Effect of ethanol vapor on ripening of tomato

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Abstract: Freshly harvested tomatoes were subjected to different ethanol vapor treatments at 4 mL kg^{-1}, 6 mL kg^{-1} and 8 mL kg^{-1} in closed bucket for 6, 9 and 12 h at ambient temperature (26.84ºC±3.0ºC) to investigate the effect of ethanol vapor on physico-chemical changes in summer variety tomato over storage period. Results revealed that ethanol vapor treatments significantly prolonged the postharvest life of tomato by inhibiting ripening process. At the end of storage period, ratio of ethanol to weight of tomato (6 mL kg^{-1}) for 12 h was found to be effective to maintain weight, firmness and attractive color attributes of tomatoes. On the other hand, bioactive compounds, such as lycopene (4.65 mg/100 g), β-Carotene (2.91 mg/100 g) and ascorbic acid (27.5 mg/100 g) were found to be highest in tomatoes treated with 4 mL kg^{-1} of ethanol for 6, 9 and 12 h respectively. Based on the findings, it can be suggested that T_6 treatment would be more effective to extend the shelf-life of fresh tomato without a significant change in postharvest qualities.

Keywords: ethanol vapor, tomato, physico-chemical, postharvest quality, ripening

Citation: Roy, J. K., R. Akram, M. A. F. Shuvo1, H. Khatun1, M. S. Awal, and M. Sarker. 2017. Effect of ethanol vapor on ripening of tomato. Agricultural Engineering International: CIGR Journal, 19(2): 168–175.

1 Introduction

Tomato (*Lycopersicum esculentum*) is one of the popular vegetables in most countries around the world and is cultivated throughout the year. In addition, it is considered as nutritionally important fruit due to providing bioactive compounds like lycopene, vitamin C and β-carotene with health-beneficial effects. In summer, the ambient temperature is higher than any other season and it is difficult to maintain the postharvest quality of tomato. Moreover, storage facility is inadequate in Bangladesh, so delay of ripening using ethanol vapor would be effective way to maintain the postharvest quality of tomato.

A list of summer varieties, likely BARI Tomato-3, BARI Tomato-5, BARI Tomato-8, BARI Tomato-10 and BARI Tomato-13 is cultivated in Bangladesh to meet the growing demand throughout the year (Zaman et al., 2006). Tomato is characterized as perishable fruit due to its typical climacteric behavior and generally, shelf-life is 8 days at ambient conditions during winter (Jany et al., 2008). The demand of fresh tomato is always high, and it may be unacceptable at consumer level if postharvest quality is not maintained properly following harvesting.

Postharvest loss is a major constrain for adequate food supply especially in developing countries. Every year huge amount of tomato is damaged due to inadequate storage system and improper post-harvest handling practices. It was reported that post-harvest loss of tomatoes ranged from 18% to 28%, therefore almost 32.90% post-harvest loss is reported in supply chain in Bangladesh (Hassan, 2010). This postharvest loss followed due to improper storage facilities, handling practice throughout the supply chain.

Delay of ripening is an important issue in the postharvest quality maintenance of climacteric fruits. Ripening and senescence of climacteric fruits can be delayed by the application of preservatives, which have no detrimental effect of health. Ethylene is recognized as food grade chemical (Pesis, 2005), which has a significant role

Received date: 2016-07-15 **Accepted date:** 2017-04-04

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to inhibit ethylene biosynthesis, regulate ripening and prolong the shelf life of fruits (Siddiqui et al., 2005; Plotto et al., 2006; Hossain et al., 2009).

Recent studies have focused that exogenous application of ethanol can inhibit the senescence of avocado (Ritenour et al., 1997), melons (Liu et al., 2012) and broccoli (Asoda et al., 2009). Use of temporary ethanol vapor treatment is an effective way to inhibit the ripening of tomato (Saltveit and Mencarelli, 1988). In addition, ethanol application improves the volatile aromatic compounds specially ethyl esters in fruits (Bai et al., 2004; Khanom and Ueda, 2008). The effectiveness of exogenous ethanol vapor is correlated with its concentration, as for table grape optimal ethanol dose is 5 mL kg^{-1} (Chervin et al., 2003).

2 Materials and Methods

2.1 Sample Collection and Ethanol Vapor Treatment

Exogenous ethanol vapor treatment was used here by exposing the tomato into ethanol vapor in a closed space immediately after harvesting. A local variety, BARI Tomato-4, specified by average weight of 40 g with slight red color and round shape was used for this experiment.

Fresh and mature tomato was collected from local field during the harvesting season (April 2015) in Kornai, Dinajpur. Collected tomatoes were subjected to ethanol vapor treatments with reagent grade ethanol (95%) in a 20 L closed bucket in single layer. After ethanol exposure, the buckets were opened and tomato was allowed to ripe in ambient condition (Temperature 26.84ºC and Relative Humidity 61.75%). In this experiment, ethanol vapor treatments were used as follow: T_0= Control, T_1= 4 mL kg^{-1} for 6 h, T_2= 4 mL kg^{-1} for 9 h, T_3= 4 mL kg^{-1} for 12 h, T_4= 6 mL kg^{-1} for 6 h, T_5= 6 mL kg^{-1} for 9 h, T_6= 6 mL kg^{-1} for 12 h, T_7= 8 mL kg^{-1} for 6 h, T_8= 8 mL/kg^{-1} for 9 h, T_9= 8 mL kg^{-1} for 12 h.

2.2 Quality Evaluation

Physicochemical parameters namely weight loss, firmness, color development, total soluble solids, pH, ascorbic acid, lycopene and β-carotene were analyzed at 3 days, 5 days, 7 days, 9 days and 11 days after treatment.

2.2.1 Weight Loss

Percent weight loss of tomatoes was calculated according to the following formula:

$$\text{Percent Weight Loss} = \frac{\text{Initial weight} - \text{Weight at the day of observation}}{\text{Initial weight}} \times 100$$

2.2.2 Firmness

Firmness of tomato was measured with a digital hand-held penetrometer according to Watkins and Harman (1981).

2.2.3 Color Measurement

Color values were measured in terms of L, a^*, b^* (SCI) using Minolta colorimeter (CM 2500d, Konica Minolta Optics Inc., Japan) by following the method developed by Iida et al. (1995). Numerical values of a^* and b^* were converted into hue angle (H=$\tan^{-1}b^*/a^*$) according to Francis (1980).

2.2.4 Total Soluble Solids Content

Total soluble solids content was determined with a small hand operated refractometer (HI 96801, Hanna Instruments, Romania) and the value was readout as °Bx from direct reading of the instrument.

2.2.5 pH

The pH of the sample was determined using a digital pH meter (pH 211, Hanna Instruments, Romania) according to Ranganna (2001). Sample was prepared by homogenizing 5.0 g of fruit pulp with 5.0 mL of distilled water.

2.2.6 Ascorbic Acid Content

At first 5.0 g of tomato fruit pulp was homogenized (Homogenizer model: OV5, Velp Scientifica) with 100 mL of oxalic acid (0.05 M) solution and centrifuged at 3600 rpm for 30 minutes then 5.0 mL of supernatant was taken in 25.0 mL volumetric flask. 0.5 mL of meta-phosphoric acetic acid, 1.0 mL of sulfuric acid (5% v v^{-1}) and 2.0 mL of ammonium molybdate (5% m v^{-1}) solution were added to the volumetric flask, the volume was made up to mark with distilled water. After keeping at room condition for 15 minutes, absorbance (Spectrophotometer model: T80, PG Instruments Ltd.) was taken at 760 nm. Ascorbic acid content was calculated in comparison with standard curve of L-ascorbic acid. (Rahman et al., 2006).

2.2.7 Lycopene and β-Carotene Content

Lycopene and β-Carotene content was determined

with a slightly modified method described by Nagata and Yamashita (1992). 1.0 g of sliced fruit pulp was homogenized (Homogenizer model: OV 5, Velp Scientifica) with 10.0 mL of acetone-hexane solution (4:6) and centrifuged at 3600 rpm for 10 minutes, the absorbance (Spectrophotometer model: T80, PG Instruments Ltd.) was measured at 663 nm, 645 nm, 505 nm and 453 nm. Lycopene and β-Carotene content were calculated by the following formula:

$$\text{Lycopene (mg/100 mL)} = -0.0458A_{663} + 0.204A_{645} + 0.372A_{505} - 0.0806A_{453}$$

$$\text{Carotene (mg/100 mL)} = 0.216A_{663} - 1.224A_{645} - 0.304A_{505} + 0.452A_{453}$$

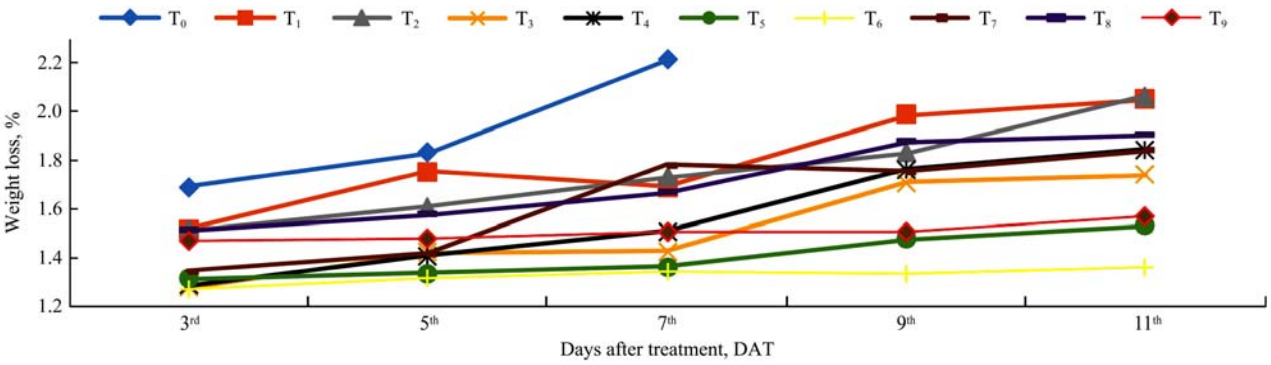
2.3 Statistical Analysis

The data on physico-chemical properties of tomato were statistically analyzed by two ways ANOVA followed by Duncan's multiple range test (DMRT) using SPSS version-20.0 (SPSS, Inc., Chicago, IL, USA). Multiple comparisons among treatments were tested by least significant difference (LSD) at a level of $p<0.05$.

3 Results and Discussion

3.1 Weight Loss

The extent of weight loss for both control and treated samples was presented in Figure 1. It was revealed that ethanol vapor treatment significantly ($p<0.01$) affected the weight loss, therefore, the control sample give the higher weight loss by average 0.33% compared to treated samples. In addition, treated samples secured marketable quality up to 11 days with a range of weight loss (1.26%-2.07%). Transpiration and respiration throughout the storage period might be possible reasons of weight loss of tomato. However, ethanol vapor treatment might reduce the weight loss by slowing down respiration process.



Note: T_0= Control, T_1= 4 mL kg^{-1} for 6 h, T_2= 4 mL kg^{-1} for 9 h, T_3= 4 mL kg^{-1} for 12 h, T_4= 6 mL kg^{-1} for 6 h, T_5= 6 mL kg^{-1} for 9 h, T_6= 6 mL kg^{-1} for 12 h, T_7= 8 mL kg^{-1} for 6 h, T_8= 8 mL kg^{-1} for 9 h, T_9= 8 mL kg^{-1} for 12 h.

Figure 1 Change in weight loss of tomato during storage

3.2 Firmness

Significant ($p<0.01$) effect of ethanol vapor treatment in respect of firmness of tomato was found. Figure 2 shows gradual decreasing (8.81% in 48 h) in firmness of both control and treated samples, while control was found more soften than treated tomatoes up to 7 days after treatment. At 11th days, significant ($p<0.01$) difference in firmness was observed among treated samples. The highest value was recorded in T_6 (0.96) while the lowest value was found in control (0.531). Results indicated that concentration of ethanol vapor and exposer time is beneficial up to a certain level. The reduction in firmness possibly occurred due to conversion of insoluble pectin to soluble by the action of pectic enzyme. Ethanol vapor treatment could reduce the softening of tomato by inhibiting ethylene synthesis which is responsible for ripening processes. Ethanol treatment could maintain the firmness of a range of climacteric and non-climacteric fruits (Pesis, 2005). Saltveit and Mencarelli (1988) noted that ripening of tomato might be suppressed by exposing to ethanol treatment.

3.3 Total Soluble Solids (TSS)

Change in total soluble solids (TSS) content in tomatoes over the storage period is shown in Figure 3. Results showed that TSS gradually increased up to the ninth days after treatment except T_7 and T_8 and thereafter started to decrease. At seven days after treatment, the highest TSS (4.96 °Bx) and the lowest TSS (4.47 °Brix) were recorded in control and T_3 treatment respectively. However, a range of TSS content in the treated samples

between 4.15 and 4.93 °Bx during storage. Retardation of ripening process due to exogenous ethanol vapor treatment might be possible reason for lower TSS in treated sample than control. TSS might be increased due to the alteration in cell wall structure and degradation of complex carbohydrates into soluble sugar during ripening. Yaman and Bayoindrili (2002) reported that suppressed respiration rate slowed down ripening which results in lower TSS. Similar results have been reported by Kishore et al. (2006) in purple passion fruits, Deepak et al. (2008) in banana and Soltani et al. (2010) in jambu air.

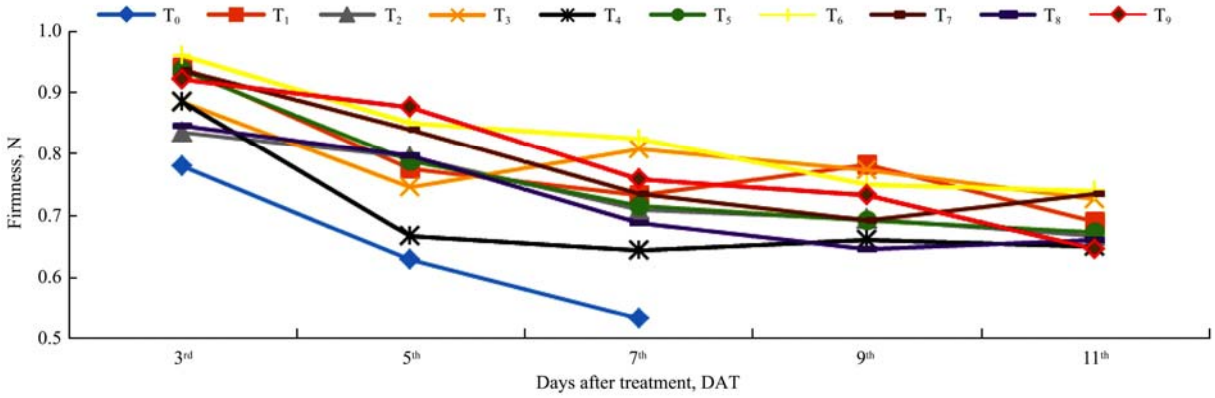


Figure 2 Changes in firmness of tomato during storage; see note to Figure 1

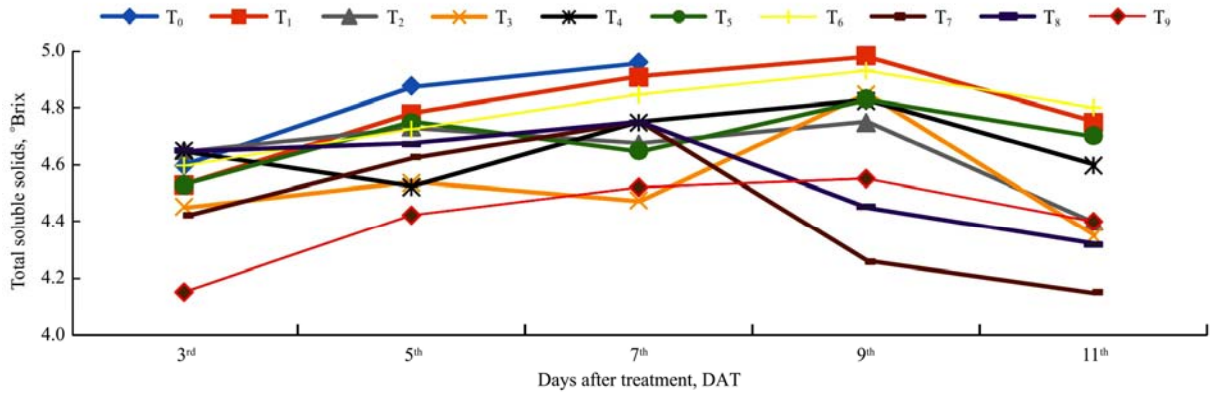


Figure 3 Changes in total soluble solids of tomato during storage; see note to Figure 1

3.4 pH

Significant (p<0.01) difference in pH among samples was found at all the stages of observation (0, 3, 5, 7, 9 and 11 DAT). Figure 4 shows that pH value of tomato increased up to 9th days of storage then gradually decreased.

The highest pH value was found in T_3 and lowest was found in T_2. The conversion of complex carbohydrates into sugars may lead the increase in pH, and further breakdown of sugar produces organic acids and lower pH value. This finding was in line with the result of Policegoudra and Aradhya (2007) who observed higher pH in mangoes with longer storage period.

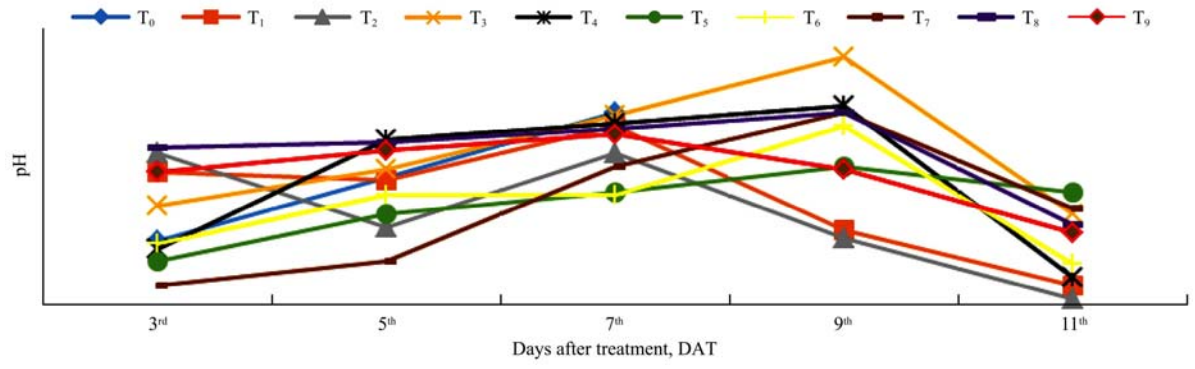


Figure 4 Changes in pH of tomato during storage; see note to Figure 1

3.5 Color

The lightness and hue angle of tomato are presented in Table 1. It is clear that significant (p<0.01) effect of ethanol vapor treatment on color change was observed during storage. The lightness of tomato tended to decrease as storage time progressed, and increase in green color indicated by lower hue angle may be attributable to the decrease in lightness of tomato.

Table 1 Changes in color of tomato during storage (*)

Treatment	Color									
	3rd DAT		5th DAT		7th DAT		9th DAT		11th DAT	
	L*	Hue	L*	Hue	L*	Hue	L*	Hue	L*	Hue
T_0	42.95^{g}	59.65^{i}	41.16^{f}	47.71^{g}	39.32^{j}	37.97^{j}				
T_1	46.70^{c}	67.79^{e}	42.60^{d}	50.88^{f}	39.64^{i}	46.60^{d}	41.25^{d}	41.20^{g}	41.13^{d}	39.72^{g}
T_2	42.16^{i}	61.12^{h}	40.20^{g}	46.80^{j}	39.97^{h}	43.94^{i}	40.66^{e}	44.31^{d}	40.60^{f}	41.54^{e}
T_3	43.59^{f}	70.27^{b}	39.19^{i}	47.28^{i}	42.76^{a}	49.74^{c}	39.80^{f}	42.43^{f}	38.79^{h}	40.25^{f}
T_4	45.39^{e}	70.19^{c}	44.87^{b}	58.49^{c}	41.19^{f}	45.06^{f}	39.55^{f}	40.32^{i}	45.68^{a}	42.72^{d}
T_5	46.49^{d}	69.76^{d}	46.80^{a}	63.17^{b}	40.06^{g}	45.32^{e}	38.77^{g}	41.01^{h}	40.98^{e}	43.68^{c}
T_6	47.69^{b}	70.19^{c}	39.04^{j}	55.65^{d}	42.30^{b}	51.30^{a}	41.98^{c}	50.56^{a}	43.72^{b}	46.67^{a}
T_7	42.85^{h}	64.29^{f}	41.94^{e}	47.43^{h}	41.96^{d}	44.99^{g}	43.90^{a}	44.11^{e}	39.53^{g}	43.88^{c}
T_8	45.44^{e}	63.78^{g}	40.14^{h}	52.79^{e}	41.37^{e}	50.53^{b}	43.96^{a}	49.71^{c}	39.53^{g}	44.70^{b}
T_9	50.59^{a}	73.14^{a}	44.44^{c}	68.60^{a}	42.24^{c}	44.38^{h}	42.68^{b}	50.46^{b}	41.84^{c}	44.88^{b}

Note: * Mean values within column with different superscripts are significantly different at p<0.01; see note to Figure 1.

3.6 Lycopene

Change in lycopene content of the present studies showed that lycopene content gradually increased along the storage time. Lycopene content of the samples ranged from 2.68 to 4.65 mg/100 g of dry weight of tomato during storage (Figure 5).

Significant (p<0.01) difference in changes of lycopene content due to ethanol vapor treatment was observed. At 7th days after treatment the highest lycopene (4.37 mg/100 g) was found in control sample whereas the lowest value (3.70 mg/100 g) was recorded for T_6. At 7th days after treatment the highest lycopene (4.37 mg/100 g) was found in control sample whereas the lowest (3.70 mg/100 g) one measured in T_6. In earlier, Brandt et al. (2009) reported that ethanol suppresses lycopene biosynthesis and action of ethylene by reducing respiration. Aguilar-Mendez et al. (2008) stated that exogenous ethanol lowers chlorophyll degradation and the synthesis of respiration.

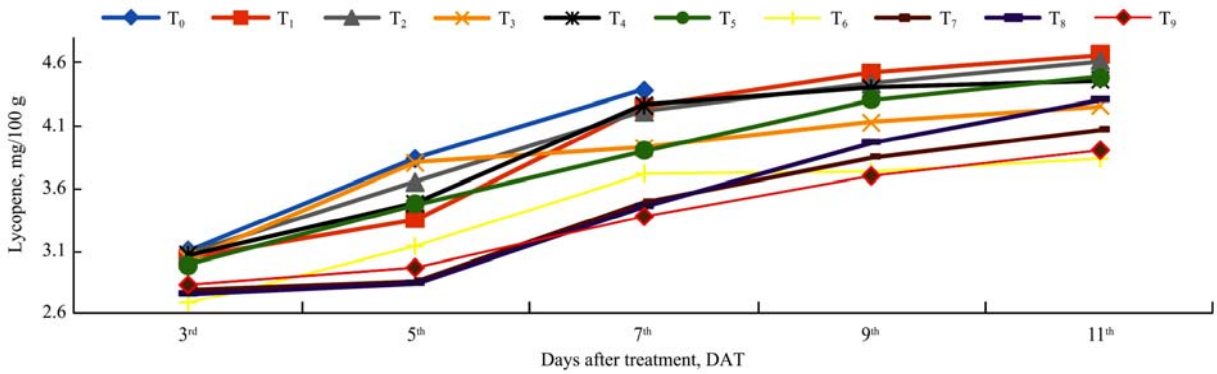


Figure 5 Changes in Lycopene of tomato during storage; see note to Figure 1

3.7 Ascorbic Acid

Figure 6 shows the change in ascorbic acid content of tomatoes during the storage period. The highest ascorbic acid content was observed in T_8 whereas the lowest was encountered in T_6. Results revealed that ethanol vapor treatment remains significant (p<0.01) in respect of ascorbic acid content. Figure shows that ascorbic acid content of samples increased up to 9th days after treatment and then decreasing was observed up to end of the storage period. An increasing in ascorbic acid content of tomato

might be due to progress of ripening. It was in agreement with the results of Sammi and Masud (2008) who reported that higher ascorbic acid in fruits during ripening stage during ripening stage.

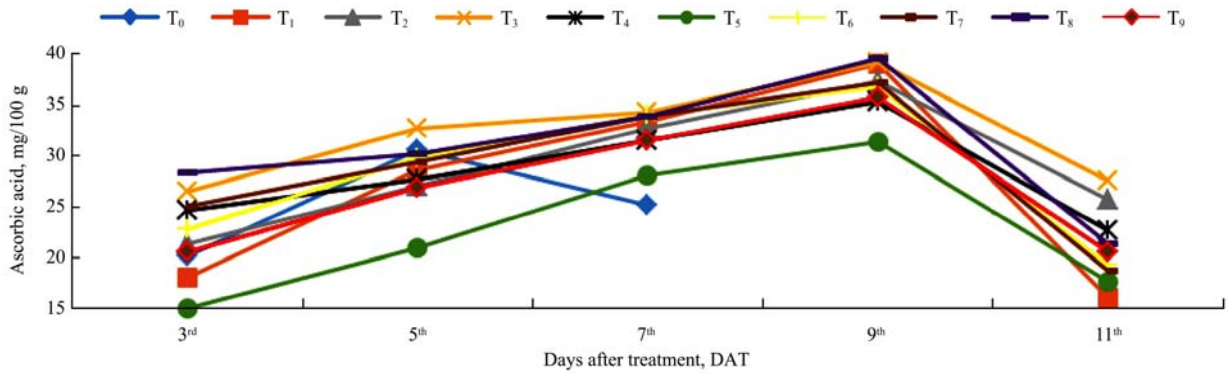


Figure 6 Change in Ascorbic Acid of tomato during storage; see note to Figure 1

3.8 β-Carotene

Results of β-carotene content of treated and control samples are presented in Figure 7. Significant (p<0.01) effect on the changes of β-carotene content among samples was observed at all the stages of observation. Results revealed that β-carotene content gradually increased throughout the storage period.

At the 7 days after treatment, the highest (2.8 mg/100 g) and the lowest (2.41 mg/100 g) β-carotene content were observed in control and T_9 sample, respectively. However, β-carotene content of treated tomatoes ranged from 2.31-2.91 mg/100 g of tomato. The increase in β-carotene content is caused by degradation of chlorophyll and synthesis of carotenoids synthesis along the storage period. Raffo et al. (2002) reported that carotenoids content of tomato was very low at the breaker stage which increased during ripening and reached peak point at full ripening stage.

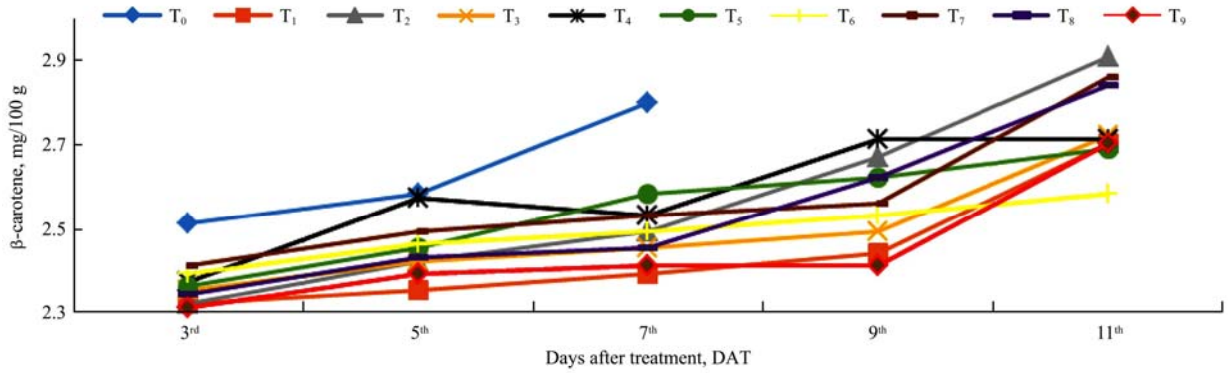


Figure 7 Changes in β-Carotene of tomato during storage; see note to Figure 1

4 Conclusion

Different doses of ethanol vapor treatment were applied to the tomato for several hours and stored at ambient condition (26.84ºC±3.0ºC and 61.75% RH) with a single layer. It was observed that the shelf life of freshly harvested tomato could be extended up to 11 days without excessive deterioration in quality using ethanol vapor treatment. Among all the treatments, T_6 (6 mL kg^{-1} and time 12 h) treatment was significantly effective for lengthening storage life of tomato; therefore, it maintained quality in terms of different physicochemical parameters. Hence, exogenous ethanol vapor treatment used in this study could be suggested as an effective way to extend the shelf life of tomato with retaining the quality, and thus postharvest loss would be minimized and have a positive impact on economy.

Acknowledgement

The authors are thankful to University Grant Commission (UGC) for providing financial support to conduct this research.

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