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SHELF LIFE OF TWO SWEET PEPPER (*Capsicum annuum*) CULTIVARS STORED AT AMBIENT AND EVAPORATIVE COOLING CONDITIONS

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ABSTRACT. *Sweet pepper (Capsicum annuum L.) is one of the most commercially important horticultural crops developed in temperate and tropical regions. This crop is highly perishable and high postharvest losses often result if handled poorly or stored in unfavorable conditions. An alternative non-refrigerated storage that can potentially maintain quality longer is the use of evaporative coolers. In this study, the effects of evaporative cooling (23.91±3.85°C, 93.84±9.33% RH, 1.79kPa VPD) on the shelf life and physico-chemical characteristics of two sweet pepper cultivars ('Smooth Cayenne' and 'Sultan') were evaluated and compared with those stored under ambient conditions (28.74±0.94°C, 65.68±7.43% RH, 13.62kPa VPD). Cultivar and storage conditions had significant effect (P ≤ 0.05) on the shelf life of the sweet peppers. Storage of sweet pepper in the evaporative cooler (EC) resulted in reduced weight loss (9.65% and 28.86% for 'Sweet Cayenne' and 'Sultan', respectively), slower decline in moisture content and longer retention of acceptable visual quality and firmness due to lesser color change and shriveling, respectively, for both cultivars. There were rapid changes in total soluble solids and titratable acidity in both cultivars stored at ambient condition indicative of ripening. Decay can however reduce benefits from EC thus moisture control is essential. The shelf life of 'Smooth Cayenne' was at 9 and 18 days when stored in ambient and EC conditions, respectively, while this was at 7 and 15 days for 'Sultan'. The shelf life of these sweet peppers was prolonged by eight days in the present burlap-walled EC.*

KEY WORDS: *sweet pepper, 'Smooth Cayenne', 'Sultan', evaporative cooler, shelf life*.

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is an economically important crop for both local and export market (Shehata et al. 2013). It is known for its antioxidant properties as it is a good source of vitamins A and C as well as phenolic compounds (Shotorbani et al. 2013). With its nutritional contribution, it is believed to prevent certain types of cardiovascular diseases, atherosclerosis, cancer, and haemorrhage (Marin et al. 2004).

Unlike dried grains and legumes, fresh fruits and vegetables such as peppers have an extremely low level of natural protection against biochemical and physiological deterioration in warm and humid places (FAO 1981). During prolonged storage, the main factors for the quality degradation of sweet pepper include poor external appearance, decay development, shriveling associated with water loss and its high susceptibility to chilling injury (Shehata et al. 2013).

Temperature management during storage period is the most effective tool in maintaining the quality and extending the shelf life of fresh horticultural crops such as sweet pepper (Leon et al. 2013). However, refrigeration requires high initial cost and power sources which cannot be afforded by most small-scale farmers, retailers and wholesalers in developing countries (Basediya et al. 2013) such as the Philippines. Evaporative cooling is a postharvest treatment that is usually done in rural areas. It is a physical process wherein evaporation of a liquid cools an object in contact with it. It is far less expensive than the usual refrigeration cooling. Bautista et al. (2007) explained that the heat of respiration of the produce evaporates the water that is applied to its immediate surroundings. When it is windy or when air movement is greater, there is also faster evaporation. Compared to the surroundings, it maintains a lower temperature and a higher relative humidity in the storage chamber (Dadhich et al. 2008).

Studies have shown the efficiency of evaporative coolers as a good postharvest treatment for fresh crops. Awole et al. (2011) conducted a study on the yield and storability of hot peppers harvested mature green and stored in two storage conditions (ambient and evaporative cooling). After 16 days of storage, nearly all pepper fruit stored at ambient condition were found to be unmarketable. On the other hand, those that were stored in the evaporative cooler chamber were kept up to 28 days. In another study conducted by Vanndy et al. (2008) using a brick-walled evaporative cooler (EC), reddening of chili was hastened but weight loss was lower regardless of variety and initial ripeness stage. Weight loss reduction is one of the primary effects of EC as a result of the humid condition in the storage chamber (Acedo 1997; Acedo et al. 2009).

The shelf life and quality of different chili cultivars were examined by Acedo et al. (2009) using three storage conditions: (1) ambient, (2) polypropylene bag as modified atmosphere package (MAP), and (3) simple EC. Chili quality deteriorated rapidly at ambient due to weight loss and shriveling although inhibited in MAP and EC. Decay incidence was very high in MAP due to moisture condensation inside the plastic bag which favored rot development. EC created a more humid and cooler environment, causing reductions in weight loss and shriveling but at lower magnitude than MAP.

The effectivity of evaporative cooling was further validated in Nigeria by Olosunde et al. (2016) who developed a solar-powered evaporative cooler (SPECSS) to help smallholder rural farmers improve the shelf life of their produce. The mangoes, tomatoes, bananas and carrots that were stored in the SPECSS had shelf lives of 14, 21, 17, and 28 days, respectively, while those that were stored in ambient condition lasted for 5-8 days only. This present study assessed the effect of ambient and evaporative cooling on the shelf life and physico-chemical characteristics of two cultivars of sweet peppers.

MATERIALS AND METHODS

Sample preparation

Freshly harvested, mature green, uniformly-sized and blemish-free ‘Smooth Cayenne’ and ‘Sultan’ sweet pepper fruit were procured from Bangkerohan, Davao City, Philippines. Samples were wiped with soft cloth moistened with distilled water to remove dirt and then surface-sterilized by soaking in 200 $mg \cdot L^{-1}$ sodium hypochlorite for 2 min. There were three replicates of 35 fruit samples each per storage condition per cultivar for a 21-day evaluation done at three day intervals.

Treatments

The sweet pepper samples were kept in two storage conditions: ambient and evaporative cooler (EC). The EC was covered with two layers of jute sack (burlap) as walls of the EC cabinet. The sack wall was constantly bathed with water from a container placed on top of the EC cabinet to keep it moistened. The EC had three racks and a burlap door.

Temperature and relative humidity (RH)

The relative humidity (RH) and temperature of the ambient and EC conditions were measured daily using a digital data logger (HOBO UX 100-003) placed inside the EC and in the laboratory for the ambient conditions.

Postharvest evaluation

Weight loss. Five samples from each replicate were weighed at the beginning and regularly throughout the storage period. The difference between the initial and final weight of each sweet pepper was considered as total weight loss during each storage interval and computed as:

$$\% \text{ Weight Loss} = (\text{initial weight} - \text{final weight}) / \text{initial weight} * 100$$

Firmness. Firmness of two intact fruit samples per replicate was measured using a Wagner fruit penetrometer using a cylindrical stainless steel probe of 8 mm in diameter.

Visual assessment. The following parameters were evaluated visually using pertinent rating scales: visual quality rating (1=excellent, fresh appearance; 2=very good, slight defects; 3=good, limit of saleability, defects progressing; 4=fair, usable but not saleable; 5=poor), shriveling (1=no shriveling; 2= slight, 1-15% of surface area shriveled; 3= moderate, 16-30% of surface area shriveled; 4= severe, 31-49% of the surface area shriveled; 5=extreme, ≥50% of the surface area shriveled), color index (1=mature green; 2=breaker; 3=turning; 4=orange; 5=light red; 6=dark red), degree of decay (1=no decay; 2=1-10% decay/slight; 3=11-25% decay/moderate; 4=26-50% decay/moderately severe; 5=more than 50% decay/severe). Samples with a visual quality rating exceeding 3 were considered as unmarketable and have reached the end of shelf life.

Moisture content. Moisture content was determined using 10 g samples from each replicate. Each fruit was cut into pieces and dried in a forced air circulation oven at 70°C to a constant weight as described by Antoniali et al. (2007).

Total soluble solid (TSS). Total soluble solids (TSS) was measured using an Atago PAL-1 digital refractometer by placing one or two drops of the juice on the prism surface**.**

Titratable acidity (TA). Titratable acidity was measured by titrating five mL of juice from three fruit samples which had been juiced using a juicer (Kyowa) against 0.1N NaOH (standardized titration solution). When the end point of titration was reached, the amount of NaOH used on the burette was read off and recorded to calculate TA using the following formula (Antoniali et al. 2007):

$$\%TA = (\text{Titer} * 0.1N\ NaOH * 0.67 \text{ malic acid}) / 1000 * 100$$

<u>Experimental design and statistical analysis</u>

The study was laid out in 2x2 factorial experiment arranged in Completely Randomized Design replicated three times with cultivar and storage condition as factors. Data were analyzed using two-way Analysis of Variance (ANOVA) through DSAASTAT. LSD test at 5% level of significance was used for treatment mean comparison.

RESULTS

<u>Temperature and Relative Humidity (RH)</u>

During the storage period, the mean temperature and RH for ambient and evaporative cooler conditions were 28.76°C ; 66.42%, and 23.94°C; 93.92% (Fig 1) respectively with vapor pressure deficits (VPD) of 13.62kPa (ambient) and 1.79kPa (EC). A difference of 4.82°C, 26.78% RH, and 11.83 kPa VPD constituted the improvement in conditions in storing produce in the present EC design.

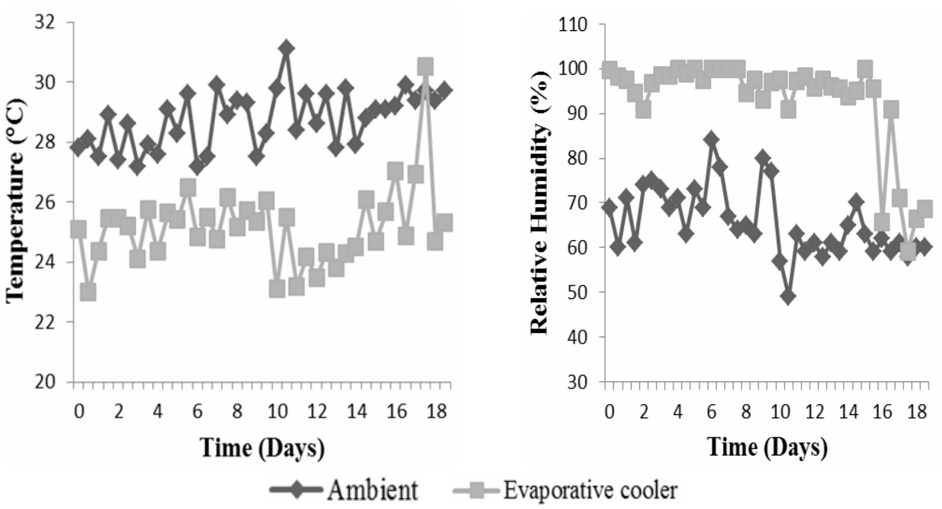

Figure 1. Temperature and relative humidity in ambient and evaporative cooling conditions.

<u>Weight Loss</u>

There was no significant difference in percentage weight loss between the two cultivars. However, in comparing the two storage conditions, all sweet peppers in ambient condition ended its shelf life on day 12 with a total weight loss of 47.84%, while the lot in EC condition which was still marketable had a weight loss of 9.65%. At day 18, when no samples remained in the ambient condition lot, sweet peppers stored in EC condition had an accumulated weight loss of 24.32% (Fig 2).

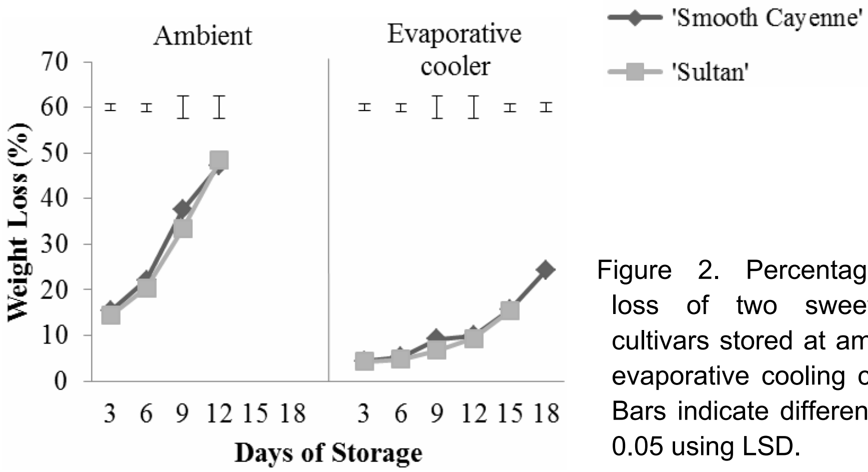

Figure 2. Percentage weight loss of two sweet pepper cultivars stored at ambient and evaporative cooling conditions. Bars indicate difference at P ≤ 0.05 using LSD.

Fruit Firmness

The effects of storage condition was highly significant on the firmness of two cultivars of sweet peppers held under ambient and evaporative cooling conditions for 18 days. The maximum and minimum fruit firmness were recorded at full green (4.37 kgf) and at complete ripe (1.48 kgf) stages, respectively (Table 1). In both storage conditions, 'Smooth Cayenne' maintained acceptable firmness longer than 'Sultan' throughout the duration of storage (Fig 3).

Table 1. Fruit firmness (kgf) of sweet pepper stored under ambient and evaporative cooling conditions*

Storage condition	Storage period (days)						
	0	3	6	9	12	15	18
Ambient	4.37^{a}	3.23^{b}	2.48^{b}	2.54^{b}	1.48^{b}	-	-
Evaporative cooler	4.00^{b}	3.43^{a}	3.38^{a}	3.69^{a}	2.23^{a}	2.80	1.93

* Means within a column followed by the same letter are not significantly different at P≤0.05

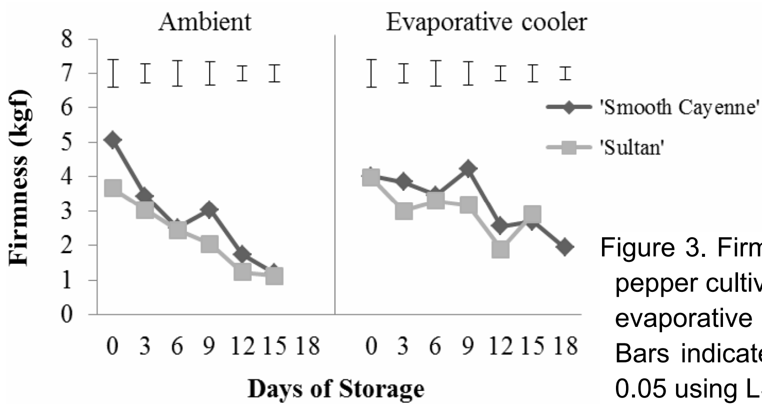

Figure 3. Firmness of two sweet pepper cultivars at ambient and evaporative cooling conditions. Bars indicate difference at P ≤ 0.05 using LSD.

Shriveling

Sweet peppers held in ambient conditions shriveled faster compared with sweet peppers stored in evaporative cooling conditions. In both storage conditions, 'Sultan' shriveled faster than 'Smooth Cayenne' (Fig 4).

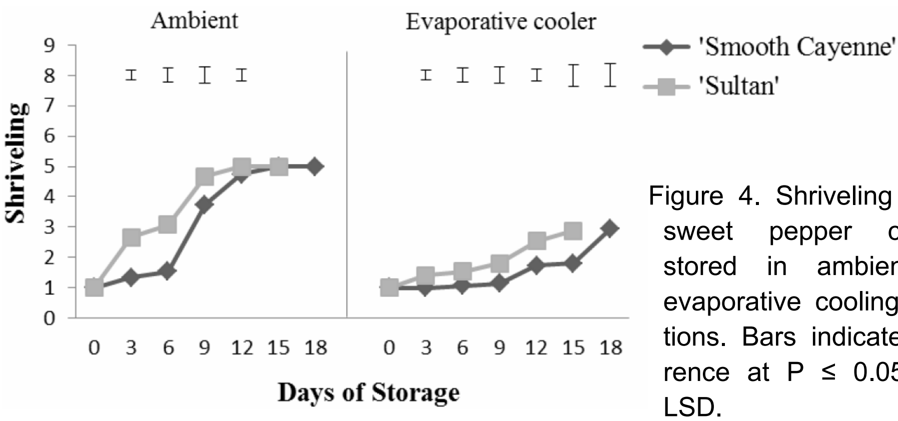

Figure 4. Shriveling of two sweet pepper cultivars stored in ambient and evaporative cooling conditions. Bars indicate difference at P ≤ 0.05 using LSD.

Color

In both storage conditions, 'Smooth Cayenne' changed color more rapidly than 'Sultan' starting at days 9 (ambient) and 12 (EC). Furthermore, 'Smooth Cayenne' reached the color index rating of 6 (full red color) but not 'Sultan'. Both cultivars held at ambient conditions changed color faster than those stored under EC condition (Fig 5). This indicated faster ripening.

Visual Quality

Visual quality of the two sweet pepper cultivars was significantly affected by cultivar and storage condition. An acceptable visual quality of 'Smooth Cayenne' was maintained longer than that of 'Sultan' (Fig 6). Sweet peppers stored in ambient condition reached its limit of shelf life at day 8 and continued to deteriorate thereafter. On the other hand, those that were stored in EC showed good quality characteristics until day 16.

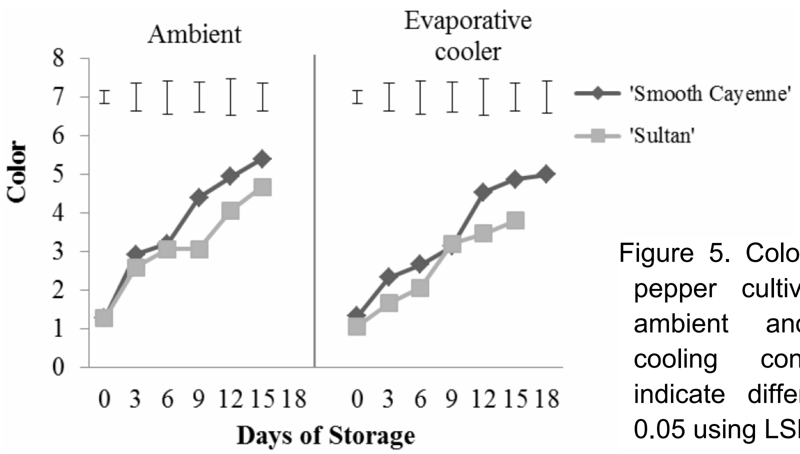

Figure 5. Color of two sweet pepper cultivars stored at ambient and evaporative cooling conditions. Bars indicate difference at P ≤ 0.05 using LSD.

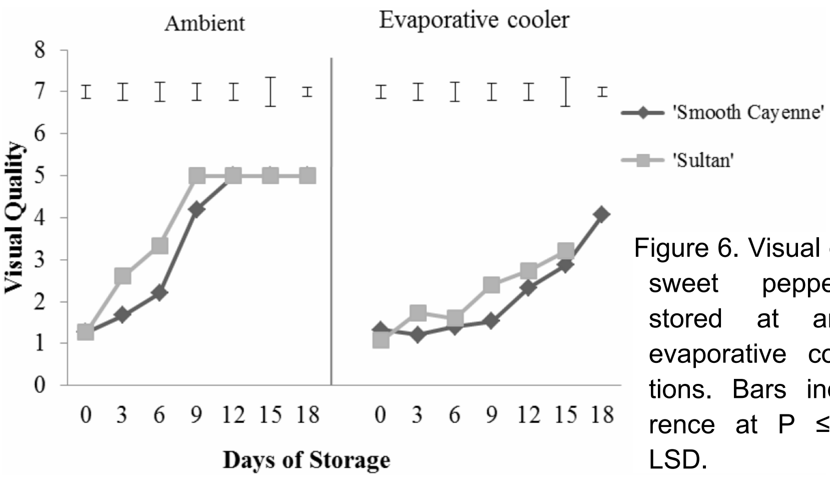

Figure 6. Visual quality of two sweet pepper cultivars stored at ambient and evaporative cooling conditions. Bars indicate difference at P ≤ 0.05 using LSD.

Degree of Decay

The onset of decay was on day 9 for both storage conditions. Sweet peppers stored in EC conditions had a higher incidence of decay especially in 'Sultan' where soft rot development was observed. On the other hand, 'Sultan' sweet peppers stored in ambient did not show any further sign of disease (Fig 7) and ended its shelf-life only when it had fully shriveled. White mold growth was observed in ‘Smooth Cayenne’ stored in the evaporative cooler. Furthermore, based on the visual symptoms, anthracnose was observed near the fruit base for ‘Smooth Cayenne’ in both ambient and EC conditions.

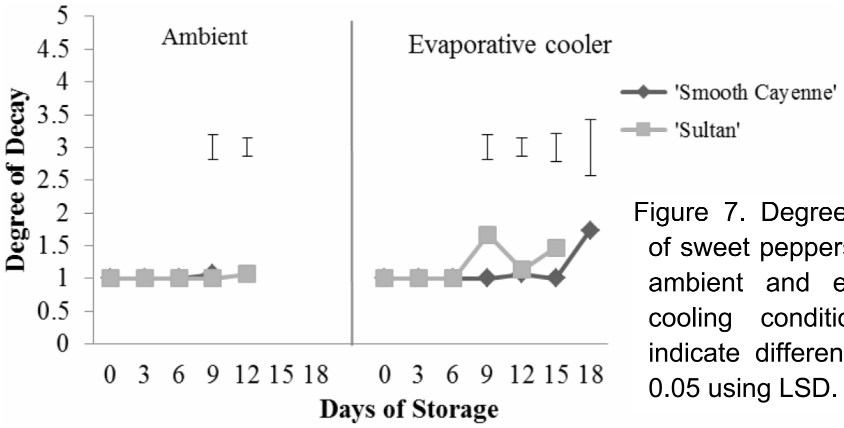

Figure 7. Degree of decay of sweet peppers stored at ambient and evaporative cooling conditions. Bars indicate difference at P ≤ 0.05 using LSD.

<u>Shelf Life</u>

Sweet peppers held in EC conditions had a longer shelf life compared to sweet peppers stored in ambient conditions. At ambient conditions, ‘Sultan’ had a shelf life of 7 while it was 9 days for ‘Smooth Cayenne’. On the other hand, ‘Sultan’ stored in EC conditions had a shelf life of 15 days and ‘Smooth Cayenne’, 18 days (Fig 8). For both storage conditions, ‘Smooth Cayenne’ exhibited a longer shelf life of about three days than ‘Sultan’ (Fig 8).

<u>Moisture Content</u>

Moisture content of the two sweet pepper varieties stored under the two storage conditions displayed a decreasing trend in significant variations ($P \leq 0.05$) throughout the storage period as shown in Fig 9. Retention of moisture content was greater in sweet peppers stored in evaporative cooler. Furthermore, between the two cultivars, ‘Sultan’ had greater moisture content than ‘Smooth Cayenne’.

<u>Total Soluble Solids (TSS)</u>

At day 6, a drop from the increasing trend for total soluble solids was observed for both cultivars and storage conditions. The TSS increased thereafter. Between the two sweet pepper cultivars, 'Smooth Cayenne' presented a higher TSS content compared with 'Sultan' almost throughout the storage period but a decrease was noted on day 15 (Fig 10).

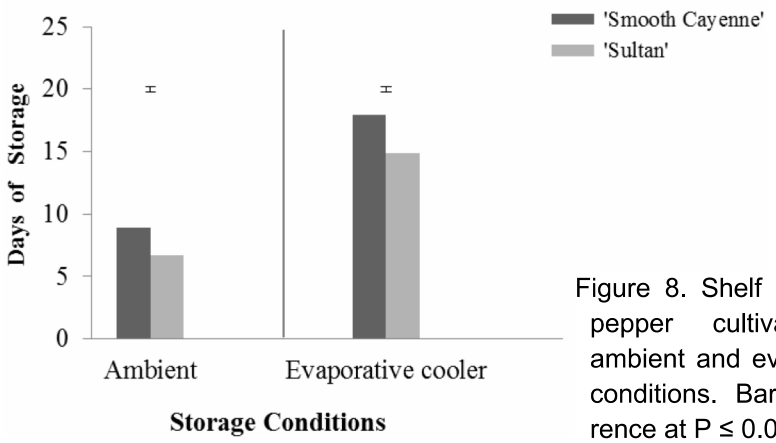

Figure 8. Shelf life of two sweet pepper cultivars stored at ambient and evaporative cooling conditions. Bars indicate difference at P ≤ 0.05 using LSD.

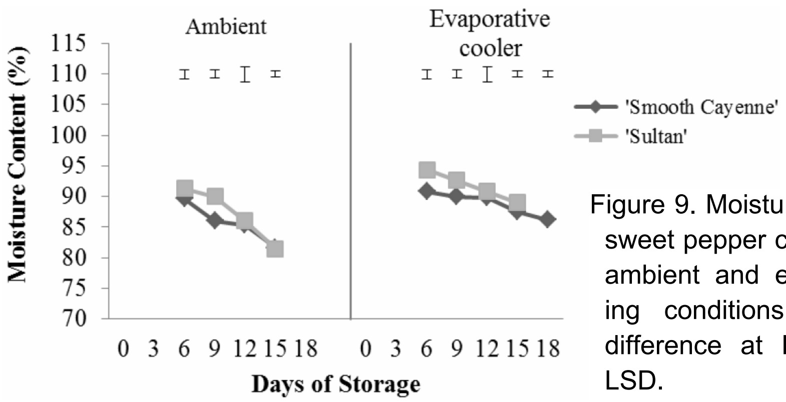

Figure 9. Moisture content of two sweet pepper cultivars stored at ambient and evaporative cooling conditions. Bars indicate difference at P ≤ 0.05 using LSD.

Titratable Acidity (TA)

There was an increasing trend for TA content of the sweet pepper cultivars and storage condition until day 9 with a drop starting at day 12. An increase in TA was exhibited in sweet peppers in EC. 'Smooth Cayenne' had greater TA than 'Sultan' in both storage conditions. Also, there was a distinct increase of TA in 'Smooth Cayenne' and almost stable TA for 'Sultan'. Sweet peppers in ambient condition resulted in faster increase in TA content until day 9 and a decline on day 12 (Table 2).

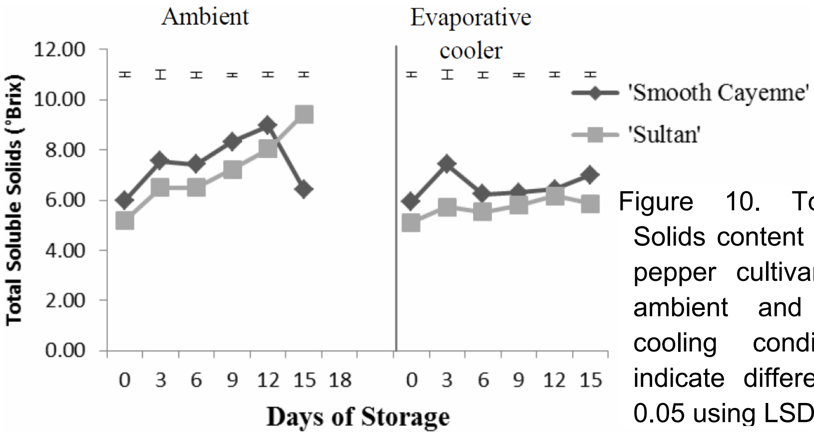

Figure 10. Total Soluble Solids content of two sweet pepper cultivars stored at ambient and evaporative cooling conditions. Bars indicate difference at P ≤ 0.05 using LSD.

Table 2. Titratable acidity (%) of two sweet pepper cultivars stored under ambient and evaporative cooling conditions*

Factors	Storage period (days)						
	0	3	6	9	12	15	18
Cultivar							
Smooth Cayenne	.03[a]	.04[a]	.05[a]	.05[a]	.04[a]	.03[a]	.04
Sultan	.02[b]	.03[b]	.03[b]	.03[b]	.03[b]	.02[b]	-
Storage							
Ambient	.02[a]	.04[a]	.05[a]	.05[a]	.03[a]	.02[a]	-
Evaporative cooler	.03[b]	.03[b]	.03[b]	.03[b]	.04[b]	.04[b]	.04

*Per factor, means within a column followed by the same letter (s) are not significantly different at P≤0.05

DISCUSSION

Temperature has been established to be the most significant factor in maintaining product quality of fresh horticultural crops such as sweet pepper longer (Leon et al. 2013). Sweet peppers stored under ambient conditions could have an excessive amount of water loss leading to quality deterioration because of its very low RH. High vapor pressure deficit may also cause wilting since it hastens transpiration of water. By maintaining an average of 23.91±3.85°C, 93.84±9.33% RH, 1.79kPa VPD for temperature, relative humidity and vapor pressure deficits, respectively, quality preservation of sweet peppers was achieved for a little over a week more

(16 days in EC, 8 days in ambient) by storing the samples in the burlap-walled evaporative cooler (EC).

Water loss is a primary physiological factor that impacts on sweet pepper fruit quality during shipment, storage and marketing (Dumville & Fry 2000). Sweet peppers stored under ambient conditions displayed a significantly higher percentage of weight losses compared to those stored under EC condition. The higher RH and reduced temperature and VPD values given by the EC relative to ambient conditions allowed the former to sustain reduced produce weight losses and at the same time slowed down the rate of shriveling. Furthermore, although there was a decline in firmness on the sweet peppers in both storage conditions, this physical characteristic was better maintained by storing the samples in the EC. The difference in average weight loss percentages between the two sweet pepper cultivars could be due to the varying morpho-anatomical characteristics, surface types and underlying tissues of the cultivar that affect the rate of water loss (Bondada & Keller 2012; Wills et al. 1998).

The ripening rates of peppers are highly variable especially among cultivars (Samira et al. 2013). This explains why the two cultivars in this study differ in their rate of color change. Furthermore, as ripening is often signaled by changes in fruit color, it can be concluded that storing sweet peppers in EC could slow done the rate of ripening. This allows farmers, retailers, and other handlers to store a fraction of their harvest for some time instead of exposing these crops to the harsh environment of the marketplace which poses a higher risk for contamination and mechanical damages.

One of the visual aspects that totally eliminate a crop from being accepted by the consumers is decay. Due to observed diseases on sweet peppers, it can be implied that the sanitizing agent (e.g. NaOCl) used may not have been sufficient to eradicate the decay-causing organism. In addition, the development of anthracnose on 'Sweet Cayenne' may have been favored by the environment inside the EC since *Colletotrichum* sp. thrives on warm wet weather at an optimum temperature and RH of 27ºC and 80%, respectively (Ali et al. 2016). There was also surface moisture in the storage walls of the EC that sometimes flowed to the shelves where the trays were placed.

Sweet peppers stored in evaporative cooling condition showed greater moisture content than sweet peppers stored in ambient condition from days 6 to 18. Furthermore, reduced respiration might have taken place because of the low temperature in the evaporative cooler which resulted in delayed fruit ripening and consequently reduced moisture loss (Atta-Aly & Brecht 1995). The percentage of decrease in moisture content was greater in sweet peppers stored at ambient condition. This was due to transpiration as well as ripening during the storage period. Ripening of sweet pepper makes variations in the permeability of cell membranes that makes them more subtle to water loss (Samira et al. 2013).

The increase in TSS content for all the sweet peppers throughout the storage in both EC and ambient conditions indicate continuous metabolic conversion of sugars from starch (Samira et al. 2013). The lower TSS content in evaporative cooling condition might be due to its high RH which reduces water loss; hence, slowing the conversion of sugars from starch which decreases the amount of soluble solids.

Change in TA content comes along with the changes in different organic acids like ascorbic acid (Salisbury & Ross 1994). Results indicate that TA in sweet peppers increases as these ripen. The decline of TA in ambient conditions might be due to high temperature which promoted high respiration that used up titratable acids as a substrate. On the other hand, the lower temperature in EC reduced the rate of respiration, decreasing the use of titratable acids (Getenit et al. 2008).

Shelf life was ended when the fruit exceeded a visual quality rating of 3 (good, limit of saleability, defects progressing). Sweet peppers stored under EC condition was kept up to 16 days of storage while those stored in ambient was 8 days.

CONCLUSIONS

This study has verified the efficiency of the evaporative cooler (EC) in prolonging the shelf life of a highly perishable crop like sweet pepper. As compared to ambient condition, the EC was able to provide a storage environment with lower temperature, lower vapor pressure deficit and a higher relative humidity. Weight loss was effectively reduced in EC as well as the extent and rate of moisture loss. Results also showed that physical characteristics of sweet pepper in terms of visual quality, color, firmness, and shriveling were maintained better when stored under EC condition. The rate of the chemical changes for total soluble solids and titratable acidity for sweet peppers stored in EC condition were slowed down contributing to its extended shelf life. Furthermore, samples in EC condition exhibited a longer shelf life of a maximum of 9 more days than those stored in ambient. Decay, however, can reduce the benefits gained from the use of the EC. Controlling the amount of moisture may reduce disease occurrence in the produce. In addition, between the two cultivars, 'Smooth Cayenne' exhibited better visual quality characteristics and longer shelf life. Hence, selecting a good cultivar of sweet pepper paired with storage in EC could lengthen the shelf life of sweet peppers.

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