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EFFECT OF SOME ACTIVE MODIFIED ATMOSPHERE TREATMENTS ON QUALITY OF TOMATO (*Solanum lycopersicum* L.) FRUITS DURING COLD STORAGE AND SHELF LIFE PERIODS

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ABSTRACT: In 2014 and 2015 growing seasons, tomato seedlings cv. Alisa were transplanted on 15th February and 6th March and harvested on 13th May and 25th May, respectively in a private farm, Belbeis district, Sharkia Governorate, Egypt and subjected to the following post-harvest treatments in Post-harvest Laboratory, Hort. Dept. Fac. Agric., Zagazig University: 1) stored in open air (control); 2) stored in active modified atmosphere (AMA) with 3% O_2+3% CO_2 ; 3) AMA with 5% O_2+3% CO_2 ; 4) AMA with 5% O_2+5% CO_2 and 5) AMA with 7% O_2+ 5% CO_2 . Fruits of all treatments were stored for 35 days at 10±1ºC and 90-95% relative humidity (RH). Samples of each treatment were randomly taken at 7 days intervals to evaluate the effect of cold storage periods and the tested (AMA) treatments on fruit quality. After each cold storage period, some of these fruits were kept for 5 days in both seasons under conditions of 20ºC and 60-70% RH to detect the effect of treatments on shelf life. The tested active modified atmosphere (AMA) treatments tended to increase fruit firmness and vitam. C content as compared with the control during both cold storage and shelf life periods. On the contrary, AMA treatments tended to decrease fruit weight losses, fruit decay, TSS and lycopene content during both cold storage and shelf life periods. The advance of storage period from zero up to 35 days caused progressive increments in fresh weight losses, fruit decay, lycopene and TSS content of the successive samples which taken during cold storage and shelf life as compared with the control. On the contrary, the advance in cold storage period depressed fruit firmness and fruit ascorbic acid contents.

Key words: Tomato, active modified atmosphere, cold storage, shelf life, fruit quality.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated and extensively consumed horticultural crops globally (Chapagain and Wiesman, 2004; Grandillo *et al.,* 1999). The world's total tomato production is 113.3 million tons; China is the largest producer followed by the USA, Turkey, Italy, Egypt and India (Alam and Goyal, 2007). Tomato contains essential as well as beneficial components like carbohydrates, fiber, minerals, protein, fat, glycoalkaloids, phytosterols *etc*. (Davies *et al.,* 1981). Several essential vitamins like vitamin A, vitamin C, vitamin E, folic acid and several water-soluble vitamins are also present in tomato fruits (Beecher, 1998). According to Brandt *et al.* (2006) it has been reported that the consumption of tomatoes reduces the risk of atherosclerosis, carcinogenesis and cardiovascular diseases and prevention of many types of cancer.

Losses in fresh horticultural produce are directly related to quality degradation. Quality loss is the result of improper handling and transportation in marketable of produce (Kumar *et al*., 2015). Tomato is one of the very perishable fruit and it changes continuously after harvesting. Depending on the humidity and temperature it ripens very soon, ultimately resulted in poor quality as the fruit become soft and unacceptable (Ullah, 2009).

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Storage under low temperature has been considered the most efficient method to maintain quality of most fruits and vegetables due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, senescence and rot development (Hardenburg *et al.,* 1986). Extending the shelf life of tomatoes is very important for domestic and export marketing. Generally, shelf life of tomatoes is extended by refrigerated storage (Risse *et al.,* 1985).

Tomato fruits kept within sealed packages resulted in an atmosphere with high CO_2 and low O_2 content. These conditions retained flesh firmness, low acidity and soluble solids concentration and delayed fruit lycopene (Saeed *et al*., 2010). Among the various techniques developed to extend fruit postharvest life, is the use of plastic film. Rosa (2006) stated that LDPE (low density polyethylene) film is generally used for the packaging of fresh fruits and vegetables, owing to its high permeability and softness when compared to HDPE (high density polyethylene) film.

Information about the effect of active modified atmosphere (AMA) packing on shelf life of tomato fruit is limited; therefore, this research was conducted to evaluate the effect of storage under active modified atmosphere (AMA) condition on shelf life and quality of tomato fruits.

MATERIALS AND METHODS

This study was carried out during 2014 and 2015 seasons on tomato fruits (*Solanum lycopersicum* L.) cv. Alisa. The plants were transplanted in a private farm, Belbeis district, Sharkia Governorate, and received the standard horticultural care adapted in the area. Tomato fruits were harvested at pink stage (red color 30-60% of the total surface area) according to USDA, (1991). Fruits were packed in carton boxes and transported directly to Post-Harvest Laboratory in Hort. Dept., Fac. Agric., Zagazig University. Fruits with any insect infestation or defects (sunburn, crack, bruise and cuts) were discarded. All fruits were dipped in aqueous solution of 0.1% imazalil for 2 minutes according to Spalding, (1980) as a disinfectant, then, air dried. A final sorting was done to recheck the fruits for any defects which were not detected at first discarding.

The experiment was done to study the effect of active modified atmosphere (AMA) on physical and chemical properties of tomato fruits during cold storage for 35 days and shelf life for 5 days. This experiment was including 30 treatments which were the combinations between 5 AMA treatments and 6 storage periods as follows:

Active Modified Atmosphere (AMA) Treatments

1. Storing fruits in net at 10±1°C as control.
2. Storing fruits in sealed low density polyethylene (LDPE) bags contain 3% O_2 + 3% CO_2 at 10±1°C.
3. Storing fruits in sealed LDPE bags contain 5% O_2 + 3% CO_2 at 10 ± 1°C.
4. Storing fruits in sealed LDPE bags contain 5% O_2 + 5% CO_2 at 10±1°C.
5. Storing fruits in sealed LDPE bags contain 7% O_2 + 5% CO_2 at 10±1°C.

Storage Periods

Ten tomato fruits (about 1 kg) were placed in carton box covered with sealed low density polyethylene (LDPE) bags and injected with the previous gases and stored at 10±1°C. Then, observations samples were taken at 7 days intervals up to 35 days (0, 7, 14, 21, 28 and 35 days). After each cold storage period some of this fruits were subjected to conditions of 20°C and 60-70% RH for 5 days as a shelf life. The number of fruits required for this experiment = 5 AMA treatments × 6 storing periods × 3 reps. × 10 fruits per each replicate = 900 fruits.

Samples of each treatment were randomly taken every 7 days intervals to evaluate the effect of AMA treatments; storing periods and their interactions on physical and chemical properties of tomato fruits during cold storage and shelf life periods.

Data Recorded

Fruit firmness (kg/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 kg/cm^2.

Weight loss (WL%)

The fruits were weighed before cold storage to obtain the initial weight and then weighed after each period of cold storage as well as after 5 days shelf life period. WL (%) was calculated according to the following equation:

$$\mathbf{WL}\ (\%) = \frac{\mathbf{Wi - Ws}}{\mathbf{Wi}} \times \mathbf{100}$$

Where:

Wi = fruit weight at initial date.

Ws= fruit weight on day of sampling observation.

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.

Ascorbic acid (mg/100ml juice)

It was determined by titration in the presence of 2, 6 dichlorophenol-indophenol dye as an indicator against 2% oxalic acid solution as substrate. Ascorbic acid was calculated as milligram L-ascorbic acid per 100 ml of juice according to the method described by AOAC (2000).

Lycopene content (mg/100g fresh fruit weight)

It was determined according the method reported by Anthon and Barrett (2007).

Juice (TSS Brix^o)

It was determined using a hand refracto-meter.

Statistical Analysis

The treatments were arranged in split plot design with 3 replicates. AMA treatments were randomly arranged in the main plots and stored periods were randomly distributed in sub plots. 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

Fruit Firmness (FF) kg/cm^2

During cold storage periods

Results in Table 1 reveal that the tested active modified atmosphere (AMA) treatments affected fruit firmness (FF) significantly in both tested seasons. As such, the highest FF values (1.07 and 0.96 kg/cm^2) were recorded by 7% O_2+5% CO_2 in the first and second seasons, respectively, as compared with control (net), without significant differences with those treated by all other AMA treatments, *i.e.,* 3% O_2 + 3% CO_2, 5% O_2 + 3% CO_2 and 5% O_2 + 5% CO_2 in both tested seasons.

Moreover, FF values were significantly decreased with advancing cold storage periods in both seasons. As such, the highest FF values (1.36 and 1.17 kg/cm^2) were recorded at initial sampling date (zero time) in the first and second seasons, respectively. While, the lowest FF values (0.69 and 0.75 kg/cm^2) were recorded at 35 days cold storage, in the first and second seasons, respectively.

In addition, the interaction between the tested AMA treatments and cold storage periods was significant in the two tested seasons. As such, the highest FF values were recorded with all tested AMA treatments × zero time. While, the lowest FF values were recorded with all tested AMA treatments × 35 days cold storage without significant differences between them in both seasons.

During shelf life periods

Results in Table 1 also show that values of FF during shelf life were significantly affected,

Table 1. Effect of some active modified atmosphere (AMA) treatments on fruit firmness (FF Kg/cm^2) of tomato fruits cv. Alisa during cold storage and shelf life periods during 2014 and 2015 seasons

AMA treatment		Firmness (FF Kg/cm^2) Cold storage period (day) 0	7	14	21	28	35	AMA (average)
		First season (2014)						
	Control(Net)	1.29ac	0.98cg	0.90di	0.83ei	0.76fi	0.65gi	0.90B
AMA	**$3\%O_2 + 3\%CO_2$**	1.30ac	1.07bf	1.05bf	1.01cf	0.96ci	0.64i	1.00A
AMA	**$5\%O_2 + 3\%CO_2$**	1.44a	1.04bf	1.04bf	0.98ch	0.83ei	0.78fi	1.02A
AMA	**$5\%O_2 + 5\%CO_2$**	1.43a	1.12ae	1.06bf	1.04bf	0.94di	0.65hi	1.04A
AMA	**$7\%O_2 + 5\%CO_2$**	1.37ab	1.23ad	1.16ae	1.08bf	0.84ei	0.76fi	1.07A
	SP(average)	1.36A	1.06B	1.04B	1.01BC	0.86C	0.69D	-
		Second season (2015)						
	Control(Net)	1.13ab	0.95ce	0.90df	0.85eh	0.78gj	0.71j	0.88B
AMA	**$3\%O_2 + 3\%CO_2$**	1.18a	1.03bc	0.95ce	0.93ce	0.84ei	0.74hj	0.94A
AMA	**$5\%O_2 + 3\%CO_2$**	1.22a	1.13ab	0.97cd	0.88dg	0.73ij	0.78fj	0.95A
AMA	**$5\%O_2 + 5\%CO_2$**	1.16a	1.14ab	0.93ce	0.90df	0.83ei	0.76gj	0.95A
AMA	**$7\%O_2 + 5\%CO_2$**	1.16a	1.11ab	0.97cd	0.91ce	0.83ei	0.78fj	0.96A
	SP(average)	1.17A	1.07B	0.94C	0.89C	0.80D	0.75D	-
		5 days shelf life						
		First season (2014)						
	Control(Net)	0.96ag	0.83bi	0.76ek	0.70fk	0.61ik	0.50k	0.72B
AMA	**$3\%O_2 + 3\%CO_2$**	1.06ad	0.92ah	0.86ai	0.82cj	0.67gk	0.53jk	0.81AB
AMA	**$5\%O_2 + 3\%CO_2$**	1.12ab	0.99af	0.89ai	0.80dj	0.69fk	0.60ik	0.84A
AMA	**$5\%O_2 + 5\%CO_2$**	1.11ac	0.96ag	0.87ai	0.83bi	0.75ek	0.68gk	0.86A
AMA	**$7\%O_2 + 5\%CO_2$**	1.15a	1.02ae	0.93ah	0.85ai	0.74ek	0.66hk	0.89A
	SP (average)	1.08A	0.94AB	0.86BC	0.80CD	0.69DE	0.59E	-
		Second season (2015)						
	Control(Net)	0.98ae	0.87fi	0.83gj	0.73km	0.68ln	0.59n	0.78B
AMA	**$3\%O_2 + 3\%CO_2$**	1.00ad	0.89ai	0.84fj	0.80ik	0.72km	0.61n	0.81AB
AMA	**$5\%O_2 + 3\%CO_2$**	1.05a	0.95bf	0.87fi	0.75jl	0.72km	0.58n	0.82AB
AMA	**$5\%O_2 + 5\%CO_2$**	1.03ac	0.95bf	0.88ei	0.84gj	0.75jl	0.63mn	0.84A
AMA	**$7\%O_2 + 5\%CO_2$**	1.05ab	0.93cg	0.91dh	0.81hk	0.75jl	0.69ln	0.85A
	SP (average)	1.02A	0.91B	0.86C	0.78D	0.72E	0.62F	-

Values having the same alphabetical letter (s) did not significantly different according to LSD at 0.05 of probability.
AMA = Active modified atmosphere, SP = Storage Period (day).

comparing to control, by the tested AMA treatments in both seasons. Whereas, the highest FF (0.89 and 0.85 kg/cm^2) were recorded by 7% O_2 + 5% CO_2 without significant differences with all other tested AMA treatments in the first and second seasons, respectively. While, the lowest FF values (0.72 and 0.78 kg/cm^2) were recorded by the control (net) without significant differences with those treated by 3% O_2+ 3% CO_2 in both seasons and 5% O_2+ 3% CO_2 in the second one.

Moreover, FF values during shelf life were significantly decreased as cold storage period was advanced. As such, the highest FF values were recorded at zero time (1.08 and 1.02 kg /cm^2) in the first and second seasons, respectively. Whereas, the lowest values (0.59 and 0.62 kg/cm^2) were recorded at 35 days cold storage. The other periods, recorded in between values.

In addition, the interaction between the tested AMA treatments and shelf life after cold storage periods was significant in both seasons. As such, the highest FF values were recorded by all tested AMA treatments at zero time without significant differences between them, while, the lowest FF values were recorded by all tested AMA treatments at 35 days cold storage without significant differences among them in both tested seasons.

Generally, the results clarify that all tested AMA treatments maintained fruit firmness (FF) at high values as compared with the control, while, FF values was decreased with the advance in cold storage period. This was true either after cold storage or after shelf life periods.

These findings were in line with Themman *et al*. (1982) who reported that, Polygalacturanase (PG) and pectinastarase (PE) are the important enzymes involved in fruit softening by solubilizing the polygalacturonic acid in the pectin fraction of the cell walls during ripening. In this respect, PG activity increased while firmness decreased with progressive stage of maturation and its synthesis only occurs in response to ethylene (Grierson and Tucker, 1983). Moreover, High CO_2 concentration inhibited ethylene production during tomato ripening (Herner, 1987). It was reported that elevated CO_2 atmosphere slow down the softening rate, but the mechanism of controlled or modified atmosphere effects on texture of fresh fruits and vegetables is not fully understood (Kader, 1986). In addition, tomato fruits (cv'Liberto') harvested at the pink stage were stored at 13°C for 60 days in a plastic packaging system compared with unwrapped fruit as a control. All fruits softened progressively during storage, but those sealed in plastic film softened significantly more slowly than those stored unwrapped (Batu and Thompson, 1998). In tomato, with the onset of ripening, pectin degrading enzymes starts to accumulate and contribute to softening the cell walls (Shama and Alderson, 2005).

Firmness of tomato generally decreases with increasing in the duration of storage (Moneruzzaman *et al*., 2008). In fact, it has been proven that the modified atmosphere decreases the activity of the pectinesterase and polygaracturonase enzymes involved in the cell wall degradation (Akbudak *et al*., 2007 and 2012). Moreover, Vunnam *et al*. (2014) stated that tomato fruits stored under MA conditions maintained greater firmness than under non-MA conditions, as the mass loss was reduced more than ten-folds by MA storage compared to perforated non-MA storage. This is indicative that moisture content of the samples along with storage conditions plays a vital role in firmness. In this respect, Domínguez *et al*. (2016) studied effect of the packaging on fruit firmness of tomatoes cvs. Delizia and Pitenza stored at 13°C and then were stored for 48 hr., in air at 20°C. They found that the modified atmosphere and the high humidity reached inside the packages slow down the process of ripening linked to the evolution of this quality parameter.

Weight Losses Percentage (WL %)

During cold storage periods

Results in Table 2 show that the control (net) treatment recorded significantly highest WL (%) (1.29 and 2.83%) in the first and second seasons, respectively, as compared with all AMA treatments which showed significant reductions in WL (%) without significant differences among them in most cases in both seasons. The lowest WL (%) values (1.05 and 1.42%) came from 3% O_2 + 3% CO_2 treatment in the first and second seasons, respectively.

Table 2. Effect of some active modified atmosphere (AMA) treatments on weight losses (WL %) of tomato fruits cv. Alisa during cold storage and shelf life periods during 2014 and 2015 seasons

	AMA treatment	Weight losses (%)						
		Cold storage period (day)						AMA (average)
		0	7	14	21	28	35	
		First season (2014)						
AMA	Control(Net)	0.00n	0.87m	0.87m	1.44ei	1.92b	2.65a	1.29A
	$3\%O_2$ + $3\%CO_2$	0.00n	0.85m	1.07jm	1.04jm	1.50dh	1.88bc	1.05B
	$5\%O_2$ + $3\%CO_2$	0.00n	0.85m	1.13im	1.23hl	1.29gk	1.74be	1.04B
	$5\%O_2$ + $5\%CO_2$	0.00n	0.94lm	1.00km	1.32fj	1.53dh	1.78bd	1.09B
	$7\%O_2$ + $5\%CO_2$	0.00n	0.84m	1.03jm	1.51dh	1.58cg	1.63bf	1.10B
	SP (average)	0.00F	0.87E	1.02D	1.31C	1.56B	1.93A	-
		Second season (2015)						
AMA	Control(Net)	0.00o	1.97fl	2.64cf	3.17bc	3.51b	5.67a	2.83A
	$3\%O_2$ + $3\%CO_2$	0.00o	1.25mn	1.28mn	1.60in	2.15ek	2.25ei	1.42C
	$5\%O_2$ + $3\%CO_2$	0.00o	1.09n	1.70hn	1.98fl	2.33dh	3.50b	1.77B
	$5\%O_2$ + $5\%CO_2$	0.00o	1.35ln	1.80gm	2.20ej	2.22ej	2.95bd	1.75B
	$7\%O_2$ + $5\%CO_2$	0.00o	1.24mn	1.51kn	1.54jn	2.44dg	2.71ce	1.57BC
	SP (average)	0.00E	1.38D	1.78C	2.10C	2.53B	3.41A	-
		5 days shelf life						
		First season (2014)						
AMA	Control(Net)	3.83o	5.13km	6.99eg	7.40df	7.84bd	9.01a	6.70A
	$3\%O_2$ + $3\%CO_2$	3.89o	4.79ln	5.53jk	6.58gi	7.36df	7.97bd	6.02B
	$5\%O_2$ + $3\%CO_2$	4.16no	5.06km	5.53jl	6.96eg	7.43df	7.51cf	6.11B
	$5\%O_2$ + $5\%CO_2$	4.31mo	5.21jl	5.96ij	6.74fh	6.84eg	8.36ab	6.23AB
	$7\%O_2$ + $5\%CO_2$	4.09no	4.99km	6.00hj	6.38gi	7.65be	8.31ac	6.23AB
	SP (average)	4.05F	5.03E	6.00D	6.81C	7.42B	8.23A	
		Second season (2015)						
AMA	Control(Net)	4.61ko	5.91gk	7.92ce	8.93bd	9.86ab	11.57a	8.13A
	$3\%O_2$ + $3\%CO_2$	3.52no	4.75kn	5.37im	6.80ei	7.41dh	8.03ce	5.98B
	$5\%O_2$ + $3\%CO_2$	2.90o	3.77mo	6.51ej	7.23dh	7.66cg	9.19bc	6.21B
	$5\%O_2$ + $5\%CO_2$	2.88o	4.11lo	6.03fk	6.94ei	7.19dh	9.24bc	6.06B
	$7\%O_2$ + $5\%CO_2$	4.55ko	4.86jn	5.71hl	5.78hl	6.00fk	7.76cf	5.77B
	SP (average)	3.69E	4.68D	6.30C	7.13B	7.62B	9.15A	-

Values having the same alphabetical letter(s) did not significantly different according to LSD at 0.05 of probability.
AMA = Active modified atmosphere, SP = Storage period (day).

The results also show that, fruit WL (%) was markedly increased as cold storage period increased. The highest values (1.93 and 3.41% in the first and second seasons, respectively) resulted at 35 days cold storage.

The interaction between AMA treatments and cold storage period was significant in both seasons. The all AMA treatments × 7 and 14 days cold storage recorded the least WL (%) values in the two seasons. Whereas the control treatment × 35 days of cold storage was recorded the highest WL (%) (2.65 and 5.67% in the first and second seasons, respectively).

During shelf life periods

The tested treatments significantly affected WL (%) after 5 days of shelf life in both seasons. The highest WL (%) was recorded by the control (6.70 and 8.13% in the first and second seasons, respectively). While, the lowest WL(%) was recorded by all other AMA treatment without significant differences among them in both seasons.

The results also indicate that WL (%) was progressively increased during shelf life period and /or cold storage period to reach a maximum values (8.23 and 9.15% in the first and second seasons, respectively) at 35 days cold storage. While, the minimum values (4.05 and 3.69% in the first and second seasons, respectively) were recorded at zero time and 5 days shelf life.

Generally, the present work revealed that fruits WL (%) were increased as cold storage period increased and the control treatment raised WL (%) compared with AMA treatments during cold storage and after shelf life periods.

The reduction in WL (%) with AMA treatments was in agreement with Gharezi *et al.* (2012) working on Cherry tomato stored at 10°C ± 2 up to 14 days of storage. The WL progressively increased with increasing storage period, irrespective of the storage condition and the previous treatments. This could be attributed to the maintenance of high humidity in the micro atmosphere within the packages by the respiring fruits and due to low water vapor transmission rates of packaging material (Moneruzzaman *et al*., 2009). Cold stored fruits had a low weight loss due to temperature effects on vapor pressure difference and increased water retention (Tasdelen and Bayindirli, 1998). In addition, Batu and Thompson (1998) reported that weight loss of the plastic film packed tomato fruits were lower and linearly increased throughout storage period. While, unwrapped fruits has achieved the highest weight losses. The lowest weight loss of fruit sealed in different films may be due to the lower respiration rate of the tomatoes 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. 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 significantly delayed fruit water loss, leading to inhibition of ripening (expressed as peel color changes).

Fruit Decay Percentage (%)

During cold storage periods

Results in Table 3 also reveal that the tested AMA treatments failed to show any significant differences regarding fruits decay percentage in both tested seasons. However, fruit decay percentage was significantly increased with the advance in cold storage period in both tested seasons. As such, the highest fruit decay percentage (2.66 and 4.66 %) was recorded at 35 days in the first and second seasons, respectively. While, all other periods came in the second rank without any decayed fruit in both seasons.

The interaction between AMA treatments and cold storage period was significant in both seasons. All tested treatments did not appear any decayed fruits until 28 days of cold storage. While, at 35 days of cold storage did not happen any decayed fruits in treatment 7%O_2+ 5% CO_2 in both seasons without significant differences with treatment 5% O_2 + 5% CO_2 in the second

Table 3. Effect of some active modified atmosphere (AMA) treatments on fruit decay percentage (%) of tomato fruits during cold storage and shelf life periods during 2014 and 2015 seasons

	AMA treatment	Fruit decay percentage (%)						
		Cold storage period (day)						AMA (average)
		0	7	14	21	28	35	
		First season (2014)						
AMA	Control (Net)	0.00b	0.00b	0.00b	0.00b	0.00b	3.33a	0.55A
AMA	$3\%O_2 + 3\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	3.33a	0.55A
AMA	$5\%O_2 + 3\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	3.33a	0.55A
AMA	$5\%O_2 + 5\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	3.33a	0.55A
AMA	$7\%O_2 + 5\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	0.00b	0.00A
	SP (average)	0.00B	0.00B	0.00B	0.00B	0.00B	2.66A	-
		Second season (2015)						
AMA	Control (Net)	0.00b	0.00b	0.00b	0.00b	0.00b	6.66a	1.11A
AMA	$3\%O_2 + 3\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	6.66a	1.11A
AMA	$5\%O_2 + 3\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	6.66a	1.11A
AMA	$5\%O_2 + 5\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	3.33ab	0.55A
AMA	$7\%O_2 + 5\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	0.00b	0.00A
	SP (average)	0.00B	0.00B	0.00B	0.00B	0.00B	4.66A	-
		5 days shelf life						
		First season (2014)						
AMA	Control (Net)	0.00b	0.00b	0.00b	0.00b	0.00b	6.66a	1.11A
AMA	$3\%O_2 + 3\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	3.33ab	0.55A
AMA	$5\%O_2 + 3\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	3.33ab	0.55A
AMA	$5\%O_2 + 5\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	6.66a	1.11A
AMA	$7\%O_2 + 5\%CO_2$	0.00b	0.00b	0.00b	0.00b	0.00b	0.00b	0.00A
	SP (average)	0.00B	0.00B	0.00B	0.00B	0.00B	4.00A	-
		Second season (2015)						
AMA	Control (Net)	0.00a	0.00a	0.00a	0.00a	3.33a	6.66a	1.66A
AMA	$3\%O_2 + 3\%CO_2$	0.00a	0.00a	0.00a	0.00a	0.00a	6.66a	1.11A
AMA	$5\%O_2 + 3\%CO_2$	0.00a	0.00a	0.00a	0.00a	3.33a	6.66a	1.66A
AMA	$5\%O_2 + 5\%CO_2$	0.00a	0.00a	0.00a	0.00a	0.00a	6.66a	1.11A
AMA	$7\%O_2 + 5\%CO_2$	0.00a	0.00a	0.00a	0.00a	0.00a	3.33a	0.55A
	SP (average)	0.00B	0.00B	0.00B	0.00B	1.33B	6.00A	-

Values having the same alphabetical letter(s) did not significantly different according to LSD at 0.05 of probability
AMA = Active modified atmosphere, SP = Storage period (day).

season only. The other treatments recorded 3.33% in the first season and 6.66% in the second one without significant differences between them.

During shelf life periods

Results in Table 3 also reveal that the tested AMA treatments failed to show any significant differences regarding fruits decay percentage during shelf life period in both tested seasons. However, fruit decay percentage was significantly increased with the advance in cold storage period in both tested seasons. Where the decayed fruit started to appear at 35 days in the first season and at 28 days in the second one. The highest fruit decay percentage (4.00 and 6.00%) was recorded at 35 days, while, all other periods came in the second rank without significant differences among them in both seasons.

The interaction between AMA treatments and cold storage period was significant in the first season only. As such, all tested treatments except those 7% O_2 + 5% CO_2 × 35 days recorded the highest decay percentage without significant differences between them. While, all other treatments × all other periods came in the second rank without any decayed fruits.

Generally, the results clear that tomato fruits did not suffer from any decay along the whole cold storage period with all tested AMA treatments, except for a few decayed fruits which, started to appear at 35 days in the first season and at 28 days in the second one. The lower fruit decay in the present study might be due to a better fruits disinfection before the onset of the cold storage.

The reduction in fruit decay percentage with MA was in agreement with Batu and Thompson (1998) working on tomato fruits (cv'Liberto') harvested at the pink stage and stored at 13°C for 60 days in a plastic packaging system. Decay was first observed on one fruit out of 60 after 40 days storage. All treatments showed some rotting after 50 days storage which increased again after 60 days. 8% of fruit had some infection after 50 days rising to 16% after 60 days. Moreover, Buescher (1979) showed that 66% of the tomatoes were decayed after 6 weeks at 12°C in air. An average of only 3.5% was decayed during the same period in atmospheres of 3% oxygen with 0, 3 or 5% CO_2 environments.

Ascorbic Acid (vitamin C) Content (mg/100ml Juice)

During cold storage periods

Results in Table 4 clarify that the tested AMA treatments had significant effect on ascorbic acid content in tomato fruit juice in both tested seasons. As such, the uppermost values of ascorbic acid (16.64 and 15.84 mg/100 ml juice in the first and second seasons, respectively), were detected in 7% O_2 + 5% CO_2 without significant differences with those treated by 5% O_2 + 5% CO_2 and 5%O_2 + 3%CO_2 in both tested seasons. In addition, the lowest values were observed with net (14.25 and 14.75 mg/100 ml juice in the first and second seasons, respectively). Fruits treated by 3%O_2 + 3% CO_2 recorded intermediate values of ascorbic acid content without significant differences with those treated by 5% O_2 + 3% CO_2 in both tested seasons.

Moreover, ascorbic acid content showed continuous and sharp reduction with the advance in cold storage periods in both seasons. As such, the highest values of ascorbic acid content were recorded at zero time (19.37 and 19.68 mg/100 ml juice) and significantly decreased with increasing in storage duration to reach the least values (11.76 and 11.59 mg/100 ml juice) at 35 days cold storage in the first and second seasons, respectively. Fruits of the other sampling periods recorded intermediate values of ascorbic acid content.

The interaction between AMA treatments and cold storage period was significant in both seasons. The highest values of ascorbic acid content were recorded by all tested treatments at zero time, without significant differences among them in both seasons. Whereas, the least values were recorded by the control (net) treatment, at 35 days cold storage without significant differences with those treated by 3% O_2 + 3% CO_2 in the second season only.

During shelf life periods

Results in Table 4 clarify that the tested AMA treatments had significant effect on ascorbic acid content in tomato fruit juice during shelf life in both tested seasons. As such, the

Table 4. Effect of some active modified atmosphere (AMA) treatments on ascorbic acid content (mg/100 ml juice) of tomato fruits cv. Alisa during cold storage and shelf life periods during 2014 and 2015 seasons

AMA treatment		Ascorbic acid content (mg/100 ml juice)						
		Cold storage period (day)						AMA (average)
		0	7	14	21	28	35	
				First season (2014)				
AMA	Control (Net)	18.81ab	16.42fi	14.94jl	13.76mn	11.69pq	9.91r	14.25C
AMA	$3\%O_2 + 3\%CO_2$	19.28a	17.48ce	16.29fi	14.51km	13.34no	11.26q	15.36B
AMA	$5\%O_2 + 3\%CO_2$	19.59a	18.07bc	16.89df	15.70gj	13.92ln	11.56pq	15.95AB
AMA	$5\%O_2 + 5\%CO_2$	19.61a	18.07bc	16.59eg	15.70hj	14.51km	12.45op	16.15AB
AMA	$7\%O_2 + 5\%CO_2$	19.58a	17.78bd	16.89ef	16.59eh	15.40ik	13.63mn	16.64A
	SP (average)	19.37A	17.56B	16.32C	15.25D	13.77E	11.76F	-
				Second season (2015)				
AMA	Control (Net)	19.44a	17.30de	15.02gh	14.08ij	11.82l	10.82m	14.75C
AMA	$3\%O_2 + 3\%CO_2$	19.95a	18.73b	16.53f	14.73hi	12.13l	10.60m	15.44B
AMA	$5\%O_2 + 3\%CO_2$	19.49a	17.67d	15.53g	14.87h	13.60jk	12.40l	15.59AB
AMA	$5\%O_2 + 5\%CO_2$	19.45a	17.93cd	16.67ef	15.07gh	13.59jk	11.87l	15.76A
AMA	$7\%O_2 + 5\%CO_2$	20.06a	18.53bc	16.40f	14.52hi	13.26k	12.27l	15.84A
	SP (average)	19.68A	18.03B	16.03C	14.65D	12.88E	11.59F	-
				5 days shelf life				
				First season (2014)				
AMA	Control (Net)	14.35a	12.63de	11.42f	10.45gh	8.75kl	7.04n	10.77C
AMA	$3\%O_2 + 3\%CO_2$	14.52a	13.32bc	12.12e	10.91fg	9.45ij	7.75m	11.34B
AMA	$5\%O_2 + 3\%CO_2$	14.63a	13.33bc	12.12e	11.39f	10.18h	8.24lm	11.65B
AMA	$5\%O_2 + 5\%CO_2$	14.43a	13.33bc	12.12e	10.91fg	9.93hi	8.48l	11.53B
AMA	$7\%O_2 + 5\%CO_2$	14.60a	13.57b	12.84cd	12.12e	11.39f	9.21jk	12.28A
	SP (average)	14.50A	13.23B	12.12C	11.15D	9.94E	8.14F	-
				Second season (2015)				
AMA	Control (Net)	17.12ab	15.28c	13.35ef	11.68g	10.75ik	9.48m	12.94C
AMA	$3\%O_2 + 3\%CO_2$	17.51ab	15.67c	13.80de	12.73f	10.93hj	9.53m	13.36B
AMA	$5\%O_2 + 3\%CO_2$	17.44ab	15.59c	14.33d	13.27ef	11.80g	10.47jl	13.81A
AMA	$5\%O_2 + 5\%CO_2$	17.57ab	15.73c	14.27d	12.87	11.52gh	10.19km	13.69AB
AMA	$7\%O_2 + 5\%CO_2$	17.77a	16.93b	15.07c	12.73f	11.40gi	9.93lm	13.97A
	SP (average)	17.48A	15.84B	14.16C	12.65D	11.28E	9.92F	-

Values having the same alphabetical letter(s) did not significantly different according to LSD at 0.05 of probability.
AMA = modified atmosphere, SP = Storage period (day).

highest values of ascorbic acid (12.28 and 13.97 mg/100 ml juice in the first and second seasons, respectively), were detected in 7%O_2+5%CO_2 without significant differences with those treated by 5%O_2+5%CO_2 and 5%O_2+3%CO_2 in the second season only. In addition, the lowest values were observed with control (10.77 and 12.94 mg/100 ml juice in the first and second seasons, respectively). Fruits treated by 3% O_2 + 3% CO_2 recorded intermediate values of ascorbic acid content without significant differences with those treated by 5% O_2 + 3% CO_2 and 5% O_2 + 5% CO_2 in the first season and those treated by 5% O_2 + 5% CO_2 in the second one.

The interaction between AMA treatments and cold storage period was significant during shelf life in both seasons. The highest values of ascorbic acid content were recorded by all tested treatments at zero time, without significant differences among them in both seasons. Whereas, the least values were recorded by the control (net) treatment, at 35 days cold storage(7.04 and 9.48 mg/100 ml juice in the first and second seasons, respectively) without significant differences with those treated by 3% O_2 + 3% CO_2, 5% O_2 + 5% CO_2 and 7% O_2 + 5% CO_2 in the second season only.

Generally, ascorbic acid content retained significantly higher values with AMA treatments, while, was decreased with the advance of cold storage period.

These findings were in line with Lee and Kader (2000) who reported that losses of vitamin C, (ascorbic acid) are accelerated at higher temperatures and with longer storage durations. However, some chilling sensitive crops show more losses in vitamin C at lower temperatures. The loss of vitamin C after harvest can be reduced by storing fruits and vegetables in reduced O_2 and/or up to 10% CO_2 atmospheres; higher CO_2 levels can accelerate vitamin C loss. Tomatoes are rich source of ascorbic acid. The ascorbic acid content of ripe tomato ranged from 15 mg to 23 mg /100 g fruit (Sánchez-Moreno *et al*., 2006). Preservation of ascorbic acid content during storage is a difficult task since it undergoes oxidation (Cantwell *et al*., 2009). Moreover, Gharezi *et al*. (2012) stored Cherry tomato cv. Marilee red harvested at pink stages at ambient temperature (25°C ± 2) as control or cold storage conditions (10°C ± 2) up to 14 days. They found that, ascorbic acid contents significantly decreased during storage. Among all treatments, control showed lowest ascorbic acid contents. Loss of ascorbic acid in cold stored tomatoes was significantly slower than air stored tomatoes.

Lycopene Content mg/kg

During cold storage periods

Results in Table 5 clarify that control treatment (net) achieved significantly highest juice lycopene content (87.41 and 74.25 mg/kg in the first and second seasons, respectively). Whereas, 7% O_2 + 5% CO_2 treatment recorded the lowest juice lycopene content (74.18 and 68.33 mg/ kg in the first and second seasons, respectively) without significant differences with those treated by 5% O_2 + 5% CO_2 in the second season only. The other tested treatment recorded intermediate values.

Moreover, the results also indicate that juice lycopene content was progressively increased with the advance in cold storage period. As such, the lowest values (64.98 and 55.39 mg/kg were recorded at zero time in the first and second seasons, respectively).While, the highest values (98.35 and 85.88 mg/kg in the first and second seasons, respectively) were recorded at 35 days. Values of lycopene content during the other storing periods came in between.

In addition, the interaction between AMA treatments and cold storage period was found to be significant in both seasons. Whereas, the highest lycopene content (103.78 and 91.91mg/kg were recorded by control (net) × 35 days, while all tested treatments at zero time recorded the lowest values without significant differences between them. The other combinations recorded intermediate values.

During shelf life periods

Results in Table 5 also show that the control treatment (net) recorded significantly highest juice lycopene content (95.50 and 79.37 mg/kg in the first and second seasons, respectively). Whereas, fruits treated by 7% O_2 + 5% CO_2

Table 5. Effect of some active modified atmosphere (AMA) treatments on lycopene content (mg/kg) of tomato fruits cv. Alisa during cold storage and shelf life periods during 2014 and 2015 seasons

AMA treatment		Lycopene content (mg/kg)						
		Cold storage period (day)						AMA (average)
		0	7	14	21	28	35	
		First season (2014)						
	Control (Net)	65.89m	75.44jk	86.45g	93.80e	99.10bc	103.78a	87.41A
	$3\%O_2 + 3\%CO_2$	65.90m	74.96k	86.77g	93.91e	96.77cd	100.91b	86.53B
AMA	$5\%O_2 + 3\%CO_2$	63.93m	77.40ij	85.25g	90.92f	95.25de	100.92b	85.51C
	$5\%O_2 + 5\%CO_2$	64.78m	69.90l	74.51k	81.82h	89.60f	96.60d	79.53D
	$7\%O_2 + 5\%CO_2$	64.42m	65.58m	69.97l	75.96jk	79.60hi	89.56f	74.18E
	SP (average)	64.98F	72.65E	80.59D	87.28C	92.06B	98.35A	-
		Second season (2015)						
	Control (Net)	54.65n	65.11k	70.71hi	78.36e	84.79c	91.91a	74.25A
	$3\%O_2 + 3\%CO_2$	55.66mn	62.49l	68.70j	73.27g	78.92e	87.14b	71.03B
AMA	$5\%O_2 + 3\%CO_2$	55.83mn	62.66l	65.85k	72.24gh	78.43e	83.76cd	69.79C
	$5\%O_2 + 5\%CO_2$	56.31mn	61.14l	64.99k	69.80ij	75.79f	82.49d	68.42D
	$7\%O_2 + 5\%CO_2$	54.52n	57.35m	64.67k	71.05hi	78.25e	84.14cd	68.33D
	SP (average)	55.39F	61.75E	66.98D	72.94C	79.23B	85.88A	-
		5 days shelf life						
		First season (2014)						
	Control (Net)	73.48n	84.49l	93.85j	101.78ef	107.56bc	111.89a	95.50A
	$3\%O_2 + 3\%CO_2$	71.69n	79.24m	85.24l	96.44i	100.63fg	105.53cd	89.79B
AMA	$5\%O_2 + 3\%CO_2$	72.96n	80.01m	86.38l	93.82j	98.78gi	104.92d	89.47B
	$5\%O_2 + 5\%CO_2$	73.91n	79.01m	86.62l	90.80k	97.50hi	108.27b	89.35B
	$7\%O_2 + 5\%CO_2$	73.06n	78.20m	85.47l	91.47jk	98.95gh	103.27de	88.40C
	SP (average)	73.02F	80.19E	87.51D	94.86C	100.68B	106.78A	-
		Second season (2015)						
	Control (Net)	57.43q	71.39lm	77.06ij	83.51df	89.82b	97.01a	79.37A
	$3\%O_2 + 3\%CO_2$	58.69q	68.21o	74.01k	80.52gh	87.01c	95.48a	77.32B
AMA	$5\%O_2 + 3\%CO_2$	57.93q	68.66no	73.44kl	79.13hi	84.45de	90.27b	75.64C
	$5\%O_2 + 5\%CO_2$	59.37q	67.39o	73.81k	81.80fg	84.41de	85.45cd	75.37C
	$7\%O_2 + 5\%CO_2$	58.81q	64.32p	70.41mn	76.74j	82.52eg	89.93b	73.79D
	SP (average)	58.44F	67.99E	73.74D	80.34C	85.64B	91.63A	-

Values having the same alphabetical letter(s) did not significantly different according to LSD at 0.05 of probability

AMA = active modified atmosphere. SP = Storage period (day).

recorded the lowest juice lycopene content (88.40 and 73.79 mg/kg in the first and second seasons, respectively). While, those treated by the other AMA treatments recorded in between values in both seasons without significant differences among them in most cases.

Moreover, lycopene content during shelf life showed continuous increase with the advance in storage period in both seasons. As such, the lowest values (73.02 and 58.44 mg/kg were recorded for zero sample in the first and second seasons, respectively).While, the highest values (106.78 and 91.63 mg/kg in the first and second seasons, respectively) were recorded at 35 days. Values of lycopene content during the other storing periods came in between.

In addition, the interaction was significant in the two seasons. As such, lycopene content reached the highest values (111.89 and 97.01 mg/kg) with control (net) at 35 days storing period. Whereas, the lowest values were recorded with zero time at all AMA treatments without significant differences between them. All other combinations gave in among values.

Generally, the results of the present work reveal that juice lycopene content was increased as cold storage period increased and the control treatment (net) raised lycopene content as compared with all tested AMA treatments during cold storage and after shelf life period.

The reduction in lycopene content with AMA treatments was in agreement with Yang *et al.* (1987). They reported that, higher CO_2 and lower O_2 inhibited further ripening by inhibition lycopene formation in packaged tomato fruits. Moreover, Kubo *et al.* (1989) stated that CO_2 concentration affected color development of tomatoes by suppression of ethylene production. Javanmardi and Kubota (2006) reported that tomatoes which stored at room temperature showed significant increase in lycopene content as compared with those stored at low temperature. In addition, Vunnam *et al.* (2014) reported that MA storage, which maintained higher CO_2 (11.3%) and lower O_2 (3.1%) concentrations plausibly inhibited further ripening of already mature red cherry tomatoes.

Total Soluble Solids (TSS Brix°)

During cold storage periods

Results in Table 6 reveal that the control treatment (net) recorded significantly highest juice TSS (4.00 and 4.08% in the first and second seasons, respectively). Whereas, fruits treated by 3%O_2 + 3% CO_2 recorded the lowest TSS (3.41 and 3.52% in the first and second seasons, respectively) without significant differences with those treated by 5% O_2 + 3% CO_2 in both tested seasons. The other tested treatments recorded in between values.

However, TSS during cold storage was gradually increased with the advance in cold storage period in both tested seasons. As such, the lowest TSS (3.23 and 3.16%) and highest TSS (4.06 and 4.20%) were recorded after zero time and at 35 days of cold storage period in both seasons, respectively. Values of TSS during the other storing periods came in between.

Moreover, the interaction between AMA treatments and cold storage periods was significant in both seasons and support the effect of each individual factor on TSS values. As such, the highest TSS values were recorded by the control × 28 or at 35 days cold storage without significant differences between them in both seasons. While, the lowest TSS values were recorded at zero time without significant differences among them in both seasons.

During shelf life periods

Results in Table 6 clarify that the tested AMA treatments had significant effect on TSS% in tomato fruit juice during shelf life in both tested seasons. As such, the uppermost values of TSS (4.19 and 4.44% in the first and second seasons, respectively) were detected in the control treatment without significant differences with those treated by 5% O_2 + 5% CO_2 and 7% O_2 + 5% CO_2 in both tested seasons. In addition, the lowest values were observed by 3% O_2 + 3% CO_2 without significant differences with all tested gas combination in the first season and 5% O_2 + 5% CO_2 and 5% O_2 + 3% CO_2 in the second one.

Moreover, TSS showed continuous and sharp increase with the advance in cold storage

Table 6. Effect of some active modified atmosphere (AMA) treatments on TSS (Brix°) of tomato fruits juice cv. Alisa during cold storage and shelf life periods during 2014 and 2015 seasons

AMA treatment		TSS (Brix°)						
		Cold storage period (day)						AMA (average)
		0	7	14	21	28	35	
		First season (2014)						
AMA	(Net) Control	3.33df	3.83bc	3.83bc	4.00b	4.50a	4.50a	4.00A
	$3\%O_2 + 3\%CO_2$	3.16ef	3.16ef	3.16ef	3.50ce	3.66bd	3.83bc	3.41C
	$5\%O_2 + 3\%CO_2$	3.00f	3.00f	3.50ce	3.66bd	3.83bc	4.00b	3.50BC
	$5\%O_2 + 5\%CO_2$	3.33df	3.50ce	3.50ce	3.50ce	3.66bd	4.00b	3.58BC
	$7\%O_2 + 5\%CO_2$	3.33df	3.33df	3.33df	3.83bc	3.83bc	4.00b	3.61B
	SP (average)	3.23D	3.36CD	3.46C	3.70B	3.90AB	4.06A	-
		Second season (2015)						
AMA	(Net) Control	3.50df	4.00bd	4.00bd	4.00bd	4.33ab	4.67a	4.08A
	$3\%O_2 + 3\%CO_2$	3.00f	3.50df	3.50df	3.66ce	3.66ce	3.83bd	3.52C
	$5\%O_2 + 3\%CO_2$	3.00f	3.66ce	3.66ce	3.66ce	3.83bd	4.00bd	3.63BC
	$5\%O_2 + 5\%CO_2$	3.16ef	3.66ce	3.83bd	3.83bd	4.00bd	4.16ac	3.77B
	$7\%O_2 + 5\%CO_2$	3.16ef	3.50df	3.83bd	3.83bd	4.00bd	4.33ab	3.77B
	SP (average)	3.16D	3.66C	3.76BC	3.80BC	3.96AB	4.20A	-
		5 days shelf life						
		First season (2014)						
AMA	(Net) Control	3.33g	4.00ce	4.33ac	4.50ab	4.50ab	4.50ab	4.19A
	$3\%O_2 + 3\%CO_2$	3.16g	3.72ef	3.83df	4.16bd	4.50ab	4.66a	4.00B
	$5\%O_2 + 3\%CO_2$	3.33g	3.50fg	4.00ce	4.33ac	4.50ab	4.66a	4.05AB
	$5\%O_2 + 5\%CO_2$	3.33g	4.00ce	4.00ce	4.16bd	4.50ab	4.50ab	4.08AB
	$7\%O_2 + 5\%CO_2$	3.33g	3.72ef	4.16bd	4.22bc	4.50ab	4.66a	4.10AB
	SP (average)	3.30E	3.78D	4.06C	4.27B	4.50A	4.60A	-
		Second season (2015)						
AMA	(Net) Control	3.66fg	4.16de	4.50bd	4.66ac	4.83ab	4.83ab	4.44A
	$3\%O_2 + 3\%CO_2$	3.66fg	4.16de	4.16de	4.16de	4.16de	4.33ce	4.11C
	$5\%O_2 + 3\%CO_2$	3.66fg	4.16de	4.16de	4.33ce	4.33ce	4.33ce	4.16BC
	$5\%O_2 + 5\%CO_2$	3.33g	4.16de	4.33ce	4.50bd	4.66ac	4.83ab	4.30AC
	$7\%O_2 + 5\%CO_2$	3.66fg	4.00ef	4.00ef	4.66ac	4.83ab	5.00a	4.36AB
	SP (average)	3.60D	4.13C	4.23BC	4.46AB	4.56A	4.66A	-

Values having the same alphabetical letter(s) did not significantly different according to LSD at 0.05 of probability

AMA = active modified atmosphere, SP = Storage period (day).

periods in both seasons. As such, the highest values of TSS (4.60 and 4.66 % in the first and second seasons, respectively) were recorded at 35 days without significant differences with those at 28 days. Whereas, the least values of TSS (3.30 and 3.60 % in the first and second seasons, respectively) were recorded at zero time. Values of TSS during the other storing periods came in between.

The interaction between AMA treatments and cold storage period was significant in both seasons and support the effect of each individual factor on TSS values.

Generally, AMA treatments decreased fruit TSS as compared with control, while TSS showed continuous and sharp increase with the advance in cold storage periods in both seasons.

These results agreed with those reported by Kays (1997) who reported that, changes in TSS contents were natural phenomenon occurred during ripening and correlated with hydrolytic changes in starch concentration during ripening in post harvest period. In tomatoes, conversion of starch to sugar is an important index of ripening. During ripening the degradation of cell wall polysaccharides (hemicellulose and pectins) occurred releasing of oligosaccharins. That known oligosaccharides with biological activity and potential intercellular signaling role (Albesshein and Darvill, 1985; Ryan and Farmer, 1991).

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تأثيـــر بعض معامــلات الجو الهوائى المعدل على جودة ثمار الطماطم أثناء فترة التخـزين المبرد والعرض على الأرفف

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فى عامى ٢٠١٤ ، ٢٠١٥ تم زراعة شتلات الطماطم صنف " أليسا" فى ١٥ فبراير ، ٦ مارس وتم حصاد ثمارها فى ١٣ ، ٢٥ مايو فى الموسم الأول والثانى على التوالى فى مزرعه خاصه بجمعية بين المطرين، بلبيس، محافظة الشرقية، مصر، وتم تعريضها لمعاملات ما بعد الحصاد فى معمل التخزين بقسم البساتين - كلية الزراعة - جامعة الزقازيق على النحو التالى: التخزين فى الهواء المفتوح، التخزين فى الجو الهوائى المعدل النشط (٣% أكسجين + ٣% ثانى أكسيد الكربون، ٥% أكسجين + ٣% ثانى أكسيد الكربون ،٥ % أكسجين + ٥% ثانى أكسيد الكربون ، ٧% أكسجين + ٥% ثانى أكسيد الكربون)، وتم تخزين ثمار كل المعاملات لمدة ٣٥ يوماً على درجة حرارة ١٠ ± ١°م ورطوبة نسبية ٩٠-٩٥%، وقد تم أخذ عينات عشوائية من كل معاملة على فترات كل ٧ أيام لتقييم تأثير فترات التخزين المبرد، معاملات الجو الهوائى المعدل، والتفاعل بينهما على جودة الثمار بعد فترات التخزين المبرد وبعد كل فترة تخزين مبرد، ثم أخذ بعض من هذه الثمار وحفظها لمدة خمسة أيام تحت ظروف ٢٠ °م ورطوبة نسبية ٦٠-٧٠% لتقدير تأثير فترة العرض على الأرفف، وقد وجد أن معاملات الجو الهوائى المعدل النشط تميل لزيادة كلاً من صلابة الثمار ومحتوى حمض الأسكوربيك عند مقارنتها بمعاملة المقارنة أثناء فترات التخزين المبرد والعرض على الأرفف، وعلى العكس، فإن معاملات التخزين فى الجو الهوائى المعدل تميل إلى نقص كلاً من فقد الثمار فى الوزن، عفن الثمار، المواد الصلبة الذائبة الكلية و محتوى الليكوبين وذلك أثناء فترات التخزين المبرد و العرض على الأرفف، وقد وجد أن التقدم فى فترة التخزين من صفر إلى ٣٥ يوماً قد سببت زيادة تدريجية فى الفقد فى الوزن الطازج، عفن الثمار والليكوبين ومحتوى الثمار من المواد الصلبة الذائبة الكلية للعينات المتتالية المأخوذة أثناء فترات التخزين المبرد والعرض على الأرفف عند مقارنتها مع معاملة المقارنة، وعلى العكس، فإن التقدم فى فترات التخزين المبرد قلل صلابة الثمار ومحتواها من حمض الأسكوربيك.

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