-harvest technologies of fruits & vegetables. DEStech Publications, Lancaster, US.

Rolle R. (2006). Improving postharvest management and marketing in the Asia-Pacific region: Issues and challenges. Postharvest Management of Fruit and Vegetables in the Asia-Pacific Region 1(1): 23-31.

Sarma P. (2018). Postharvest losses of tomato: A value chain context of Bangladesh. International Journal of Agricultural Education and Extension 4(1): 085-092.

Sarma P. Ali M. (2019). Value chain analysis of tomato: A case study in Jessore District of Bangladesh. International Journal of Science and Research 8(2): 924-932.

Semida W, Emara A, Barakat M. (2019). Improving quality attributes of tomato during cold storage by preharvest foliar application of calcium chloride and potassium thiosulfate. International Letters of Natural Sciences 76: 98-110.

Seyoum T, Woldetsadik K. (2004). Forced ventilation evaporative cooling: a case study on banana, papaya, orange, mandarin, and lemon. Tropical Agriculure 81: 1-6.

Sharma G., Singh S. (2011). Economic analysis of post-harvest losses in marketing of vegetables in Uttarakhand. Agricultural Economics Research Review 24(2). 309-315.

Sibomana S, Audain K. (2016). A review of postharvest handling and losses in the fresh tomato supply chain: A focus on sub-Saharan Africa. Food Security 8:389-404.

Sibomana C, Opiyo A, and Aguyoh J. (2015). Influence of soil moisture levels and packaging on postharvest qualities of tomato *(Solanum lycopersicum)*. African Journal of Agricultural Research 10(12): 1392-1400.

Singh V, Hedayetullah M, Zaman P, Meher J. (2014). Postharvest technology of fruits and vegetables: An overview. Journal of Postharvest Technology 2(2): 124-135.

Suslow T, Cantwell M. (2009). Tomato-recommendations for maintaining postharvest quality. Produce Facts. Postharvest Technology Research & Information Center, UC, Davis-CA.

Tadesse T, Ibrahim A, Abtew W. (2015). Degradation and formation of fruit color in tomato *(Solanum lycopersicum L.)* in response to storage temperature. American Journal of Food Technology 10(4): 147-157.

Tigist M, Workneh T, and Woldetsadik K. (2013). Effects of variety on the quality of tomato stored under ambient conditions. Journal of Food Science and Technology 50(3): 477-488.

Tilahun S. (2010). Feasibility and economic evaluation of low-cost evaporative cooling system in fruit and vegetables storage. African Journal of Food, Agriculture, Nutrition and Development 10(8): 2984-2997.

Weingerl V, Unuk T. (2015). Chemical and fruit skin colour markers for simple quality control of tomato fruits. Croatian Journal of Food Science and Technology 7(2): 76-85.

Wills R, Ku V. (2002). Use of 1-MCP to extend the time to ripen of green tomatoes and postharvest life of ripe tomatoes. Postharvest Biology and Technology 26(1): 85-90.

Yahia E, Soto-Zamora G, Brecht J, Gardea A. (2007). Postharvest hot air treatment effects on the antioxidant system in stored mature-green tomatoes. Postharvest Biology and Technology 44(2): 107-115.

Žnidarčič D, Ban D, Oplanić M, Karić L, Požrl T. (2010). Influence of postharvest temperatures on physicochemical quality of tomatoes *(Lycopersicon esculentum Mill)*. Journal of Food Agriculture & Environment 8(1): 21-25.

Žnidarčič D, Požrl T. (2006). Comparative study of quality changes in tomato cv.'Malike'(*Lycopersicon esculentum* Mill.) whilst stored at different temperatures. Acta Agriculturae Slovenica 87(2): 235-243.