Journal of Energy and Natural Resources
2019; 8(4): 137-145
http://www.sciencepublishinggroup.com/j/jenr
doi: 10.11648/j.jenr.20190804.12
ISSN: 2330-7366 (Print); ISSN: 2330-7404 (Online)

Effect of Postharvest Temperatures and Packaging Materials on Shelf Life and Fruit Quality of Selected Hybrid of Sweet Pepper

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To cite this article:

Md. Abdus Sattar, Md. Abdul Quddus, Md. Habibur Rahman, Md. Ashraf Hossain, Mohammad Hossain Sarker, Md. Rabiul Islam. Effect of Postharvest Temperatures and Packaging Materials on Shelf Life and Fruit Quality of Selected Hybrid of Sweet Pepper. *Journal of Energy and Natural Resources*. Special Issue: *Assessment of Potassium Element on Lentil (Lens culinaris Medic) Agronomy and Nutrient Use Efficiency in Calcareous Soils*. Vol. 8, No. 4, 2019, pp. 137-145. doi: 10.11648/j.jenr.20190804.12

Received: October 29, 2019; **Accepted**: November 18, 2019; **Published**: December 2 2019

Abstract: Field and laboratory studied were conducted at the research field of Olericulture Division and laboratory of Postharvest Technology Section under the Horticulture Research Center (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur to find out the suitable sweet pepper hybrid ($P_7 \times P_8$) and to determine the appropriate storage temperature and storage material on shelf life and fruit quality of hybrid sweet pepper. The laboratory result reveal that perforated poly bag was found better in reducing fungal decay (6.02%) as well as for better visual appearance and excellent nutritive quality during 10th day of storage irrespective of temperature. The minimum weight loss of fruits was (0.86%) noted at temperature of 4°C kept in perforated poly bags at 10th day of storage. Higher TSS value (5.49% in 10th day and 5.58% in 20th day of storage) was attained under ambient temperature with perforated package. Maximum beta carotene value in fruit (42.78 µg per 100 g) was observed during 10 days storing at perforated poly bag of 4°C temperatures. However, freshness of fruits was up to the marks and senescence of fruits was delayed in 4°C and in perforated poly bag up to 10th day of storage. These temperature (4°C) and perforated poly bag might be afforded a beneficial balance to visual appearance and nutritional status. The results suggest that fruits of sweet pepper at 4°C stored in perforated poly bag for a period of 10th day might be appropriate regarding the firmness, good visual appearance and fruit quality.

Keywords: Temperature, Packaging Material, Fruit Quality, Genotype, Yield

1. Introduction

Sweet pepper (*Capsicum annuum* L.) is one of the non-pungent with thick flesh most important high valued vegetable crops grown extensively throughout the world especially in the temperate countries [1, 2]. Capsicum belonging to the family *Solanaceae* is very sensitive to soil nutrients and environmental factors [3]. The optimum temperature for capsicum ranged 16° to 26°C [4].

Sweet pepper is a minor vegetable in Bangladesh and its production statistics are not available. Small scale cultivation is found in peri-urban areas for the supply to some city markets in Bangladesh. The crop has high export potentiality. Considering its high nutritive value and export potentiality and low production, it is imperative to take attempts for its successful cultivation and keeping the postharvest quality in the country. Sweet pepper should be harvested at full maturity to achieve the maximum quality in relation to flavour and colour.

However, the fruit qualities are highly worsening, with soft texture, high softening rate and highly susceptible to fungal attack and mechanical injury [5]. High perishable with poor keeping quality of sweet pepper at ambient temperature makes postharvest management and maintain market qualities very difficult [6]. Such as higher storage temperature result in higher respiration rates and shorter storage period, which are in turn associated with the loss of fruit quality [7, 8]. The fresh fruits of sweet pepper cannot be stored for long time due to their inherent compositional and textural characteristics. Relatively low temperature storage remains the most effective tool for maintaining quality and extending shelf life, but it results in chilling injury. In addition, modified atmospheres are designed to slow down respiration and thus senescence by reducing oxygen or increasing CO_2 concentrations [9]. Nevertheless, sweet pepper is moderately sensitive to high CO_2 (5-10%) damage. Pre-packaging and storage of sweet pepper at ambient conditions are commonly practiced in Bangladesh but their potential in maintaining produce quality is not well understood. Determining the best pre-packaging for sweet pepper may assist the growers, dealers and consumers in maintaining the quality of the sweet pepper. Sweet pepper contain high ascorbic acid concentration have protective roles against reactive oxygen species [10]. The rate of ascorbic acid degradation depends on several factors such as storage temperature, water, pH and cultivar [11, 12]. However, ascorbic acid is very labile and under adverse conditions, undergoes oxidation [13]. The effect of packaging materials and cultivars on quality and shelf life of sweet pepper fruits have been described by many workers [14, 15] but physical quality, nutritional effect and storage data on different cultivars grown in tropical and sub-tropical regions are scanty. It is urgent to standardize the packaging system for storage of sweet pepper with maximizing the quality attributes. Hence, the study was under taken to evaluate the suitable genotypes for developing of sweet pepper hybrids and to find out the appropriate storage temperature and storage material on shelf life and fruit quality sweet pepper.

2. Materials and Methods

2.1. Site and Experimental Description

Field experiment was conducted at the research field of Olericulture Division under the Horticulture Research Center (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur to find out the selected hybrid material ($P_7 \times P_8$) for laboratory analysis during October 2012 to April 2014. The land of Gazipur is medium high with fine-textured (clay loam) grey terrace soils. It belongs to Chhiata soil series under the agroecological zone - Madhupur Tract (AEZ-28). The climatic condition is characterized by relatively high monsoon rainfall, high humidity, and high temperature. Long day with less clear sunshine, sometimes the sky remains cloudy for heavy rainfall during April to September. The scanty rainfall, low humidity and low temperature, short day and more clear sunshine during October to March. Average temperature ranged from 13.0-36.1°C and the experimental area received rainfall from 1.30 to 505 mm during October to April. The initial soil (0-15cm) sample was analyzed as outlined by Page et al. [16] and following standard methods. The analytical results of soil was 0.95% organic matter (OM), 0.05% N, 9 ppm P, 0.17 meq.100 g^{-1} K, 15 ppm S, 1.4 ppm Zn and 0.10 ppm B. The soil pH was 6.2.

2.1.1. Laboratory Experiment

The laboratory experiment was conducted at the laboratory of Postharvest Technology Section, HRC, BARI, Gazipur from October 2014 to April 2015.

2.1.2. Fruit Material

Sweet pepper was collected among the previously selected hybrid *viz.* $P_7 \times P_8$ grown in the experimental field for laboratory analysis.

2.1.3. Flower Tagging and Fruit Harvest

Flowers were tagged at anthesis for fruit development and 20 fruits were randomly selected from 20 plants and were harvested at 45 days after anthesis (DAA). Harvested sweet peppers were immediately sorted to eliminate damaged fruit and selected for uniform size and colour.

2.1.4. Treatment of the Laboratory Experiment

The experiment was consisted of two factors such as-

Factor A: Three storage temperature *viz.* 4°C, 6.5°C and ambient room temperature (25±1°C and 70±5% RH).

Factor B: Three packaging system *viz.* perforated poly bag, non-perforated poly bag and unpacked or control condition at ambient room temperature (25±1°C and 70±5% RH).

Hence, treatment combinations had been made 9 comprising of factor A and B.

2.1.5. Experimental Design

The experiment was carried out in a Factorial Completely Randomized Design (CRD) with three replications.

2.1.6. Storage Conditions

The fruits were randomly grouped into batches of each ten unpackaged, perforated polyethylene bag and non-perforated polyethylene bags (12µm thick – gauge 48). The fruits were then stored at ambient conditions (about 25±1°C). The experimental design was a factorial (completely randomized design) with packaging (3) and storage temperature (3) as main and sub-treatment factors, respectively. Each treatment was replicated three times. The fruits were stored until the unpackaged ones held at ambient conditions became unmarketable due to loss in quality. The selected fruits of hybrid $P_7 \times P_8$ were randomly distributed among 9 treatment groups. Ten fruits for each treatment were packed in a 1) 1% perforated polyethylene bag, 2) non-perforated polyethylene bag and 3) unpackaged which were weighed before and after addition of fruit. After that fruit of all polyethylene bags including unpackaged fruits were kept in lab at open shelf's tray under ambient room conditions (25±1°C and 70±5% RH). Three trays were removed from the shelf in every 10th day up to 20th day for assessing fruit quality.

2.2. Collection of Data

Data were collected from the randomly selected ten fruits of each replicate polyethylene bag and unpackaged tray. The data were recorded on the following parameters:

(i) *Loss of freshness or percent fruit decay:* The freshness loss of fruits was determined by visual inspection on harvesting days during the storage period on the basis of visible fruit surface damage including fungal decay. Fruits with visible mycelia growth and/or at least 1/3 damaged surface area including bruising, softening or easily ruptured skin surface were removed and the loss of fruit was determined as the percentage of the number of sweet peppers.

(ii) *Weight losses of fruit:* Sweet peppers were weighed at the beginning of the experiment and thereafter every 10 day until 20th day during the storage period. Weight loss was expressed as the percentage weight loss of initial total weight.

(iii) *Measurements of total soluble solids (TSS):* Total soluble solid content was determined by a Refractometer. Five mature fruits of each unit plot under different treatments were taken randomly. A drop of juice squeezed from the sample was placed on the surface of the prism of the refractometer (Model No. ATAGONI- Brix 0-32) and per cent Total Soluble Solid (TSS) was obtained from direct reading and means of five fruits were calculated.

(iv) *Measurements of ascorbic acid content in fruits:* Total ascorbic acid was determined by the AOAC (Association of Official Analytical Chemists) microfluorometric method (984.26). The sample composites were blended in meta phosphoric-acetic acid extractant (without the addition of ascorbic acid) to prevent ascorbic acid oxidation. Recovery of added vitamin C which was determined by standard addition (50 mg spike) prior to blending of the composites was 94 {4.2% (*n* Å 2)}. Sample preparation for ascorbic acid analysis was completed under yellow light (Sylvania Gold F40/GO, 40W) to minimize photo oxidation. All analyses were completed in duplicate.

(v) *Measurements of beta carotene content of fruits:* The estimation of ß-carotene content was done after extraction of the sample with diacetone alcohol and petroleum ether and further purification with diacetone alcohol, 5% KOH solution and distilled water. The resulting solution was filtered with anhydrous sodium sulphate and read on a T80 UV/VIS Spectrophotometer (PG Instrument Ltd., United Kingdom) at 451 nm against petrolium ether as a blank [17].

2.3. Statistical Analysis

The data of all parameters were recorded and compiled. The statistical analysis was completed through partitioning the total variance with the help of computer MSTAT-C program. Means were separated by using Duncan's Multiple Range Test (DMRT).

3. Results

3.1. Effect of Temperature and Packaging Materials on Hybrid Sweet Pepper

3.1.1. Loss of Firmness/Percent Fruit Decay

Fungal decay was the major contributor to loss of visual quality of sweet pepper. Fruit under ambient conditions (25±1°C) showed 26.36% decay at the 10th day of storage which sharply increased over time and reach to 38.50% decayed on 20th day (Figure 1). Decay of sweet pepper stored at 4°C and 6.5°C were initiated to a lesser extent (0.83 and 3.29%, respectively) on 10th day, increased thereafter and reached finally 1.99 to 5.04%, respectively at 20th day of storage. In contrast, storage at 4°C conditions significantly ($P<0.01$) delayed the incidence of fungal decay of sweet pepper. Significant differences were observed among the different temperature during whole storage period. Among the studied in packaging system, the maximum fruits of $P_7 \times P_8$ kept in unpackaged were decayed (15.48%) at 10th day of storage followed by the fruits of non-perforated poly bags (8.10%) while at that time perforated packaging exhibited the minimum decayed fruits (6.02%). At the end of the storage, the maximum decayed fruits were also observed from unpackaged (23.25%) and the minimum was found in perforated poly bags (9.39%) (Figure 2).

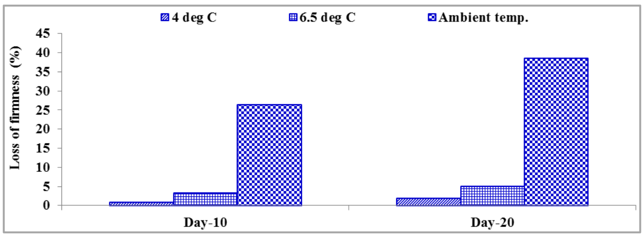

Figure 1. Effect of temperature on loss of firmness (%) of sweet pepper fruits during storage period.

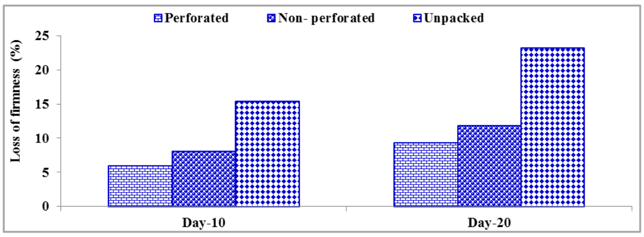

Figure 2. Effect of packaging materials on loss of firmness (%) of sweet pepper fruits during storage period.

3.1.2. Weight Loss

Percent weight loss was the major contributor to loss of visual quality of sweet pepper. Fruit under ambient conditions (25±1°C) showed 21.53% decay by the 10th day of storage which sharply increased over time and reached to 27.72% decayed on day 20th (Figure 3). Decay of sweet pepper (2.05 and 3.38%) stored at 4°C and 6.5°C were initiated to a lesser extent on 10th day, increased thereafter and reached to 4.08 to 5.63%, respectively at 20th day of storage. In contrast, storage at 4°C conditions significantly (P<0.01) delayed the weight loss of sweet pepper. No decay was detected in fruits stored at 4°C until 10th day, however; by the end of storage period only 4.08% decayed fruit was recorded. Significant differences were observed among the different storage temperature during whole storage period. Weight loss from the sweet peppers gradually increased over time and was affected by packaging materials (Figure 4). After 10th day of storage a clear increase in weight loss was observed in fruits stored at different packaging system. Sweet pepper kept in unpackaged system suffered constantly with higher rate of weight loss compared to other treatments throughout the storage period and the loss was recorded by 13.86% and 18.64% on the 10th day and the 20th day (end of storage), respectively. In contrast, fruits stored in perforated polythene bags significantly reduced the weight loss and the minimum weight loss (5.80%) was found at 10th day which reached 7.03% at the end of storage (20th day). At non perforated conditions it was 7.30% on the 10th day and 9.97% on 20th day of storage (Figure 4).

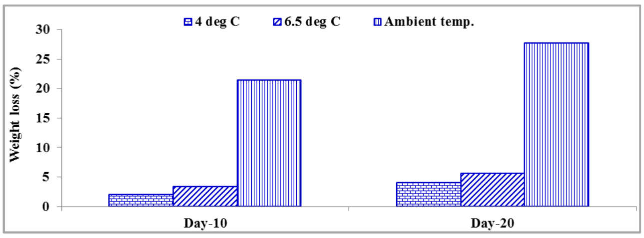

Figure 3. *Effect of storage temperature on weight loss (%) of sweet pepper fruits during storage period.*

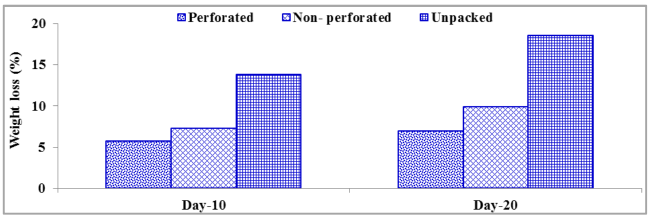

Figure 4. *Effect of packaging materials on weight loss (%) of sweet pepper fruits during storage period.*

3.2. Interaction Effect of Storage Temperature and Packaging Materials

3.2.1. Loss of Firmness

Considering storage temperature and packaging materials of selected hybrid highly significant variation was observed in visual quality of fruit firmness. Very few decay was detected in fruits kept in 4°C temperatures at perforated poly bags until day 10 compared to fruits of same temperature stored at non perforated poly bags. But at ambient and unpackaged conditions all the sweet pepper fruits started to loss their freshness/firmness from 10th day of storage. The maximum loss of firmness was recorded at ambient temperature with unpackaged packaging which was at par with non-perforated packaging and the minimum from 4°C perforated packaging (0.35%) which was at par with non-perforated packaging (0.67%) at 10th day. Increasing trend of firmness loss was also observed in same packaging and temperature (59.17%) while the minimum was observed in 4°C with perforated packaging (0.96%) recorded at 20th day (Table 1).

Table 1. *Effect of temperature and packaging on loss of firmness of hybrid sweet pepper fruits during storage period.*

Treatment	Loss of firmness (%)	
	Day-10	Day-20
Temperature × Packaging		
4°C		
Perforated	0.35 g	0.96 f
Non- perforated	0.67 g	1.78 ef
Unpacked	1.48 fg	3.23 ef
6.5°C		
Perforated	2.25 ef	3.64 e
Non- perforated	2.80 e	4.12 e
Unpacked	4.82 d	7.35 d
Ambient temp. (25±1°C)		
Perforated	17.28 c	25.26 c
Non- perforated	21.65 b	31.08 b
Unpacked	40.14 a	59.17 a
Level of significance	**	**
CV (%)	4.79	2.06

Figures having the same letter (s) in a column do not differ significantly by DMRT

* Significant at 5% level of significance; ** Significant at 1% level of significance

3.2.2. Weight Loss

Considering storage temperature and packaging materials, highly significant variation was observed in weight loss in sweet pepper. Fruits stored in perforated poly bag at different temperature showed significant weight loss at day 10 of storage. At 10th day of storage, the maximum weight loss (31.09%) was observed in unpackaged condition at 10th day at ambient temperature. On the other hand, the minimum weight loss of fruits was (0.86%) recorded at temperature of 4°C kept in perforated poly bags at 10th day of storage. Fruits of different temperature exhibited a gradual weight loss from 10th day up to 20th days of storage (Table 2).

Table 2. *Effect of temperature and packaging on weight loss of hybrid sweet pepper fruits during storage period.*

Treatment	Weight loss (%)	
	Day-10	Day-20
Temperature × Packaging		
4°C		
Perforated	0.86 g	2.06 g
Non- perforated	0.92 g	3.25 fg
Unpacked	4.36 e	6.93 e
6.5°C		
Perforated	1.48 fg	3.84 f
Non- perforated	2.54 f	4.16 f
Unpacked	6.12 d	8.90 d
Ambient temp. (25±1°C)		

Treatment	Weight loss (%)	
	Day-10	Day-20
Perforated	13.94 c	19.07 c
Non- perforated	19.56 b	24.00 b
Unpacked	31.09 a	40.08 a
Level of significance	**	**
CV (%)	5.19	3.04

Figures having the same letter (s) in a column do not differ significantly by DMRT

* Significant at 5% level of significance; ** Significant at 1% level of significance

3.3. Total Soluble Solids (TSS)

Considering different temperatures of selected sweet pepper hybrid not significant variation was observed in TSS content of fruit. The total soluble solid (TSS) content in sweet pepper was about 5.38% at harvest, which was increased little bit during storage period (Figure 5). At the end of storage not identical TSS was observed from fruits stored at 4°C, 6.5°C and ambient temperature during 10th day and 20th day. All fruits stored at different temperature did not show any significant differences among treatments on 10th and 20th day.

Among the packaging materials, same amount of TSS was recorded from fruits of all packaging at fresh condition (5.38%) which was gradually increased over storage period and revealed the highest at every day of observation. At the same time, unpackaged fruit exhibited the lowest content of TSS during day 10 as well as whole storage period. At the end of storage same perforated packaging exhibited the maximum TSS (5.54%) followed by non-perforated packaging (5.52%) which was statistically similar shown in Figure 6.

The interaction effect of storage temperature and packaging of selected hybrid showed non-significant variation in TSS content of fruits. The TSS of fresh sweet pepper of all combination was 5.38% and it gradually increased with the increase in storage duration and temperature. On 10th day of storage, the maximum TSS content was found in fruits stored at ambient temperature (5.49%) kept in perforated package and it increased sharply and attaining 5.58% on 20th day of storage. However, the minimum TSS content was recorded in unpackaged fruits kept at 4°C (5.39%) and (5.49%) at 10th day and 20th day, respectively (Table 3).

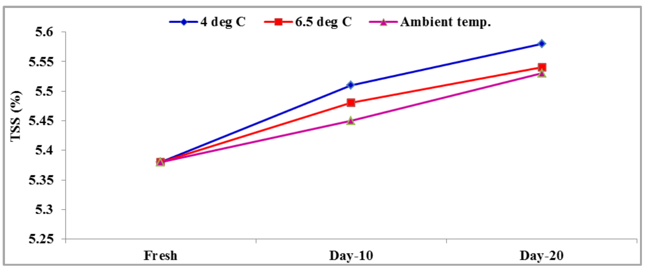

Figure 5. *Effect of storage temperature on TSS (%) of sweet pepper fruits during storage period.*

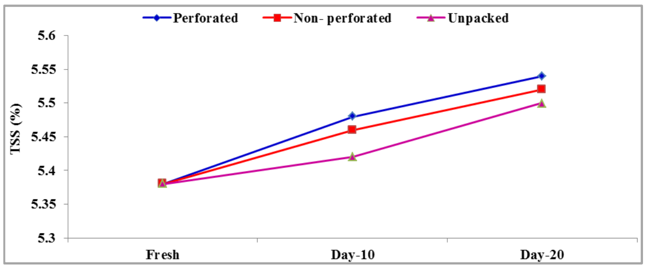

Figure 6. *Effect of packaging materials on TSS (%) of sweet pepper fruits during storage period.*

Table 3. *Effect of temperature and packaging on TSS content in fruits of hybrid sweet pepper during storage period.*

Treatment	TSS (%)		
	Fresh	Day-10	Day-20
Temperature × Packaging			
4°C			
Perforated	5.38	5.41	5.48
Non- perforated	5.38	5.43	5.46
Unpacked	5.38	5.39	5.49
6.5°C			
Perforated	5.38	5.45	5.50
Non- perforated	5.38	5.42	5.52
Unpacked	5.38	5.46	5.54
Ambient temp. (25±1°C)			
Perforated	5.38	5.49	5.58
Non- perforated	5.38	5.48	5.52
Unpacked	5.38	5.46	5.49
Level of significance	ns	ns	ns
CV (%)	1.73	1.09	1.41

Figures having the same letter (s) in a column do not differ significantly by DMRT

* Significant at 5% level of significance; ** Significant at 1% level of significance

ns = non-significant

3.4. Ascorbic Acid

Considering storage temperature significant variation was observed in ascorbic acid content in sweet pepper fruits. At harvest, the ascorbic acid content in sweet pepper was 114.3 mg per 100 g for all fruit samples (Figure 7). But ascorbic acid content at 4°C, 6.5°C and ambient temperature it decreased gradually at 10th day and 20th day. During 10th day ascorbic acid content of fruits attained to 108.3 mg per 100 g at 4°C and at the end of study period it was 96.51 mg per 100 g. Under ambient temperature, the fruits showed significantly ($P<0.01$) higher rate of decrease in ascorbic acid content over time compared to 6.5°C. Irrespective of packaging materials the ascorbic acid content of sweet pepper varied significantly and a declining trend was observed during storage period (Figure 8). At the initial stage of study, the ascorbic acid content was highest at perforated poly bag (114.3 mg per 100 g) and it started to decline bit by bit at 10th and 20th day (106.4 and 94.38 mg per 100 g, respectively). Fruits of non-perforated poly bag (102.6 mg per 100 g) exhibited the second highest ascorbic acid content at every observation and at the end of storage period it became 91.14 mg per 100 g. Similarly, fruits of unpackaged poly bag exhibited the minimum ascorbic acid content (99.05 mg per 100 g) initially. During storage period it started to decline and was the lowest at every observation and found 86.63 mg per 100 g at 20th day. Interaction effect of temperature and packaging on ascorbic acid content in sweet pepper was non-significant (Table 4). In case of 10th day of storage, the maximum content of ascorbic acid was found in fruits at 4°C with perforated packaging (109.1 mg per 100 g) followed by the fruits of non-perforated packaging condition (108.6 mg per 100 g). The ascorbic acid content in fruits of non-perforated packaging started to decline up to 20 day of storage and attained to 98.06 mg per 100 g. Fruits stored in unpackaged condition revealed that the minimum ascorbic acid content after 10 days of storage (107.2 mg per 100 g) and it sharply declined and attained 94.84 mg per 100 g on 20th day of storage (Table 4). At 6.5°C in case of 10th day of storage, the highest ascorbic acid content was recorded in fruits with perforated packaging (106.7 mg/ 100 g) followed by the fruits of non-perforated packaging condition (104.6 mg/100 g). The ascorbic acid content in fruits of perforated and non-perforated packaging started to decline up to 20 day of storage and achieved to 91.28 and 93.07 mg/100 g, respectively. Fruits stored in unpackaged condition at ambient temperature (25±1°C) revealed the minimum ascorbic acid content after 10 days of storage (91.26 mg per 100 g) and it sharply declined and attained 80.05 mg per 100 g on 20th day of storage (Table 4).

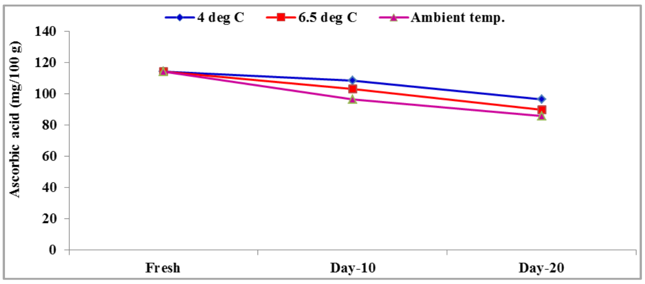

Figure 7. *Effect of storage temperature on ascorbic acid content of sweet pepper fruits during storage period.*

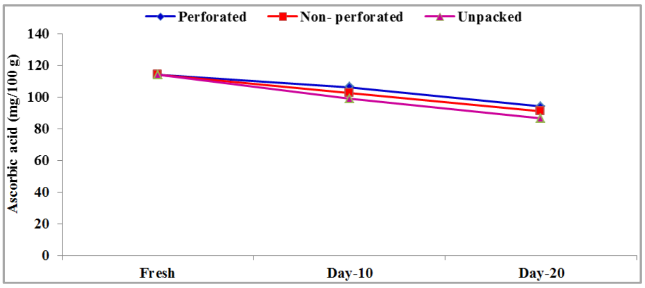

Figure 8. *Effect of packaging materials on ascorbic acid content of sweet pepper fruits during storage perio.*

Table 4. *Effect of temperature and packaging on ascorbic acid content of hybrid sweet pepper fruits during storage period.*

Treatment	Ascorbic acid (mg/100g)		
	Fresh	Day-10	Day-20
Temperature × Packaging			
4°C			
Perforated	114.3	109.1 a	96.64 a
Non- perforated	114.3	108.6 a	98.06 a
Unpacked	114.3	107.2 a	94.84 a
6.5°C			
Perforated	114.3	106.7 a	91.28 ab
Non- perforated	114.3	104.6 a	93.07 ab
Unpacked	114.3	98.65 ab	85.00 bc
Ambient temp. (25±1°C)			
Perforated	114.3	106.0 a	95.23 a
Non- perforated	114.3	92.08 b	82.28 c
Unpacked	114.3	91.26 b	80.05 c
Level of significance	ns	**	**
CV (%)	1.53	1.82	1.92

Figures having the same letter (s) in a column do not differ significantly by DMRT

* Significant at 5% level of significance; ** Significant at 1% level of significance

ns = not significant

3.5. Beta Carotene

Considering the storage temperature non-significant variation was observed in beta carotene content in sweet pepper fruits. At harvest, the beta carotene content in sweet pepper was 42.46 µg per 100 g at all storage temperature (Figure 9). But beta carotene content in 4°C, 6.5°C and ambient temperature conditions, increased gradually at 10th day and 20th day but showed statistically insignificant. In case of 10th day of storage, beta carotene content of fruits attained to 43.28 µg per 100 g at 4°C and at the end of study period it was 44.53 µg per 100 g. At 6.5°C the fruits showed higher rate of increase in beta carotene content over time compared to ambient temperature.

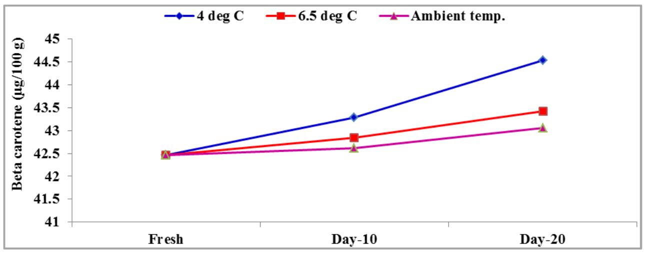

Figure 9. *Effect of storage temperature on beta carotene content of sweet pepper fruits during storage period.*

Irrespective of packaging materials the beta carotene content of sweet pepper varied insignificantly and an increasing trend was observed during storage period (Figure 10). At the initial stage of study, the beta carotene content was same. But it was the highest at perforated packaging (43.98 µg per 100 g) and it started to increase bit by bit at day of 20 (44.83 mg per 100g). Fruits of non-perforated packaging exhibited the second highest ascorbic acid content at every observation and at the end of storage period it became 43.05 µg and 43.62 µg per 100 g. Similarly, fruits of unpackaged condition exhibited the minimum beta carotene content (42.46 µg per 100 g) initially. During storage period it started to increase at every observation and found 42.86 µg per 100 g at 10th day and 43.19 µg per 100 g at end of the storage period.

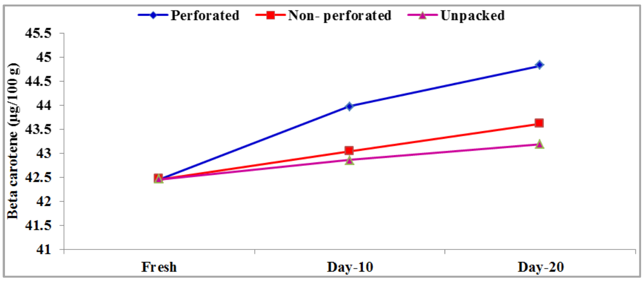

Figure 10. *Effect of packaging materials on beta carotene content of sweet pepper fruits during storage period.*

Interaction effect of storage temperature and packaging on beta carotene content in sweet pepper was also insignificant initially (Table 5). On 10th day of storage, the maximum beta carotene content was found in fruits of 4°C stored at perforated packaging (42.78 µg per 100 g) followed by same temperature stored at non-perforated packaging (42.65 µg per 100 g) and both was alike. The beta carotene content in fruits of 4°C with perforated packaging started to increase very small amount at 20th day and attained to 44.00 µg per 100 g. Fruits at ambient temperature stored in unpackaged condition revealed the minimum beta carotene content at 10th day of storage (39.28 µg per 100 g) and it sharply decrease and attained 31.26 µg per 100 g on 20th day of storage (Table 5).

Table 5. *Effect of temperature and packaging on beta carotene content of hybrid sweet pepper fruits during storage period.*

Treatment	Beta carotene (µg/100g) content at different days after storage		
	Fresh at harvest	Day-10	Day-20
Temperature × Packaging			
4°C			
Perforated	42.46	42.65	43.16 ab
Non- perforated	42.46	42.78	44.00 a
Unpacked	42.46	42.24	43.04 ab
6.5°C			
Perforated	42.46	42.00	42.42 ab
Non- perforated	42.46	42.37	43.19 ab
Unpacked	42.46	41.67	41.08 ab
Ambient temp. (25±1°C)			
Perforated	42.46	42.20	39.00 bc
Non- perforated	42.46	41.00	37.08 c
Unpacked	42.46	39.28	31.26 d
Level of significance	ns	**	**
CV (%)	1.89	1.87	1.85

Figures having the same letter (s) in a column do not differ significantly by DMRT

* Significant at 5% level of significance; ** Significant at 1% level of significance

ns= not significant

4. Discussion

Temperature and packaging both are played significant role for protection of postharvest quality loss of fruits and vegetables. Increasing temperature causes an increase in the rate of natural respiration of all produce and food reserves and water content become depleted. The cooling of produce will be extended shelf life by slowing the rate of respiration [18]. In this study, fungal decay was the major contributor to loss of visual quality of sweet pepper. Sweet pepper fruit under ambient conditions achieved lower decay at the 10th day of storage which sharply increased over time. Decay of sweet pepper stored at 4° was initiated to a lesser extent on 10th day, increased thereafter at 20th day of storage. In the experiment, a very little decay was identified in fruits kept in 4°C temperatures at perforated poly bags until 10 day of storage. But the maximum loss of firmness was recorded at ambient temperature with unpackaged packaging. The experimental results were similar to those of Sigge et al. [19], who stated that storage in 5.5°C with perforated poly bags resulted in better visual quality than at non perforated polythene bag, which was better than unpackaged conditions, as they did not find any incidence of fungal decay even after 10 days of storage at ambient conditions. Gorini et al. [20] found that sweet pepper storage in perforated poly bags with 6.5°C resulted in lower decay with better visual quality than non-perforated poly bags, which were better than at ambient temperature and unpackaged conditions. Nyanjage et al. [21] observed that the perforated poly bag was the major factor in determining the post-harvest performance of sweet pepper. The interaction of lower temperature (5.5°C) and perforated polythene packaging produced the best results. The maximum weight loss was observed in unpackaged condition at ambient temperature. However, the minimum weight loss of fruits was found at temperature of 4°C kept in perforated poly bags. Fruits of different temperature exhibited a gradual weight loss from 10th day up to 20th days of storage. Chae et al., [14] documented that harvested fruits and vegetables continue to respire and lose of water to the environment and weight loss is occurred. The rate of water loss is largely depending on ambient temperature and humidity. Possibly, high rate of transpiration at room temperature could be main cause of higher weight loss. Hameed et al. [5] also reported that storage duration and room temperature having significant effect on weight loss. These results were in agreement with Halloran et al. [22], who found that the weight losses of sweet pepper stored at ambient condition with unpackaged condition were about 16 and 23 % on 7th day and 14th day, respectively. Nyalala and Wainwright [23] also reported that weight loss of sweet pepper stored at room temperature with unpackaged condition increased rapidly from 10th day until end of storage. Nyanjage et al. [21] found that sweet pepper stored at ambient conditions with bored poly package, only 6.12% weight loss was recorded, while at ambient temperature without packaged it was 16.25% at 10th day of storage which was partially in agreement with the finding of the present observation.

In the present study, the TSS of fresh sweet pepper in all combination was gradually increased with the increase in storage duration and temperature. The maximum TSS content in 10th day of storage was found in fruits stored at ambient temperature in perforated package which increased sharply on 20th day of storage. However, the minimum TSS content was recorded in unpackaged fruits kept at 4°C in both days of storage. This result verified the report of Nyalala and

Wainwright [23], who obtained the TSS of fruit stored in perforated poly pack under ambient temperature, exhibited an increase with the increase in storage time and the rate of increase was non-significantly higher in control than in other treatments during the entire storage period. Jimenez et al. [24] found a non-significant effect of temperature and packaging materials on TSS content of sweet pepper fruits. Their finding was in line with that of present observation. In the experiment, the ascorbic acid content was decreased gradually at 4°C, 6.5°C and ambient temperature at 10th day and 20th day. The result was in full conformity with the result of Kevresan et al. [25]. The results of the present experiment were in line with the results obtained by Howlader and Hossain [26], who reported that ascorbic acid contents of sweet pepper remained almost unchanged for the first 5 days of storage and then declined. The declining rate was slower at 4°C than 6.5°C. In the study, the ascorbic acid content was highest at perforated poly bag after that declined bit by bit at 10th and 20th day of storage. Fruits of non-perforated poly bag showed second highest ascorbic acid content and end of storage period it became lower. Similarly, fruits of unpackaged poly bag demonstrated the minimum ascorbic acid content initially and then declined the last storage period. Jimenez et al. [24] found the initial content of total ascorbic acid ranged from 47 to 80 mg per 100 g of fresh fruit in 'Cayenne' and 'Sondela' sweet pepper cultivars, respectively. Ayala-Villegas et al. [7] reported that cv. 'Sankeshwar' had consistently the highest total ascorbic acid content. The variation in total ascorbic acid throughout the storage period showed that the vitamin C content can be affected not only by the cultivar but also by the packaging [27]. These findings partially supported the result of the present investigation. In case of interaction effect of temperature and packaging, in 10th day of storage, the maximum content of ascorbic acid was obtained in fruits at 4°C with perforated packaging. The ascorbic acid content in fruits of perforated and non-perforated packaging started to decline up to 20 day of storage. Fruits stored in unpackaged condition exposed of minimum ascorbic acid content at 10 days of storage and it sharply declined on 20th day of storage. Similar outcomes showed at 6.5°C in different packaging materials in case of 10th day and 20th day of storage. Fruits stored in unpackaged condition at ambient temperature (25±1°C) revealed the minimum ascorbic acid content after 10 days of storage and it rapidly declined on 20th day of storage. Nyanjage et al. [21] found that ascorbic acid concentration of red ripe sweet pepper were relatively stable until 9th day of storage and then decreased more rapidly in perforated than in non-perforated packaging. The result is in full conformity with the result of Kevresan et al. [25]. In the study, the beta carotene content in sweet pepper at harvest was 42.46 µg per 100 g at all storage temperature. However, the beta carotene content was gradually increased in 4°C, 6.5°C and ambient temperature conditions at 10th day and 20th day of storage. In case of at 6.5°C the fruits of sweet pepper exhibited higher rate of increase in beta carotene content over time compared to ambient temperature. The results of the present experiment also supported the results obtained by Nyanjage et al. [21], who reported that beta carotene contents of sweet pepper increase sharply for first 10 day of storage and then slowly increased. The increasing rate was higher at 4°C than ambient temperature. In the experiment, beta carotene content of sweet pepper was observed an increasing trend due to different packaging during storage period. Initially the beta carotene content was similar but it was the highest at perforated packaging and increasing it bit by bit at day of 20. Fruits of unpackaged condition exhibited the minimum beta carotene content and it was happening to increase during storage period. Combination of storage temperature and packaging contributed positively on beta carotene content in sweet pepper. The maximum beta carotene content was found in fruits at 4°C stored at perforated packaging after 10 day of storage and started to increase very small amount at 20th day. Fruits at ambient temperature stored in unpackaged condition revealed the minimum beta carotene content at 10th day of and it sharply decrease on 20th day of storage. The increasing rate was higher at 4°C with perforated packaging than ambient temperature but insignificant different among the different temperature.

5. Conclusion

Among the storage materials perforated poly bag was found better in reducing fungal decay as well as for better visual appearance and excellent nutritive quality during 10th day of storage irrespective of temperature. Change in scanty of freshness, fruit quality and nutrient values of sweet pepper under storage in perforated poly bag compared to other packaging system. However, freshness of fruits was up to the marks and senescence of fruits was delayed in 4°C and in perforated poly bag up to 10th day of storage. These temperature (4°C) and perforated poly bag might be facilitated to sustain visual appearance and nutritional status of fruits. From this study it was concluded that fruits of 4°C stored in perforated poly bag for a period of 10th day was found to be acceptable regarding freshness, appearance and fruit quality.

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