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Comparative Assessment of Solar Refrigerated and Evaporative Cooled (SREC) Structure for On-Farm Storage of Tomatoes

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ABSTRACT

Tomato is an important horticultural crop that is grown worldwide. However tomato is a perishable fruit that needs storage facilities to retard the ripening after harvest, to increase shelf life. Solar refrigerated and evaporative cooled (SREC) structure has developed at the Indian Agricultural Research Institute (IARI) in New Delhi, is an on-farm, off-grid, cold storage option for perishable horticultural produce. SREC storage structure uses an evaporative cooling with solar refrigeration system that provides small holder farmers affordable access to cold storage facility without electrical connection to keep harvested farm produce cool and fresh in farmer's field. Therefore study of comparative assessment of SREC structure for on-farm storage of tomatoes was conducted. Experiments were conducted to determine and compare interaction of operational parameters temperature and relative humidity and crop parameters weight loss, color change, firmness of tomatoes stored in four storage conditions SREC, EC (evaporative cooled), UL (uncooled laboratory), and REF (refrigerator). The temperature in SREC varied between 4 and 16 °C with relative humidity of 85–100% while UL ambient condition temperature varied between 10 and 35°C. Storage conditions affected the weight loss, color change, firmness of tomato significantly ($p<0.05$). Overall, the postharvest quality retention was better in SREC and REF as compared to EC and ambient condition.

Keywords Evaporative cooled, On-farm cold storage, Shelf life, Storability.

INTRODUCTION

Tomato is a vital vegetable crop grown in many countries all over the word ranked second to potato, widely cultivated in Asia, Europe, North and South America (Dorais *et al.* 2008, Garuba *et al.* 2018, Ayomide *et al.* 2019) Tomato fruit contain lycopene carotenoid having antioxidant properties, and ascorbic acid that are important constituents in a human diet (Luthria *et al.* 2006, Nour *et al.* 2013, Akhtar 2014). It contains bioflavonoids that help to combat cancer and are good for liver health. It is used for salads, cooked vegetable tomato paste, ketchup and sauce. It is an important cash crop through imports and exports and offers opportunities for entrepreneurs (Robinson and

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Kolavalli 2010). In order to maintain the freshness of tomatoes during storage a proper storage environment is required. There are several factors that affect tomatoes' freshness and shelf life during storage, such as temperature, relative humidity, storage time, respiration. The higher temperature leads to higher respiration rate which increases the rate of deterioration, resulting in a shorter shelf life of the product (Liberty *et al.* 2013). Temperature is directly related to the rate of respiration and metabolic activities in the fruit (Moretti *et al.* 2010). Their storage at higher temperature leads to weight loss, rotting, wilting, color change, flavors decay, and nutrients loss.

Reduce postharvest losses pose a significant challenge. Post-harvest fruit wastage has become a growing concern in developing countries. The farmers in India face limitations in storage options and access to basic cold storage. The situation is worse for smallholder farmers. Smallholder farmers in India have limited access to cold storage facilities because it is energy-intensive and expensive, requiring an initial capital investment of a large amount, and requiring a continuous supply of electricity, which is not readily available in many part of India. Solar energy is abundant, safe and environmentally friendly. Therefore, solar powered refrigeration systems have been receiving much attention as it is being eco-friendly and low cost. Solar refrigerated and evaporative cooled (SREC) structures developed at the Indian Agricultural Research Institute (IARI) in New Delhi. SREC structure is an on-farm, off-grid, cold storage option for perishable horticultural produce. SREC storage structure has used evaporative cooling in combination with a solar refrigeration system to keep harvested agricultural produce cool and fresh in the farmer's field. The SREC storage has a capacity of two tonnes of fruits and vegetables. This facility provides low-cost cold storage to smallholder farmers, even if they do not have access to electricity and improves their crop marketing control. Therefore, the study was conducted to study comparative assessment of solar refrigerated and evaporative cooled (SREC) structure for on-farm storage of tomatoes

MATERIALS AND METHODS

Experimental site : The study was conducted at the Division of Agricultural Engineering, Indian Agricultural Research Institute, New Delhi. Raw materials were bought in the morning hours from Azadpur mandi, New Delhi. Tomatoes were washed with clean water and air-dried at atmospheric temperature. Fresh, mature green at color turning stage, uniform size, without any fungal infection and mechanical injury were selected for the experiment.

Storage conditions : In this study, four different storages were used. (i) Solar-refrigerated evaporative-cooled (SREC), (ii) Evaporative-cooled (EC), (iii) Uncooled laboratory (UL) ambient condition, (iv) Household refrigerator (REF). The Solar-refrigerated evaporative-cooled storage structure with size (3 m × 3 m × 3 m). It has a storage capacity of up to 2 metric tons. For passive evaporative cooling it has wetted fabric over iron mesh walls. It includes autoclaved aerated concrete blocks (AAC) and styrofoam panels for insulation. For respiration a solar-powered, mini-split inverter air-conditioning unit is used. It also includes water-based thermal storage instead of batteries for night time cooling. The structure also includes an advanced solar sensor that balances the refrigeration demand with availability of solar energy. The SREC structure is unique among clean energy storage concepts. Evaporative cooled (EC) structure of capacity 2 tons was used as previously described (Chopra and Beaudry 2018). The household refrigerator (REF), (Samsung-275L) was used in the experimental study.

Evaluation of quality parameters

For tomato, weight loss, color change, firmness quality parameters are very important from consumer point of view. Therefore, these quality parameters changes were selected for experimental study. The objective was to understand the storage behavior of tomatoes within varying storage facilities and their comparative assessment for on farm storage of tomatoes.

Weight loss

Weight loss is one of the vital factors that determine the quality of stored agricultural produce. Observations of weight loss of stored tomato were monitored at three days intervals. The percent weight loss of the stored tomatoes was calculated by following equation (1).

$$\text{PLW (\%)} = \frac{\text{Initial mass} - \text{Final mass}}{\text{Initial mass}} \times 100 \quad \ldots\ldots (1)$$

Color changes

The attribute of color is widely acknowledged as a quality indicator for vegetables. Product colors can affect consumer acceptance after harvesting, as fruits continue to ripen. These measurements were taken with color difference meter (AMTAST colorimeter, 8 MM Digital Precise color analyzer) and color change is expressed as L*, a*, b* color values. Where lightness is defined by (L*), while the red/green value is defined by (a*) and the yellow/blue value by (b*). The colorimeter was calibrated with black and white calibration tiles given with the device prior to measurement. For color determination of each sample, measurements of color values were taken at three different points on each sample. The average of these values was then recorded for the study. The following equation (2) was used to calculate color difference values (ΔE) (Checmarev *et al.* 2017).

$$\text{Color change } (\Delta E) = \sqrt{\Delta L^{*2} + \Delta a^{*2}\, \Delta^{*2} + \Delta b^{*2}} \quad \ldots. (2)$$

Fruit firmness

A texture analyzer (TA-XTplus, Stable Micro Systems, Ltd, Surrey, UK) in compression mode with a 2-mm diameter cylindrical probe (SMS-P/2, Stable Micro Systems, Ltd, Surrey, UK) was used to determine tomato firmness. The greatest force recorded in a force–time curve acquired during the probe's compression of tomato was used to determine firmness. Tomato firmness was measured three times and the average values were reported for the study.

Data analysis

An analysis of experimental data were performed with the use of the statistical package SPSS. The data were analyzed using analysis of variance (ANOVA) and the least significant difference (LSD) method used for separation of means, subsequently followed by the Tukey significant difference test for comparisons of means.

RESULTS AND DISCUSSION

Temperature and RH profile of storages

The temperature profiles in the four storage structures, SREC, EC, UL and REF, were monitored over the duration of each experiment. The temperature profile at the time of tomato storage study represented in (Fig. 1). For a typical experimental run, tomato storage study during Oct-Nov 2020, the temperature in SREC varied between 4 to 16°C. REF storage temperature varied between 1.5 to 8.3°C. During the same period, the temperature profile in EC varied from 13 to 30°C, and the UL condition temperature varied between 10 to 35°C. Relative humidity trends at the time of tomato storage study is represented in (Fig. 2). This storage study was conducted in Oct-Nov 2020. The relative humidity range in the SREC was between 70 and 100 % and the relative humidity in the EC storage was between 70% and 100%. The relative humidity in the UL (ambient condition) varied between 55% and 100%, while the RH in REF was lowest and varied between 36% and 68%.

Weight loss : Water is a major component of fruits and vegetables, and it contributes to their overall weight. As the storage period increases weight loss occurs it leads to overall weight loss of the product. Weight loss of agricultural produce is affected by biotic and abiotic factors. Storage temperature is the main factor affecting weight loss. Mature green tomatoes stored in SREC structure had the lowest overall weight loss as compared to REF, EC and UL (ambient) storage conditions. Graph was plotted to understand the variability in weight loss of stored tomato with change in independent variables, different storage structure and days (Fig. 3).

After 21 days of storage period it was observed that weight loss occurred in UL (11.71%), EC (5.37 %), REF (3.25 %) and in SREC (2.24 %). If we compare SREC and REF storage condition REF has higher weight loss than SREC it's because lower relative humidity in REF than SREC. Higher relative humidity and low temperature reduces vapour pressure

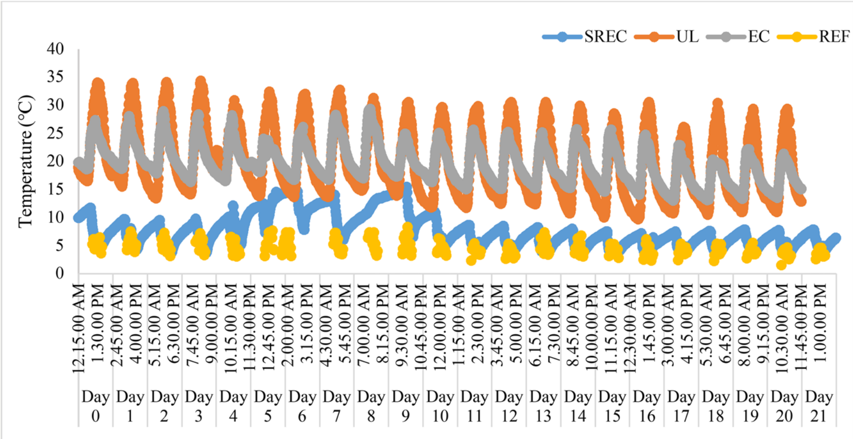

Fig. 1. Temperature profiles of SREC (solar refrigerated and evaporative cooled) structure, EC (evaporative cooled) structure, UL (uncooled laboratory) and REF (refrigerator) during storage study of tomato.

deficit which result less weight loss from fruits and vegetables. High relative humidity maintain a better post-harvest quality appearance, weight, taste, nutrition, firmness of stored tomatoes (Arah *et al.* 2015). Maintaining lower temperature and higher relative humidity in the storage structure is the best solution to avoid respiration and water loss during tomato storage (Ayomide *et al.* 2019). Analysis variance at 5% level of significance revealed a highly significant model for predicting weight loss. Result showed that the storage condition had a significant effect at ($p<0.05$) on weight loss. Correlation coefficient (R^2) for weight loss of tomato was found 0.99. It is also found that the effect of interaction of storage conditions with storage days had a significant effect on the weight loss of vegetables. The least square means for the effect of structure type*days (Table 1) shows significant difference in weight loss of tomatoes stored in SREC,

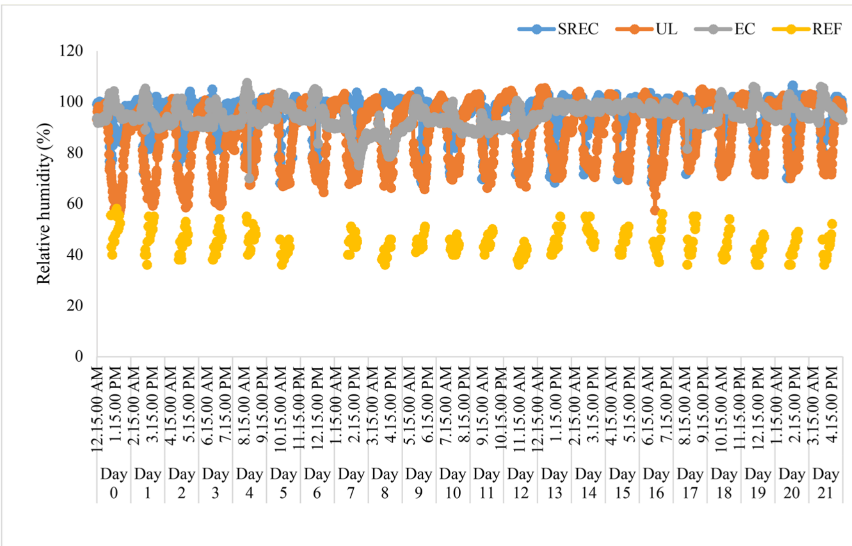

Fig. 2. Relative humidity profiles of SREC (solar refrigerated and evaporative cooled) structure, EC (evaporative cooled) structure, UL (uncooled laboratory) and REF (refrigerator) during storage study of tomato.

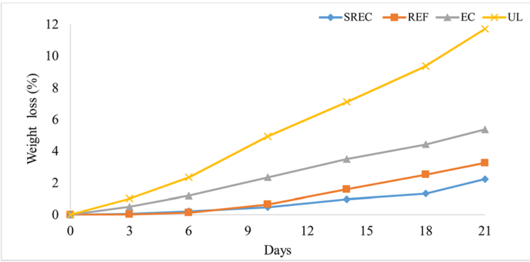

Fig. 3. Weight loss of tomatoes stored in, SREC (solar refrigerated and evaporative cooled) structure, EC (evaporative cooled) structure, UL (uncooled laboratory) and REF (refrigerator) during storage period.

REF, EC and UL storage conditions.

The main reasons for the greater loss in weight of tomatoes stored under ambient conditions is due to the dehydration of tomatoes during storage (Fagundes *et al.* 2015), sweat and respiration rate (Gharezi *et al.* 2012). In addition, ambient temperature conditions will increase the vapour pressure difference between the tomato and surrounding environmental conditions, which is one of the important factors causing the fast transmission of humidity from the tomato to the surrounding air (Tadesse *et al.* 2015). Under environmental storage conditions, lower relative humidity reduces the moisture content of fresh produce, resulting in weight loss (Ayomide *et al.* 2019). This finding is in line with the findings of a previous study (Park *et al.* 2018). They also discovered that fresh tomatoes stored at 20°C lose more weight (7.18%) than tomatoes stored at 12°C (3.32%) or tomatoes stored at 8°C (1.91%) during a 20-day storage period.

Table 1. Comparison of least square means and significant difference test for observed means at ($p<0.05$) for weight loss of tomatoes stored in, SREC (solar refrigerated and evaporative cooled) structure, EC (evaporative cooled) structure, UL (uncooled laboratory) and REF (refrigerator) during storage period for respective storage day.

Storage condition	Weight loss with storage period in days						
	D_0	D_3	D_6	D_{10}	D_{14}	D_{18}	D_{21}
SREC	0.00^a	0.05^c	0.22^c	0.48^c	0.97^c	1.32^c	2.24^c
EC	0.00^a	0.50^b	1.20^b	2.35^b	3.51^b	4.43^b	5.37^b
UL	0.00^a	1.01^a	2.35^a	4.94^a	7.11^a	9.38^a	11.71^a
REF	0.00^a	0.02^c	0.13^c	0.65^c	1.60^c	2.52^c	3.25^c
Significance	ns	**	**	**	**	**	**

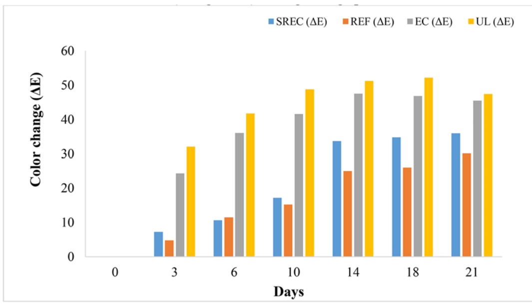

Fig. 4. Color change of tomatoes stored in, SREC (solar refrigerated and evaporative cooled) structure, EC (evaporative cooled) structure, UL (uncooled laboratory) and REF (refrigerator) during storage period.

Pinheiro *et al.* (2013) reported similar findings, about stored tomatoes. According to Javanmardi and Kubota (2006), tomatoes stored at higher temperatures lose more weight than tomatoes stored at lower temperatures. Therefore, it is not recommended to store tomato fruits at higher temperatures, as this can cause excessive weight loss.

Color changes

The color of fruits and vegetables is one of the main factor which is related to consumer attraction. It is a critical external characteristic for determining tomato ripeness and further shelf life of tomatoes, which is also a key factor in the consumer's purchasing decision. Marketability of tomatoes depends on its color stage. (Lim *et al.* 2010). Graphs were plotted to understand the variability in different color parameters such as lightness, redness and total color change of stored tomato in SREC, REF, EC and UL storage structure (Fig. 4).

It can be clearly seen from the results that during the storage process, the color of the stored tomatoes was significantly affected ($p<0.05$). Under all storage conditions, the lightness value (L*) and yellowness value (b*) of stored tomatoes decreased, while the redness value (a*) increased with the storage time. The decrease in L* value during storage indicates an increase in tomato darkness due to carotenoid synthesis (Yahia *et al.* 2007). The brightness reduction of tomatoes stored in UL is more obvious, followed by EC SREC and REF storage conditions. Under all storage conditions, the redness value increased

Table 2. Least square means and its comparison for color change (ΔE), L*, a* and b* value of tomatoes stored in, SREC (solar refrigerated and evaporative cooled) structure, EC (evaporative cooled) structure, UL (uncooled laboratory) and REF (refrigerator) during storage period for respective storage day.

Storage condition	Color change (ΔE) with storage period in days						
	D_0	D_3	D_6	D_{10}	D_{14}	D_{18}	D_{21}
SREC	0^{a}	7.21^{c}	10.66^{b}	17.14^{b}	33.68^{b}	34.74^{c}	35.99^{c}
EC	0^{a}	24.32^{b}	36.02^{a}	41.60^{a}	47.52^{a}	46.83^{b}	45.46^{b}
UL	0^{a}	32.04^{a}	41.76^{a}	48.77^{a}	51.26^{a}	52.19^{a}	47.39^{a}
REF	0^{a}	4.80^{c}	11.51^{b}	15.20^{b}	25.02^{b}	25.99^{c}	30.06^{c}
Significance	Ns	**	**	**	**	**	**
Storage condition (L value)	L* value with storage period in days						
	D_0	D_3	D_6	D_{10}	D_{14}	D_{18}	D_{21}
SREC	57.43^{a}	56.04^{a}	55.67^{a}	54.21^{a}	46.73^{a}	44.56^{ab}	45.98^{b}
EC	57.43^{a}	52.73^{ab}	46.53^{c}	44.46^{b}	39.34^{b}	40.01^{bc}	39.18^{a}
UL	57.43^{a}	49.29^{b}	42.23^{b}	41.15^{b}	38.30^{b}	38.30^{c}	38.40^{a}
REF	57.43^{a}	56.22^{a}	54.33^{a}	54.14^{a}	50.67^{a}	47.80^{a}	45.09^{b}
Significance	Ns	**	**	**	**	**	**
Storage condition (a-value)	a* value with storage period in days						
	D_0	D_3	D_6	D_{10}	D_{14}	D_{18}	D_{21}
SREC	-11.51^{a}	-7.72^{c}	-3.59^{b}	4.83^{b}	20.19^{b}	20.58^{c}	22.00^{b}
EC	-11.51^{a}	10.61^{b}	21.14^{a}	27.24^{a}	32.35^{a}	31.90^{b}	30.03^{a}
UL	-11.51^{a}	15.85^{a}	26.57^{a}	34.38^{a}	36.01^{a}	36.93^{a}	31.75^{a}
REF	-11.51^{a}	-8.62^{c}	-3.98^{b}	2.10^{b}	11.39^{b}	12.14^{d}	15.33^{c}
Significance	Ns	**	**	**	**	**	**
Storage condition (b-value)	b* value with storage period in days						
	D_0	D_3	D_6	D_{10}	D_{14}	D_{18}	D_{21}
SREC	20.91^{a}	26.88^{bc}	27.69^{a}	24.52^{a}	24.67^{a}	23.77^{a}	27.22^{a}
EC	20.91^{a}	29.66^{b}	31.41^{a}	28.05^{a}	18.92^{b}	19.07^{b}	18.21^{b}
UL	20.91^{a}	35.37^{a}	28.67^{a}	23.12^{a}	19.12^{b}	17.62^{b}	17.78^{b}
REF	20.91^{a}	24.39^{c}	28.00^{a}	26.58^{a}	28.19^{a}	25.44^{a}	26.40^{a}
Significance	Ns	**	ns	ns	**	**	**

significantly ($p<0.05$). Red (value*) represents the transformation of a green tomato into a red one as it ripens. Therefore, an increase in the a* value indicates that the fruit becomes redder with storage. Under all storage conditions, the total color difference (ΔE) combines the changes of the three color attributes (L*, a* and b*) and increases with the storage time (Table 2). But compared with SREC and REF storage, this increase is more in EC and UL storage conditions. After 15 days of storage, the ΔE values of tomatoes under storage conditions REF, SREC, EC and UL storage conditions were observed to be 25.99, 37.75, 46.83 and 52.19 respectively. The big difference in color change was found in the first 0-10 days. The rate of color change was slowed when a tomato was harvested and stored at a lower temperature.

Analysis variance at 5% level of significance indicated that there was a significant difference on the color change, L*, a* and b* values of stored tomatoes under different storage conditions. Analysis of variances indicated that the number of days spent in storage had a substantial impact on the color change, L*, a* and b* values of stored tomatoes. It is also found that effect of interaction of storage condition with storage days had significant effect at level ($p<0.05$) on the color change, L* a*, b* values of stored tomatoes. Least square means for effect of structure type*days shows significant difference on color change, L* a*, b* values of tomatoes. Correla-

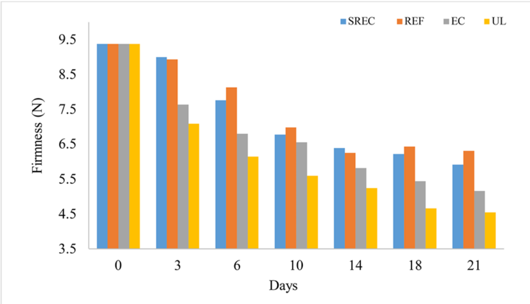

Fig. 5. Firmness of tomatoes stored in, SREC (solar refrigerated and evaporative cooled) structure, EC (evaporative cooled) structure, UL (uncooled laboratory) and REF (refrigerator) during storage period.

tion coefficient (R^2) for color change of tomato was found 0.98 and for L*, a* and b* tomatoes were found 0.97, 0.98 and 0.94 respectively.

The a * value changes from green (-) to red (+) color, especially at higher temperature storage structure, is primarily due to the breakdown of chlorophyll, pigment synthesis during ripening (Tigist *et al.* 2013, Kim *et al.* 2019) and ethylene biosynthesis (Hatami *et al.* 2013) assist in development of red color (Weingerl and Unuk 2015). This has also been recorded for tomatoes that have been preserved for 7 and 14 days and then placed in ripe tomatoes for 20 days at 20°C (Park *et al.* 2018). Munhuewyi (2012) has demonstrated that storing tomatoes at room temperature can provide perfect circumstances for ripening, resulting in an increase in the red value (a*) when compared to low temperature storage. Zou *et al.* (2018) mentioned that cherry tomatoes stored at 25°C have a higher red development rate than after 28 days of storage at 10 °C and 4°C. Pinheiro *et al.* (2013) observed a significant increase in a* value ($p < 0.05$) and a significant decrease in L* value ($p < 0.05$) during the storage of at all temperatures (2°C, 5°C and 20°C). Investigated in the study. However, a delay in the development of red was observed during storage at 2°C and 5°C. Islam *et al.* (2012) demonstrated the same trends for tomato fruits L*, a* and b* values stored at ambient condition and zero energy cool chamber having average storage temperature 24°C. The study showed no significant differences in the b * value of the fresh tomato during storage for 10 days, and the trend of b* values increased and then decreased in UL and EC, but in REF and SREC the trend was increasing. This could be connected to the fact mentioned by Messina *et al.* (2012) that before maturation, the yellowish color reaches its peak concentration.

The results showed that tomato fruits stored in EC, UL, and SREC storage structures retained their color characteristics better than those stored in low temperature REF storage structures. The rate of increment of color value was significantly higher in EC and UL stored tomato fruits than in REF and SREC storage structures. Similarly, Tadesse *et al.* (2015), mentioned that increased color indices could be a sign of dark red color development due to lycopene accumulation linked to the internal membrane system. According to their studies, tomatoes stored at 20°C and 30°C displayed a brighter red color than those stored at 4°C.

Fruit firmness

When storing tomatoes, texture is considered to be the most important factor by the consumers. Texture of stored tomatoes was determined in terms of firmness (N). Firmness and ripening of fruits and vegetables are inextricably linked. Even after harvest, chemical activity and respiration continues which affects the firmness of stored products. Higher the firmness more the marketability of tomatoes stored so it is important to study firmness quality parameter. Graph was plotted to understand the variability in firmness of stored tomato with change in independent variables, different storage structure and days (Fig. 5).

It is evident from Fig. 5 that the firmness of the stored tomatoes gradually decreases during storage from the initial value 9.37 to 5.91 N and 6.30 N till the end of storage period of 21 days in the SREC and REF structure, respectively (Table 3). The reduction in firmness was highest in tomatoes stored in UL 4.54 N (ambient conditions). The highest decrease was observed in tomatoes stored at UL (51.54%) followed by EC room (44.93%) and then SREC (36.92%) and REF (32.76 %). A similar trend for firmness has been reported for tomato fruit by (Lana *et al.* 2005, Islam *et al.* 2012). Results revealed that firmness of tomato decreases at a slow rate when stored in low temperature storage structures (REF and SREC) as

Table 3. Least square means and its comparison for firmness of tomatoes stored in, SREC (solar refrigerated and evaporative cooled) structure, EC (evaporative cooled) structure, UL (un-cooled laboratory) and REF (refrigerator) during storage period for respective storage day.

Storage condition	D_0	Firmness with storage period in days D_3	D_6	D_{10}	D_{14}	D_{18}	D_{21}
SREC	9.37[a]	8.99[a]	7.76[a]	6.76[ab]	6.38[a]	6.21[a]	5.91[ab]
EC	9.37[a]	7.63[b]	6.79[b]	6.55[ab]	5.82[ab]	5.43[b]	5.16[bc]
UL	9.37[a]	7.08[b]	6.13[b]	5.59[b]	5.24[c]	4.65[c]	4.54[c]
REF	9.37[a]	8.93[a]	8.12[a]	6.98[a]	6.24[a]	6.42[a]	6.30[a]
Significance	ns	**	**	**	**	**	**

compared to ambient high temperature conditions. Analysis of variances 5% level of significance showed that storage conditions had a significant effect on the firmness of stored tomatoes. Additionally, the interaction between storage conditions and storage days had significant effects on the firmness of stored tomatoes. Least square means for effect of interaction structure type*days (Table 3) shows significant difference on firmness of tomatoes stored in different conditions.

Tissue softening, which is caused by one of two mechanisms: Weight loss or enzyme activity, is the fundamental issue with tomato firmness. Weight loss is a non-physiological phenomenon that occurs as a result of post-harvest dehydration, resulting in turgor loss. This quality measure can be used to determine tomato quality, because it affects the tissues to become dull and very soft, with a lot of moisture loss. The hardness change associated with enzyme activity is due to the activity of pectin methylesterase and polygalacturonase. The enzymatic decomposition of pectin by PME and PG causes the demethylated pectin chains to become shorter, which leads to a drastic change in texture, which is softening (Vu *et al.* 2004). Tomato fruit firmness is related to the amount of weight loss and the level of decay or microbial growth during storage and ripening. Tomato softening is connected to an increase in Pectin-Methylesterase (PME) activity, according to Rugkong *et al*. (2010). Pinheiro *et al.* (2013) also mentioned that the changes in firmness are linked to the activity of enzymes such as PME and Poly-Galacturonase (PG). The results of the study showed that tomatoes stored in SREC and REF cold storage structures maintained a better firmness during the entire storage period than in EC and UL storage conditions. This could be due to increased metabolic activity as well as the action of cell wall disintegrating enzymes, which soften the peel and increase cell permeability, so tomatoes stored in UL ambient conditions have higher water losses than those stored in cold SREC and REF storage. Water loss can also cause wilting, shrinkage, and loss of strength. Therefore, as observed in this study, a higher percentage of moisture loss indicates lower strength.

The effectiveness of a solar refrigerated and evaporative cooled structure in preserving the post-harvest product quality of mature green tomatoes was investigated in this study. When compared to the Solar Refrigerated and Evaporative Cooled and refrigerator storage conditions, the temperatures in the UL (ambient condition) and EC evaporative cooled structure were approximately 15°C higher. The greatest temperature differences were observed in the afternoon, indicating greater cooling capacity. SREC temperatures were noticeably lower than ambient temperatures. Relative humidity was higher in SREC, however, this is not documented in the case of refrigerated storage structures. The relative humidity differences between the SREC and the UL (ambient condition) were between 0 and 47% depending on the time of day. The SREC maintained a constant high relative humidity of more than 85% up to 100 %. The deteriorative processes of moisture loss, color change, loss of firmness were slowed by the lower storage temperature and higher relative humidity maintained in SREC. Because the relative humidity in REF was lower than in SREC, moisture loss was greater in REF than in SREC.

CONCLUSION

The findings of this study demonstrated that the SREC Solar Refrigerated and Evaporative Cooled structure effectively mitigated the deteriorative processes associated with moisture loss, color change, loss of firmness and preserved the quality of tomatoes better compared to UL (ambient conditions). In this present study, the considerably lower temperature in the SREC and higher relative humidity in the storage structure caused a lower vapour pressure difference and consequently reduced weight loss, firmness and color parameters degradation of stored tomato. As a result, postharvest losses were reduced, and the storage ability of stored vegetables was improved. According to the experimental study, the rate of senescence in UL and EC stores was faster than in SREC stores and refrigerators. An innovative off grid battery less Solar refrigerated and Evaporative Cooled (SREC) structure preserve the perishable agricultural produces in term of quality parameter such as moisture loss, color change, loss of firmness comparatively better than evaporative cooled (EC) and UL (ambient) storage condition. This permits smallholder farmers in developing countries such as India to have affordable access to cold storage even if they do not have an electrical connection. This will help them to achieve higher financial returns as it extends the marketing period and improves their control over the marketing of their commodity.

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