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RESEARCH ARTICLE

Relationship between moisture loss and physicochemical quality attributes of tomato under different storage conditions

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ABSTRACT

Moisture loss (ML) from fresh produce reduces its mass, appearance and quality, depends upon on surrounding's temperature (T) and relative humidity (RH).The current study was designed to appraise the influence of storage conditions (SC) on tomato fruit quality and to develop relationship between ML and fruit quality under different SC. Freshly harvested tomato after washing and air drying were kept at ambient conditions and under zero energy cool chamber (ZECC) for fourteen days and analyzed on alternate days for fruit quality determination. ML (9.72%), total soluble solids (4.79 °Brix) and fruit internal temperature (29.29°C) was higher at ambient conditions and lower (3.23%, 4.59 °Brix and 25.12 °C, respectively) in ZECC. ML had significant negative relationship with ascorbic acid (r=-0.469 and r=-0.584) and significant positive relationship with internal temperature (r=0.834 and r=0.596) and pH (r=0.766 and r=0.542) of tomato in both ZECC and at ambient conditions respectively. ML and TSS had significant negative correlation (r=-0.498) in ZECC while, positive butt non-significant correlation (r=0.342) at ambient conditions.

Keywords: Ambient conditions; biochemical quality, moisture loss; tomato; zero energy cool chamber

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INTRODUCTION

At the stage of harvest, fruits and vegetables had high water content and had crispy texture and fresh appearance. On detaching, water supply to plant stops which leads to weight reduction of the fresh produce in the process of respiration. It not only involve in ML from fresh produce but also losses mass and quality degradation such as firmness loss, shrivelling, gloss reduction, visual quality degradation and nutritional loss (Caleb et al., 2013; Holcroft, 2015). Product ML also linked with monetary loss as it reduces the marketable mass, owing to shrivelling of the fresh produce (Caleb et al., 2013; Veraverbeke et al., 2003). Transpiration and respiration processes are responsible for removal of moisture from fresh commodities. It brings produce shelf-life (SL) into a contest against the clock for vendors, processors and farmers to uphold quality and lessen food

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loss (Mahajan et al., 2015). Transpiration and respiration process depends upon the surrounding RH and temperature which interns determine the SL and quality of fresh produce (Castellanos and Herrera, 2015). Storage potential of most perishable commodities decreased with increased in handling temperature (Lisa, 2013).

The point at which ML influences the produce quality differs for different products. The maximum permitted mass loss for leafy vegetables, carrot, grape and tomato is 3-5%, 4%, 5% and 4% while for nectarine and summer squash is 21%and 24% respectively (Kays and Paull, 2004; Thompson et al., 2008; Holcroft, 2015). In case of grape tomatoes the transpiration rate increased as increased temperature from15°C to 20°C, whereas it declined for RH 80%-92% (Xanthopoulos et al., 2014). Mahajan et al. (2008) established that by increasing the RH from 76 to 96 percent for whole mushrooms, transpiration rate declined by 87 percent at 4°C, while at 96 percent RH, reducing temperature from 16°C to 4°C the transpiration rate decreased by 61percent. Caleb et al. (2013) stated that increase in RH from 76% to 96% transpiration rate of pomegranate arils decreased by 83.5 percent at 5◦C, whereas transpiration rate declined by 68.9% as temperature reduces from 15◦C to 5◦C.

Moisture in form of vapors (Fockens and Meffert, 1972) stays on the epidermis of leaves through pores such as stomata, epidermal cells, cuticles and lenticels (Ben-Yehoshua and Rodov, 2003). Tomato contains 95% water (Kays and Paull, 2004) and most of the gases and water vapor exchange occur through the stem scar (Holcroft, 2015) as tomato lack stomata or lenticels. After harvest conditions suitable to water loss leads to prompt loss of Vita-C in green leafy vegetables (Lee and Kader, 2000). Hence, contact of harvested produce to unfavorable conditions (high T and low RH) can results in an increase in the vapor pressure deficit, which in turn increases the transpiration rate and leads to increased water loss. So, optimal temperature and RH should be retained in order to prolong SL and preserve produce quality.

ZECC is developed on the principle of direct evaporative cooling and does not require power or electricity to work (Kumar et al., 2018). The temperature variation among ambient conditions and evaporative cool chamber was oscillated between 4 to10◦C and considerably higher RH of about 80-100 percent was observed in evaporative cool chambers (Ambuko et al., 2017). Several studies reported positive influence of ZECC of fresh produce quality as compared to ambient conditions (Rajput et al., 2020; Khalid et al., 2020; Bayogan et al., 2017) and being a low cost technology can radially be adopted by marginal farmers. Tomato fruit were kept under two different temperatures in ZECC and ambient conditions to develop relationship between ML and physiochemical attributes during fourteen days storage.

MATERIALS AND METHODS

Tomatoes were harvested from Adoptive Research Farms in Vehari, Punjab, Pakistan and brought to Environmental Sciences Department, COMSATS University Islamabad, Vehari Campus. Tomatoes were washed with tap water after sorting and air dried at room temperature. Fruit on stage 4 were used and divided into forty five lots with four fruit per lot. Three lots were analyzed at harvest and from remaining forty two lots (2 SC × 7 removals × 3 replications) half of the lots (twenty one) were kept in ZECC and other half (twenty one) were kept at ambient conditions in laboratory. Fruit were analyzed on alternate days for a period of fourteen days.

Temperature (◦C) and relative humidity (%)

Temperature (◦C) and RH (%) of ZECC and laboratory was determined three times a day with the help of thermo-hygrometer (TFA Dostman/D-97877 Wertheim).

Moisture loss (%) and shelf-life (days)

On each removal ML (%) of tomatoes was determined by the following formula:

$$\text{Moisture loss} = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \times 100$$

SL of tomatoes was determined in days. Five percent ML was measured as an index which indicates end of SL of tomato.

Firmness (kg)

Firmness was determined with the help of fruit pressure tester T 327 and expressed in kg.

Electrical conductivity (EC) (S/m)

Tomato juice EC was determined by taking the juice in a beaker and dipping the electrode of digital EC meter (LovibondSenso Direct Con 110) in it.

Internal temperature (°C)

Internal temperature was measured with the help of probe thermometer by inserting its needle inside the fruit.

pH and TSS (°Brix)

Tomato juice was extracted after grinding in pastel and mortar and pH of the juice was determined with digital pH meter (Milwaukee pH55). Tomato juice was extracted and analyzed with digital refractometer (ATAGO PAL-1) by adding 1 to 2 drops of juice on the prism surface and reading was taken.

Titratable acidity (TA) (%)

It was measured by the following method defined by Hortwitz (1960) and Dashtiet al., (2014). Ten mL juice sample was titrated with 0.1 N sodium hydro oxide solution by adding 2 to 3 drops of indicator (phenolphthalein) and the results were calculated as percentage.

Ascorbic acid (AA) (mg100mL^{-1})

Ruck (1969) method was used to measure the ascorbic acid contents of tomato juice. Five mL of filtered aliquot (having 10 mL of tomato juice and 90 mL of oxalic acid solution 0.4%) was titrated against 2,6-dichlorophenolindophenol dye solution.

Statistical analysis

A two-factor (SC and SD) factorial CRD (Completely Randomized Design) was used to analyze the data by using Statistix 8.1 software. Means were compared at p≤0.05 by using LSD (Least Significant Difference test). Pearson coefficient correlation was also developed between ML and fruit quality parameters at both SC.

RESULTS AND DISCUSSION

Temperature (°C) and relative humidity (%)

Temperature in ZECC was low (27.68°C) and RH was high (74.49%) as compare to laboratory where temperature was high (30.78°C) and RH (28.03%) was low (Fig. 1). Low temperature and high RH in ZECC might be due to evaporation of water which was applied to the sand. Water while evaporating absorbs heat from its surroundings resulted in reduction of temperature inside ZECC. As water evaporates it raises the RH inside the chamber (Lal Basediya et al., 2013). Similarly Khalid et al. (2020) reported a T and RH difference of 3.41°C and 38.22% respectively between ZECC and ambient conditions. Bayogan et al. (2017) reported a 5°C fall in temperature and 27.5% rise in RH inside cool chamber as compared to ambient conditions. Similarly, Samira et al. (2018) found a reduction of 13°C temperature and an increment of 29% RH in ZECC as compared to ambient conditions.

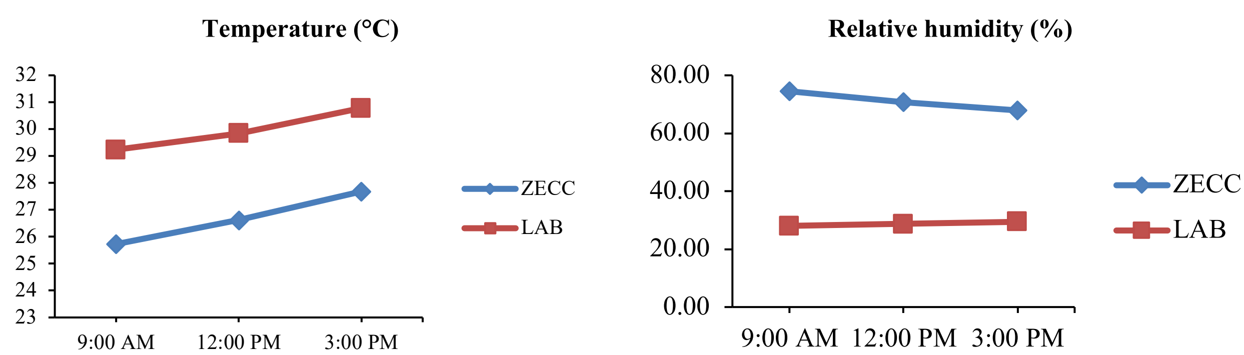

Figure 1: Temperature (°C) and relative humidity (%) during the study

Effect of storage conditions (SC) and storage duration (SD) on physical attributes of tomato

SC and interaction of SC x SD had statistically significant influence on ML (%) (Table 1). After fourteen days storage, maximum ML (9.72%) was recorded at ambient condition whereas minimum ML (3.23%) was recorded in ZECC. This could be owing to lesser temperature and higher RH inside ZECC as compared to ambient conditions (Fig. 1). Less RH and higher temperature resulted in more ML from fresh produce (do NascimentoNunes, 2008) due to high respiration, transpiration and VPD (vapor pressure deficit) between fresh produce and its surroundings, which might be the reason of more ML at ambient conditions as compared to ZECC. Similarly, Rajput et al. (2020) reported lesser mass loss (23.76%) in tomato stored in ZECC as compared to ambient conditions (35.86%). Maximum ML was recorded in ambient condition (23.4%) at seventh removal and minimum ML was in ZECC (0.53%) at first removal. Tomato stored at ambient conditions had lower SL of six days as compared to ZECC with fourteen days of SL (Table 1). This might be due to temperature difference between the two SC. High temperature can reduce the potential SL of fresh fruit and vegetables (do Nascimento Nunes, 2008) due to higher metabolic activity and respiration rate (Gast, 2001). Rajput et al. (2020) reported more SL of tomato (10 days) in ZECC as compared to ambient conditions (4 days). Similarly, Omodara and Babarinsa, (2016) reported 13 days SL of tomatoes stored in ZEEC as compared to five days in ambient conditions. Moreover, Islam and Morimoto (2012) described an extended SL of 16 days for tomato fruit kept in ZECC as compared to seven days at ambient conditions. Storage environment had significant influence on fruit internal temperature (°C) (Table 1). Fruit internal temperature was significantly low (25°C) in ZECC as compared to ambient conditions (29°C). SC had no significant influence on firmness (kg) and EC (S/m) and interaction of SC and SD had no significant influence on fruit internal temperature (°C), firmness (kg) and EC (S/m) during study (Table 1).

Table 1: Influence of storage conditions on moisture loss (%), firmness (kg), internal temperature (°C) and EC (S/m) of tomatoes during storage

Removal	Moisture loss (%)		Firmness		Internal temperature (°C)		EC (S/m)	
	ZECC	Ambient conditions	ZECC	Ambient conditions	ZECC	Ambient conditions	ZECC	Ambient conditions
At harvest	-	-	3.43	3.43	28.63	28.63	2.23	2.23
2DAH	0.53g	1.92efg	3.10	3.70	21.17	25.20	2.11	1.97
4DAH	0.92fg	3.99defg	2.03	2.50	21.13	26.93	2.15	1.99
6DAH	2.11efg	**5.73***def	4.17	2.33	23.53	29.00	2.09	2.09
8DAH	3.32defg	7.49cd	3.73	3.27	26.30	30.70	1.97	2.05
10DAH	3.72def	11.03bc	1.63	2.03	27.00	30.40	2.04	2.10
12DAH	4.38defg	12.17bc	2.07	1.67	27.07	32.37	1.94	2.05
14DAH	**5.38***defg	23.49a	3.40	2.60	26.13	30.60	2.09	2.21
Mean	**3.2376b**	**9.72a**	**2.82**	**2.69**	**25.12b**	**29.29 a**	**2.08**	**2.09**
P-value condition = 0.0000			0.5419		0.0000		0.7935	
P-value condition × removal = 0.0008			0.0783		0.3084		0.3472	

**5% moisture loss is the index of end of shelf life; DAH=Days after harvest*

Influence of SC and SD on biochemical attributes of tomato

SC and interaction of SC x SD had significant influence on TSS (°Brix) of tomato juice (Table 2). Maximum TSS (4.79 °Brix) was found in ambient conditions while minimum TSS (4.59 °Brix) was found in ZECC. Higher TSS contents at ambient conditions might be due to conversion of starch into sugar and loss of moisture from the produce at higher temperature (Samira et al., 2013). ML at higher temperature and lower RH resulted in increasing the concentration of soluble solids which might have resulted in higher TSS at ambient conditions. Similar findings were also described in pear (Singh et al., 2017), tomato (Sarkar et al., 2014) and bell pepper (Bayogan et al., 2017). Storage environment had significant influence on TA during study (Table2). Maximum TA (5.46%) was found in ZECC while, minimum TA (4.16%) was found at ambient conditions. Lower TA at ambient conditions might be due to more utilization of organic acid in respiration at higher temperature (Samira et al., 2013) as compared to ZECC. Similar findings were reported in jamun cv Goma Priyanka (Kanak and Singh, 2013) and banana (Parasad et al., 2015). SC and interaction of SC x SD had no considerable influence on pH and AA during study (Table 2).

Table 2: Influence of storage conditions on biochemical quality attributes of tomatoes during storage

Removal	TSS (°Brix)		pH		Titratable acidity (%)		(mg 100mL^{-1})	
	ZECC	Ambient conditions	ZECC	Ambient conditions	ZECC	Ambient conditions	ZECC	Ambient conditions
At harvest	4.63cdef	4.63cdef	3.87	3.87	4.22	4.22	34.90	34.90
2DAH	4.87abc	4.70bcdef	3.70	3.67	5.55	4.48	69.81	57.12
4DAH	4.83bcd	4.57cdef	4.03	3.90	5.38	3.41	66.64	60.29
6DAH	4.70bcdef	4.73bcde	4.20	4.10	5.55	5.01	76.16	72.98
8DAH	4.30ef	5.30a	4.16	4.27	7.64	5.44	55.53	60.29
10DAH	4.70bcdef	4.50cdef	4.23	4.20	6.21	2.00	53.94	52.36
12DAH	4.27f	4.80bcd	4.37	4.30	5.33	3.95	61.88	42.84
14DAH	4.40def	5.13ab	4.40	4.20	3.79	4.74	26.97	42.84
Mean	**4.59b**	**4.79a**	**4.12**	**4.06**	**5.46a**	**4.16b**	**55.73**	**52.95**
P-value condition = 0.0117			0.0921		0.0014		0.4948	
P-value condition × removal = 0.0010			0.5145		0.0603		0.5391	

DAH=Days after harvest; AA=Ascorbic acid; TSS=Total soluble solids

Table 3: Correlation between moisture loss (%) and fruit quality under different storage conditions

Parameters	ZECC	Ambient conditions
Firmness	-0.114	-0.283
	P(0.6225)	*P(0.2137)*
Internal temperature	0.834*	0.596*
	P(0.0000)	***P(0.0044)***
TSS	-0.498*	0.342
	P(0.0214)	*P(0.1289)*
TA	-0.081	-0.01
	P(0.7261)	*P(0.9662)*
TSS/TA	0.163	0.082
	P(0.4805)	*P(0.7251)*
pH	0.766*	0.542*
	P(0.0001)	***P(0.0111)***
Ascorbic acid	-0.469*	-0.584*
	P(0.0319)	***P(0.0055)***
EC	-0.142	0.444*
	P(0.5382)	***P(0.0436)***

N=21; n=19; r= 0.433; $p \leq 0.05$

Correlation between moisture loss (%) and fruit quality attributes

ML had significant negative relationship with ascorbic acid (r=-0.469; r=-0.584) and significant positive relationship with internal temperature (r=0.834; 0.596) and pH (r= 0.766;0.542) of tomato at ZECC and ambient conditions respectively. ML had significant negative (r=-0.498) relationship with TSS in ZECC while significant positive relationship with EC at ambient conditions. ML had non-significant negative and positive relationship with TA and TSS/TA ratio respectively at both SC.

ML (%) was inversely related with firmness at both ZECC and ambient conditions. Similar relation between ML and firmness was also reported by Nunes and Emond (2007) in many horticultural crops. Significant negative relation between moisture losses with TSS in ZECC might be due to low temperature in the ZECC which reduces the rate of respiration and conversion of starch into simple sugars. Also under low temperature due to reduced respiration ML is reduced as loss of water molecule is also a product of respiration (Starr et al., 2020) which results in dilution of sugars and hence reduced TSS.

CONCLUSION

ML from fresh commodities increased with an increase in storage temperature and decrease in RH. ML positively correlated with fruit internal temperature and pH and negatively correlated with ascorbic acid in both ZECC and ambient conditions. ML and TSS had significant negative correlation in ZECC.

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