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ROLE OF MODIFIED ATMOSPHERE AND SOME PHYSICAL TREATMENTS UNDER COOL STORAGE CONDITIONS IN CONTROLLING POST-HARVEST CHERRY TOMATOES SPOILAGE

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ABSTRACT: The importance of the cool and modified atmosphere in cherry tomato fruit storing is its usage to increase the fruit longevity, quality appearance and prevention of spoilage diseases caused by *Botrytis cinerea* Pers.: Fr. and *Alternaria alternata* (Fr.) Keissi. Cherry tomatoes (*Lycopersicon esculentum* Mill. var. *cerasiforme* Dunal) was stored under cool condition and three modified atmosphere levels. Results clearly showed that modified atmosphere level (12% CO₂ + 6% O₂) under cooling storage (7°C±1 + 90% RH±3), was significantly decreased incidence and severity percentage of cherry tomato spoilage more than the other two modified atmosphere levels. In parallel with this data our consequence proved that, these storage conditions preservation quality of cherry tomato parameters (firmness, TSS, vitamin C, lycopene and color) in pretty shape for consumer, marketing and exportation. Treated cherry tomatoes with calcium chloride and salicylic acid extending shelf life, improve fruit quality appearance and stability parameters of cherry tomato with less spoilage disease incidence under previously storage conditions.

Key words: Modified atmosphere, cherry tomatoes, post-harvest, quality parameters, *Alternaria alternata*, *Botrytis cinerea*.

INTRODUCTION

Cherry tomato (*Lycopersicon esculentum* Mill. var. *cerasiforme* Dunal) is a tomato variety with small fruits, having different shapes and colors. It is used mainly for fresh consumption (Gudeva and Dedejski, 2012). Cherry tomato is one of the most important supplementary sources of minerals, vitamins and antioxidants in human diet.

Cherry tomatoes are grown for edible fruits, which can be consumed either fresh as a salad or after cooking as snacks. Cherry tomato needs storehouse necessary conditions to maintain its antioxidants such as lycopene, ascorbic acid, sugars, carotenoids and phenols in good quality.

Cherry tomato is a climacteric and perishable fruit with short shelf life ranging from 15 to 21 days depending upon the storage conditions and post-harvest treatments (Nitin *et al.*, 2020).

Post-harvest losses of fruits and vegetables is a serious problem worldwide, due to decreased values of fresh product during transport from the farm to the consumers table. Preservation of agriculture products is very important due increased consumer population as well as increase demands for fruits and vegetables. Fungal pathogens are mainly responsible for post-harvest losses of fruits and vegetables (Korsten, 2006).

Cherry tomato fruit is susceptible to post-harvest diseases caused by various pathogenic

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fungi. *Botrytis cinerea* Pers.: Fr. and *Alternaria alternata* (Fr.) Keissi., cause gray mold and black rot, respectively. The two fungal pathogens are among the most common fungal pathogens responsible for post-harvest decay on cherry tomato fruits (Wang et al., 2010; Raafat et al., 2016; Firas et al., 2017). Controlled atmosphere or modified atmosphere (CA or MA) combined with cold storage extend cherry tomatoes shelf - life (Akbudak and Akbudak 2007; Cantwell et al., 2009).

Post-harvest recommendations indicated that tomatoes, including cherry and grape tomatoes, should be stored at 10°C or higher to avoid chilling injury (Jimenez et al., 1996). Low oxygen atmosphere level (3-5%) retard tomato ripening while high level of carbon dioxide (7%) are damaging for tomatoes. Low O₂ injury is characterized by uneven ripening and off-flavor due to increases in ethanol. Carbon dioxide higher than 5% may cause surface discoloration, softening, and uneven coloration (Sargent and Moretti, 2004)).

Cherry and grape tomatoes are sometimes kept at lower than recommended temperature and are used as components on fresh-cut vegetables trays under modified atmosphere, with excepted shelf-life of 14- 18 days at 2-5°C (Akbudak and Akbudak, 2007).

Controlled atmosphere of 3 or 10% oxygen with 0, 7, 12 or 18% carbon dioxide at 5°C provide little benefit but is tolerated by grape tomatoes for up to 3 weeks based on visual appearance, discoloration, decay, off-odors, and changes in composition sugars, vitamin C, ethanol and acetaldehyde concentrations. (Cantwell et al., 2009; Manasa et al., 2018).

Acetyl salicylic acid may have potential post-harvest application alleviating chilling injury, maintain quality and improves the health benefit of pomegranate fruit consumption by inducing antioxidant system (Aghdam et al., 2012). The important role of salicylic acid (SA) against fruit fungal pathogens has been studied by several research workers (Aghdam et al., 2012; Gharezi et al., 2012)

Different studies explained that calcium chloride reduced post-harvest decay, controlled development of physiological disorders, improved

quality and delayed aging or ripening. In addition, CaCl₂ dip or controlled atmospheres maintained firmness and visual quality resulting in long shelf life (Rosen and Kader, 1989).

The present study aimed at evaluating the effect of modified atmosphere, cool storage conditions, salicylic acid and calcium chloride in controlling fungal spoilage of cherry tomato fruit. Also, the output of all aforementioned treatments in maintain fruit quality parameters were studied.

MATERIALS AND METHODS

Healthy Fruits

Fruits of cherry tomato (*Lycopersicon esculentum* Mill. var. cerasiforme Dunal) cv. Catalina 522 were picked at red stage of maturity (red color covering between 60 and 90% of fruit surface), as described by Helyes et al. (2006) and immediately transported to the laboratory. Fruits were selected for uniformity in size, appearance, firmness, ripeness and absence of physical defects, damage and fungal infection. The selected fruits were randomized before being used for all next treatments.

Fruits were washed with distilled water then, disinfested by immersing in ethanol 70% for 2 min, washed twice with double sterile distilled water (5 min each), then allowed to dry in laminar flow for one hour.

Fungal Spore Preparation

Fungal cultures used in this research were previously isolated and identified (Raafat et al., 2016). Fresh cultures were prepared and grown in PDA plate, spore suspension of *Alternaria alternata* and *Botrytis cinerea* (20 days old) were carefully removed from surface of the media with a sterilize glass rod and suspension prepared in sterile water. The spore concentration was adjusted to 10⁶ spores/ml by the aid of hemocytometer (El-Katatny and Emam, 2012).

Modified Atmosphere

Modified atmosphere (MA) of O₂ % and CO₂% was established according to the methods of Tian et al. (2000) and Das et al. (2006). In the present study the following levels were used.

- Level 1 (CO₂ 6 % + O₂ 3%)
- Level 2 (CO₂ 6 % + O₂ 6%)
- Level 3 (CO₂ 12 % + O₂ 6%)

Storage Conditions

Experiments of storage fruit were conducted in a computerized cold room at Horticulture Dept. Lab., Fac. Agric., Zagazig Univ., Egypt, which maintained at 7±1°C and 90% ± 3 relative humidity (RH) under aforementioned (MA) and/or under ambient condition.

Fruit Inoculation

Sterilized cherry tomatoes were superficially wounded one time in the equator with a sterilized stainless-steel rod with a probe tip 1 mm wide and 2 mm in deep. Using micropipette the wounded fruits were separately inoculated with the pathogen by placing 10 µl of a spore suspension containing 10⁶ spores/µl of *Alternaria alternata* and/or *Botrytis cinerea* in each wound, while control treatment was inoculated with sterilized water. Following incubation at 20°C for 24 hr., inoculated fruits were treated with the experimental treatments. Ten treated fruits were placed in sterilized plastic boxes (14 x 11 x 5 cm) and stored under the three modified atmosphere (MA) in a computerized cold storage room. Each treatment was applied in three replicates according to **Fagundes et al. (2014)**. Disease incidence and severity were assessed after 10 and 20 days of storage.

Disease Assessment

Incidence of cherry tomatoes black spot or gray mold was assessed as the number of infected fruits and reported as the percentage of disease incidence with respect to the control treatments. Disease severity was determined according to **Romanazzi et al. (2006)** as the empirical scale as follows:

- 0 = Healthy fruit.
- 1 = One very small lesion (beginning of infection).
- 2 = One lesion 10 mm² in size.
- 3 = Several lesions of 25% of the fruit infected.
- 4 = 26-50% of the fruit surface infected, sporulation present.
- 5 = More than 50% of the fruit surface infection, sporulation present.

Both disease incidence and severity were assessed after 10 and 20 days of storage.

$$\text{Disease severity (\%)} = n \times v / 5n \times 100$$

Where:

(n) = Number of fruits in each category

(v) = Numerical values of symptoms category

N = Total number of fruits, (5) = Maximum numerical value of symptoms category.

Salicylic Acid Treatment

Fruits of cherry tomatoes Catalina 522 cultivar were wounded as previously mentioned and dipped in 2% salicylic acid solution for 5 minutes and/or in sterile distilled water as control treatment. Then after, fruits were inoculated with *A. alternata* and/or *B. cinerea* as mentioned before and directly stored in plastic boxes under MA (6% CO₂ + 12% O₂ and 7°C ± 1 + 90% RH ± 3) in a computerized cold storage room. Each treatment was applied in three replicates. Disease incidence and severity and quality parameters were assessed after 15, 30 and 45 days of storage.

Calcium Chloride Treatment

Calcium chloride (CaCl₂) solution was prepared in sterile distilled water to obtain 2% concentration.

Fruits were wounded as previously mentioned and dipped in the previously mentioned concentration of CaCl₂ for five minutes or in sterilized distilled water as a control treatment. Then cherry tomato fruits were individually inoculated with *A. alternata* and *B. cinerea* as mentioned before and directly stored in plastic boxes under MA (6% CO₂ + 12% O₂ and 7°C ± 1 + 90% RH ± 3) in a computerized cold storage room. Three replicates per each treatment were used. Evaluation of total soluble solids (TSS), firmness (Firm) and vitamin C (Vitam. C), total sugar (TS), lycopene (L), color and weight loss were recorded 3 times, every 15 days intervals (**Nasrin et al., 2008**).

Quality Parameters Determination

Total soluble solids (TSS)

TSS content expressed in ° (Brix) was detected using ago (Japan) NI refractometer according to **Kader (1991)**.

Firmness (Firm)

Firmness, was measured as the maximum penetration force reached during tissue breaking of each fruit with hand penetrometer equipped with 1-9mm diameter plunger (g/cm^2) according to **Kader (1991)**.

Ascorbic acid (Vitamin C.)

Ascorbic acid content in juice (mg/g fresh weight) was determined in juice 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 as described by **Lucoss (1994)**.

Lycopene content and color measurement

Both of lycopene content and color (where, L: luminance, a: redness and b: yellowness.) measurement were tested in fruits using Tomato Meter Cloroflex Ez, according to **Tabaestani *et al.* (2013)**.

Quality parameters determination in the MA experiment were assessed at zero time as a control and after 10 and 20 days of storage

Statistical Analysis

Collected data were subjected to proper statistical analysis of variance according to **Snedecor and Cochran (1980)** and the differences among treatments were compared using LSD at 0.05 level.

RESULTS

Effect of Three Modified Atmosphere (MA) Levels in Controlling Cherry Tomatoes Fungal Spoilage

The effect of tested modified atmosphere levels (L), (L1: 3% CO_2 + 6% O_2 , L2: 6% CO_2 + 6% O_2 and L3: 6% CO_2 +12% O_2) on prevention or reduction the potential of cherry tomato spoilage disease incidence and severity during storage period are presented in Table 1.

Results showed that, MA level 3 significantly decreased spoilage incidence and severity percentage of tomatoes inoculated with *A. alternata* and/or *B. cinerea* after 10 - and 20 - days storage time, followed by those stored

under modified atmosphere of level 1, while level 2 was the lowest in preventing spoilage diseases (Figs. 1, 2 and 3). Proportion of cherry tomato spoilage diseases for all tested storage period was completely arrested at level 3 of MA.

Results in Table 1 also show that, under ambient storage condition diseased cherry tomato fruits progressed strongly during storage period, (100% as disease incidence and disease severity after 20 days of storage). Inoculation with *A. alternata* or *B. cinerea*, compared with the control treatment showed 60% disease incidence and 75% disease severity. Effectiveness of level 3 modified atmosphere (12% CO_2 + 6% O_2) under cool storage conditions ($7 \pm ^\circ\text{C}$ 1 + 90% RH+ 3) was the most effective in controlling spoilage incidence and severity than those obtained from level 1 and 2 MA and ambient conditions , respectively.

Results in Table 2 show the effect of some modified atmosphere levels under cold storage conditions in cherry tomatoes quality parameters. Results revealed marked reduction in firmness fruits of inoculated with *A. alternata* and/or *B. cinerea* by advancing storage period, while slight decrease was detected in firmness of healthy fruits stored under levels 1 and 3 of MA high level of CO_2 . The lowest firmness was under level 2 of MA (low CO_2 level under cold storage and inoculation with *B. cinerea* after 20 days of storage time being 313 compared with control treatment being 463).

Marked increase in TSS of fruits stored under the level 3 MA, were recorded being, 7.83 and 7.08 of control healthy fruit treatment after 10 and 20 days of storage time, respectively. TSS of all (MA) treatments, showed slight decreases with increasing time of storage than the initial zero time (8.75).

Significant decrease in vitamin content of inoculated cherry tomatoes was observed compared with healthy ones. Significant increase in vitamin C in the control healthy cherry tomato fruit than those inoculated with fungal spoilage pathogens. Decreased vitamin C content was observed with increasing the storage time at all MA levels especially level 3.

Table 1. Effect of three modified atmosphere levels under cold storage conditions (7°C ± 1 + 90% RH+ 3) in controlling cherry tomato spoilage disease incidence (DI) and severity (DS) percentage after 10 and 20 days

Treatment	10 Days								20 Days							
	Ambient		Level 1		Level 2		Level 3		Ambient		Level 1		Level 2		Level 3	
	DI	DS	DI	DS	DI	DS	DI	DS	DI	DS	DI	DS	DI	DS	DI	DS
Control (wounded uninoculated)	3	50	0	0	0	0	0	0	6	75	0.66	25	1	58.33	0	0
<i>Alternaria alternata</i>	6	75	0.33	8.33	0.66	33.33	0.33	8.33	10	100	1	33.33	1.66	58.33	0.33	16.66
<i>Botrytis cinerea</i>	5	50	0.33	16.66	1	25	0.33	8.33	10	100	1	33.33	1.66	41.66	0.33	8.33

LSD at 5% for: % DI = 0.508 % DS = 11.384 Days: 15.709 Fungi: NS



Control Ambient



Control Ambient

(Zero time) (After 20 days of storage) appearance senescence Exhibited



After 20 days of inoculation by *A. alternata*

Rot symptoms



After 20 days of inoculation by *B. cinerea*

Rot symptoms

Fig. 1. Spoilage development on cherry tomato fruits stored under ambient condition (20 days of storage period)



Control (Healthy)

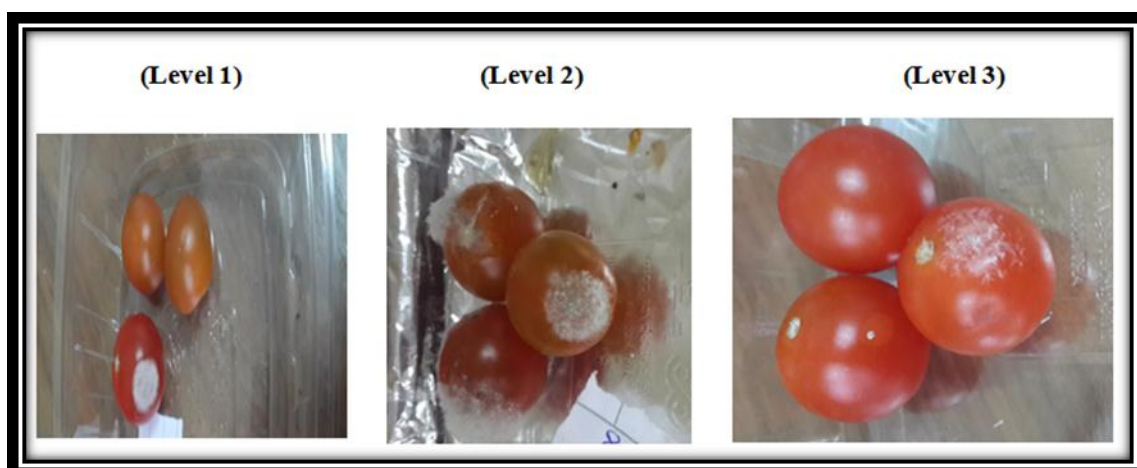


Fig. 2. Effect of modified atmosphere levels (L1, L2 and L3) on *Alternaria* black rot prevention of cherry tomato fruits (20 days of storage period)

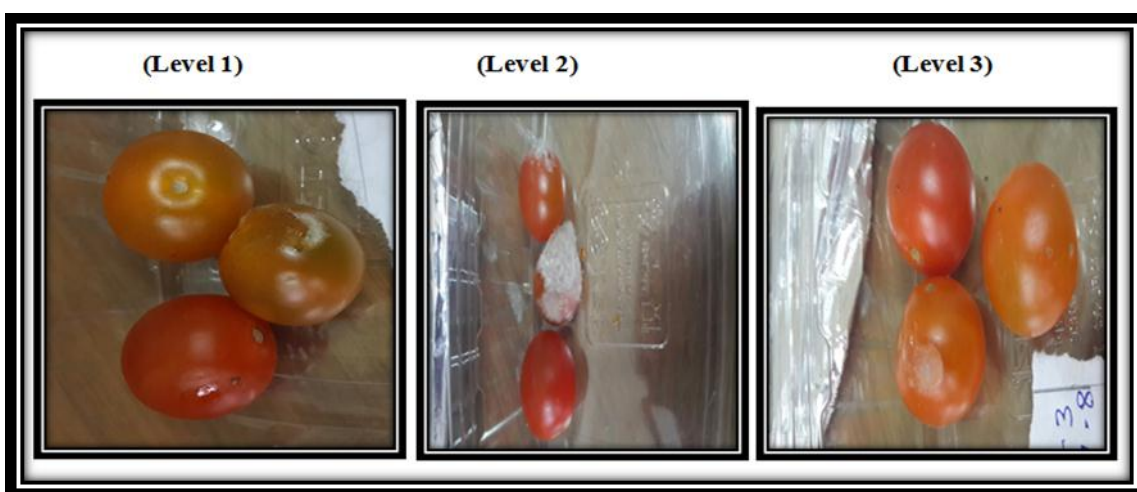


Fig. 3. Effect of modified atmosphere levels (L1, L2 and L3) on *Botrytis* gray mold prevention of cherry tomato fruits (20 days of storage period)

Table 2. Impact of three modified atmosphere levels (MA) under cool storage condition on some fruit quality parameters of infected cherry tomato fruits by *A. alternata* and *B. cinerea*

Storage period	Treatment	(M A) levels	Firmness	TSS	Antioxidant fraction		Color			
					Vitamin C	Lycopene	L*	a*	b*	
10 Days	Control	Initial time	-	711	8.75	21.73	88.00	21.45	10.77	9.74
	Control Healthy	L1	490	7.25	18.33	82.33	25.35	15.35	13.09	
		L2	470	7.00	16.00	74.33	15.35	15.35	13.54	
		L3	490	7.83	19.00	83.33	14.60	14.60	13.09	
	<i>A. alternata</i>	L1	386	7.00	16.86	78.33	14.21	14.21	12.76	
		L2	383	6.00	15.00	73.33	12.93	12.93	12.51	
		L3	396	7.16	16.80	80.66	14.51	14.51	12.78	
	<i>B. cinerea</i>	L1	470	7.50	16.13	78.00	13.70	13.70	13.09	
		L2	470	6.50	14.60	74.00	12.68	12.68	11.10	
		L3	480	7.66	16.13	80.00	25.72	14.87	13.10	
	20 Days	Control Healthy	L1	510	7.08	16.06	64.00	14.38	8.14	9.38
			L2	463	6.33	15.86	52.00	19.08	11.67	10.16
			L3	520	7.08	18.60	78.00	19.49	9.59	8.67
		<i>A. alternata</i>	L1	430	7.91	15.06	52.00	18.80	9.27	8.44
			L2	353	6.91	12.56	50.00	22.07	11.27	10.15
L3			440	8.41	13.33	70.00	26.66	14.85	13.06	
<i>B. cinerea</i>		L1	433	8.08	17.53	63.00	21.29	11.17	8.88	
		L2	313	7.00	14.86	45.00	19.04	8.11	8.58	
		L3	433	8.02	15.73	74.00	23.90	13.47	11.76	

LSD 5% at For Firm. NS TSS: 0.564 Vit. C: 0.978 Lycopene: 3.945 Color: L: 1.704 a: 1.521 b: 938

L*: luminance a*: redness b*: yellowness

All treatments showed significant increase in lycopene during storage period. The highest amount of lycopene was recorded in the control treatment. On the other hand, at all of storage time (10 and 20 days), lycopene content of inoculated fruits with spoilage pathogens stored under level 3 of MA, showed higher content in this respect as compared with the other two MA levels (1 and 2).

Color value of L (luminance) of healthy (control treatment) and fruits inoculated with *A. alternata*/or *B. cinerea* showed increases after 10 days of storage time than the initial time (21.45).

The same trend occurred with other values of colors (redness and yellowness), with initial time being 10.77 and 9.74, respectively.

Nevertheless, level 3 of MA storage recorded higher color values (L, a and b) than the other levels of MA storage condition.

Effect of Calcium Chloride and/or Salicylic Acid Application in Controlling Spoilage Disease Incidence of Cherry Tomatoes during Storage Time

It is evident from Table 3 that calcium chloride and/or salicylic acid 2% as dipping treatment resulted in complete preventing *A. alternata* and/or *B. cinerea* fruit rots throughout the first 15 days storage period of inoculated fruits under cold storage conditions of modified atmosphere. Perfectly, result was detected when treated healthy cherry tomato fruits with 2% of salicylic acid after 15 days of storage time under the same storage conditions.

Table 3. Effect of calcium chloride and salicylic acid applications in controlling spoilage disease incidence (DI) and severity (DS) caused by *A. alternata* and *B. cinerea* of cherry tomato fruits stored in plastic boxes under Level 3 MA and cold storage room

Treatment	<i>Alternaria alternata</i>						<i>Botrytis cinerea</i>					
	Storage period (day)						Storage period (day)					
	15		30		45		15		30		45	
Disease assessment	DI	DS	DI	DS	DI	DS	DI	DS	DI	DS	DI	DS
Healthy (Control)	0	0	0.66	8.33	2	41.66	0	0	0.66	8.33	2	41.66
Inoculated	1	16.66	1.66	33.33	3	100	25	1.33	2.66	33.33	4	100
CaCl ₂ (2%)	0	0	0.66	25	1.33	33.33	0	0	0.66	25	1.33	33.33
CaCl ₂ + Inoculated	0.66	16.66	1.33	33.33	2	50	50	1	1.66	75	2.66	50
Salicylic acid (2%)	0	0	0.66	50	2	50	0	0	0.66	50	2	50
Salicylic acid + Inoculated	1	25	2	50	2.33	50	25	1	2.66	50	2	75

LSD at 5 % For: Disease incidence = 0.539 Disease severity = 21.219.

According to results in Table 3 control healthy cherry tomato fruits exhibited low decay incidence percentage (both 0.66 % and 2%) compared with infected control or inoculated and decay severity (both 50 %) after 30 and 45 days of storage time, respectively. Salicylic acid treatment of inoculated fruits with the two fungal spoilage pathogens caused marked control of fruit spoilage disease incidence (2 and 2.33% and 50% disease severity against *A. alternata* after 30 and 45 days of storage), however, being 25 and 2.66% and 50 and 75% of spoilage disease incidence and disease severity after 30 and 45 days, respectively against *B. cinerea*.

Fruits treated with calcium chloride had greater control effect against decay incidence and severity percentage (0.66 and 1.33%) as well as 25 and 33.33% after 30 and 45 days of storage, respectively. CaCl₂ treated inoculated cherry tomatoes lead to control of spoilage incidence and severity percentage being 0.66 and 2% and 50 and 50% after 30 and 45 days of storage, respectively.

Visible control effect was observed against *A. alternata* and *B. cinerea* when inoculated fruits treated with CaCl₂ 2% (2 and 2.66% disease incidence and both 50% disease severity, respectively after 45 days of storage).

Fruits coated with CaCl₂ and inoculated by *A. alternata* controlled spoilage disease being 2% incidence and 50% severity at the end of storage period. Similarly, coated fruits with salicylic acid and inoculated with *A. alternata* showed spoilage control (incidence 2.33% and 75% severity).

The same trend was detected in spoilage incidence and severity percentage of coated fruit with CaCl₂ and/or SA inoculated with *B. cinerea* (2.33% incidence and 50% severity for CaCl₂ treatment) and (2% incidence and 75% severity for SA treatment) at the end of storage time (45 days).

Fruit treatment with CaCl₂ resulted in higher firmness, which recorded 666 and 600 for coated fruits (healthy and inoculated, respectively) compared with healthy uncoated (556), after 15 days storage time (Table 4).

On the other hand, all fruits softened progressively during storage time. In addition, CaCl₂ treated fruits and inoculated with *A. alternata* and/or *B. cinerea* revealed spoilage lateness in fruit. The same observation occurred as a result of SA fruit treatment, in healthy and inoculated cherry tomatoes at all storage time. Calcium chloride dip treatment retarded the metabolism as indicated by the slow ripening rate. CaCl₂ improves the firmness of tomato fruits.

Table 4. Effect of calcium chloride and salicylic acid applications during three storage periods on some quality parameters of cherry tomatoes inoculated with spoilage fungal pathogens (*A. alternata* and *B. cinerea*)

Fungus	<i>Alternaria alternata</i>									<i>Botrytis cinereas</i>								
	15			30			45			15			30			45		
Storage Days																		
Treatments	Firmness	TSS	Vitam. C	Firmness	TSS	Vitam. C	Firmness	TSS	Vitam. C	Firmness	TSS	Vitam. C	Firmness	TSS	Vitam. C	Firmness	TSS	Vitam. C
Control (Healthy)	556	4.66	21.20	500	3.50	19.66	420	2.50	17.26	556.66	4.66	21.20	500	3.53	19.66	420	2.50	17.26
Inoculated	503	4.00	18.86	466.66	2.5	16.50	353.33	2.13	14.63	466.66	3.75	17.26	350	2.5	15.16	300	2.0	14.2
CaCl ₂	666	5.58	24.10	556.66	4.58	21.83	500	3.00	19.53	666.66	5.58	24.11	556.66	4.58	21.83	500	3.00	19.53
CaCl ₂ + Inoculated	600	5.33	20.6	513.33	3.41	18.83	406.66	2.50	17.36	513.33	4.66	19.66	450	3.41	17.26	303.33	2.50	16.0
Salicylic acid	520	4.91	23.9	460	3.75	22.63	440	2.58	19.7	520	4.91	23.9	460	3.75	22.63	440	2.58	19.7
Salicylic acid + Inoculated	473	4.41	20	416.66	3.50	18.63	366.66	2.10	16.7	416.66	4.33	19.2	388.33	3.66	16.96	340	2.4	15.41

LSD 5% at For: Firm: (g / cm²) = 39.759 TSS: °(Brix) = 0.416 vit. C: (mg/g) = 0.781

There were visible increases of TSS of fruits coated with CaCl₂. The TSS values were higher in inoculated fruits coated with CaCl₂ and/or SA than un-coated inoculated fruits and being 3.41 and 3.50 values of inoculated with *A. alternata* and coated with CaCl₂ and SA, respectively compared with inoculated, 2.5°(Brx) after 30 days of storage time. The same results were observed with tomatoes inoculated with *B. cinerea*., The TSS of all experimental treatments (CaCl₂ and/or SA) decreased with increasing storage time.

Generally, results of Vitam. C. values showed significant decrease by increasing the storage time. In addition, coating fruits with CaCl₂ and/or SA resulted in increase of Vitam. C. being 14.10 and 13.9 mg/ 100 g juice as a result of treating by CaCl₂ and SA, respectively compared to control (11.20) after 15 days of storage time. The same trend was obtained at 30 and 45 days of storage. Fruits inoculated with spoilage pathogens and coated with CaCl₂ and / or SA lead to observe increase in Vitam. C. values than those untreated inoculated ones.

DISCUSSION

Concerning the effect of treated cherry tomatoes with some physical treatment pre-stored under cooling and modified atmosphere on controlling spoilage disease and improve

fruit quality appearance were studied. The current work revealed that the effectiveness of level 3 modified atmosphere (12% CO₂ + 6% O₂) under cool storage conditions (7 ± °C 1 + 90% RH+ 3) was the best MA treatment in controlling cherry tomatoes spoilage incidence and severity.

Post - harvest treatment with low O₂ and / or high CO₂ to control fungal decay in cherry fruits is considered as pleasant alternative control methods against spoilage diseases (**Ke et al., 1991; Prusky et al., 1997**).

In this respect, several research works revealed that low O₂ concentration during apple storage appears to have limited fungi static properties and is less effective than elevated CO₂ (**Sitton and Patterson, 1992**). As well as high CO₂ controlled atmosphere have been shown to reduce significantly post-harvest storage decay caused by many fungi in many different types of fruits (**Ceponis and Cappellini, 1985; De Vries-Paterson et al., 1991**). Therefore, it seems necessary in MA storage to combined cooling storage with high CO₂ and/or low O₂ for controlling post-harvest diseases (**Woodward and Topping, 1972; Tian et al., 2000**).

The main aim of modified atmosphere packing (MAP) is to arrangement the atmosphere composition around the product so

that the storage life of the products can be prolonged. Most fruits and vegetables age less quickly when the atmosphere oxygen level surrounding them is depressed. This is because the reduced oxygen slows down the respiration and metabolic rate of the products and therefore slow down the natural aging process (Woodward and Topping, 1972). Raising carbon dioxide level to 2% or more can also be beneficial. Elevated CO₂ levels can decrease the ethylene sensitivity of products, it can also slow the chlorophyll loss which is the green color of fruits and vegetables. Increase CO₂ level in MA arrest or reduce the growth of most post-harvest spoilage fungi. Modified atmosphere effects can help producers and wholesalers to prolong both of fresh product storage and shelf life (Jenny, 2000).

Results revealed that marked significant reduction in firmness of inoculated fruits with *A. alternata* and/or *B. cinerea* by advancing in the storage period, while slight decrease was detected in firmness values of healthy fruits stored under levels 1 and 3 of MA high level of CO₂. The lowest firmness values were obtained under level 2 of MA (low CO₂ level under cold storage condition and inoculated with *B. cinerea* after 20 days of storage time). Similar result was obtained by light increase during storage period (Jian *et al.*, 2002) when he found that fruit firmness of "Napoleon cv." in controlled atmosphere (CA) with 5% O₂ + 10 CO₂ showed a slight increase during storage period. Results obtained revealed that, the high CO₂ of storage condition was more effective for good maintaining cherry fruit firmness than other storage condition. The results are convergent with a previous findings of Tian *et al.* (2000) and Moneruzzaman *et al.* (2009).

Fruit softening takes place because of the deterioration in the cell wall composition, cell structure, and intracellular materials (Mwaurah *et al.*, 2020). These biochemical processes involve the direct suppression of the activities of pectin polygalacturonase and esterase enzymes causing either postharvest softening of fruit structure or blockage of the synthesis of ethylene.

Our results clearly showed that, marked significant increase in TSS values of fruits stored under the level 3 MA. Regarding TSS of

all tested MA treatments, it was noticed that slight decrease in TSS values occurred by increasing the time of storage than the initial time (Zero time). TSS increased during the ripening due to degradation of polysaccharides to simple sugars thereby causing an increase in TSS (Gharezi *et al.*, 2012). These results were in conformity with Ozkaya *et al.* (2009) who reported that storage time affected strawberry quality as increasing the storage period resulted in decreases TSS. TSS increased gradually with the advancement of storage period. This might be due to moisture loss during storage and the decrease in TSS was associated with the oxidative breakdown of sugar as a result of respiration and over ripening (Antala *et al.*, 2014). The results regarding changes in vitamin C as influenced by MA of cherry tomato fruit showed that significant decrease in vitamin C content of inoculated cherry tomatoes was observed compared to healthy ones. It was noticed that significant increase in vitamin C in control healthy cherry tomato fruit than those inoculated with both fungal spoilage pathogens. Decreasing in vitamin C content was observed by increasing the storage time at all MA levels especially level 3. This result was in consistent with those obtained by Moneruzzaman *et al.* (2009), who reported that, all quality parameters values except vitamin C were gradually increased with exceeding of storage time regardless of storage conditions.

As demonstrated in the present study, the lycopene content was decreased as the storage period advanced of all experimental treatments. The highest amount of lycopene was recorded in control treatment of cherry tomato fruits than those inoculated with *A. alternata* and / or *B. cinerea*. Lycopene content of inoculated cherry tomato fruits with spoilage pathogens stored under level 3 of MA, showed the highest content at all of storage time (10 and 20 days). These results are in agreement with those obtained by Tabaestani *et al.* (2013). It is worthy to mention that formation of lycopene was dependent upon the level of O₂ presence which differ from one level to the another one and also, the temperature range (Passam *et al.*, 2007; Nitin *et al.*, 2020).

The surface color of tomato fruit is one of the most pleasant factor influenc in tomato

marketing and consumption. Color values of L (luminance, redness and yellowness) of healthy (control treatment) and inoculated cherry tomato fruits by *A. alternata*/or *B. cinerea* were increased after 10 days of storage time than the initial time. Nevertheless, level 3 of MA storage condition recorded higher color values (L, a and b) than the other levels of MA storage condition. The change in color during ripening of cherry tomatoes is mainly due to conversion of chloroplasts into chromoplast, which lead to the lycopene accumulation and chlorophyll degradation (Tadesse *et al.*, 2015). A delay in color change due to treatments has been reported in tomato by Ali *et al.* (2010).

It can be concluded from the aforementioned results that, the modified atmosphere storage condition of level 3 (12% CO₂ + 6% O₂) + (7°C ± 1 + 90% RH ± 3), was the most significantly preferable storage conditions for controlling cherry tomato spoilage disease incidence and severity percentage. At the same time, these storage conditions preservation cherry tomato quality parameters in pretty shape for consumer, marketing and exportation. These results are in harmony with the results obtained by Cantwell *et al.* (2009) who demonstrated that, the high quality of grape tomatoes tolerate and controlling decay were recorded under storage condition of high carbon dioxide atmosphere (7–18% CO₂) in combination with 3 – 10 % O₂ for 3 weeks at 5°C. In addition Manasa *et al.* (2018) reported that cherry tomato stored under 3% O₂ + 5% CO₂ + 92%N has shown long shelf life of 33 days and 15 days in disease control. Various post - harvest dip treatments have been used to control or attenuate degradable changes and extend the storage life of fruits and vegetables.

Stored the treated coated fruits with CaCl₂ and/or salicylic acid and inoculated by *A. alternata* led to control of spoilage disease incidence and severity at the end of storage period. The same trend was detected in spoilage incidence and severity percentage of coated fruit with CaCl₂ and /or SA and inoculated by *B. cinerea* at the end of storage time (45 days).

Results obtained in the current study were in agreement with those obtained by Nirupama *et al.* (2010), who concluded that post-harvest CaCl₂ and SA chemical treatment and has

potential of spoilage incidence control, extend the storage life and preserve valuable attributes of post-harvest tomato, presumably because of its effect on inhibition of ripening and delay senescence processes.

Regarding utilization of calcium during the post -harvest of fruit, studies were conducted to show that it reversed their qualities, impeded physiological disorders, reduced the rate of respiration and slowed the ripening process in apple, tomatoes and peaches (Burns and Pressey, 1987). It was also observed that the post-harvest life of apples and tomatoes was prolonged, firmness improved and rottenness reduced during the storage under influence of calcium (Nirupama *et al.*, 2010).

According to the results obtained by Andrea *et al.* (1999), immersing strawberry fruits in calcium (0.5 and 1%), increased their post-harvest life from 3 to 21 days, with no attack by the tested fungus and without any change in their external appearance. Probably the calcium was joined into the cell wall of fruits granting high resistance of infection (Wang *et al.*, 1993).

Furthermore, many researchers reported that coated tomato fruits with SA had greater control of decay incidence and severity percentage caused by *A. alternata* and/or *B. cinerea* (Silvia, 2014; Golding and Ron, 2016).

Results in Table 4 clearly show that, all fruits softened progressively during storage time, while treatment cherry tomatoes by CaCl₂ resulted in higher firmness compared to others fruits compared to healthy uncoated after 15 days storage time.

In addition, CaCl₂ and/or salicylic acid treated fruits and inoculated with *A. alternata* and/or *B. cinerea* revealed spoilage lateness in healthy and inoculated cherry tomatoes at all storage time fruit. Calcium chloride dips treatment retarded the metabolism as indicated by the slow ripening rate. CaCl₂ improves the firmness of tomato fruits. All treatments delayed ripening and improved the storage life and quality significantly (Gharezi *et al.*, 2012).

Our results also are in agreement of those reported by Dilmacunal *et al.* (2011). They reported that spraying 0.5% CaCl₂ significantly increased the firmness index of tomato fruits.

The same trend was also suggested by **Huang *et al.* (2008)** for SA fruit treatments.

The results visible the increase of TSS values of fruits coated with CaCl₂. Also, TSS values were higher in the inoculated fruits coated with CaCl₂ and/or SA than un-coated inoculated fruits and inoculated by *A. alternata* and coated with CaCl₂ and SA compared with inoculated after 30 days of storage time.

The same results were observed when cherry tomatoes inoculated with *B. cinerea*. Moreover, the TSS values of all experimental treatments (CaCl₂ and/or SA) decreased with increasing storage time, and exhibited statistically significant differences at 0.05, compared with the control treatment. Such results might be due to a decrease respiration rates and also show down the synthesis and use of metabolites resulting in lower TSS (**Yaman and Bayindirli, 2002**). **Dilmacunal *et al.* (2011)**, reported that treated bunch tomatoes with CaCl₂ and/or SA led to increasing tomato fruits TSS values.

Generally, results of vitamin C. values revealed that a significant decrease occurred by increasing the storage time. In addition, coating cherry tomatoes fruits with CaCl₂ and/or SA resulted in statistical significant increase of Vitam. C. contents being 14.10 and 13.9 mg/100 g juice as a result of treating by CaCl₂ and SA, respectively compared to control (11.20) after 15 days of storage time. The same trend was observed at 30 and 45 days of storage. Furthermore, inoculated fruits with spoilage pathogens and coated with CaCl₂ and / or SA led to observe increase in Vitam. C. values than those untreated inoculated ones.

Treatment cherry tomato fruits with CaCl₂ recorded significantly higher mean of ascorbic acid than over all other treatments, followed by control treatments (**Gharezi *et al.*, 2012**). An increase in ascorbic acid content in fruit is thought to be an indication that the fruits are still in ripening stage, while a decrease indicates a senescent fruit (**Erip –Roberts *et al.*, 2002**). Also, salicylic acid in nutrient solution treatment is effective in increasing the quality parameters such as color, lycopene content, firmness and vitamin C (**Mohamed *et al.*, 2018**). These results suggested that SA could maintain fruit

antioxidant activity and nutrition which was shown by the increase in antioxidant levels.

Conclusion

It can be concluded from aforementioned results that, the modified atmosphere storage condition of level 3 (12% CO₂ + 6% O₂) + (7°C ± 1 + 90% RH ± 3), was the most significantly preferable storage conditions for controlling the cherry tomato spoilage disease incidence and severity percentage. As well as, these storage conditions preservation cherry tomato quality parameters in pretty shape for consumer, marketing and exportation. Results showed that MA could be effectively used in retention of maximum quality and shelf life of cherry tomato fruits. Furthermore, the same results were detected when fruits treated by CaCl₂ and/or salicylic acid before storage under the previous conditions.

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دور الجو المعدل وبعض المعاملات الطبيعية في مقاومة أعفان ما بعد حصاد الطماطم الشيرى

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يعد من الأهمية بمكان، استخدام الجو المعدل والمبرد في تخزين ثمار الطماطم الشيرى لحمايتها من الإصابة بالأعفان التى تنتسب عن فطرى البوتريتس سينيريا والألترناريا ألتيروناتا ، وكذا إطالة عمر الثمار مع احتفاظها بخصائص جودتها. لهذا خزنت ثمار الطماطم الشيرى تحت ظروف ثلاثة مستويات من الجو المعدل والمبرد، وقد أظهرت النتائج أن مستوى الجو المعدل (١٢% ثانى أوكسيد الكربون + ٦% أوكسجين) وتحت جو مبرد (٧ درجة مئوية ± ١ ورطوبة نسبية ٩٠% ± ٣)، قد قلل من نسبة حدوث مرض أعفان ثمار الطماطم الشيرى وكذا شدة المرض بصورة معنوية، وذلك مقارنة بباقي مستويات الجو المعدل المستخدمة فى الدراسة، واتساقا مع النتائج السابقة، فإن ظروف التخزين المشار إليها، أدت إلى احتفاظ الثمار بصفات جودتها، مثل صلابة الثمار، ومستويات كل من المواد الصلبة الذائبة الكلية، فيتامين ج، الليكوبين ولون الثمار، وذلك بمظهر ومستويات تناسب رغبة المستهلك من ناحية ولغرض التسويق والتصدير من ناحية أخرى، وكان لمعاملة ثمار الطماطم الشيرى بكلوريد الكالسيوم وحمض الساليسيلك، أثرًا واضحًا ومعنويًا فى إطالة عمر الثمار وتحسين صفات جودتها مع وقاية الثمار من الإصابة بأمراض الأعفان عند تخزينها تحت نفس ظروف التخزين السابقة.

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