EFFECT OF STORAGE METHODS AND RIPENING STAGES ON POSTHARVEST QUALITY OF TOMATO (*LYCOPERSICOM ESCULENTUM* MILL) CV. CHALI

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Abstract
Tomato (Lycopersicon esculentum L) is one of the most widely consumed fresh vegetable. However, its highly perishable nature limits its postharvest life. Temperature and relative humidity management to extend shelf life and maintain postharvest quality of perishables is the main problem in tropical countries like Ethiopia. Though mechanical refrigerators are the best option to do, it is unaffordable for farmers and small retailers in developing countries to buy and run. So development of cheap storage is important task to overcome the problem. The current study conducted to determining the effect of different storage methods and ripening stages on shelf life and postharvest quality of tomato. A factorial CRD design was laid with two factors being storage methods (ZECC, pot in pot storage, desert cooler and the control), and two ripening stages (breaker and light red stage) with three replications. Average daily temperature, relative humidity, shelf life, deterioration and weight loss percentage, titratable acidity, total soluble solid, fruit firmness, Lycopene, β-carotene, Chlorophyll A and B were evaluated as response variables. Result of the study showed that retaining of tomato postharvest quality and shelf life were much better inside evaporative coolers as compared to control. Weight loss and deterioration percentage, Total Soluble Solid, Lycopene and β-carotene content increased with the storage period, but were faster on tomatoes stored at room temperature. Titratable acidity, fruit firmness, Chlorophyll A and B contents were decreased with the storage periods compared with control. In this study concluded that evaporative coolers gives an alternative approach on temperature and relative humidity management to mechanical refrigerator.

Keywords: tomato, evaporative coolers, shelf life, temperature, relative humidity

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1.INTRODUCTION

Tomato (*Lycopersicom esculentum* L.) is botanically classified as a fruit. It is a warm-season crop, member of the Solanaceae family; originated from the elevated regions of Peru, Ecuador and parts of central Mexico (Islam et al., 2012). The introduction of cultivated tomato into Ethiopian agriculture dates back to the period between 1935 and 1940 (Workneh and Woldetsadik, 2004).

Earlier, tomatoes were thought to be poisonous and long before it was considered fit to eat, it was grown only as an ornamental garden plant. Today, tomato is recognized as one of the most important commercial and dietary vegetable crops (Bauer et al. 2004). It is a major horticultural crop with an estimated total world production 152.9 million tons with a value of $74.1 billion (FAOSTAT, 2009). The annual production of tomato in Ethiopia is 4,593 hectares which yields about 89,702 tons (FAOSTAT, 2010). Fresh-market tomatoes are a popular and versatile fruit vegetable, making significant contributions to human nutrition throughout the world for their content of sugars, acids, vitamins, minerals, lycopene and other carotenoids, among other constituents (Toor and Savage, 2006).

Tomato like most fruits and vegetables are classified as perishables, because of its tendency to rapidly deteriorate soon after harvesting (Frazier and Westholf, 1986). Due to improper storage there is a loss in fresh weight of about 10-15%. It is susceptible to tremendous chemical changes when separated from its parent plant until spoilage finally sets in as a result of attack from bacteria, yeast, mold and viruses (Fiddler, 1982). Being a climacteric and perishable vegetable makes

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tomatoes to have a very short life span, usually 2-3 weeks. Thus, an increase in the storage life and improvement of tomato fruit quality is really desirable.
Though proper harvesting time determines the nutritional contents as well as storage durability of the fruit, suitable harvesting stage (maturity) of the fruit and optimum ripening conditions to have the best quality and longer storage of tomato has not completely been recognized for developing countries (Moneruzzaman et al. 2009). Improper harvesting stage, ripening conditions and lack of suitable storage facilities cause a glut during the peak harvesting period and a large portion of yield is sold very cheap. Kitinoja and Gorny (2009) reported that, an estimated loss of perishables in developing countries is in the range of 20% to 50% and it is estimated in the range of 20-40% in Ethiopia (Lemma, 2001). High loss occurs at field during harvest, transport and marketing.
Maintenance of low temperature and high relative humidity is a great problem in a tropical country like Ethiopia. Though refrigerated cool stores are the best method of preserving fruits and vegetables they are expensive to buy and run for small scale farmers and retailers. In addition they need electric power and are not eco-friendly. Consequently, in developing countries like Ethiopia there is an interest in simple low-cost alternatives and environmentally friendly technologies, like pot in pot, zero energy cooling and other simple evaporative cooling storages. As these technologies are simple, cheap and do not require any external power supply. With these, the objective of current study is to determine the effect of different storage methods and ripening stages on qualitative, quantitative loss and shelf life of tomato fruit.

2. MATERIAL AND METHODS

2.1. Experimental Materials

Fresh Chali variety tomatoes brought from Melkassa Agricultural Research Centre on the second day of harvest. Fruits with uniform size, free from damage and fungal infection were washed and air dried. Six ZECC with dimensions (L×W×H) of the outer and inner brick walls 200 cm × 200 cm × 100 cm and 100 cm × 100 cm × 100cm respectively were constructed. The 25 cm gap between the outer and inner wall was filled with sand. Six pots in pot storages of 40 cm height and a wall thickness of 12mm were used. The diameters of small pots are 25 cm and 60 cm for the larger pots. The small pot was placed inside another slightly bigger pot leaving a space of 7 cm and filled with river sand. Six desert coolers were constructed from locally available wood (Eucalyptus sticks) and totally covered with jut sacks. The dimensions (L×W×H) of the passive cooler were 100 cm × 100 cm × 60 cm. The three storages constructed under shade and under same conditions. For tomatoes stored under room temperature in box made of wood was considered as the control.

2.2. Experimental Design

The experiment was a 4x2 factorial design arranged in completely randomized design (CRD). It consists of four storage methods: control (**C**=storage at room temperature), **S1**= storage zero energy cooling, **S2**= storage with pot in pot and **S3**= storage with desert cooler and two ripening stage (Breaker Stage: yellow, pink or red is 10% or less of the tomato surface and Light Red stage: Pinkish-red or red color shows on over 60% but red color covers not more than 90% of the tomato surface) with a total of three replications.

2.3. Data collected

Temperature and Relative Humidity (RH)

The inside storages temperature and RH were recorded two times per day (in the morning and in the afternoon) every day at the same time. Hygrometer (PWT -101, UK) was used to record both temperature and RH. Room temperature and RH of the storage was also recorded two times per day to compare the difference with the evaporative coolers.

Fruit Firmness

Fruit firmness was evaluated by using digital penetrometer (TA-XT Plus, UK). From each treatment two fruits were used at a time and average result was used for the analysis.

Physiological Weight Loss (PWL)

The weight loss of tomato fruit sample was calculated as the percentage of the initial day fruit weight. The following formula used to compute physiological weight loss:

Physiological weigh loss=

$$\frac{Intial\ weight - Final\ weight}{Initial\ weight}$$

Decay or Rotting

Decay or rotting was determined by visual observation. Development of spots on the fruit and softening and rotting of the fruits was recorded.

Shelf life

The shelf life of tomatoes were determined by counting the days required to attain the last stage of ripening, but up to the stage when fruit remains still acceptable for marketing (Monerzumma et al 2009).

pH, Titratable Acidity, Total Soluble Solid

The pH of tomatoes was determined by the method described by Rangana (1979). Tomatoes were crushed and made into juice. By using standardized pH meter (CP-505) the values of all samples were recorded every five days. Titratable acidity (TTA) of the samples was determined by titrating 5-ml of juice with 0.1 N sodium hydroxide, using phenolphthalein as an indicator. Total soluble solids (TSS) content of the fruit was determined by using refractometer (Bellingham + Stanley 45-2, UK). Homogenous sample was prepared by blending the tomato flesh in blender. The sample was thoroughly mixed and a few drops were taken on prism of refractometer and direct reading was taken by reading the scale in meter.

Lycopene, β-carotene, and Chlorophyll A and B contents

Both the carotenoid and Chlorophyll content of the fruit were analyzed according to method describe by Nippon, (1992). Tomatoes were crushed and well homogenized, and then one gram of the sample (tomato pulp) was taken. All pigments in the sample were extracted by acetone and hexane by the ratio of 4:6. The samples were well homogenized by using homogenizer to extract all pigments in the fruit. Then samples placed to separatory funnel and allowed to stand for about 15 minutes so that there is a clear layer between the pigments and the extractors (acetone and hexane). Finally the pigments were collected to spectrophotometer's (T80 UV/VIS, UK) cuvette and measurement of absorbance at 663nm, 645nm, 505nm and 453nm were done.

Statistical Analysis

Collected data were subjected to Analysis of Variance (ANOVA) using SAS version9.2 computer software. Fisher's Least Significance Difference (LSD) was used to establish the multiple comparisons of mean values. Mean values were considered at 5% significance level ($p < 0.05$).

3. RESULTS AND DISCUTION

3.1. Temperature and Relative Humidity

Temperature and relative humidity are major factor that affect the shelf life of perishables. Generally on current study the evaporative cooler storages decreased inside storage temperature and increased the relative humidity as compared to control throughout the storage period. The low inside temperature of the evaporative coolers maintained based on the principles of passive evaporative cooling mechanism. ZECC reduced the inside storage temperature to 21.37 ^{0}C, pot in pot storage to 20.03 ^{0}C, and desert cooler to 21.02 ^{0}C; while the average room temperature was 26.01 ^{0}C. The average inside storage relative humidity for ZECC was 87.86%, 88.47% for pot in pot storage and 84.74% for desert cooler storages; while the average room relative humidity was 54.22%. Figure 1 clearly shows that there is difference in maintaining the storage temperature, while average best result was recorded for pot in pot storages.

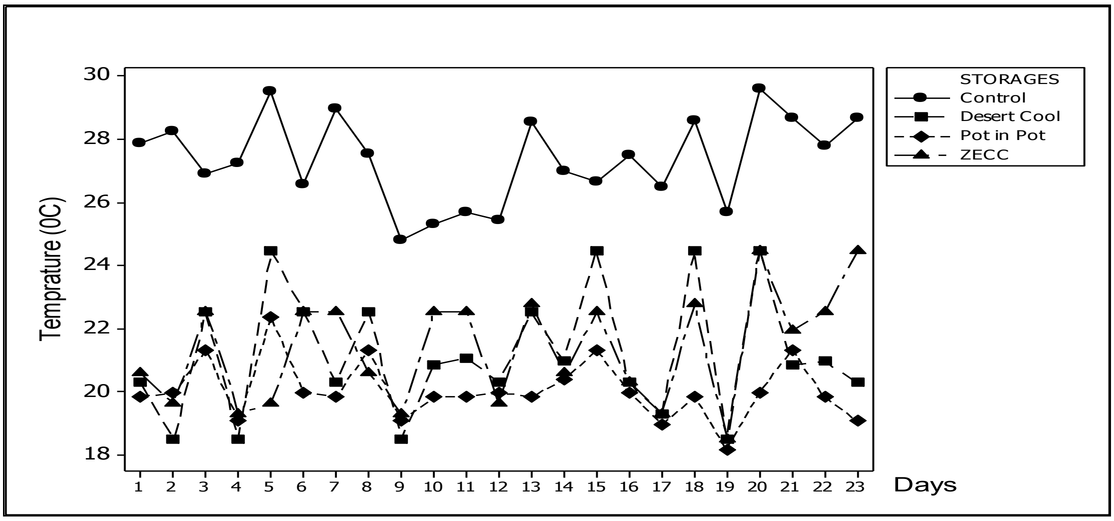

Fig. 1. Average daily temperature (^{0}C) of ZECC, pot in pot, desert cooler and control for 23 days

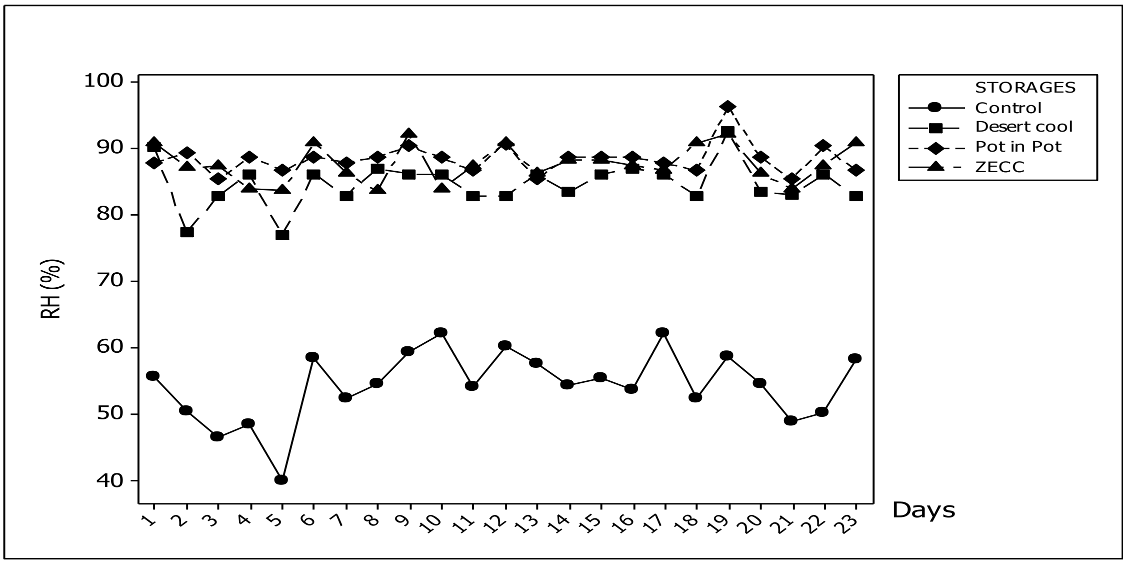

Fig. 2. Daily relative humidity (%) of ZECC, pot in pot, desert cooler and control for 23 days

Susanta and Emirutus, (2012) supported that ZECC reduce the inside storage temperature to 10-15 ^{0}C. Islam *et al*., 2012 also reported zero energy cooling chambers reduce the storage temperature to 13.8^{0}C when frequently watered and reduce to 25.4^{0}C when there is no watering. Ponia et al. (2011) also confirms that desert coolers reduce the inside storage temperature up to 25.8 ^{0}C, while the outside was 37.5 ^{0}C.

Islam et al. (2012) also reported the average inside storage relative humidity values of ZECC with water spray and no water spray is 91.7% and 64.1 % respectively, both under shade condition. Murugan et al. (2011) reported that the earthen pot cool chamber increase the inside storage relative humidity to 70%. Workneh and Woldetsadik, (2004) also reported cool chambers maintain high humidity of about 95%. Ponia et al. (2011) also confirmed the same result that desert coolers increased the inside storage relative humidity to 55% while the outside was 18%. Figure 2 is representing clearly the relative humidity in all storage conditions of the storage periods.

3.2. Fruit firmness

Desert cooler storage retained higher firmness (6.142N) followed by ZECC (5.902N), and less firmness was recorded for tomatoes stored at ambient temperature (4.757N) at breaker ripening stage after 10 days of storage. Highest firmness was retained for tomatoes at light red stage stored inside pot in pot (5.598N) followed by desert cooler (5.386N) and least firmness was recorded for tomatoes stored at room temperature (3.585N) and inside ZECC (3.585N) after 10 days of storage.

The stage of ripening during harvest has direct effect on retaining firmness of tomato fruit. Tomatoes are less firm as they get ripe, the result in Table 1 shows tomatoes at breaker stages are firmer than tomatoes at light red stages during the storage period irrespective of the storage methods. The mean fruit firmness was the highest (7.90 N) at breaker stage, which declined 6.95 and 6.3 N in fruit harvested at yellow stage and pink mature stages. As the fruit get to red ripe stage it involves in cell wall breakdown, so that the fruit gets less firm (Wakabayashi, 2000). It could also be observed as in Kitinoja and Kader (2003) that warmer fruits (20°C) were less firm compared to the colder ones (12°C) during the storage period.

The fruit firmness, i.e. softening of the fruits is an important quality attribute that influences consumer's acceptance (Chang- Hai et al. 2006). Islam et al. (2012) reported that it is significantly affected by storage time and temperature. Ball (1997) also suggested that a postharvest change in firmness can occur due to loss of moisture through transpiration, as well as enzymatic changes. In addition, Paul et al. (1999) stated that, during tomato fruit ripening the hemicelluloses and pectin become more soluble, which resulted in disruption and loosening of the cell walls which makes the fruit soft.

3.3. Physiological weight loss (PWL)

Weight loss of tomatoes increased progressively during the storage period, however the rate of weight loss recorded minimum for tomatoes stored inside the evaporative coolers. The mean weight loss was least in tomatoes stored inside pot in pot storages (2.58%) followed by ZECC (8.97%) and desert cooler (9.84%); while highest value recorded for control (15.45%) after 10 days all at breaker ripening stage. The maximum weight loss was seen on tomatoes stored at room temperature (18.36%), and followed by ZECC storage (12.58%) and Desert cooler (12.37%), while the minimum weight loss was seen on tomatoes stored inside pot in pot storage (4.08%) after 10 days.

The intensity of weight loss during storage depends on maturity stage (Moneruzzaman et al. 2009).

Table 1: Firmness and Weight loss mean of tomato fruit stored under different storage methods and ripening stages for 10 days

Treatment combinations	**Firmness (N)**			**Weight Loss%**	
	Day 1	**Day 5**	**Day 10**	**Day 5**	**Day 10**
CR_1	6.88^a	5.20^e	4.75^e	11.34^b	15.44^b
CR_2	5.80^b	4.82^f	3.58^f	13.35^a	18.36^a
S_1R_1	6.80^a	6.30^b	5.90^b	6.10^f	8.97^f
S_1R_2	5.70^c	4.92^f	3.58^f	9.20^d	12.58^c
S_2R_1	6.84^a	6.30^c	5.47^{cd}	1.90^h	2.58^h
S_2R_2	5.78^{bc}	6.10^c	5.59^c	3.04^g	4.08^g
S_3R_1	6.88^a	6.51^a	6.14^a	7.27^e	9.84^e
S_3R_2	5.78^{bc}	5.87^d	5.38^d	10.27^c	12.37^d
LSD (5%)	**0.096**	**0.095**	**0.136**	**0.151**	**0.167**
CV (%)	**0.738**	**0.984**	**1.370**	**1.108**	**0.906**

Means with the same letter (a, b, c.) within the column are not significantly different

Where: CR_1 = control breaker stage, CR_2= control light red stage, S_1R_1= ZECC breaker stage, S_1R_2= ZECC light red stage, S_2R_1= pot in pot breaker stage, S_2R_2= pot in pot light red stage, S_3R_1= desert cooler breaker stage, S_3R_2= desert cooler light red stage, LSD= Least Significance Difference, and CV= Coefficient of Variation.

Weight loss of fresh tomatoes is primarily due to transpiration and respiration. Cold stored fruits have low weight loss due to temperature effects on vapor pressure difference and increased water retention.

Parvez and Tetsuo (2012) reported that there is a significant difference in PWL of tomato and eggplant stored in the ZECC (at average temperature of 15°C) and at room temperature (average of 25°C). Tomato stored outside the ZECC showed PWL of 5.4% after seven days, while tomato stored inside the ZECC showed 5.35% after 16 days. Rab et al. (2013) reported that the weight loss of tomato fruit is significantly affected by harvest stages. The mean weight loss was the least (9.133%) in fruits harvested at yellow stage of maturity, which was statistically at average with breaker mature stage (9.833%) but significantly lower than fruit harvested at pink mature stage (11.167%).

3.4. Decay Percentage and Shelf Life

In present study it is clearly identified that decay percentage increased with the storage time for all storage methods and ripening stages. For all evaporative cooler storage methods decay of the fruit starts at day 9, while decay starts early at day 6 for tomatoes stored at ambient temperature. The total decay percentage of tomato stored at room temperature, breaker stage was 16.66% on day 6, and then raised to 70% on day 12. Total deterioration of the fruit was recorded on day 15. Tomatoes at light red stage showed rapid deterioration, which was 36.66% on day 6 and soon raised to 70% on day 9, and the fruit totally deteriorated by day 12. However the total decay of tomato fruit started on day 9 for most of the fruit stored inside the evaporative coolers.

Although the percentage of deterioration was high at the initial days it got faster with the storage period and was recorded faster for tomatoes at light red stage compared with tomatoes at breaker ripening stage.

The main cause for fruit deterioration is fruit ripening and ethylene production. High temperature fastens the rate of fruit ripening, thus fastens the rate of fruit deterioration. The evaporative coolers reduce the inside storage temperature which slows the rate of fruit ripening and ethylene production. These have a direct effect on extension of shelf life of the fruit.

This finding is in accordance with the work done by Moneruzzaman et al. (2009) who reported that storage of tomato at low temperature and high relative humidity decrease the early deterioration percentage. Table 2 is representing the clear data about decay % in all the storages.

3.5. pH, Total Titratable Acidity, and Total Soluble Solid Content

The changes in pH, TTA and TSS of the tomatoes stored inside evaporative coolers and at room temperature are shown in table 3. In general, pH of the tomatoes increased with the advancement of fruit ripening. Since acidity of the fruits is due to various organic acids that are consumed during respiration (Albertini*et al*., 2006), the acidity thus decreased with advancing maturity or increasing storage duration with a corresponding increase in fruit pH (Moneruzzaman*et al*., 2009).

Highest pH value was recorded for tomatoes stored inside ZECC (4.79) followed by room temperature storage (4.58), and least value was recorded for pot in pot storage method (4.10) after 10 days all at light red ripening stage. Tomatoes harvested at breaker stage the maximum pH value was recorded for control (4.49) followed by ZECC storage (4.39), and the least pH value was recorded for pot in pot storage (3.99) after 10 days.

Islam (2012) confirm the same result that, after 17 days storage of tomatoes at ZECC the pH value slowly increased ranging from 3.97 to 4.38. Nirupama et al. (2010) reported that pH of the fruit pulp treated with postharvest treatments was found relatively in lesser range of pH (i.e. 4.20 to 4.26) as compared to the fruits of control set having higher pH (4.33) after 10 days of their storage. Okoli and Sanni (2012) also reported that pH value of tomato increased after 14 days of storage time.

Table 2: Decay percentage of tomato fruit stored under different storage methods and ripening stages

Treatment combinations	Decay (%)						Shelf life (Days)
	Day 6	**Day 9**	**Day 12**	**Day 15**	**Day 18**	**Day 21**	
CR1	**16.66**(0.0016)^{b}	**33.33**(0.0033)^{b}	**70.00**(0.0078)^{b}	**100**(0.0157)^{a}	**100**(0.0157)^{a}	**100**(0.0157)^{a}	**14**
CR2	**36.66**(0.0037)^{a}	**70.00**(0.0078)^{a}	**100**(0.0157)^{a}	**100**(0.0157)^{a}	**100**(0.0157)^{a}	**100**(0.0157)^{a}	**11**
S1R1	0.0000^{c}	**3.33**(0.0013)^{c}	**13.33**(0.0013)^{de}	**33.33**(0.0033)^{cd}	**70**(0.0078)^{bc}	**100**(0.0157)^{a}	**19**
S1R2	0.0000^{c}	**13.33**(0.0013)^{c}	**36.66**(0.0037)^{c}	**70.00**(0.0078)^{a}	**100**(0.0157)^{a}	**100**(0.0157)^{a}	**14**
S2R1	0.0000^{c}	0.0000^{c}	0.0000^{e}	**15.00**(0.0015)^{de}	**40.00**(0.0041)^{e}	**75**(0.0085)^{c}	**24**
S2R2	0.0000^{c}	**3.33**(0.0003)^{c}	**10.00**(0.0010)^{de}	**40.00**(0.0041)^{c}	**63.33**(0.0068)^{c}	**100**(0.0157)^{a}	**21**
S3R1	0.0000^{c}	**10.00**(0.0010)^{c}	**13.33**(0.00130^{de}	**23.33**(0.0023)^{cde}	**43.33**(0.0044)^{de}	**70.00**(0.0078)^{c}	**23**
S3R2	0.0000^{c}	**6.67**(0.0009)^{c}	**26.66**(0.0026)^{cd}	**40.00**(0.0041)^{c}	**73.33**(0.0083)^{b}	**100**(0.0157)^{a}	**21**
LSD (5%)	**0.0005**	**0.0019**	**0.0015**	**0.0018**	**0.0010**	**0.0009**	
CV	**10.92**	**10.22**	**9.58**	**8.86**	**5.58**	**5.25**	

Table 3: pH of tomato fruit stored under different storage methods and ripening stages for 10 days

Treatment combinations	**pH**		
	Day 1	**Day 5**	**Day 10**
CR1	3.87^{b}	4.35^{b}	4.49^{bc}
CR2	4.15^{a}	4.26^{c}	4.58^{b}
S1R1	3.87^{b}	4.27^{c}	4.39^{cd}
S1R2	4.19^{a}	4.62^{a}	4.79^{a}
S2R1	3.85^{b}	3.90^{f}	3.99^{e}
S2R2	**4.17^{a}**	**3.98^{e}**	**4.10^{e}**
S3R1	3.90^{b}	4.03^{e}	4.12^{e}
S3R2	4.18^{a}	4.13^{d}	4.27^{d}
LSD (5%)	**0.053**	**0.055**	**0.139**
CV (%)	**0.752**	**0.752**	**1.831**

Means with the same letter (a, b, c.) within the column are not significantly different

On day 10, effect due to storage methods and ripening stages shows a highly significance difference at $p < 0.05$. The total titratable acidity was highest on tomatoes stored inside pot in pot storage (0.23%) and desert cooler (0.23%) followed by ZECC storage (0.20%), while minimum TTA was recorded for control (0.11%) after 10 days all at breaker ripening stage. In general tomatoes harvested at light red ripening stage showed higher total titratable acidity percentage as compared to ambient temperature storage. Titratable acidity of fruits is an important factor in determination of fruit maturity. Titratable acidity gives the total or potential acidity, rather than indicating the number of free protons in any particular sample. It is a measure of all aggregate acids and sum of all volatile and fixed acids (Naik et al. 1993). In general TTA decreased with advancement in maturity and during the storage period. However it was rapid on tomatoes stored at room temperature as compared to those stored inside evaporative coolers. The mean total soluble solid content of tomato stored at room temperature (5.03 ^{0}Brix) and inside desert cooler (5.03 ^{0}Brix) was higher than tomatoes stored inside pot in pot (4.47 ^{0}Brix) and the ZECC (4.70 ^{0}Brix) after 10 days of storage all for tomatoes at light red ripening stage. Tomatoes at breaker stage showed high record of TSS for those stored inside desert coolers (4.73 ^{0}Brix) followed by ZECC (4.23 ^{0}Brix), and least TSS content was recorded for tomatoes stored inside pot in pot (3.90 ^{0}Brix) after 10 days of storage. Results of the titratable acidity and total soluble solid contents are presented in table 4.

The total soluble solids acts as a rough index of the amount of sugars present in fruits. It is the amount of sugar and soluble minerals present in fruits and vegetables. Generally TSS increased with advancement in maturity and during storage period.

During ripening the degradation of cell wall polysaccharides (hemicellulose and pectin) occurred which led to the release of oligosaccharides (simple sugars) (Dumville and Fry, 2000). Azzolini (2002) also confirm TSS content depends on the maturity stage, and it generally increased progressively during the ripening process due to the hydrolysis of polysaccharides to maintain the respiration rate.

Islam et al. (2012) reported that the TSS of tomatoes increased from 4.20 to 5.00 after 7 days of storage at room temperature and from 4.10 to 4.90% at ZECC after 17 days of storage. Rab*et al.* (2013) reported that the mean TSS content in tomatoes without pre-cooling was increased by 8.66% while the pre-cooled fruit increased by 8.33%. The means for harvesting stages revealed that total soluble solids were the highest in fruits harvested at pink mature stage (8.86%) as compared to yellow and breaker stages (8.75 and 7.91% respectively).

3.6. Lycopene, β-Carotene, Chlorophyll A and B

After 10 days of storage maximum lycopene content was recorded for tomatoes stored at room temperature (5.70mg/100mL) followed by desert cooler (4.214 mg/100mL) and ZECC (3.33 mg/100mL), while minimum Lycopene was recorded for tomatoes stored inside pot in pot (2.96 mg/100mL) all at breaker ripening stage. For tomatoes at light red ripening stage, maximum Lycopene content was recorded for tomatoes stored at room temperature (5.51mg/mL) and ZECC (5.50 mg/100mL) followed by desert cooler (4.71 mg/100mL) and minimum value recorded for tomatoes stored inside the pot in pot (4.47) all at light red stage.

Generally Lycopene increased with advancement in maturity and during storage period. This is because of the pigments that changed during ripening is characterized by a loss of chlorophyll and rapid accumulation of carotenoids, particularly lycopene due to conversion of chloroplasts to Chromoplasts (Hobson and Davies, 1971).

Table 4: Lycopene and β -Carotene content of tomato fruit stored under different storage methods and ripening stages for 10 days

Treatment combinations	Lycopene (mg/100mL)			β-Carotene (mg/100mL)		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
CR1	2.38^c	4.92^a	5.70^a	0.96^e	4.40^a	5.23^b
CR2	3.67^a	4.50^b	5.51^a	1.08^b	4.54^a	5.99^a
S1R1	2.34^c	2.60^f	3.33^e	0.99^{ed}	1.24^d	2.90^{de}
S1R2	3.49^b	4.68^b	5.50^a	1.04^{bc}	3.09^b	4.44^c
S2R1	2.37^c	2.63^f	2.93^f	0.32^d	1.55^d	2.44^e
S2R2	3.61^{ab}	4.07^c	4.47^c	1.16^a	3.31^b	4.24^c
S3R1	2.27^c	3.63^e	4.21^d	0.52^a	1.26^d	2.53^e
S3R2	3.52^b	3.88^d	4.71^b	1.01^{cd}	2.22^c	3.38^d
LSD (5%)	**0.119**	**0.185**	**0.211**	**0.040**	**0.376**	**0.580**
CV (%)	**2.551**	**2.745**	**2.652**	**2.232**	**7.952**	**8.511**

Means with the same letter (a, b, c.) within the column are not significantly different

Radvevicius et al. (2009) reported that lycopene in all the investigated tomato varieties during fruit ripening significantly increased. Syamal (1991) also observed an increasing trend in lycopene content of different tomato cultivars which were harvested at pink stage. β-Carotene showed a significant increment with the storage period irrespective of the ripening stage and storage methods. The development of the carotenoid is rapid in tomatoes stored at room temperature, while it was observed to be slow for tomatoes stored in evaporative coolers. After 10 days of storage maximum amount of β-Carotene was recorded in tomatoes stored at room temperature (5.24mg/100mL) followed by ZECC (2.90 mg/100mL) and minim β-Carotene content was recorded in tomatoes stored inside desert cooler (2.57 mg/100mL) and pot in pot storage (2.44 mg/100mL) all at breaker ripening stage. For tomatoes at light red ripening stage, maximum β-Carotene content was recorded for tomatoes stored at room temperature (5.99mg/mL) followed by ZECC (5.44 mg/100mL) and pot in pot (4.24 mg/100mL), while the minimum value was recorded for tomatoes stored inside the desert cooler storage method (3.38 mg/100mL) all at light red ripening stage. Data about Lycopene and β-Carotene is depicted in table 5.

Both on day 5 and day 10 effects due to ripening stages and storage methods showed a highly significant difference for chlorophyll A and B. Table 6 is clearly an evident that there is a decrease of both Chlorophyll A and B during the storage period. However, a fast decrement in both Chlorophyll A and B content was observed in tomatoes stored at room temperature as compared to tomatoes stored inside the evaporative coolers. This is because chlorophyll evidently degraded enzymatically during tomato ripening. The change of chlorophyll pigment content from fruit and vegetables have a great importance for their color variation during the maturation phase.

The work done by Kozukue and Mendel (2003)also supports this idea, where they reported that both chlorophyll A and B content decreased by about 25% to 75% during different ripening stages which then dropped precipitously to a value near zero during the final stage. The ratio of chlorophyll A to B also declined with the stage of ripening.

4. CONCLUSIONS

Results of the study showed that all the three evaporative coolers maintain quality and extend the shelf life of tomato as compared to storage at room temperature. ZECC extended for 19 days, pot in pot 24 days and desert cooler for 23 days tomatoes harvested at light stage while it was only 4 days for storage at room temperature. Generally, evaporative coolers decrease the storage temperature as compared to room temperature storage.

Table 5: Chlorophyll A and B content of tomato fruit stored under different storage methods and ripening stages

Treatment combinations	Chlorophyll A (mg/L)			Chlorophyll B (mg/L)		
	Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
CR1	0.76^{ab}	0.43^{d}	0.21^{f}	1.24^{a}	0.63^{dc}	0.33^{e}
CR2	0.54^{c}	0.25^{f}	0.17^{g}	0.95^{c}	0.57^{d}	0.30^{f}
S1R1	0.75^{c}	0.52^{c}	0.47^{c}	1.18^{ab}	1.03^{a}	0.81^{a}
S1R2	0.57^{c}	0.56^{c}	0.33^{e}	0.92^{c}	5.67^{d}	3.25^{b}
S2R1	0.78^{a}	0.71^{a}	0.68^{a}	1.14^{b}	0.85^{b}	0.67^{b}
S2R2	0.57^{c}	0.53^{c}	0.45^{cd}	0.90^{c}	0.85^{b}	0.62^{c}
S3R1	0.78^{a}	0.63^{b}	0.53^{b}	1.15^{b}	0.81^{c}	0.60^{c}
S3R2	0.57^{c}	0.54^{c}	0.42^{d}	0.88^{c}	0.60^{cd}	0.33^{e}
LSD (5%)	**0.0263**	**0.035**	**0.031**	**0.080**	**0.067**	**0.028**
CV (%)	**2.266**	**3.854**	**4.378**	**4.393**	**5.184**	**3.229**

Means with the same letter (a, b, c.) within the column are not significantly different

The average room temperature throughout the storage period was 26.43 ^{0}C while it was 21.37 ^{0}C, 20.03 ^{0}C, and 21.02 ^{0}C for Zero energy cooling chambers, pot in pot storage and passive/desert cooler storages respectively.

The evaporative coolers increased the inside storage relative humidity as compared to control. While the average relative humidity throughout the storage period was 54.22% for ambient, the average relative humidity were 87.86, 88.47, and 84.74% for ZECC, pot in pot storage and desert cooler respectively. The evaporative coolers maintain a better quality in the physic chemical characteristics of the fruit. Decay percentage was also fastest for tomatoes stored at room temperature as compared to the evaporative coolers. Firmness of the tomatoes was better until the final day of the storage inside the evaporative coolers as compared to the ambient storage. Weight loss was highest for tomatoes stored at room temperature and was lowest for tomatoes stored inside the evaporative coolers.

In general weight loss percentage, deterioration percentage, Total soluble solid, Lycopene and β-carotene content increased with the storage period, but were faster in tomatoes stored at room temperature as compared to the evaporative coolers. Titratable acidity, fruit firmness, Chlorophyll A and B content decreased with the storage times which were faster on tomatoes stored at room temperature. Tomatoes harvested at light red stage ripening stage have a shorter shelf life as compared to those harvested at breaker ripening stage.

Tomato is an important part of the human food diet and nutrition. Conservation of nutritional content of tomatoes during postharvest handling and storage is therefore important which help in protecting chronic diseases such as coronary heart diseases and cancer. The current study provides strong evidence that postharvest storage temperature and relative humidity affects fresh tomato characteristics such as firmness, carotenoids content and physiological weight loss. The evaporative coolers give an alternative approach to mechanical refrigerator for prolonging postharvest shelf life and maintain quality of tomatoes. However, all the above conclusions were derived from results of studies conducted within one time. So, further studies on storage methods at different ripening stages (as tomato has six stages of ripening) in different months and locations should be conduct on tomatoes in order to give confirmative results. In addition experiment on different perishables on these storages should also be conduct to increase usage of the storage methods.

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