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USING MODIFIED ATMOSPHERE TREATMENTS FOR PROLONGING STORAGE AND SHELF LIFE OF SWEET PEPPER FRUITS

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ABSTRACT: This work was carried out in Post-Harvest Laboratory, Horticulture Department, Faculty of Agriculture, Zagazig University, Egypt during 2015 and 2016 seasons, to determine the effect of modified atmosphere (MA) treatments on storability and quality of sweet pepper fruits during cold storage and shelf life period. Storing sweet pepper fruits in different mixtures of O_2 and CO_2 in active modified atmosphere (AMA) containing 6% O_2+4% CO_2, 4% O_2+ 4% CO_2, 2% O_2+ 4% CO_2 and 3% O_2 +3%CO_2 as well as storing in perforated LDPE bags at 0.50% and 0.25% decreased fresh weight loss percentage (FWL) of fruits and maintained fruit firmness and total chlorophyll in fruit tissues compared to passive modified atmosphere (PMA) during cold storage and shelf life periods in both seasons. Storing sweet pepper fruits in AMA containing 4% O_2+4% CO_2 or 2% O_2+4% CO_2 decreased FWL of fruits. Moreover, storing fruits in AMA containing 2% O_2+4% CO_2 maintained fruit firmness at 28 days of cold storage and shelf life in both seasons. No decay was observed and general appearance (GA) of fruits was excellent at 28 days of cold storage in both seasons with storing in AMA, perforated low density polyethylene (LDEP) bags and PMA. Storing green pepper fruits in AMA containing 2% O_2+4% CO_2 maintained the best quality characters at 28 days at 8±1^{o}C and 90-95% RH. Fresh weight loss percentage and fruit decay were gradually increased with the advance of cold storage periods .On the contrary, fruit firmness, general appearance and total chlorophyll in fruit tissues were gradually decreased with the advance of cold storage periods.

Key words: Sweet pepper, modified atmosphere, fresh weight loss, decay, fruit firmness, general appearance.

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is an important crop for local and exportation markets and can be consumed in many colours (Frank *et al*., 2001). Pepper is rich in vitamins, especially A and C, and is low in calories (Howard *et al*., 1994). About 40 – 50% of horticultural crops produced in developing countries are lost before they can be consumed, mainly because of high rates of bruising, water loss, and subsequent decay during postharvest handling (Kitinoja, 2002; Ray and Ravi, 2005). Approximately one third of all fresh fruits and vegetables were lost before it reaches to the consumers (Kader, 2002). Another estimate suggested that about 30–40% of total fruits and vegetables production were lost in between harvest and final consumption (Salami *et al.*, 2010).

The main factors of quality degradation of sweet pepper during prolonged storage are decay development (Barkai-Golan, 1981), shriveling associated with rapid water loss (Maalekuu *et al*., 2003), poor external appearance (Ceponis *et al*.,1987) and susceptibility to chilling injury (CI), which limits storage to temperature above 7ºC (Paull, 1990). Peppers are non-climacteric and produce very low levels of ethylene at 0.1 to 0.2 µl kg^{-1} h^{-1} at 10 and 20°C (50 and 68°F), respectively. Fresh peppers can be kept for 2 to 3 weeks at 7°C (45 °F) with 90 to 95% RH. Storage-life can be extended another week by packaging in moisture-retentive films at 7 to 10°C (Gross *et al*., 2016).

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Peppers derive a slight benefit from controlled atmosphere (CA) storage (Saltveit, 1997). Low O_2 atmospheres (2 to 5% for bell and 3 to 5% for chili) retard ripening and respiration during transit and storage, and have a slight benefit on quality. At 10°C (50°F), high CO_2 (> 5%) can cause calyx discoloration, skin pitting, discoloration and softening in both bell and chili peppers. 3% O_2 + 5% CO_2 atmosphere is more beneficial for red than green peppers stored at 5 to 10°C (41 to 50 °F) for 3 to 4 weeks. Before processing, chili peppers can be stored under 3 to 5% O_2 + 15 to 20% CO_2 for up to 3 weeks at 5°C (41 °F) without appreciable chilling injury or quality loss. Freshly harvested chili or other hot peppers should be stored under the same temperature and RH conditions as sweet peppers (Gross *et al*., 2016).

Modified atmosphere packaging (MAP) is technique that has been used to inhibit fruit respiration, delay ripening, decrease ethylene production, retards softening, maintains color and extend the shelf life of pepper fruits (Ben-Yehoshua *et al*., 1983; Miller *et al*., 1986; Gonzalez and Tiznado, 1993). These beneficial effects can be explained by the MA created inside the package, as well as the reduction in water loss, high CO_2 and/or low O_2 atmospheres have been reported of bell peppers during storage (Luo and Makitzel, 1996).

Therefore, the objective of this work was to study the effect of some modified atmosphere (MA) treatments on storability and quality of sweet pepper fruits during cold storage and shelf life periods.

MATERIALS AND METHODS

This work was carried out in Post-Harvest Laboratory, Horticulture Department, Faculty of Agriculture, Zagazig University, Egypt during 2015 and 2016 seasons, to determine the effect of modified atmosphere (MA) treatments on storability and quality of sweet pepper fruits during cold storage and shelf life periods.

Seeds of green sweet pepper (*Capsicum annuum* L.) cv. Top Star F1 were sown in the nursery on September 15th, 2015 and September 20th, 2016 and seedlings were transplanted on November 1st and 5th in the first and second seasons, respectively, in sandy soil under low plastic tunnels conditions at private farm, Al-Khattara region, Sharkia Governorate, Egypt. Fruits were harvested with a short calyx (1 cm long) and uniformed size at green ripe stage in the first week of March in 2015 and 2016 seasons. The source of Top Star F1 (type Japanase) was Gaara Company- Import and Export, Cairo, Egypt.

Green sweet pepper fruits were packed in carton boxes and transported directly to the Post-Harvest Laboratory, Hort. Dept., Fac. Agric., Zagazig University. Fruits without any insect infestation or defects (sunburn, crack, bruise and cuts) were discarded. All fruits were washed with regular tap water and soap and then rinsed with water to remove the residue of soap, dipped in aqueous solution of 0.1% imazalil for two minutes according to Spalding (1980) as a disinfectant, then, air dried. This experiment included 7 treatments as follows:

1. Storing fruits in active modified atmosphere (AMA) containing 6% O_2 + 4% CO_2.
2. Storing fruits in AMA containing 4% O_2 + 4% CO_2.
3. Storing fruits in AMA containing 2% O_2 + 4% CO_2.
4. Storing fruits in AMA containing 3% O_2 + 3% CO_2.
4. Storing fruits in perforated low density polyethylene (LDPE) bags at 0.50%.
6. Storing fruits in perforated LDPE bags at 0.25%.
7. Storing fruits in passive modified atmosphere (PMA).

These treatments were arranged in a randomized compete block design. Each treatment was divided into three replicates, uniform fruits were taken at random for each replicate. Ten fruits were placed in carton box which were covered with low density polyethylene (LDPE) bags and injected with the previous gases (AMA) or covered with perforated LDPE bags with 0.25 and 0.50% or covered with sealed LDPE bags (PMA), then stored at 8 ± 1°C and 90-95% RH. The samples of each treatment were randomly taken weekly intervals (at 0, 7, 14, 21, 28, 35 and 42 days of

storage periods). After each cold storage period the fruits were subjected to conditions of 20 ± 2ºC and 60- 70% RH for three days as a shelf life (similarly as super market conditions).

Data Recorded

Fresh weight loss (FWL%)

The fruits will be weighed before cold storage to obtain the initial weight, and then weighed after each period of storage as well as shelf life (AOAC, 2007).

$$FWL\,(\%) = \frac{Wi - Ws}{Wi} \times 100$$

Where:

Wi = fruit weight at initial date.

Ws = fruit weight at sampling date.

Fruit decay percentage

Decay of fruit was recorded as soon as fungal mycelia appeared on the calyx or peel of the fruit and it was calculated as a percent of the number of decayed fruits to the total number of fruits at each sampling date (El-Mougy *et al.,* 2012).

Fruit firmness (g/cm^2)

It was determined on five fruits per replicate and measurements were taken from each fruit using a Push Pull dynamometer (Model FD 101). The values were expressed as g/cm^2.

General appearance (GA)

It was evaluated by using a scale from 1-9 with: 9 = excellent , 7 = good, 5 = fair, 3 = poor, 1 = unsalable, and fruits rating 5 or below were considered unmarketable (Shehata *et al*., 2013).

Total chlorophyll

A spectrophotometric method was used for determination of chlorophyll a and chlorophyll b (Wettestein, 1957).

Statistical Analysis

The analysis of variance was calculated according to Snedecor and Cochran (1980). Means separation was done according to LSD at 0.05% level.

RESULTS AND DISCUSSION

Fresh Weight Loss Percentage (FWL)

During cold storage periods

Fresh weight loss percentage (FWL) increased with the advance of cold storage periods (Table 1). Storing sweet pepper fruits in AMA containing 6% O_2+4% CO_2, 4% O_2+ 4% CO_2, 2% O_2+4%CO_2, 3% O_2 +3% CO_2 and storing in perforated LDPE bags at 0.50 and 0.25% decreased FWL of fruits at 28, 35 and 42 days of cold storage compared to storing fruits in PMA, except storing in perforated LDPE bags at 0.50 and 0.25% in the 2nd season. Storing fruits in AMA containing 4% O_2 + 4% CO_2 and 2% O_2+4% CO_2 decreased FWL of fruits at 28 days of cold storage in both seasons with no significant differences with storing in AMA containing 6% O_2+4% CO_2, 3% O_2+ 3% CO_2 and perforated LDPE bags with 0.50 in the 1st season.

Shehata *et al*. (2013) found that active modified atmosphere at 5% O_2 + 10% CO_2 treatment was the promising technique for maintaining quality and extending storage period of sweet pepper fruits. Weight loss percentage increased with prolonging cold storage periods (Shehata *et al*., 2013; Tsegay *et al*., 2013).

The lowest weight loss of fruit sealed in different films may be due to the lower respiration rate of the pepper which would have occurred with the higher CO_2 and lower O_2 levels inside these films. Moreover, the weight loss reduction is mainly a consequence of the water vapor accumulation within the plastic bags during storage (Akbudak *et al.,* 2012). Water loss can be one of the main causes of deterioration, since it not only results in indirect quantities losses, but also causes losses in appearance (due to wilting and shriveling) and nutritional quality. Modified atmosphere (MA) does not directly affect the rate of water loss, but the need for a gas tight environment for MA storage and transport often results in significantly higher relative humidity around the commodity and consequently reduces water loss compared to air storage (Kader, 1986). The present study demonstrates that the high humidity obtained within the MA packages,

Table 1. Effect of modified atmosphere on fresh weight loss percentage of sweet pepper fruits during cold storage periods in 2015 and 2016 seasons

Treatment		Storage period (day)					
		7	14	21	28	35	42
				2015 season			
AMA	6% O_2+4%CO_2	0.31	0.47	0.52	0.63	0.63	1.21
	4% O_2+4%CO_2	0.48	0.52	0.54	0.69	0.73	1.03
	2% O_2+4%CO_2	0.31	0.51	0.60	0.64	0.90	0.96
	3% O_2+3%CO_2	0.43	0.44	0.59	0.61	0.95	1.25
Perforated LDPE	0.50%	0.46	0.49	0.58	0.72	0.91	1.24
	0.25%	0.47	0.60	0.68	0.69	0.82	1.19
PMA	Sealed LDPE	0.53	0.58	0.82	0.94	1.15	1. 47
LSD at 0.05 level		0.08	0.12	0.28	0.13	0.16	0.13
				2016 season			
AMA	6% O_2+4%CO_2	1.69	1.78	2.24	2.23	2.23	2.74
	4% O_2+4%CO_2	1.47	1.56	1.89	2.04	2.25	2.56
	2% O_2+4%CO_2	1.39	1.46	1.94	2.00	2.53	2.54
	3% O_2+3%CO_2	1.24	1.94	2.20	2.25	2.85	2.96
Perforated LDPE	0.50%	1.36	1.60	2.16	2.28	2.88	2.95
	0.25%	1.41	1.77	2.05	2.19	2.75	2.83
PMA	Sealed LDPE	1.27	1.62	2.31	2.39	3.17	3.13
LSD at 0.05 level		0.19	0.15	0.15	0.16	0.13	0.14

LDPE: Low density polyethylene bags, AMA: Active modified atmosphere, PMA: Passive modified atmosphere

significantly delayed fruit water loss, leading to inhibition of ripening (expressed as peel color changes).

During shelf life periods

Obtained results in Table 2 show that, after three days of shelf life, FWL increased with the advance of cold storage periods in both seasons. During shelf life periods, there were no significant differences among all modified atmosphere (MA) treatments, however storing sweet pepper fruits in AMA containing 4% O_2 + 4% CO_2, 2% O_2 + 4% CO_2 and storing in perforated LDPE bags at 0.50% gave the lowest values of FWL at 28 days of cold storage in both seasons with no significant differences with storing in AMA containing 6% O_2 + 4% CO_2 and storing in perforated LDPE bags at 0.25% in the 1 st season.

After three days of shelf life, storing fruits in all AMA treatments and perforated LDPE bags at 0.50% and 0.25%, decreased FWL of fruits compared to PMA at 28 and 35 days of cold storage in both seasons.

Anandaswamy *et al*. (1959) indicated that the shelf life of the green pepper fruits cloud be prolonged by using perforated polyethylene bags. Ventilation of the packages should be adequate to avoid off flavor development and moisture condensation inside the packages.

Decay Percentage (DP)

During cold storage periods

Results presented in Table 3 show that DP increased with the advance of cold storage periods. This may be due to the continuous chemical and biochemical changes in the fruits such as transformation of complex compounds to simple forms that more liable to fungal infection. All treatments did not show any decayed fruits until 28 days of cold storage in both seasons.

Table 2. Effect of modified atmosphere on fresh weight loss percentage of sweet pepper fruits during shelf life periods in 2015 and 2016 seasons

Treatment		Storage period (day)					
		7	14	21	28	35	42
				2015 season			
AMA	6% O_2+4% CO_2	6.04	8.60	8.66	8.82	11.14	11.48
	4% O_2+4% CO_2	7.05	8.27	8.21	8.84	13.82	14.06
	2% O_2+4% CO_2	5.95	7.49	8.50	8.50	16.35	16.82
	3% O_2+3% CO_2	5.51	7.85	8.00	9.89	14.00	14.00
Perforated	0.50%	6.20	7.33	8.17	8.71	11.01	12.64
LDPE	0.25%	5.83	7.24	7.50	8.71	14.86	15.20
PMA	Sealed LDPE	5.80	8.49	8.84	14.76	18.24	16.11
LSD at 0.05 level		0.63	0.68	0.65	0.84	0.93	0.80
				2016 season			
AMA	6% O_2+4% CO_2	12.66	14.60	16.39	16.74	24.67	50.64
	4% O_2+4% CO_2	12.98	13.12	14.24	16.38	21.55	48.67
	2% O_2+4% CO_2	14.43	14.46	14.85	15.88	23.76	46.47
	3% O_2+3% CO_2	14.85	14.46	15.79	16.85	24.33	46.47
Perforated	0.50%	14.08	14.22	14.63	16.25	22.66	55.99
LDPE	0.25%	15.93	15.96	16.34	17.32	19.44	35.02
PMA	Sealed LDPE	14.77	16.43	17.67	18.73	25.72	56.11
LSD at 0.05 level		1.07	0.86	1.35	0.85	1.03	1.41

LDPE: Low density polyethylene bags, AMA: Active modified atmosphere, PMA: Passive modified atmosphere

Table 3. Effect of modified atmosphere on decay percentage of sweet pepper fruits during cold storage periods in 2015 and 2016 seasons

Treatment		Storage period (day)					
		7	14	21	28	35	42
				2015 season			
AMA	6% O_2+4%CO_2	0	0	0	0	25.00	18.88
	4% O_2+4%CO_2	0	0	0	0	36.66	27.77
	2% O_2+4%CO_2	0	0	0	0	30.00	22.22
	3% O_2+3%CO_2	0	0	0	0	30.09	11.33
Perforated	0.50%	0	0	0	0	6.66	0.00
LDPE	0.25%	0	0	0	0	41.11	16.66
PMA	Sealed LDPE	0	0	0	0	48.33	33.33
LSD at 0.05 level		--	--	--	--	2.84	3.71
				2016 season			
AMA	6% O_2+4%CO_2	0	0	0	0	0.00	11.11
	4% O_2+4%CO_2	0	0	0	0	0.00	0.000
	2% O_2+4%CO_2	0	0	0	0	0.00	0.000
	3% O_2+3%CO_2	0	0	0	0	0.00	20.22
Perforated	0.50%	0	0	0	0	0.00	22.22
LDPE	0.25%	0	0	0	0	0.00	11.11
PMA	Sealed LDPE	0	0	0	0	22.22	22.22
LSD at 0.05 level		--	--	--	--	0.25	1.67

LDPE: Low density polyethylene bags, AMA: Active modified atmosphere, PMA: Passive modified atmosphere

At 35 days of cold storage, in the 1st season, storing fruits in perforated LDPE bags at 0.50% recorded the lowest decayed (6.66%), whereas, in the 2nd season, storing fruits in AMA containing 6% O_2 + 4% CO_2, 4% O_2 + 4% CO_2, 2% O_2 + 4% CO_2, 3% O_2 + 3% CO_2 and perforated LDPE bags at 0.5 and 0.25% did not show any decayed fruits. Also, storing in AMA containing 4% O_2+4%CO_2 and 2% O_2 + 4% CO_2 did not show any decayed fruits during cold storage periods in the 2nd season at 42 days.

In general, no decay was observed in all treatments until 28 days of cold storage period in sweet pepper fruits. These results may be due to good disinfection after harvest.

Decayed fruit was expressed as loss of appearance and freshness due to wilting, shriveling and brown spots on the peel of decayed fruits. The highest disease incidence observed with non-perforated packaging may be due to high relative humidity and water condensation around fruits which promotes the development of post-harvest decay (Coates *et al*., 1995).

During shelf life periods

Results in Table 4 show that, during shelf life period, all treatments did not show any decayed fruits until 21 days of cold storage. In general, after three days of shelf life, AMA treatments and perforated LDPE bags gave the lowest values of decay percentage compared to PMA (sealed LDPE bags) at 28, 35 and 42 days of cold storage. Storing fruits in AMA containing 2% O_2 + 4% CO_2 in the 1st season as well as in perforated LDPE bags at 0.50 and 0.25% at 28 days of cold storage did not show any decay after three days of shelf life in both seasons.

Fruit Firmness (FF as g/cm^2)

During cold storage periods

Results in Table 5 show that storing of green sweet pepper fruits in AMA and perforated LDPE bags gave the highest fruit firmness compared to storing in PMA during cold storage periods.

Storing in AMA containing 2% O_2 + 4% CO_2 gave the highest fruit firmness at 28 days of cold storage in both seasons with no significant differences with AMA containing 6% O_2 + 4% CO_2, 4% O_2 +4% CO_2 and perforated LDPE bags at 0.25 and 0.50% in the 2nd season.

Elevated CO_2 in AMA containing 2% O_2 + 4% CO_2 maintained fruit firmness at higher values compared to the lower CO_2 levels. These results can be explained by the fact that low O_2 or elevated CO_2 treatments decreased respiration rates, ethylene production and enzymatic activity, and delayed the conversion of protection the soluble pectin and fruit senescence. Higher water loss of fruit stored in air led to the loss of cell turger which accelerators the decrease in firmness (Zhang *et al.,* 2001).

Fruit firmness values decreased with advancing cold storage periods up to 42 days in both seasons. The decline in fruit firmness may be due to the gradually breakdown of proto-pectin to lower molecular fractions which are more soluble in water and this was directly correlated with the rate of softening of the fruit (Wills *et al.,* 1981).

Hussein *et al*. (1998) indicated that the rate of degradation of insoluble protopectins to simple soluble pectins was increased with progress of storage time. Pectiessterase activity, also, is expected to increase progressively during storage and this led to decrease in firmness of peel and pulp of fruits during storage (Ponomarev, 1968)

During shelf life periods

Results in Table 6 show that after three days of shelf life, storing of green sweet pepper fruits in all AMA and perforated LDPE bags during cold storage periods gave the highest values of fruit firmness compared to PMA.

Shelf life period after 28 days of cold storage in AMA containing 2% O_2 +4% CO_2 gave the highest fruit firmness in both seasons with no significant differences with storing in perforated LDPE bags in the 1st season and storing in AMA containing 4% O_2+4% CO_2 in the 2nd season. Fruit firmness values decreased with the advance in storage periods up to 42 days in both seasons.

Table 4. Effect of modified atmosphere on decay percentage of sweet pepper fruits during shelf life periods in 2015 and 2016 seasons

Treatment		Storage period (day)					
		7	14	21	28	35	42
				2015 season			
AMA	6% O_2+4% CO_2	0	0	0	16.66	16.66	33.33
	4% O_2+4% CO_2	0	0	0	8.33	33.33	33.33
	2% O_2+4% CO_2	0	0	0	00.00	33.33	33.33
	3% O_2+3% CO_2	0	0	0	16.66	16.66	33.33
Perforated	0.50%	0	0	0	0.00	16.66	50.00
LDPE	0.25%	0	0	0	0.00	16.66	50.00
PMA	Sealed LDPE bags	0	0	0	33.33	50.00	50.00
LSD at 0.05 level		--	--	--	3.96	2.52	3.06
				2016 season			
AMA	6% O_2+4% CO_2	0	0	0	16.66	33.33	66.77
	4% O_2+4% CO_2	0	0	0	11.11	33.33	66.77
	2% O_2+4% CO_2	0	0	0	11.11	44.44	66.77
	3% O_2+3% CO_2	0	0	0	20.22	44.44	66.67
Perforated	0.50%	0	0	0	0.00	22.22	66.77
LDPE	0.25%	0	0	0	0.00	22.22	66.67
PMA	Sealed LDPE	0	0	0	22.22	50.00	77.77
LSD at 0.05 level		--	--	--	0.30	6.69	12.53

LDPE: Low density polyethylene bags, AMA: Active modified atmosphere, PMA: Passive modified atmosphere

Table 5. Effect of modified atmosphere on fruit firmness (g/cm^2) of sweet pepper fruits during cold storage periods in 2015 and 2016 seasons

Treatment		Storage period (day)						
		0	7	14	21	28	35	42
					2015 season			
AMA	6% O_2+4% CO_2	870	864.67	825.00	789.00	725.00	724.33	710.67
	4% O_2+4% CO_2	870	831.67	828.33	774.67	744.00	753.00	717.33
	2% O_2+4% CO_2	870	867.67	839.33	797.33	794.67	694.00	686.00
	3% O_2+3% CO_2	870	831.00	825.00	748.67	742.67	709.67	684.33
Perforated	0.50%	870	835.67	806.00	746.00	708.67	656.33	601.00
LDPE	0.25%	870	861.67	836.33	768.00	763.00	744.33	677.67
PMA	LDPE	870	718.00	704.67	686.67	656.33	646.67	674.67
LSD at 0.05 level			36.51	13.06	47.40	23.10	26.20	18.39
					2016 season			
AMA	6% O_2+4% CO_2	985	924.33	880.33	864.67	816.67	806.33	719.67
	4% O_2+4% CO_2	985	884.33	927.00	908.00	864.00	784.33	720.33
	2% O_2+4% CO_2	985	949.00	914.33	906.33	859.33	794.67	785.33
	3% O_2+3% CO_2	985	911.00	873.67	832.33	805.00	743.00	740.00
Perforated	0.50%	985	959.33	886.67	852.00	831.33	789.00	702.00
LDPE	0.25%	985	982.00	939.33	842.33	821.00	800.67	730.67
PMA	Sealed LDPE	985	884.33	787.67	765.67	726.00	716.00	680.00
LSD at 0.05 level			47.02	50.46	37.28	47.86	46.85	41.62

LDPE: Low density polyethylene bags, AMA: Active modified atmosphere, PMA: Passive modified atmosphere

Table 6. Effect of modified atmosphere on fruit firmness (g/cm^2) of sweet pepper fruits during shelf life periods in 2015 and 2016 seasons

Treatment		Storage period (day)						
		0	7	14	21	28	35	42
					2015 season			
AMA	6% O_2+4% CO_2	870	770.00	755.56	659.63	639.57	591.33	321.33
	4% O_2+4% CO_2	870	711.67	705.97	692.90	634.08	569.33	308.33
	2% O_2+4% CO_2	870	742.57	705.83	698.62	685.67	591.00	549.00
	3% O_2+3% CO_2	870	781.43	714.17	703.42	625.65	609.67	590.00
Perforated	0.50 %	870	768.33	713.49	711.93	685.74	619.67	558.33
LDPE	0.25 %	870	723.12	714.89	704.17	698.33	627.00	481.00
PMA	Sealed LDPE	870	690.83	679.10	662.67	605.55	565.33	241.00
LSD at 0.05 level			65.86	66.57	28.48	43.45	29.42	52.84
					2016 season			
AMA	6% O_2+4% CO_2	985	785.33	767.00	738.33	700.33	687.67	680.33
	4% O_2+4% CO_2	985	816.67	798.33	797.67	777.67	745.67	650.67
	2% O_2+4% CO_2	985	833.67	762.00	777.00	774.33	707.33	642.00
	3% O_2+3% CO_2	985	793.67	759.67	733.33	678.00	639.00	608.33
Perforated	0.50 %	985	786.67	714.00	712.67	695.33	666.67	587.00
LDPE	0.25 %	985	787.67	779.33	755.33	697.33	651.67	634.00
PMA	Sealed LDPE	985	760.67	754.33	751.00	655.33	625.67	551.33
LSD at 0.05 level			51.81	44.75	34.50	28.62	24.42	34.40

LDPE: Low density polyethylene bags, AMA: Active modified atmosphere, PMA: Passive modified atmosphere

General Appearance (GA)

During cold storage periods

The obtained results in Table 7 show that general appearance (GA) of sweet pepper fruit was excellent (GA score was 9) till 28 days of cold storage, then GA decreased. At 42 days of cold storage, sweet pepper fruits were considered unmarketable (GA score was 5 or below). There were no significant differences among modified atmosphere treatments in GA of sweet pepper fruits up to 28 days of cold storage, since all treatments were gave excellent GA (fruits were free from wilting and shriveling). At the end of storage period all treatments gave fair GA of fruits.

Modified atmosphere treatments did not exhibit and change in GA of sweet pepper fruits up to 28 days of storage. This may be due to the lowest weight loss resulted of high moisture around the produce in the sealed LDPE bags. This increases in relative humidity and reduces vapor pressure defect and transpiration. In addition, packaging creates a modified atmosphere with higher concentration of carbon dioxide and reduced oxygen around the produce, which slows down the metabolic processes and transpiration (Thompson, 1996).

During shelf life periods

Results in Table 8 show that, after three days of shelf life, GA of sweet pepper fruits decreased with the advance of cold storage period.

After three days of shelf life, the cold storage period reflected fair GA of fruits (GA score was 5 or below) after 28 days of cold storage. In general, there were significant differences among modified atmosphere treatments in GA of fruits during cold storage periods, except at 21, 28 in the 1st season and at 35 days in both seasons.

These results may be due to that water loss can be one of the main causes and deterioration, since it not only results in indirect quantities losses, but also losses in appearance and nutritional quality. Reduction of water loss, especially diffusion through the cuticle, should help maintain textured quality and external appearance and thus improved sweet pepper storage life.

Table 7. Effect of modified atmosphere on fruit general appearance (GA) of sweet pepper during cold storage periods in 2015 and 2016 seasons

Treatment		Storage period (day)						
		0	7	14	21	28	35	42
					2015 season			
AMA	6% O_2+4%CO_2	9.00	9.00	9.00	9.00	9.00	4.71	3.94
	4% O_2+4%CO_2	9.00	9.00	9.00	9.00	9.00	4.33	2.56
	2% O_2+4%CO_2	9.00	9.00	9.00	9.00	9.00	3.44	2.83
	3% O_2+3%CO_2	9.00	9.00	9.00	9.00	9.00	4.46	2.95
Perforated	0.50 %	9.00	9.00	9.00	9.00	9.00	5.83	4.61
LDPE	0.25 %	9.00	9.00	9.00	9.00	9.00	5.55	2.88
PMA	Sealed LDPE	9.00	9.00	9.00	9.00	9.00	5.83	3.33
LSD at 0.05 level			NS	NS	NS	NS	NS	1.81
					2016 season			
AMA	6% O_2+4%CO_2	9.00	9.00	9.00	9.00	8.77	7.66	1.22
	4% O_2+4%CO_2	9.00	9.00	9.00	9.00	8.77	6.77	1.44
	2% O_2+4%CO_2	9.00	9.00	9.00	8.55	8.77	7.22	1.00
	3% O_2+3%CO_2	9.00	9.00	8.77	8.77	8.55	6.55	2.33
Perforated	0.50 %	9.00	9.00	9.00	9.00	8.33	5.22	1.22
LDPE	0.25 %	9.00	9.00	9.00	8.55	7.66	4.99	1.88
PMA	Sealed LDPE	9.00	9.00	9.00	9.00	9.00	6.77	2.33
LSD at 0.05 level			NS	NS	NS	NS	1.79	NS

LDPE: Low density polyethylene bags, AMA: Active modified atmosphere, PMA: Passive modified atmosphere, 9: excellent, 7: good, 5: fair, 3 : poor, 1: unsalable and fruits rating 5 or below were considered unmarketable

Table 8. Effect of modified atmosphere on fruit general appearance (GA) of sweet pepper during shelf life periods in 2015 and 2016 seasons

Treatment		Storage period (day)						
		0	7	14	21	28	35	42
					2015 season			
AMA	6% O_2+4% CO_2	9.00	9.00	8.66	7.50	5.00	4.33	2.66
	4% O_2+4%CO_2	9.00	9.00	8.00	7.72	6.55	5.00	2.00
	2% O_2+4% CO_2	9.00	7.83	8.33	7.77	7.00	2.33	3.00
	3% O_2+3% CO_2	9.00	8.66	7.83	7.83	7.00	3.66	2.66
Perforated	0.50 %	9.00	8.66	8.16	7.61	6.77	5.66	2.00
LDPE	0.25 %	9.00	9.00	8.00	8.00	6.94	4.00	2.33
PMA	Sealed LDPE	9.00	8.66	8.00	7.38	6.50	3.66	2.00
LSD at 0.05 level			NS	NS	0.40	0.65	1.98	NS
					2016 season			
AMA	6% O_2+4% CO_2	9.00	7.67	7.00	7.00	5.88	4.88	3.05
	4% O_2+4% CO_2	9.00	7.44	6.99	6.66	4.33	3.66	3.22
	2% O_2+4% CO_2	9.00	7.66	7.00	5.66	4.32	2.32	2.99
	3% O_2+3% CO_2	9.00	7.66	6.77	6.33	4.55	2.33	2.94
Perforated	0.50%	9.00	7.44	6.55	6.33	6.33	2.55	2.60
LDPE	0.25%	9.00	7.00	7.00	6.77	4.66	3.88	3.66
PMA	Sealed LDPE	9.00	7.88	7.22	6.33	6.11	3.33	2.88
LSD at 0.05 level			NS	NS	NS	NS	1.92	NS

LDPE: Low density polyethylene bags, AMA: Active modified atmosphere, PMA: Passive modified atmosphere, 9: excellent, 7: good, 5: fair, 3 : poor, 1: unsalable and fruits rating 5 or below were considered unmarketable

Total Chlorophyll (Chl. a+b)

During cold storage periods

Presented results in Table 9 show that, storing green sweet pepper fruits in all AMA treatments, perforated LDPE bags and PMA had significant effect on concentration of total chlorophyll (a+b) in fruit tissues. Total chlorophyll (a+b) in green sweet pepper fruits reduced with the advance in cold storage periods.

Storing green sweet pepper fruits with different AMA and perforated LDPE bags showed delay total chlorophyll (a+b) degradation in green sweet pepper fruits compared to PMA. At 35 and 42 days of cold storage, the degradation total chlorophyll (a+b) increased.

LDPE based modified atmosphere packaging (MAP) had the best results at preventing chlorophyll degradation. The effect of MAP on chlorophyll content were due to low oxygen concentration and low respiration, thus MAP had also been showed delay in chlorophyll degradation in green vegetables (Barth *et al*., 1993).

During shelf life periods

Presented results in Table 10 show that, after three days of shelf life storing green sweet pepper fruits in all AMA treatments, perforated LDPE bags and PMA had significant effect on concentration of total chlorophyll (a+b) in fruit tissues. After three days of shelf life, total chlorophyll (a+b) in green sweet pepper fruits reduced with the advance in cold storage periods.

In general, storing green sweet pepper fruits with different AMA treatments and perforated LDPE bags showed delay in total chlorophyll (a+b) degradation fruits compared to PMA after three days of shelf life. At 35 and 42 days of cold storage, the degradation of total chlorophyll (a+b) increased during shelf life period.

Table 9. Effect of modified atmosphere on total chlorophyll (a+b) contents in sweet pepper fruits (mg/100 g FW) after cold storage in 2016 seasons

Treatment		Storage period (day)						
		0	7	14	21	28	35	42
		2016 season						
AMA	6% O_2+4% CO_2	570.00	526.68	466.68	426.64	388.00	337.36	286.67
	4% O_2+4% CO_2	570.00	539.99	529.32	533.32	405.36	398.68	296.00
	2% O_2+4% CO_2	570.00	550.65	496.89	496.00	369.32	306.64	256.00
	3% O_2+3% CO_2	570.00	560.00	556.01	473.79	398.00	382.68	340.00
Perforated	0.50 %	570.00	565.33	531.99	417.32	394.68	388.00	346.68
LDPE	0.25 %	570.00	509.33	436.00	428.00	353.32	322.64	301.32
PMA	Sealed LDPE	570.00	446.68	412.00	374.64	312.00	300.68	246.68
LSD at 0.05 level			18.90	10.70	41.86	11.98	8.39	15.89

LDPE: Low density polyethylene bags, AMA: Active modified atmosphere, PMA: Passive modified atmosphere

Table 10. Effect of modified atmosphere on total chlorophyll (a+b) in sweet pepper fruits (mg/ 100 g FW) after shelf life in 2016 season

Treatment		Storage period (day)						
		0	7	14	21	28	35	42
		2016 season						
AMA	6% O_2+4% CO_2	570.00	496.00	453.36	425.32	388.00	484.00	
	4% O_2+4% CO_2	570.00	464.00	412.00	408.68	322.68	301.32	
	2% O_2+4% CO_2	570.00	490.68	465.32	420.00	418.65	312.00	
	3% O_2+3% CO_2	570.00	458.00	446.64	439.99	300.00	260.00	
Perforated	0.50 %	570.00	481.35	460.00	445.32	354.68	278.68	
LDPE	0.25 %	570.00	465.32	456.68	392.00	330.68	266.67	
PMA	Sealed LDPE	570.00	454.68	385.32	358.00	328.00	200.00	
LSD at 0.05 level			9.52	9.07	40.26	10.83	31.21	

LDPE: Low density polyethylene bags, AMA: Active modified atmosphere, PMA: Passive modified atmosphere

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استخدام معاملات الجو الهوائـــى المعدل لإطالة العمر التخزينى وفترة العرض لثمار الفلفـل الحلـو

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أجرى هذا العمل فى معمل التخزين بقسم البساتين, كلية الزراعة, جامعة الزقازيق خلال موسمى ٢٠١٥ و٢٠١٦ لاختبار تأثير بعض معاملات الجو الهوائى المعدل على القدرة التخزينية وجودة ثمار الفلفل الحلو اثناء فترة التخزين المبرد وفترة العرض، أدى تخزين ثمار الفلفل الحلو تحت ظروف الجو الهوائى المعدل النشط بنسبة ٦% أ٢ + ٤% ك أ٢ , ٤% أ٢ + ٤% ك أ٢, ٢% أ٢ + ٤% ك أ٢, ٣ أ٢ + ٣% ك أ٢ وتخزين الثمار فى أكياس بولى اثيلين مثقبة بنسبة ٠,٥٠ و٠,٢٥% إلى نقص نسبة الفقد فى الوزن الطازج للثمار والحفاظ على صلابة الثمار ومحتوى أنسجة الثمرة من الكلوروفيل الكلى بالمقارنة بتخزين الثمار في الجو الهوائي المعدل السالب أثناء فترة التخزين المبرد وفترة العرض، كذلك أدى تخزين ثمار الفلفل الحلو تحت ظروف الجو الهوائي المعدل النشط ٤% أ٢ + ٤% ك أ٢ , ٢% أ٢ + ٤% ك أ٢ إلى نقص نسبة الفقد فى الوزن الطازج للثمار بينما أدى التخزين في جو هوائى معدل بنسبة ٢% أ٢ + ٤% ك أ٢ إلى الحفاظ على صلابة الثمار عند ٢٨ يوم من التخزين المبرد وبعد فترة العرض فى كلا الموسمين، لم يلاحظ تلف فى الثمار وظهرت الثمار بمظهر ممتاز حتى ٢٨ يوم من بداية التخزين المبرد عند التخزين فى الجو الهوائى المعدل النشط, التخزين فى أكياس بولى ايثيلين مثقبة, التخزين فى الجو الهوائى المعدل السالب، أدى التخزين فى الجو الهوائى المعدل النشط بنسبة ٢% أ٢ + ٤% ك أ٢ إلى الحفاظ على صفات الثمار جيدة حتى ٢٨ يوم من التخزين المبرد على درجة ٨°م ورطوبة نسبية ٩٠- ٩٥%، نسبة الفقد فى الوزن الطازج ونسبة تلف الثمار ازدادت تدريجيا مع تقدم فترات التخزين المبرد حتى ٤٢ يوم، على العكس, فإن صلابة الثمار ومظهر الثمار ومحتوى أنسجة الثمرة من الكلوروفيل الكلى انخفضت تدريجيا مع تقدم فترات التخزين المبرد حتى ٤٢ يوم .

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