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RESEARCH ARTICLE

Effects of packaging materials and storage conditions on storability of pepper (*Capsicum frutescens* L.) fruits

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ABSTRACT

Pepper is a perishable seasonal vegetable fruit that requires appropriate postharvest handling and storage to extend its shelf-life and preserve quality of the Pepper Fruit (PF). However, there is dearth of information on its handling and storage in Southwest Nigeria. Pepper grown in the organic field, Teaching and Research Farm, Federal University University, OyeEkiti were harvested with and without pedicels at 10 and 100% ripeness. Postharvest handling was evaluated by comparing packaging in perforated polyethylene, non-perforated polyethylene and aluminium-foil before storing in either Ambient Conditions (AC) of 21.9-33.5°C and 58-62% Relative Humidity (RH); Refrigerator (4.0°C and 40-45% RH) or Evaporative Coolant Structure (ECS) (10.0-15.8°C and 70-75% RH). Percentage Weight Loss (WL) was calculated. Firmness (FM) and Decay Level (DL) were evaluated on a scale of 1 to 4 and General Appearance (GA) on scale of 1 to 5. Data were analysed using correlation coefficient and ANOVA at $p \leq 0.05$. The shelf-life of PF harvested with pedicels at 10% ripeness and stored in refrigerator, ECS and AC was 27, 20 and 6 days respectively while shelf life of PF harvested at 100% ripeness was 21, 14, and 3 days, respectively. In contrast, the shelf life of PF harvested without pedicel at 10% ripeness was 21, 18 and 5 days while for 100% ripeness, it was 18, 15 and 2 respectively. The WL, DL, GA and firmness of fruits harvested at 10% with pedicels and stored in refrigerator was 14.0%, 3.0, 4.0 and 3.5. The PF packaged in the aluminium-foil had significantly longer (30 days) shelf life than those packaged in perforated polyethylene (21 days) and non-perforated polyethylene (15 days). Storability of PF was best at 10% ripeness with pedicel.

Keywords: Pepper storability, Packaging, *Capsicum frutescens*, Postharvest, Quality

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INTRODUCTION

Various authorities have estimated 25 - 70 % of fresh fruit and vegetables produced lost after harvest (Daramola and Okoye, 1998). These losses have been found to be due to loss of moisture, changes in composition during metabolism, pathogen attack, temperature and relative humidity of the storage environment. Other factors that contribute to deterioration include initial quality of crop, mechanical injury, transportation method, maturity stage and harvesting method. The storage life of produce is highly variable and can be related to the wide range of respiration rate among different plant tissues. Peppers stored above 7.5 °C suffer more water loss and shrivel. Storage below 7.5 °C is best for maximum shelf life of 3 - 5 weeks, although injury might begin after that period (Bechmann and Earles, 2,000). The storage temperature for pepper also depends on use and moisture level. Dried pepper are allowed to equalise in moisture content, they are then packed tightly into sacks and stored in non-refrigerated warehouses for up to 6 months. Storage under low temperature aids loss of red colour and slowing down insect activities. Rapid pre-cooling of harvested pepper is essential in reducing marketing losses and this can be

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done by forced air cooling, hydro-cooling or vacuum-cooling, if hydro-cooling is used, care should be taken to prevent development of decay (Wills et al*.,* 1989). The use of polyethylene bags provides better storage, ensures pods maintain constant moisture content during storage up till the time of grinding. Various researches were carried out to investigate the effectiveness of the evaporative coolant structure in prolonging shelf-life of horticultural crop. Babatola and Adewoyin(2005) observed that *Cucumissativus* stored best for 3 weeks under the refrigerator followed by evaporative coolant structure and then open shelf. The evaporative coolant stored cucumber fruit effectively for 2 weeks. Babatola and Adewoyin (2006) also investigated the effect of storage conditions on nutrient composition and quality of *Capsicum frutescens* under three storage conditions. Observations were made on colour, firmness, weight loss, disease incidence and pungency level of pepper fruit. It was observed that pepper fruits kept well for 21 days in the evaporative coolant structure at a temperature of 20 - 22°C. Babatola and Adewoyin (2007) further investigated the effect of NPK fertilizer levels on growth, yield and storage of pepper on *Capsicum annum*. The result showed that fruits stored in the refrigerator stored best for 3 weeks, followed by evaporative coolant structure which stored for 2 weeks while fruits under the ambient condition deteriorated rapidly after 4 days. The quality of fruit and vegetable cannot be improved but it can be preserved. Good quality is obtained when harvesting is done at the proper stage of maturity. Immature fruit when harvested will give poor quality and erratic ripening. Delay harvesting of fruits however may increase their susceptibility of decay, resulting in poor quality and low market value. Harvesting of crops is very important togrowers of vegetable. Some vegetables are harvested when tender like green beans before developing high fibre and lignin. Fresh produce is ready for harvest when it has developed to the ideal condition for consumption. This condition is usually referred to as harvest maturity. Botanical maturity refers to the time when the plant has completed its active growth and arrived at the stage of flowering and seed production.But harvest maturity refers to the time vegetables are ready for harvest and musttake into account the time required to reach market and how it will be managed before getting to consumer.

MATERIALS AND METHODS

The experiment was a factorial arrangement in completely randomised design replicated three times. Pepper fruits of uniform sizes harvested with pedicels at 10 % ripeness were randomly selected for the experiment. Fruits weighing 500 g were packaged into the different packaging materials that were sealed before placing in the different storage conditions. The packaging materials were transparent non-perforated polyethylene bag, perforated polyethylene bag, aluminium foil paper, and unpackaged fruits (control). The storage conditions were ambient (21.9 - 33.5 °C; 58 - 62 %RH), evaporative coolant structure (Figure 1) (10 - 15.8 °C; 70 - 75 %RH), and refrigerator (4 °C; 40 - 45 %RH).Observations were made at six days intervals on the following parameters.

Weight loss

The Percentage change in weight was calculated by using following formula

$$\text{Weight loss} = \frac{\text{Loss in weight}}{\text{Original weight}} \times 100$$

Freshness

Freshness was assessed at six days intervals of storage using a scale of 0 - 4 as described by IPGRI/IITA (1998) where 0 = Poor (musty odour, turns brown, slimy and decayed), 1 = Unacceptable (no freshness, fruit with black streak), 2 = Acceptable (appearance of limited acceptability), 3 = Good (overall appearance good), and 4 = Excellent (overall appearance excellent).

Firmness

Observations were made at 6 days interval by hand feel to determine using the following scale. Not firm = 1; slightly firm = 2; Firm = 3; very Firm = 4 (Babatola and Adewoyin, 2002).

Data Analysis

Data were subjected to Analysis of Variance (ANOVA) and Correlation analysis. Means were separated using Duncan Multiple Range Test (DMRT) at $p < 0.05$.

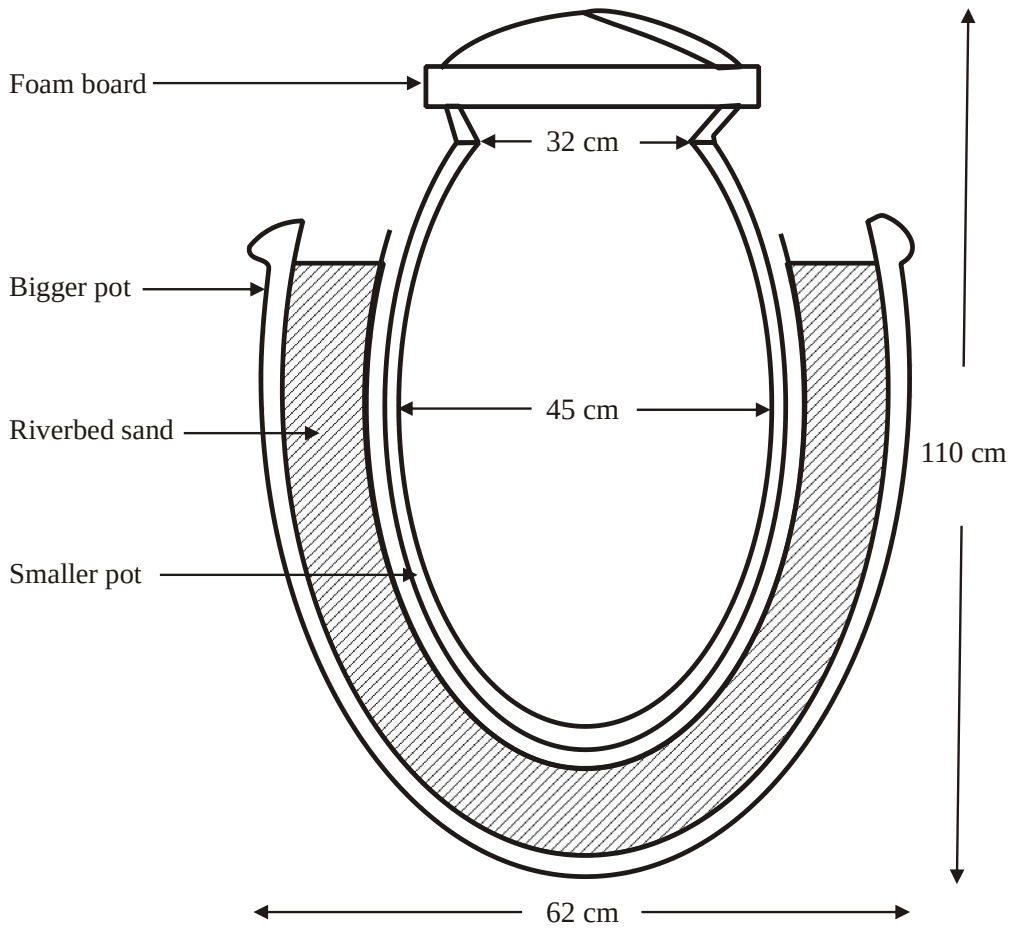

Figure 1. Structure of evaporative coolant

RESULTS AND DISCUSSION

Weight Loss

Pepper fruits kept in the refrigerator had the lowest WL of 2.8 to 11.8 % from 3 to 30 DIS compared with the corresponding values of 6.4 to 23.5 % and 3.5 to 20.9 % for ambient and ECS respectively. However WL of fruits kept in the ECS were lower than those in the ambient condition (Table 1).Pepper fruits packaged in aluminium foil had significantly lower

WL of 3.2 to 13.6 % from 3 to 30 DIS compared with the corresponding values of 3.5 - 14.6 % for fruits packaged in perforate polyethylene, 4.8 to 22.4 % for non-perforated polyethylene and 5.4 to 24.4 % for unpackaged fruits respectively (Table 1).The interactions of packaging materials and storage conditions were significant on weight loss at 3, 9, 15, and 27 DIS (Table 1). Pepper fruits packaged in aluminium foil and stored in the refrigerator had lower weight loss of 2.1 % at 3 DIS to 7.2 % at 27 DIS compared to those packaged in perforated polyethylene with a weight loss of 2.6 % at 3 DIS to 9.2 % at 27 DIS followed by non-perforated polyethylene package with a weight loss value of 3.2 % at 3 DIS to 10.4 % at 27 DIS. Unpackaged pepper fruits had the highest weight loss of 3.8 % at 3 DIS to 14.2 % at 27 DIS.

Table 1: Effects of packaging materials and storage conditions on weight loss (%) of pepper fruit

Treatment	Days in Storage					
	3	9	15	21	27	30
Storage Conditions						
Ambient	6.4a	11.2a	17.0a	20.5a	22.7a	23.5a
Evaporative coolant structure	3.5b	8.2b	12.6b	16.0b	18.8b	21.0b
Refrigerator	2.8c	6.7c	7.9c	8.9c	10.3c	11.8c
SE	0.09	0.07	0.11	0.12	0.12	0.11
Packaging Methods						
Aluminium foil	3.2d	5.9d	7.9d	10.6d	12.0d	13.6d
Perforated Polyethylene	3.5c	8.2c	10.7c	13.4c	14.7c	14.6c
Non-perforated Polyethylene.	4.8b	9.7b	14.8b	17.4b	19.7b	22.4b
Unpackaged (control)	5.4a	11.1a	16.5a	19.2a	22.0a	24.4a
SE	0.04	0.09	0.13	0.13	0.14	0.13
SE (Packaging × Storage)	0.09*	0.13*	0.23*	0.24ns	0.11*	0.1ns

ns = Not significant, * = Significant at $p < 0.05$; For each factor, means followed by the same letter(s) in columns are not significantly different by Duncan Multiple Range Test (DMRT) at $P < 0.05$.

Pepper Fruit Firmness

Firmness of pepper fruits differed significantly among the three storage conditions: refrigerator, ECS and ambient following the order refrigerator > ECS > ambient from 3 to 30 DIS (Table 2). Fruits kept in refrigerator had the highest firmness values of 4.0 to 1.7 from 3 to 30 DIS compared to corresponding values of 3.7 to 1.1 and 3.3 to 1.1 for ECS and ambient respectively. Firmness of pepper fruit was significantly affected by packaging materials at 3 to 30 DIS, those fruits packaged in aluminium foil had the highest values (3.8 to 1.6) than all the other treatments at 3 to 30 DIS, also fruits packaged in the perforated polyethylene had higher values (3.0 to 1.3) compared to those fruits in the non-perforated polyethylene at 9 to 30 DIS. The unpackaged fruits as well as those in the non-perforated polyethylene had lower values which were similar at 27 and 30 DIS (Table 2).

The interaction of packaging materials and storage conditions on firmness score of pepper fruits was significant at 3, 9, 15, 21, 27 and 30 DIS (Table 2). Pepper fruits packaged with aluminium foil kept in refrigerator consistently had the highest firmness score of 3.4 to 2.6 at 9 to 27 DIS while the unpacked fruits kept under ambient condition had the lowest values (2.7 to 1.5). At 3 DIS, fruits kept in the refrigerator after packaging with foil and perforated polyethylene had score of 4.0 that was highest while the unpacked fruits had the lowest value (3.5). Firmness of pepper fruits followed the order ambient < ECS <

refrigerator for storage condition, with respect to packaging materials, pepper fruit firmness followed the order aluminium > perforated polyethylene > non-perforated polyethylene > unpackaged fruits in all the storage conditions from 9 to 30 DIS.

Freshness

Freshness of pepper fruits was significantly affected by storage conditions at 3 to 27 DIS. Freshness score were highest on the fruits stored in the refrigerator at 3, 15, and 21 DIS and maximum at 9, 27, and 30 DIS. Freshness score of pepper fruits with respect to storage also followed the order refrigerator > ECS > ambient condition at 3 and 21 DIS while the ones in ECS had values comparable to the maximum at 9, 27, and 30 DIS. Pepper fruits stored in the refrigerator had higher freshness score of (3.8 to1.8) compared to ECS (3.5 to 1.5) and ambient (2.6 to 1.0) from 3 to 30 DIS. Pepper fruits freshness reduced as storage duration increased from the 3rd to 30th day in storage. Pepper fruits packaged in aluminium foil had significantly higher freshness than all other packaging treatments at 3, 9 and 15 DIS and those fruits in non-perforated P.E and unpackaged fruits at 21 and 27 DIS.

Furthermore, fruits packaged in perforated P.E had higher firmness score than those without packaging and those in non- perforated P.E at 3, 9, 21 and 27 DI S as well as the unpackaged fruits at 15 DIS. Fruits in the non- perforated P.E also had higher pepper fruit freshness than the unpackaged fruits at 9 and 15 DIS. At 21 and 27 DIS no difference was observed in fruits packaged with aluminium foil and perforated P.E. The interaction of packaging materials and storage conditions on freshness score of pepper fruits was significant at 15, 21 and 27 DIS (Table 3). Fruits packaged in aluminium foil, kept in the refrigerator had the highest freshness value among various under combinations while the unpackaged fruits kept in the ambient had the lowest values. The freshness values of fruits packaged with perforated P.E under the ambient was comparable to that of unpackaged fruits in ECS at15 DIS. Fruits packaged with aluminium foil kept in the ambient also had freshness value comparable to those packaged with non-perforated P.E kept in the refrigerator at 21 DIS.

Table 2. Effects of packaging methods and storage conditions on firmness of pepper fruits

Treatments	Days in Storage					
	3	9	15	21	27	30
Storage Conditions						
Ambient	3.3a	2.6a	2.2a	1.9a	1.5a	1.1a
Evaporative coolant structure	3.7b	3.1b	2.7b	2.3b	2.8b	1.1b
Refrigerator	4.0c	3.7c	3.1c	2.4c	2.9c	1.7c
SE	0.01	0.01	0.01	0.01	0.02	0.01
Packaging Methods						
Aluminium foil	3.8a	3.2a	2.9a	2.5a	2.1a	1.6a
Perforated Polyethylene	3.6b	3.0b	2.6b	2.3b	1.9b	1.3b
Non-perforated Polyethylene	3.6b	2.8c	2.4c	2.2c	1.4c	1.1c
Unpackaged (control)	3.5c	2.6d	2.2d	1.9d	1.4c	1.1c
SE	0.01	0.01	0.01	0.01	0.02	0.21
SE (Packaging × Storage)	0.04*	0.02*	0.03*	0.04*	0.08*	0.02*

Firmness scoring scale =1 to 4 (1=Not firm; 2=Slightly firm; 3=Firm; 4=Very Firm); * = Significant at $p < 0.05$; For each factor, means followed by the same letter(s) in columns are not significantly different by Duncan Multiple Range Test (DMRT) at $P < 0.05$

Table 3. Effects of packaging methods and storage conditions on freshness of pepper fruits

Treatment	Days in storage					
	3	9	15	21	27	30
Storage Conditions						
Ambient	2.6c	2.5b	2.2c	1.8c	1.6b	1.0b
Evaporative Coolant Structure	3.5b	3.0ab	2.7b	2.4b	2.1ab	1.5ab
Refrigerator	3.8a	3.6a	3.4a	2.8a	2.5a	1.8a
SE	0.05	0.34	0.07	0.09	0.20	0.18
Packaging Methods						
Aluminium foil	3.8a	3.5a	3.2a	2.8a	2.5a	1.6a
Perforated Polyethylene.	3.3b	3.1b	2.8b	2.6a	2.2a	1.3a
Non-perforated Polyethylene.	3.0c	2.9c	2.6c	1.8b	1.4b	1.2a
Unpackaged (control)	2.9c	2.6d	2.3c	2.1b	1.1b	1.0a
SE	0.06	0.04	0.08	0.11	0.24	0.21
SE (Packaging × Storage)	0.04ns[4]	0.20ns	0.03*	0.02*	0.03*	0.07ns

Freshness scoring scale of 0 to 4 (0 = poor, 1= unacceptable, 2 = acceptable 3 = good, 4 = excellent); ns = Not significant, * = Significant at $p < 0.05$; For each factor, means followed by the same letter(s) in columns are not significantly different by Duncan Multiple Range Test (DMRT) at $P < 0.05$

Correlation of firmness, freshness and weight loss of pepper fruits

Freshness and firmness of pepper fruit were positively correlated at 3 to 30 DIS while both parameters were negatively correlated with weight loss of pepper fruits at the corresponding DIS (Table 4).

DISCUSSION

Fruits packaged in aluminium foil and stored under ambient conditions with the temperature fluctuating between 21.9 °C and 33.5 °C and relative humidity of 58 – 62 % lost moisture very rapidly after five days. The characteristic high temperature and relative humidity of the tropics have been extensively reported as the most important environmental conditions in determining shelf life of fruits and vegetables (Willis et al*.,* 1998). The high temperature led to increased rate of respiration and other metabolic processes that caused depletion of substrates like sugar and protein resulting in increased weight loss. Fruits packaged in perforated polyethylene bag, placed in refrigerator extended shelf life to 21 DIS. Moisture saturated atmosphere within the packaging material decrease moisture loss due to transpiration thereby extended postharvest longevity of pepper fruits (Banaras et al*.,* 2005). Horticultural crops continue their living process after harvesting therefore, there is a need for air circulation to maintain the CO_2/O_2 ratio within the packaging material, hence the essence of perforation in this study. Pepper fruits packaged in perforated polyethylene bag stored in ECS for 18 DIS while fruits placed under ambient deteriorate rapidly after three days in storage (Babatola and Adewoyin, 2009). This study showed that weight loss, firmness and freshness of Pepper fruits were maximally conserved in fruits packaged in aluminium foil and placed inside refrigerator (4 °C) which remained firm, fresh with reduced WL for a longer period (30 DIS) compared to those in ECS (27 DIS) and ambient condition (9 DIS). Fruits packaged in perforated polyethylene bag however remained firm for 21 DIS in the refrigerator, 15 DIS in the ECS and 5 DIS under ambient condition showing corresponding difference in period between aluminium foil and perforated polyethylene of 9, 12 and 4 DIS shelf-lives respectively.

Table 4. Correlation coefficient (r) among fruit quality traits in pepper (n = 36)

	Days in Storage																	
	3	9	15	21	27	30	3	9	15	21	27	30	3	9	15	21	27	30
	Freshness						Firmness						Weight loss					
Freshness 3 DIS																		
Freshness 9 DIS	0.84																	
Freshness 15 DIS	0.74	0.97																
Freshness 21 DIS	0.81	0.96	0.95															
Freshness 27 DIS	0.71	0.91	0.95	0.98														
Freshness 30 DIS	0.69	0.94	0.93	0.97	0.96													
Firmness 3 DIS	0.83	0.90	0.85	0.80	0.73	0.77												
Firmness 9 DIS	0.86	0.83	0.75	0.88	0.84	0.81	0.73											
Firmness 15 DIS	0.86	0.87	0.83	0.91	0.87	0.82	0.77	0.95										
Firmness 21 DIS	0.81	0.82	0.77	0.85	0.79	0.77	0.79	0.88	0.88									
Firmness 27 DIS	0.80	0.74	0.71	0.85	0.81	0.74	0.54	0.82	0.81	0.71								
Firmness 30 DIS	0.51	0.71	0.70	0.69	0.70	0.74	0.56	0.60	0.61	0.45	0.58							
Weight loss 3 DIS	-0.89	-0.89	-0.82	-0.88	-0.81	-0.82	-0.91	-0.91	-0.92	-0.86	-0.70	-0.54						
Weight loss 9 DIS	-0.86	-0.94	-0.89	-0.94	-0.88	-0.88	-0.85	-0.92	-0.95	-0.91	-0.78	-0.59	0.92					
Weight loss 15 DIS	-0.81	-0.93	-0.88	-0.92	-0.86	-0.88	-0.88	-0.85	-0.89	-0.87	-0.74	-0.63	0.92	0.97				
Weight loss 21 DIS	-0.81	-0.95	-0.92	-0.92	-0.86	-0.89	-0.91	-0.79	-0.84	-0.85	-0.69	-0.66	0.90	0.94	0.97			
Weight loss 27 DIS	-0.74	-0.95	-0.94	-0.94	-0.89	-0.92	-0.86	-0.75	-0.81	-0.82	-0.70	-0.67	0.85	0.92	0.96	0.99		
Weight loss 30 DIS	-0.64	-0.89	-0.91	-0.92	-0.89	-0.91	-0.77	-0.70	-0.76	-0.75	-0.73	-0.67	0.78	0.86	0.93	0.93	0.97	

Fruits packaged in non-perforated polyethylene bag and unpackaged fruits were lower in firmness, freshness and had higher WL. Mordi and Olorunda, (2003) reported shelf-life of unpackaged fresh tomatoes in evaporative cooler environment as 11 days from the 4 days shelf life under the ambient conditions while in combination with sealed but perforated polyethylene bags was 18 DIS in ECS and 13 DIS under the ambient condition. In this study, when packaged in a non-perforated polyethylene bag, pepper fruits placed in refrigerator appeared more wholesome with shelf-life of 12 DIS compared to 9 and 3 DIS for those in the ECS and ambient condition respectively (Babatola and Adewoyin, 2006). Pepper fruits without packaging materials lost weight more rapidly in all storage conditions with shelf-life of 12, 9 and 3DIS for refrigerator, ECS and ambient condition respectively. The higher WL observed for the unpackaged pepper fruits throughout the various storage conditions could be attributed to air movement which tend to sweep away the layer of air (at equilibrium vapour pressure with the tissues) adjacent to the surface of the produce thus increasing vapour deficit (Willis et al*.,* 1998).Pepper fruits packaged in aluminium foil and placed inside refrigerator (4°C) remained significantly higher in freshness for 30 DIS compared to those in ECS (27 DIS) and ambient condition (9DIS) respectively. Higher temperature gives rise to higher physiological activities, and increase in respiration rate in plants. Wills et al. (1998) observed that at high temperature water evaporates from the tissue, turgor pressure decreases and the cell begins to shrink and collapse thus leading to loss of freshness. Pepper fruits packaged in non-perforated polyethylene bag placed in refrigerator were less wholesome after 18 DIS compared with aluminium foil and perforated polyethylene. Fruits stored in non-perforated polyethylene bag placed in ECS kept for 12 DIS. Freshness and firmness of pepper fruit were positively correlated at 3 to 30 DIS while both parameters were negatively correlated with weight loss of pepper fruits at the corresponding DIS.

CONCLUSION

Pepper fruits exhibited more acceptable quality indices such as higher freshness, firmness and lower WL for fruits packaged in aluminium foil compared to perforated polyethylene bag and then non-perforated polyethylene bag while the unpackaged lot deteriorated faster and had reduced shelf-life. This showed that good packaging is imperative in extending shelf life of pepper fruits.

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