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IMPACT OF SOME PLANT ESSENTIAL OIL TREATMENTS ON CONTROLLING CHERRY TOMATOES SPOILAGE, IMPROVEMENT SHELF LIFE AND QUALITY ATTRIBUTES DURING STORAGE

Shaymaa M. Raafat[1*], M.I. Abou-Zaid[2], M.R. Tohamy[2] and H.E. Arisha[3]

1. Egyptian Plant Quarantine, Ismailia, Egypt

2. Plant Pathol. Dept., Fac. Agric. Zagazig Univ., Egypt

3. Hort. Dept., Fac. Agric. Zagazig Univ., Egypt

ABSTRACT

Food safety is one of the major issues to fresh fruits and vegetables. The preservation of freshness quality of cherry tomato (*Lycopersicon esculentum* Mill.) is relevant due to their economical impact. Under modified atmosphere (MA) (12% CO_2 + 6% O_2) cool storage conditions (7º C ± 1 and RH 90 ± 3%), some essential oils (black seed, fenugreek, cinnamon, spearmint, basil, and thyme) were used to treat, healthy and inoculated fruits with spoilage pathogens *Alternaria alternata* and *Botrytis cinerea.* The results indicated that fruits decay decreased in coated fruits treated with essential oils. However, as the storage period progressed, a general declining trend in all fruits quality parameters were observed for all treatments except for tomatoes treated with the essential oils, which, showing a lowest weight loss, firmness, Total Soluble Solids (TSS), pH, sugar fractions and antioxidant components (vitamin C., lycopene and phenolic fractions). The highest color changes were found in control group, inoculated fruits and untreated group. The obtained results suggested that essential plant oils may improve control decay of fruits, enhancement fruit shelf life and quality-related attributes on top of the well- documented antimicrobial protection during cold storage.

Key words: Essential oils, cherry tomato, quality parameters, spoilage, *Alternaria alternata, Botrytis cinerea.*

INTRODUCTION

Postharvest losses of fruits and vegetables is a serious problem caused by fungi, bacteria and unfavourable condition during marketing and storage. Fungal pathogens are mainly responsible for postharvest losses of fruits and vegetables (Korsten, 2006). Cherry tomato (*Lycopersicon esculentum* Mill. var. Catalena) is perishable and susceptible to postharvest diseases owing to the warm and humid climate. *Alternaria alternata* (Fr.) and *Botrytis cinerea* (Fr.Pers)., are a major saprophytic pathogens causing postharvest black rot and gray mold, respectively in cherry tomato (Feng and Zheng, 2007; Wang *et al*., 2010; Tian *et al*., 2011; Chen *et al*., 2014 ; Yan *et al*., 2014).

The use of synthetic preservatives as antimicrobial agents to control fungal spoilage of food has been practiced for many years. However, this had led a number of environmental and health problems because of the carcinogenicity, teratogenicity, high acute toxicity and long degradation periods of the synthetic preservatives (Lingk, 1991).

The antimicrobial properties of plant products such as essential oils, have been recognized and used for food preservation and in medicine since ancient times in the world (Tian *et at*., 2011). Essential oils as antimicrobial agents have two

***Corresponding author: Tel. :** +201006276432
E-mail address: dr_sh.m@hotmail.com

main advantages the first one, their natural origin means the majority of them are safer for consumers, and the second they have low risk of developing pathogen resistan strains (Cardile *et al*., 2009).

A new worldwide trend to explore alternatives that control postharvest diseases, giving priority to decay- preventing methods with minimal impact on human health and environment. In addition, consumer have become more health- conscious regarding safety aspects concerning the handling of fruit and vegetables (Dulce *et al*., 2010).

In this regard, treating fresh fruit and vegetables with edible coating and essential oils is an important approach that holds promise for the extension of storage life of fresh horticultural crops (Tabaestani *et al*., 2013). These natural compounds are generally recognized as safe for environment and human health, so interest in their use in the goal for sustainable agriculture has increased and a lot of research has been done, proving, in many cases, that plant essential oils and extracts many have a role as pharmaceuticals and food preservations (Hammer *et al*., 2001).

In recent years, numerous studies have documented the antifungal effect of plant essential oils to control food spoilage fungi (Tzortzakis, 2009; Dulce *et al*., 2010; Shirzad *et al*., 2011; Tian *et al*., 2011; Xing *et al*., 2011; Tabaestani *et al*., 2013 ; Chen *et al*., 2014; Yan *et al*., 2014).

The essential oils of thyme, cinnamon, anise and spearmint have more effect on fungal development and subsequent mycotoxin production in wheat grains (Soliman and Badeaa, 2002).

Tian *et al*. (2011) reported that results of both *in vitro* and *in vivo* studies on fungal spoilage of cherry tomatoes indicate that employing dill (*Anethun graveolens* L.) oil as a significant potential fumigant against *A. alternata* and *Aspergillus* spp extended usual storage and transport period is very promising. Xing *et al*. (2011) suggested that microencapsulated cinnamon oil could reduce cherry tomato fruits decay and keep their quality.

In addition, cumin essential oil possess strong antifungal activity against *A. alternata* and could be a promising natural products for use as anti - *A. alternata* agent to control black rot in cherry tomato (Tabaestani *et al*., 2013).

In vivo A. alternata black rot disease incidence of cherry tomato treated with citronella essential oil was significantly reduced compared with the control treatment 5 days after storage at 25°C and 95% relative humidity (Chen *et al*., 2014).

Evaluation of antifungal activity of thyme, ajowan, fennel and summer savory essential oils against postharvest gray mold (*Botrytis cinerea* PERS; FR) of kiwi fruits showed that increase in their tested concentrations and antifungal activity (Shirzad *et al*., 2011).

The aim of this study was to improve cherry tomatoes storability by testing the effect of some essential oils on postharvest cherry tomatoes spoilage caused by *Alternaria alternata* and *Botrytis cinerea* and postharvest quality parameters.

MATERIALS AND METHODS

Plant Materials

Cherry tomatoes were harvested at red stage of maturity (red color covering between 60-90% of fruit surfaces) as described by (Helyes *et al*., 2006). Healthy selected fruits were washed with distilled water then, disinfected by immersing them in ethanol 70% for 2 min. Sterilized fruits washed twice with sterile double – distilled water (5min each), and allowed to dry for 1 hr., in laminar flow.

Fungal Isolates and Detection the Tested Fungi

The tested fungi, *Alteraria alternata* and *Botrytis cinerea* were isolated from infected cherry tomato fruits showing typical symptoms of black rot and gray mold, respectively detected in Pl. Path. Lab. Fac. of Agriculture, Zagazig University according to key of Brown (1924) and Barnett (1962) and identified in Mycological Center of Assiout Univ. (MCAU). Identified stock cultures were maintained on Potato Dextrose Agar (PDA) slant medium at 4°C for sporulation.

Both fungi (*A. alternata* and *B. cinerea*) were grown on PDA medium and incubated at 25°C in the dark for 7 days. Resulted conidia were scrapped out from agar surface and suspended in sterile distilled water and fungal concentrations were adjusted to be 10^6 conidia /ml using a haemacytometer.

Essential Oils

Pure essential oils of black seed (*Nigella sativa* L.), fenugreek (*Trigonella foenum-graecum* L.), cinnamon (*Cinnamomum zeylanicum* L.), spearmint (*Mentha peperita* L.) basil (*Ocimum basilicum* L.) and thyme (*Thymus vulgaris* L.), were purchased from International Flavor and Plant Oils Res Inst., Giza, Egypt. All plant oils were stored in dark bottles at 4ºC for further studies.

In vivo Assessment of Antifungal Activity of some Essential Oils on Cherry Tomato Fruits Spoilage

The antifungal assay of the essential oils against spoilage cherry tomato fruits caused by *Alternaria alternata* and *Botrytis cinerea in vivo* was conducted as disease incidence and severity according to Tian *et al.* (2011) and Tabaestani *et al.* (2013).

The previously sterilized fruits were superficially wounded four times in the equator by the aid of sterilized stainless steel rod with a probe tip measured 1mm wide and 2 mm in length. Sterilized wounded fruits were dipped in spore suspension containing 10^6 spores / ml of *A. alternat*a and / or *B. cinerea* and incubated at 20°C for 24 hr., to resemble common fungal infections. Nevertheless wounded un inoculated, fruits were treated and preserved as a control treatments.

The plant oils treatments consisted of five minutes immersion of aforementioned fruits (inoculated wounded fruits) in plant oils individually (10% concentration) and / or in sterilized distilled water in case of control treatment. Fruits were then forced-air cooled to 5°C and placed in white plastic containers (14 × 11 × 5 cm) each contains 10 fruits.

The experiments conducted 36 treatments each, which were the combination of two fungi (*A. alternata* and *B. cinerea*), three times (15, 30 and 45 days) and 6 oil treatments was used in this experiment. In all treatments three replicates were used and experimental testes evaluation were contained out every 15 days for up to 45 days. All storage experiments were conducted in a cold room of Horticulture Dept., Fac. Agric., Zagazig Univ., which maintained at 7 ± 1°C and 90 ± 3% relative humidity (RH) under modified atmosphere conditions (MA) (12% CO_2+6% O_2).

Quality parameters of oil – treated / untreated fruits were evaluated after 15, 30 and 45 days storage for fruit firmness (Firm) Kader (1991), Total Soluble Solids (TSS) Kader (1991), Ascorbic acid (Vitamin C.) Loucoss (1994), pH of fruits juice was measured using a pH meter (HI 198/30 Hanna instrument), sugars fractions by photometrical methods (Bernfeld, 1955; Miller, 1959) phenolic fractions was determined using the colorimetric method (Snell and Snell, 1953) and Folin-Denis reagent preparation (Guttinger, 1981), lycopene fruit content and color measurement (were, L : luminance, a: redness and b: yellowness.) with the help of (Tomato Meter) Cloroflex Ez, according to Tabaestani *et al*. (2013). The weight loss of tomato fruits was calculated by differences between initial weight and final weight divided by initial weight (Moneruzzaman *et al*., 2009 ; Gharezi *et al*., 2012). Shelf life was calculated by counting the days required to attain the last stage of ripening, but up to the stage when fruits remained still acceptable for marketing.

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 AND DISCUSSION

Isolation and Identification

The fungi isolated from cherry tomato fruits exhibiting typical black rot and gray mold were detected as on *Alternaria alternata* (FR.) Keissl *Botrytis cinerea* (Fr.Res)., respectively according to Mycological Center of Assiout Univ. (MCAU).

In vivo Assessment of Antifungal Activity of some Essential Oils on Cherry Tomato Fruits Spoilage

The antifungal activity of some essential oils *in vivo* on cherry tomato is shown in Tables 1- a, b, and c.

From Table 1-a *Alternaria alternata* and *Botrytis cinerea*, isolated from cherry tomato fruits, showed complete growth inhibition when exposed to black seed (*Nigella satival* L.) and fenugreek (*Trigonella foenum – graecum* L.) 15 days after storage. In addition, the same result was observed after 30 days of storage against *A. alternata* and *B. cinerea* when treated with fenugreek oil.

Treating fruits with black seed oil reduced deeply fruits decay incidence and percentage severity of *A. alternata* which recorded 1.66, 8.33% for disease incidence and percentage severity, compared with the control (0.66% and 1.66%). Also recorded (0.33, 8.33%, respectively for disease incidence and percentage severity of *B. cinerea,* respectively compared with the control (1 and 25%) after 45 days of storage .

The black seed oil treatment caused evident reduction of *A. alternaria* and *B. cinerea* spoilage (disease incidence and percentage severity) of cherry tomatoes fruits than the others of all untreated fruits after 30 and 45 days of storage.

Data also indicated that, treating cherry tomato fruits with fenugreek oil was the most effective treatment which significantly decreased the disease incidence and percentage severity of *A. alternata* and *B. cinerea* spoilage than the control treatments after 30 days of storage.

Table (1- b) shows the effect of cinnamon and spearmint oils treatment on inoculated and uninoculated cherry tomato fruits with spoilage pathogens (*A. alternata* and *B. cinerea*). After 15 days of storage, the essential oil treatments caused complete prevention of fruit spoilage diseases incidence and percentage severity at all treatments of the experiment which evenness the healthy and inoculated control treatment. The same result was observed for both cinnamon and spearmint oils treatment against *A. alternaria* spoilage and the same pattern was recorded for spearmint against *B. cinerea* cherry tomato spoilage after 30 days of storage, when compared with control treatment and also the inoculated fruits.

In general, after 45 days of storage spearmint and cinnamon essential oils treatment caused allowanced spoilage incidence and severity against *A. alternaria* and *B. cinerea*. In addition, the essential oils tested had (cinnamon and spearmint) highest effect against *A. alternaria* being 1% and 0.33% of disease incidence in inoculated fruits than *B. cinerea* being 1 and 0.66% for cinnamon and spearmint oil, respectively at 45 days after storage. On the other hand, spearmint oil caused the highest decrease in disease incidence and percentage severity.

The beneficial effect of cinnamon oil to control postharvest diseases has been recorded by Cruz (2003) who reported that more disease control were achieved by immersing banana fruits into the essential oil of (*Cinnamomum zeylaniam*) against *Colletotrichum musae*.

In addition, Sajad *et al.* (2011) evaluated the effect of natural components (oils of *Thyme vulgaris* and *Mentha piperita*) on citrus green mould control and they found that such treatment improved postharvest quality and decreased decay (27%) compared to the control.

Result obtained from Table 1-c reveal that using essential oils treatments of basil and thyme completely inhibited spoilage of cherry tomato fruits caused by *A. alternata* and *B. cinerea*, after 15 days of storage.

Spraying or dipping fruits in lemongrass and thyme essential oils for controlling postharvest diseases of several fruits were reported by several investigators (Somda *et al*., 2007; Tzortzakis and Economakis, 2007). Thyme oils vapors was the most effective treatment which reduced strawberry gray mold and inhibited various fungi including food spoilage, mycotoxin producing fungi and postharvest pathogenic fungi as mentioned by Nguefak *et al.* (2004), Sun Og *et al*. (2007) and Abd - Alla *et al*. (2011).

Table 1-a. Effect of black seed and fenugreek essential oil treatments on spoilage disease incidence and severity percentage caused by *Alternaria alternata* and *Botrytis cinerea* under modified atmosphere storage conditions

	Alternaria alternata						*Botrytis cinerea*					
Days	**15**		**30**		**45**		**15**		**30**		**45**	
Treatment	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**
Control	0	0	0.66	1.66	1	16.66	0	0	1	25	1.33	33.33
Inoculated (Inc.)	0	0	1	16.66	2.66	33.33	0	0	1	8.33	3.33	33.33
Black seed	0	0	0.66	1.66	1.66	8.33	0	0	0.33	8.33	1.66	33.33
Black seed +Inc.	0	0	0.66	8.33	1.66	33.33	0	0	0.66	8.33	2.33	33.33
Fenugreek	0	0	0	0	0.66	8.33	0	0	0	0	0.33	16.66
Fenugreek +Inc.	0	0	0	0	1.33	16.66	0	0	0	0	0.33	16.66

LSD at 5% for Disease [D (%)]: NS for Severity [S (%)]: NS

a- Effect of *A. alternata* and *B. cinerea* on spoilage disease incidence and severity (%)

Fungi	**D**	**S**
A. alternata	0.666	8.055
B. cinerea	0.759	12.5
F. test	NS	NS
LSD 5%	—	—

b- Effect of storage time (days) on spoilage disease incidence and severity (%)

Days	**D**	**S**
15	0	0
30	0.5	7.222
45	1.638	23.611
F. test	NS	NS
LSD 5%	—	—

c- Effect of oil treatments on spoilage disease incidence and severity (%)

Treatment	**D**	**S**
Control	0.666	12.777
Inoculated (Inc.)	4	15.277
Black seed	2.166	8.611
Black seed +Inc.	2.666	15.277
Fenugreek	0.833	4.166
Fenugreek +Inc.	1.166	5.555
F. test	**	*
LSD 5%	0.577	8.581

Thyme oil exhibited a high degree of inhibition of *A. alternaria* and *B. cinerea* in tomato (Bouchra *et al*., 2003 ; Feng and Zheng, 2007).

It has been observed that thyme oil treatments inhibited completely the percentage of spoilage cherry tomato fruits incidence and severity, which recorded 00.00% for *A. alternata* and *B. cinerea* after 30 days of storage. The same result was recorded when treated cherry tomato fruits with basil oil against *B. cinerea* gray mold, while thyme oil treatment caused the highest effect against *B. cinerea* compared to basil oil treatment Table (1-c).

Results also show that highest reduction of cherry tomato spoilage incidence caused by *A. alternata* and *B. cinerea* when fruits treated with both essential oils (thyme and basil) after 15 and 30 days of storage.

Similar observations were also recorded by Bouchra *et al*. (2003) who demonstrated that *Thymus glandulosus* Req. was the most efficient in controlling *Botrytis cinerea*, a most critical pathogen in postharvest. Also, the essential oil and crude extract of wild basil were tested on the mycelial growth of *Alternaria alternata* which lead to total inhibition of the fungal mycelial growth (Benini *et al*., 2010). In addition, thyme and oregano oil reduced rot development in tomatoes caused by *B. cinerea* and *A. alternate* (Plotto *et al*., 2003).

In conclusion, mechanism underlying the action of essential oil enrichment on the switch between vegetative and reproductive phases of fungal development remains to be fully understood. The negative impact of essential oils on fungi sporulation may reflect the effect of the volatiles emitted by oils on surface mycelial development and / or the precipitation / transduction of signals involved in the switch from vegetative to reproductive development.

Nevertheless, suppression of spore production by essential oils could play a major role in limiting pathogen spread by lowering spore load under storage atmosphere and on surfaces of plant (Tzortzakis and Economakis, 2007).

Fruits and vegetables are highly perishable products particularly once they have been harvest. Being metabolically active, they tend to lose energy reserves through respiration and water through transpiration. In addition to the biochemical changes, there may be losses in quality through mechanical damage, pests and diseases, as well as physiological disorders induced by high or low temperature or incorrect storage atmosphere. Improving the existing practices of handling and storage as well as developing new techniques in order to maintain post-harvest quality has always been a challenge to the researchers (Debeaufort *et al*., 1998). In this regard, treating fresh fruits and vegetables (cherry tomatoes in our study) with edible coating is an important approach that holds promise for the extension of storage life of fresh horticultural crops similarly to the results obtained by Tabaestani *et al*. (2013).

Total Soluble Solids (TSS)

Total soluble solids (TSS) is an indication of soluble sugars level in fruits and therefore sweetness (Saltveit, 2005).

It is evident from results in Table 2-a that total soluble solids of cherry tomatoes was found to be affected by coating treatment with fenugreek and black seed essential oils, especially fenugreek oil treatment, while inoculated fruits with *A. alternata* and / or *B. cinerea* lead to decline of TSS value especially after 30 and 45 days from storage. However, as the storage progressed a general declining trend in the TSS was observed for all treatment (Table 2-a). The changes in TSS were significantly influenced by the duration of storage. In yet other studies revealed that gradual decrease in TSS of tomatoes associated with increasing storage time has been reported (Kumarrai *et al*., 2012; Kagan-Zur and Mizrahim, 1993).

The same trend was observed when treated cherry tomatoes with cinnamon and spearmint essential oils Table (2-b) and also in case of basil and thyme oils treatment Table (2-c).

Firmness

The texture of tomato is a very important major quality feature for consumers. Texture in tomato is a function of skin toughness. Also, sufficient softening is necessary to lend the fruit's edibility and to release the cell content during chewing for the olfactory perception of the fruit aroma eating and flavor. It is commonly accepted that consumer preference is for firm fruit which do not lose juice during eating or slicing (Frankel and Jen, 1989).

Table 1-b. Effect of cinnamon and spearmint essential oil treatments on spoilage disease incidence and percentage severity caused by *Alternaria alternata* and *Botrytis cinerea* under (MA) conditions

	Alternaria alternata						*Botrytis cinerea*					
Days	15		30		45		15		30		45	
Treatment	D	S	D	S	D	S	D	S	D	S	D	S
Control	0	0	0.66	33.33	1	8.33	0	0	1	25	1.66	33.33
Inoculated (Inc.)	0	0	1.33	16.66	2	100	0	0	1.66	25	3.33	33.33
Cinnamon	0	0	0	0	1	8.33	0	0	0.33	1.66	1	16.66
Cinnamon +Inc.	0	0	0.33	8.33	1.66	25	0	0	0.66	8.33	2.33	25
Spearmint	0	0	0	0	0.33	1.66	0	0	0	0	0.66	16.66
Spearmint +Inc.	0	0	0.66	6.66	1	16.66	0	0	0.33	16.66	1.66	33.33

LSD at 5% for Disease [D (%)]: NS for Severity [S (%)]: NS

a- Effect of *A. alternata* and *B. cinerea* on spoilage disease incidence and severity (%)

Fungi	D	S
A .alternata	0.555	13.333
B. cinerea	0.814	9.018
F. test	*	NS
LSD 5%	0.367	—

b- Effect of storage time (days) on spoilage disease incidence and severity (%)

Days	D	S
15	0	0
30	0.583	5.75
45	1.472	27.777
F. test	**	NS
LSD 5%	0.475	—

c- Effect of oil treatments on spoilage disease incidence and severity (%)

Treatment	D	S
Control	0.722	12.666
Inoculated (Inc.)	1.388	25.277
Cinnamon	0.388	4.222
Cinnamon +Inc.	0.833	9.833
Spearmint	0.166	5.555
Spearmint +Inc.	0.611	9.5
F. test	**	*
LSD 5%	0.295	7.706

Table 1-c. Effect of basil and thyme essential oil treatments on spoilage disease incidence and percentage severity caused by *Alternaria alternata* and *Botrytis cinerea* under (MA) conditions

	Alternaria alternata						*Botrytis cinerea*					
Days	15		30		45		15		30		45	
Treatment	D	S	D	S	D	S	D	S	D	S	D	S
Control	0	0	0.66	16.66	1	16.66	0	0	1	8.33	1	16.66
Inoculated (Inc.)	0	0	1	16.66	2	33.33	0	0	1	33.33	3.33	33.33
Basil	0	0	0	0	1	25	0	0	0.33	8.33	1	33.33
Basil +Inc.	0	0	0.66	8.33	1.66	16.66	0	0	0.66	16.66	2.66	33.33
Thyme	0	0	0	0	0.66	16.66	0	0	0	0	1	16.66
Thyme +Inc.	0	0	0	0	1	33.33	0	0	0.33	1.66	1.66	8.33

LSD at 5% for Disease [D (%)]: NS for Severity [S (%)]:18.87

a- Effect of *A. alternata* and *B. cinerea* on spoilage disease incidence and severity (%)

Fungi	D	S
A. alternata	0.537	13.333
B. cinerea	0.777	9.018
F. test	NS	NS
LSD 5%	—	—

b- Effect of storage time (days) on spoilage disease incidence and severity (%)

Days	D	S
15	0	0
30	0.472	9.166
45	1.5	23.611
F. test	NS	NS
LSD 5%	—	—

C- Effect of oil treatments on spoilage disease incidence and severity (%)

Treatment	D	S
Control	0.611	9.722
Inoculated (Inc.)	1.222	19.444
Basil	0.388	11.111
Basil +Inc.	0.944	12.5
Thyme	0.277	5.555
Thyme +Inc.	0.5	7.222
F. test	*	N.S
LSD 5%	0.589	—

In this study, as revealed by the puncture test values of different essential oils coating treatments, it has made statistically great impact to maintain firmness for long time during experiment.

According to Tables 2-a, b and c, all tested essential oil treatments enhanced the firmness of healthy and treated infected fruits compared to untreated infected ones. In addition inoculated fruits treated with essential oils tented to be firmer than healthy ones.

Also, it was found that oil untreated fruits were softer than the other oil treatments at the end of storage period (45 days).

Generally, after 45 days of storage (the end of storage period), firmness values observed for healthy fruits and treated with black seed, fenugreek, cinnamon, spearmint, basil and thyme recorded 300, 370, 417, 466.66 , 403 and 330, respectively. However, inoculated control fruits with *A. alternata* being 276.66, 300 and 200, respectively. While the inoculated control fruits with *B. cinerea* bing 267.66, 200 and 300, respectively. However, firmness values of healthy fruits and treated with aforementioned oils recorded 333.33, 403.33, 393.33, 440, 416.66 and 466.66, respectively.

According to the result obtained in Tables 2-a, b and c, all oil treatments enhanced the firmness of healthy and inoculated fruits compared to untreated fruits in control treatment. In addition, inoculated fruits tended to be firmer than healthy ones. Also, it was found that oil untreated fruits were softer than all treated ones. In this respect some reports revealed that essential oils coating fruits significantly delayed the softening of whole tomato during storage (Tabaestani *et al*., 2013). Also, Serrano *et al.* (2005) reported that treated sweet cherry fruits with essential oils such as eugenol, thymol and menthol showed benefit in maintenance fruit firmness comparing with control treatments.

pH values

From data in Tables 2-a, b and c, significant decrease was observed in pH values of all treatments at the end of storage time compared with the initial storage time.

The fenugreek essential oil treatment caused clear increasing in pH values than the all other treatments being 3.16, 3.63 and 2.26 for control treatment, coated with fenugreek oil and coated and inoculated with *A. alternate,* respectively after 15 days of storage, while at the end of storage time (45 days) being 1.2, 2.2 and 1.1, respectively.

The same trend was observed in fruits inoculated with *B. cinerea* and treated with fenugreek oil which recorded 2.2, 2.96 and 1.8 after 15 days of storage time and 0.93, 0.7 and 0.5 after 45 days of storage, respectively.

The results presented in Table (2- c) indicate that all basil oil treatments at all storage time recorded lowest values than the control treatment and / or inoculated cherry tomato fruits with *A. alternata* while, only pH value was increased at all storage time than those of other treatments when cherry tomatoes were inoculated with *B. cinerea*.

The present results suggest that using cinnamon essential oil as an edible coating, the pH values increased at all storage time in inoculated cherry tomato fruits with *A. alternaria* and / or *B. cinerea* than those of other treatments. Our results confirmed other studies carried by Deirdre *et al*. (1999) Tzortzakis (2007) and Marjanlo *et al*. (2009).

Sugar Fractions

The sugar fractions values of cherry tomatoes inoculated with *A. alternate* and / or *B. cinerea* and/or non inoculated and treated with different essential oils, then stored under modified atmosphere (MA) conditions were presented in Table 3.

According to data in Table 3, inoculated fruits with spoilage pathogens caused significant reduction over all total sugar percentage which had 4.37 and 4.84 compared with healthy fruits (control) as a result of inoculated with *A. alternata* and *B. cinerea* respectively.

In addition healthy fruits treated with black seed, fenugreek and thyme oils lead to significant increase in all sugar fraction amounts in the case of *A. alternata*. Fruits inoculated with *A. alternata* and coated with thyme oil caused increase of all sugar fraction concentrations (total, reducing and non reducing). The same trend was also observed in case of fruits inoculated with *B. cinerea* and coated with cinnamon and fenugreek oil, respectively.

Table 2-a. Effect of black seed and fenugreek essential oils treatments on total soluble solids (TSS), firmness and pH of storage cherry tomatoes under (MA) conditions

	Alternaria alternata									*Botrytis cinerea*								
Days	**15**			**30**			**45**			**15**			**30**			**45**		
Treatment	**Firm**	**TSS**	**pH**	**Firm**	**TSS**	**pH**	**Firm**	**TSS**	**pH**	**Firm**	**TSS**	**pH**	**Firm**	**TSS**	**pH**	**Firm**	**TSS**	**pH**
Control	523.33	4.66	3.16	426.66	3.00	1.96	320	2.25	1.2	583.33	5.50	2.2	390	3.41	1.53	296.66	2.16	0.93
Inoculated (Inc.)	473.33	4.83	2.03	360	2.83	1.46	276.66	1.66	1.13	493.33	4.75	1.24	306.66	2.50	1.06	276.66	2.00	0.33
Black seed	523.33	5.00	2.43	493.33	3.91	1.7	300	2.25	1.1	496.66	5.33	2.5	446.66	3.58	2.00	333.33	3.00	0.8
Black seed +Inc.	453.33	5.16	1.28	346.66	2.41	1.23	250	1.00	0.93	436.66	5.33	1.93	400	1.1	1.1	300	1.9	0.73
Fenugreek	600	5.25	3.63	586.66	4.58	2.73	370	3.50	2.2	660	5.66	2.96	510	2.33	2.33	403.33	3.00	0.7
Fenugreek +Inc.	570	5.33	2.26	523.33	3.91	1.73	346.66	2.66	1.1	386.66	4.16	1.8	436.66	1.00	1.00	306.66	2.00	0.5

LSD at 5% for Firm= 61.97 TSS= NS pH= NS

a- Effect of *A. alternata* and *B. cinerea* on total soluble solids (TSS), firmness and pH

Fungi	**Firm**	**TSS**	**pH**
A. alternata	430.185	3.563	1.874
B. cinerea	413.148	3.735	1.453
F. test	N.S	N.S	**
LSD 5%	—	—	3.364

b- Effect of storage time (days) on total soluble solids (TSS), firmness and pH

Days	**Firm**	**TSS**	**pH**
15	516.666	5.073	2.358
30	433.333	3.59	1.627
45	315	2.283	1.005
F. test	**	**	**
LSD 5%	47.262	0.411	0.185

c- Effect of oil treatments on total soluble solids (TSS), firmness and pH

Treatment	**Firm**	**TSS**	**pH**
Control	423.333	3.481	1.833
Inoculated (Inc.)	364.444	3.097	1.283
Black seed	427.777	3.847	1.755
Black seed +Inc.	364.444	3.191	1.277
Fenugreek	521.666	4.569	2.438
Fenugreek +Inc.	428.333	3.708	1.394
F. test	**	**	**
LSD 5%	25.301	0.377	0.159

Table 2-b. Effect of cinnamon and spearmint essential oils treatments on total soluble solids (TSS), firmness and pH of storage cherry tomatoes under (MA) conditions

	Alternaria alternata									*Botrytis cinerea*								
Days	15			30			45			15			30			45		
Treatment	Firm	TSS	pH	Firm	TSS	pH	Firm	TSS	pH	Firm	TSS	pH	Firm	TSS	pH	Firm	TSS	pH
Control	480	5.00	3.1	440	3.08	2.16	376.66	2.58	1.7	610	4.58	2.93	406.66	3.00	2.00	296.66	1.75	0.9
Inoculated (Inc.)	470	4.75	2.63	376.66	3.08	2.06	300	2.08	0.63	526.66	3.08	2.06	386.66	3.00	1.76	200	1.5	1.16
Cinnamon	606.66	4.83	3.26	570	4.66	2.56	417	3.00	1.9	636.66	5.08	2.73	583.33	4.58	2.20	393.33	2.83	1.3
Cinnamon +Inc.	503.33	5.5	2.26	443.33	3.66	1.56	360	2.66	1.1	500	4.41	1.83	400	3.5	1.26	260	2.00	0.56
Spearmint	543.33	5.25	3.03	493.33	4.75	1.86	466.66	3.16	0.9	583.33	4.41	2.63	543.33	4.00	1.83	440	3.08	0.93
Spearmint +Inc.	483.33	5.33	2.33	423.33	3.25	1.23	333.33	2.00	0.9	506.66	4.41	2.03	400	3.08	1.50	330	2.75	0.63

LSD at 5% for Firm= NS TSS= NS pH= NS

a- Effect of *A. alternata* and *B. cinerea* on total soluble solids (TSS), firmness and pH

Fungi	Firm	TSS	PH
A.alternata	450.555	3.824	1.946
B.cinerea	444.629	3.361	1.666
F. test	NS	*	NS
LSD 5%	—	0.202	—

b- Effect of storage time (days) on total soluble solids (TSS), firmness and pH

Days	Firm	TSS	pH
15	537.5	4.673	2.58
30	457.5	3.652	1.811
45	347.777	2.451	1.027
F. test	**	**	**
LSD 5%	38.933	0.244	0.234

c- Effect of oil treatments on total soluble solids (TSS), firmness and pH

Treatment	Firm	TSS	pH
Control	435	3.333	2.133
Inoculated (Inc.)	380.555	2.916	1.722
Cinnamon	534.444	4.055	2.227
Cinnamon Inc.	411.111	3.652	1.45
Spearmint	511.666	4.111	1.866
Spearmint +Inc.	412.777	3.486	1.438
F. test	**	**	**
LSD 5%	46.206	0.382	0.445

Table 2-c. Effect of basil and thyme essential oils treatments on total soluble solids (TSS), firmness and pH of storage cherry tomatoes under (MA) conditions

	Alternatia alternata									*Botrytis cinerea*								
Days	15			30			45			15			30			45		
Treatment	Firm	TSS	pH	Firm	TSS	pH	Firm	TSS	pH	Firm	TSS	pH	Firm	TSS	pH	Firm	TSS	pH
Control	413.33	4.58	2.83	390	3.41	1.9	316.66	1.66	1.66	1.00	2.25	3.23	413.33	3.58	2.93	376.66	2.58	2.33
Inoculated (Inc.)	393.32	4.58	1.83	306.66	2.5	1.16	200	1.03	1.30	0.9	5.66	2.63	373.33	3.00	2.3	300	2.08	2.00
Basil	533.33	5.33	3.13	523.33	3.58	2.16	403	3.08	3.08	0.93	5.08	2.53	473.33	4.58	2.36	416.66	3.00	1.56
Basil +Inc.	446.66	4.25	2.03	430	3.33	1.36	250	1.75	1.75	0.33	4.83	2.33	420	2.75	1.63	360	2.66	1.2
Thyme	660	4.91	2.9	470	5.41	1.86	330	2.00	2.00	0.76	6.00	3.23	466.66	4.58	2.66	466.66	3.16	2.06
Thyme+ Inc.	456.66	3.41	1.7	510	4.16	1.26	320	2.16	2.16	0.66	5.75	2.56	443.33	4.00	2.13	333.33	2.00	1.46

LSD at 5% for Firm= 75.24 TSS=1.06 pH= NS

a- Effect of *A. alternata* and *B. cinerea* on total soluble solids (TSS), firmness and pH

Fungi	Firm	TSS	pH
A. alternata	408.518	3.418	1.611
B. cinerea	442.407	3.916	2.294
F. test	*	*	*
LSD 5%	32.456	0.49	0.442

b- Effect of storage time (days) on total soluble solids (TSS), firmness and pH

Days	Firm	TSS	pH
15	503.055	4.972	2.58
30	433.888	3.763	1.98
45	339.444	2.266	1.297
F. test	**	**	**
LSD 5%	25.987	0.408	0.065

c- Effect of oil treatments on total soluble solids (TSS), firmness and pH

Treatment	Firm	TSS	pH
Control	400.555	3.513	2.372
Inoculated (Inc.)	339.444	3.2	1.805
Basil	495	4.111	2.155
Basil +Inc.	400.555	3.263	1.483
Thyme	493.888	4.333	2.25
Thyme +Inc.	423.333	3.583	1.65
F. test	**	**	99
LSD 5%	30.716	0.435	0.178

Table 3. Sugar fractions of cherry tomatoes stored under (MA) cold conditions affected by the interaction of spoilage pathogens inoculation (*Alternaria alternata* and *Botrytis cinerea*) and essential oil treatments

Treatment	*Alternaria alternata*			*Botrytis cinerea*		
	Total	Reducing	Non-reducing	Total	Reducing	Non-reducing
Control initial time	3.5	1.24	2.26	3.5	1.24	2.26
Control end time	5.30	2.06	3.24	6.53	2.36	4.17
Inoculated (Inc.)	4.37	1.61	2.76	4.84	1.96	2.88
Black seed	5.68	2.27	3.41	3.85	1.36	2.49
Black seed+ Inc.	4.76	2.16	2.60	4.19	1.45	2.74
Fenugreek	6.07	2.43	3.64	6.10	2.24	3.86
Fenugreek +Inc.	4.34	1.59	2.75	5.92	2.15	3.77
Cinnamon	4.62	1.91	2.71	5.95	2.13	3.82
Cinnamon + Inc.	3.94	1.36	2.58	6.11	2.20	3.91
Spearmint	3.76	1.36	2.40	3.96	1.44	2.52
Spearmint + Inc.	3.86	1.44	2.42	4.13	1.58	2.55
Basil	4.24	1.83	2.41	3.90	1.38	2.52
Basil + Inc.	3.83	1.54	2.29	3.30	1.39	1.91
Thyme	5.30	2.05	3.25	4.17	1.55	2.62
Thyme + Inc.	6.10	2.75	3.35	4.80	1.63	3.17

LSD at 5% for: Total sugars = 0.037 Reducing sugars =0.024 Non- reducing sugars = 0.023

These results were in agreement with those reported by Ozkaya *et al.* (2009) who reported that strawberries had higher glucose amount after 10 days of (MA) storage compared with control.

It was observed that the increase in reducing, non-reducing and total sugar with the storage long time (From 3.5% at initial time to 5.3% and 6.53% at the end time of storage). The obtained results of sugar content in cherry tomato are in agreement with the findings of (Moneruzzaman *et al*., 2009; Gharezi *et al*., 2012). Increased total sugar content might be due to conversion of starch into sugars (Tsuda *et al*., 1999). Also, Vesaltalab and Gholami (2012) and Nabifarkhani *et al*. (2015), they suggested that total sugar content increased during storage period that may be due to the dehydration and decomposition of organic acids (used as an energy source) in the fruits.

It is evident from Table 3 that control treatment recorded significantly higher mean reducing, non- reducing and total sugar contents over all other treatments. This result was agree with the previous report carried out by Gharezi *et al*. (2012).

Vitamin C. amount

Data in Tables 4-a, b and c show, general significant decrease in vitamin c. content of inoculated cherry tomato fruits with both *A. alternata* and / or *B. cinerea*. Storage cherry tomatoes (healthy and inoculated) and/or coated with tested essential oil treatments caused a greatest relative decrease in vitamin c. content.

Also, gradual decrease in content of vitamin c. of all treatments influenced by the duration of the storage time. The fenugreek oil treatment

Table 4-a. Changes in some antioxidant contents (Vitamin C. and Lycopene) of cherry tomatoes treated by black seed and fenugreek essential oil and inoculated with spoilage pathogens (*Alternaria alternata* and *Botrytis cinerea*) during (MA) storage

	Alternaria alternata						*Botrytis cinerea*					
Days	15		30		45		15		30		45	
Treatment	Vit. C.	Lycop.	Vit. C.	Lycop.	Vit. C.	Lycop.	Vit. C.	Lycop.	Vit.C.	Lycop.	Vit. C.	Lycop.
Control	13.03	90	10.93	85	8.5	76	10.13	83	8.53	77	5.66	60
Inoculated (Inc.)	10.63	78	98.23	67	5.3	56	8.83	75	6.56	64	4.9	56
Black seed	11.33	80	8.66	78	6.1	60	12.63	87	9.76	72	7.06	63
Black seed + Inc.	9.23	71	6.83	69	3.9	52	9.53	69	7.06	50	5.36	46
Fenugreek	13.6	64	9.06	55	7.36	50	12.66	54	9.6	42	8.9	33
Fenugreek + Inc.	10.86	62	7.96	47	6.53	39	9.86	64	7.76	59	7.6	53

LSD at 5% for Vit. C = 0.597

a- Effect of *A. alternata* and *B. cinerea* on Vitamin C. and Lycopene

Fungi	Vit. C. mg/ 100 g juice	Lycopene mg/ 100 g fresh weight
A. alternata	8.785	65.5
B. cinerea	8.433	61.5
F. test	NS	-
LSD 5%	—	-

b- Effect of storage time (days) on Vitamin C. and Lycopene

Days	Vit. C. mg/ 100g juice	Lycopene mg/ 100g fresh weight
15	10.975	73.083
30	8.402	63.75
45	6.441	53.666
F. test	**	-
LSD 5%	0.664	-

c- Effect of black seed and fenugreek oil treatments on Vitamin C. and Lycopene

Treatment	Vit. C. mg/100g juice	Lycopene mg/100g fresh weight
Control	9.483	78.5
Inoculated (Inc.)	7.3	66
Black seed	9.261	73.333
Black seed+ Inc.	6.961	59.5
Fenugreek	10.2	49.666
Fenugreek +Inc.	8.433	54
F. test	**	-
LSD 5%	0.597	-

caused slight increase in vitamin c value compared with the other treatments especially at 15 days after storage as a result of inoculated fruits with *A. alternata* and/or *B. cinerea* (Table 4-a). The same trend was observed in case of cherry tomato fruits inoculated by *B. cinerea* and treated with thyme oil. while, thyme oil treatment caused increase in vitamin c content at all days of storage being 11.36, 9.06 and 7.2 after 15, 30 and 45 days of storage, respectively (Table 4-c).

According to the results in Table 4-b cinnamon oil treatment caused insignificant increase of vitamin c content among the postharvest oil fruit treatment at all stages of storage (15, 30 and 45 days of storage being 12, 10.36 and 7.73 mg/100g , respectively .

An increase in ascorbic acid (vitamin c) content in fruits is thought to be an indication that the fruits are still in the ripening stage, while a decrease indication senescent fruit (Erip-Roberts *et al*., 2002). In addition, Miller and Evans (1997) reported that phenolic substances have been found to play a protective effect on tissue ascorbic acid content. The presence of phenolic in the fruit cells may help to maintain the ascorbic acid content value.

In general, essential oils coating cherry tomato fruits could inhibit vitamin c loss by cutting as an abiotic elicitor generating reactive oxygen species, or due to the protection of antioxidant in essential oils (Kumarrai *et al*., 2012 ; Xing *et al*., 2011).

While, tomato fruits inoculated with *A. alternata* and treated with thyme oil being 84, 80 and 64 mg/100g fresh weight after 15, 30 and 45 days of storage, respectively. These results are in agreement with those obtained by Ali and Keith (1998) and Tabaestani *et al*. (2013).

Lycopene contents

The lycopene content and antioxidant activity of tomatoes varies between cultivars and is highest in cherry or small, cocktail fruits (Kaur *et al*., 2004; Molyneux *et al*., 2004). There were a correlation between fruit color and total antioxidant concentration observed with lycopene content which increase from the rose to red color stages (Brand *et al*., 2006; Helyes *et al*., 2006). This explained the fact that mature green tomatoes might having a significantly lower total antioxidant content than red tomatoes (Wold *et al*., 2004).

Because of importance of antioxidant to human health (Madhavi and Salunkhe, 1998), antioxidants may be considered a valuable quality attribute of tomatoes and it is important to minimize losses of these compounds during the post – harvest period (Passam *et al*., 2007).

It is clear from data presented in Tables 4-a, b and c that all lycopene amount were decreased during storage time of all experimental treatments. Also, inoculated fruits with *A. alternata* and *B. cinerea* and untreated fruits with the essential oils caused clear decreasing in lycopene amounts with progressing of storage time.

Phenolic Fractions

As shown in Table 5, cherry tomato fruits coated with basil and or cinnamon essential oils had the slight increase amounts of total phenols being 7mg/100g fruits fresh weight of both above mentioned oils compared with untreated one (6.75 mg/100g). On the other hand , treated fruits (inoculated by *A. alternata* and / or *B. cinerea)* with thyme, cinnamon, black seed and fenugreek oils lead to slightly increase of total phenolic compounds.

With the exception of cherry tomato fruits coated with spearmint, it was observed that significantly increase in free phenolic values for all inoculated fruits by *A. alternata*. The same trend was observed in case of fruits inoculated with *B. cinerea*, except of fruits coated with cinnamon oil. It may be concluded that infection with the spoilage pathogens enhanced the natural defense mechanism of plant tissues. Our result in term of phenolic fractions was in agreement with other studies (Capassoll and Torresll, 2013 ; Petriccione *et al*., 2015).

Regarding phenolic content in tomato fruits of all treatments, it was noticed that significant decrease of phenolic compounds value occurred by prolonging the time of storage. These results are consistent with the findings of other researches (Tian *et al*., 2011; Tabaestani *et al*., 2013; Chen *et al*., 2014 ; Xu *et al*., 2014).

Table 4-b. Changes in Vitamin C. (mg/100g juice) and Lycopene (mg/100 g F.w.) of cherry tomatoes treated by cinnamon and spearmint essential oil and inoculated with spoilage pathogens (*Alternaria alternata* and *Botrytis cinerea*) during (MA) storage

	Alternaria alternata						*Botrytis cinerea*					
Days	**15**		**30**		**45**		**15**		**30**		**45**	
Treatment	**Vit.c**	**Lyco.**	**Vit.c**	**Lyco.**	**Vit.c**	**Lyco.**	**Vit.c**	**Lyco.**	**Vit.c**	**Lyco.**	**Vit.c**	**Lyco.**
Control	11.36	92	9.63	80	7.6	79	11.3	79	8.73	45	6.2	37
Inoculated (Inc.)	10.5	78	9.46	67	6.3	63	10.63	67	7.00	65	5.33	44
Cinnamon	12.00	59	10.36	54	7.73	45	10.3	84	8.23	78	6.46	56
Cinnamon +Inc.	10.03	84	8.6	80	6.4	64	9.3	70	7.43	67	6.00	54
Spearmint	9.16	78	7.9	71	6.53	68	11.2	64	9.26	50	7.93	47
Spearmint+ Inc.	8.73	75	7.63	59	5.16	47	9.53	68	7.43	54	6.03	44

LSD at 5% for Vit. C = 0.62

a- Effect of *A. alternata* and *B. cinerea* on Vitamin C. (mg/100g juice) and Lycopene (mg/100 g F.w.)

Fungi	**Vit. C. mg/ 100g Juice**	**Lycopene mg/ 100g fresh weight**
A. alternata	8.696	69.055
B. cinerea	8.261	60.111
F. test	NS	-
LSD 5%	—	-

b- Effect of storage time (days) on Vitamin C. (mg/100g juice) and Lycopene (mg/100 g F.w.)

Days	**Vit. C. mg/100g Juice**	**Lycopene mg/ 100g fresh weight**
15	10.458	75.583
30	8.475	64.166
45	6.502	54
F. test	**	-
LSD 5%	0.725	-

c- Effect of cinnamon and spearmint oil treatments on Vitamin C. (mg/100g juice) and Lycopene (mg/100 g F.w.)

Treatment	**Vit. C. mg/100g juice**	**Lycopene mg/100g fresh weight**
Control	9.227	68.666
Inoculated (Inc.)	8.261	65.5
Cinnamon	9.183	62.666
Cinnamon +Inc.	7.961	69.833
Spearmint	8.816	63
Spearmint+ Inc.	7.422	57.833
F. test	**	-
LSD 5%	0.62	-

Table 4-c. Changes in Vitamin C. (mg/100g juice) and Lycopene (mg/100 g F.w.) of cherry tomatoes treated by basil and thyme essential oil and inoculated with spoilage pathogens (*Alternaria alternata* and *Botrytis cinerea*) during (MA) storage

	Alternaria alternata						*Botrytis cinerea*					
Days	**15**		**30**		**45**		**15**		**30**		**45**	
Treatment	**Vit.c**	**Lyco.**	**Vit.c**	**Lyco.**	**Vit.c**	**Lyco.**	**Vit.c**	**Lyco.**	**Vit.c**	**Lyco.**	**Vit.c**	**Lyco.**
Control	10.2	75	8.96	60	6.26	50	11.4	79	9.36	62	6.5	58
Inoculated (Inc.)	9.46	62	7.66	54	4.76	44	9.33	54	7.8	46	5.63	33
Basil	9.06	92	8.16	85	6.13	73	10.76	75	8.4	69	5.93	55
Basil + Inc.	8.76	67	6.9	51	5.2	43	8.63	67	5.76	58	3.86	47
Thyme	11.36	50	9.06	45	7.2	31	11.63	84	8.33	71	4.33	62
Thyme + Inc.	9.4	83	8.06	80	5.63	64	826	71	6.36	64	4.1	55

LSD at 5% for Vit. C = 0.675

a- Effect of *A. alternata* and *B. cinerea* on Vitamin C. (mg/100g juice) and Lycopene (mg/100 g F.w.)

Fungi	**Vit.C. mg/ 100g Juice**	**Lycopene mg/ 100g fresh weight**
A. alternata	7.902	61.611
B. cinerea	7.568	61.666
F. test	NS	-
LSD 5%	—	-

b- Effect of storage time (days) on Vitamin C. (mg/100g juice) and Lycopene (mg/100 g F.w.)

Days	**Vit. C. mg/ 100g Juice**	**Lycopene mg/ 100g fresh weight**
15	9.858	71.583
30	7.885	62.083
45	5.463	51.25
F. test	**	-
LSD 5%	0.697	-

c- Effect of basil and thyme oil treatments on Vitamin C. (mg/100g juice) and Lycopene (mg/100 g F.w.)

Treatment	**Vit. C. mg/100g Juice**	**Lycopene mg/100g fresh weight**
Control	8.775	64
Inoculated (Inc.)	7.427	48.833
Basil	8.077	74.833
Basil + Inc.	6.522	55.5
Thyme	8.655	57.166
Thyme + Inc.	6.955	69.5
F. test	**	-
LSD 5%	0.675	-

Table 5. Impact of phenolic fractions affected by some essential oil treatments and inoculated with spoilage pathogens (*Alternaria alternata* and *Botrytis cinerea*) of cherry tomatoes

Treatment	*Alternaria alternata*			*Botrytis cinerea*		
	Total	Free	Compound	Total	Free	Compound
Control Initial time	8.75	5.00	3.75	8.75	5.00	3.75
Control End time	6.25	2.50	3.75	6.50	2.50	3.75
Inoculated (Inc.)	6.25	4.75	1.50	6.25	4.75	1.50
Black seed	6.50	2.75	3.75	6.50	2.75	3.75
Black seed+ Inc.	7.00	3.25	3.75	7.00	2.50	4.50
Fenugreek	6.25	2.25	4.00	6.25	2.25	4.00
Fenugreek+ Inc.	6.50	3.25	3.25	6.75	4.25	2.50
Cinnamon	7.00	4.75	2.25	7.00	4.75	2.25
Cinnamon + Inc.	6.75	4.75	2.00	6.50	2.25	4.25
Spearmint	6.75	3.00	3.75	6.75	3.00	3.75
Spearmint + Inc.	6.25	2.50	3.75	7.00	3.75	2.25
Basil	7.00	3.50	3.50	7.00	3.50	3.50
Basil + Inc.	7.00	3.50	3.50	7.00	4.00	3.00
Thyme	6.75	3.75	3.00	6.75	3.75	3.00
Thyme+ Inc.	7.00	4.50	2.50	7.25	5.00	2.25

LDS at 5% for Total phenol = NS Free = 0.94 Compound = NS

L*ycopersicon esculentum* is one of the most widely consumed fresh and processed vegetables in the world. It contains bioactive key components as phenolic compounds profile which differ among tomato varieties, which were related to genetic features, cultivation conditions, handlings methods and postharvest treatments (Barros *et al*., 2012). In addition, cherry tomato had a significantly higher content of total phenolic compounds than the other's tomato varieties (Marsic *et al*., 2011).

Color (L*, a*, b*)

Fruit color is virtually a major quality characteristic in all fruits and vegetables. Also uniformity of color within tomatoes is principal requirement of the European Union (EU) quality standards for this crop. Since the deposition of carotenoid pigments is responsible for the characteristic color of ripe tomatoes (Fraser *et al*., 2000), an understanding of carotenoid synthesis in tomato is of immediate relevance to quality (Passam *et al*., 2007). During fruit ripening maximum concentrations of α and β-carotene occur at the turning to breaking stages (Meredith and Purcell, 1966), after which lycopene accumulates (Davies and Hobson, 1981).

Fruit color is probably the most important attribute that determines overall quality as it affects consumer perception (Tabaestani *et al*., 2013).

Inoculated cherry tomato frutis with *A. alternata* and/or *B. cinerea* caused clear decrease in L, a and b values than control treatments (un inoculated healthy fruits), (Tables 6 - a, b and c). The color values (L, a and b) of all experimental treatments were gradually decreased with progressing time of storage (Tables 6 -a, b and c). Our result was in agreement with those obtained by Ali *et al*. (2010) and Tabaestani *et al*. (2013).

In conclusion, the essential oil treatments enhanced the color values of healthy fruits compared to untreated one (control treatment) being 22.82, 11.70, 9.88 for, L, a and b, respectively for (black seed oil treatment) and 21. 47, 9.24, 9.79 for L, a and b, respectively for (cinnamon oil treatment) and 21.40, 14.15, 9.06 for L, a and b, respectively for (spearmint oil treatment) compared to untreated and inoculated fruits with *A. alternaria* at the end of storage time.

In addition inoculated fruits with *A. alternaria* and treated with fenugreek and thyme essential oils true up to be colored than inoculated ones. Also, the same result was obtained by *B. cinerea* inoculated fruits and treated with fenugreek, thyme and basil oils than only inoculated fruits (Tables 6-a, b and c).

A delay in color change due to oil treatments has been reported in tomato (Ali *et al*., 2010). Coating of tomatoes with basil gum delayed color change (Tabaestan *et al*., 2013).

Weight loss percentage

It is evident from (Fig. 1- a and b) that weight loss percentage increased significantly with the prolongation of the storage period for all treatments. Generally, the weight loss occurs during storage due to its respiration process, the transference of humidity and some process of oxidation (Ayranic and Tunc, 2003). However, all treatments significantly reduced weight loss of tomatoes during storage compared to control treatment.

Significant difference in weight loss of fruits was observed due to the effects of oil treatments and time of storage and their interaction.

Generally it was found from data in Fig. 1 that treated fruits with fenugreek, cinnamon and thyme oils resulted in the lowest fruits weight loss being 10.22, 11.41 and 12.43%, respectively compared with control treatments (16.57%) at the end of storage time (45 days).

A similar percentages trend of oils coating treatment was detected when stored inoculated cherry tomato fruits with *A. alternata* and /or *B. cinerea* and treated with all the essential oils tested, specially fenugreek, cinnamon and thyme oils, respectively.

The reduction in weight loss was probably due to the effects of the coating oils used as a semi-permeable barrier against O_2, CO_2, moisture and solute movement, through reducing respiration, water loss and oxidation rates.

A similar effect was observed by Ben-Yehoshua (1969) for orange fruits coated with wax and those of Banks (1984), who reported that sucrose ester-based coating on banana fruits extended their storage life.

A similar result was reported by Tabaestani *et al*. (2013) which suggest that the cherry tomatoes weight loss can be delayed and storage period life can be extended when tomatoes stored at 20°C.

Shelf life

Extending the shelf life of tomatoes is very important for domestic and export marketing.

For results in Fig. 2 overall, the application of essential oils as cherry tomatoes coating could be a promising treatment to extend the shelf life of cherry tomatoes. Fruit under control treatment was recorded to give the longest life (12 days). The highest shelf life (15.5 days) was observed in thyme oil treatment, followed by oils treatment of cinnamon (15 days) of healthy fruits, while the lowest shelf life was recorded by spearmint and basil oils (10 and 9 days) respectively, similar to those obtained by Moneruzzaman *et al*. (2009).

From point of view the lowest days of shelf life (2 days) was recorded by fruits inoculated with both *A. alternata* and *B. cinerea* and oils untreated (Fig. 2 a and b).

In conclusion, from all aforementioned results, sensory evaluation proved the efficacy of coating fruits with essential oils and combined with modified atmosphere and cold storage conditions by maintaining the overall quality of tomato fruit during the storage period compared uncoated fruits.

Obtained results were in agreement with those reported sby Tabaestani *et al*. (2013), who concluded that coating cherry tomato fruits using basil mucilage edible coating and cumin essential oil and stored under 20ºc improved tomato storability and extended the shelf life of cherry tomatoes.

Table 6-a. Effect of black seed and fenugreek essential oil treatments on color changes of inoculated cherry tomato fruits with (*Alternaria alternata* and *Botrytis cinerea*) stored under (MA) conditions

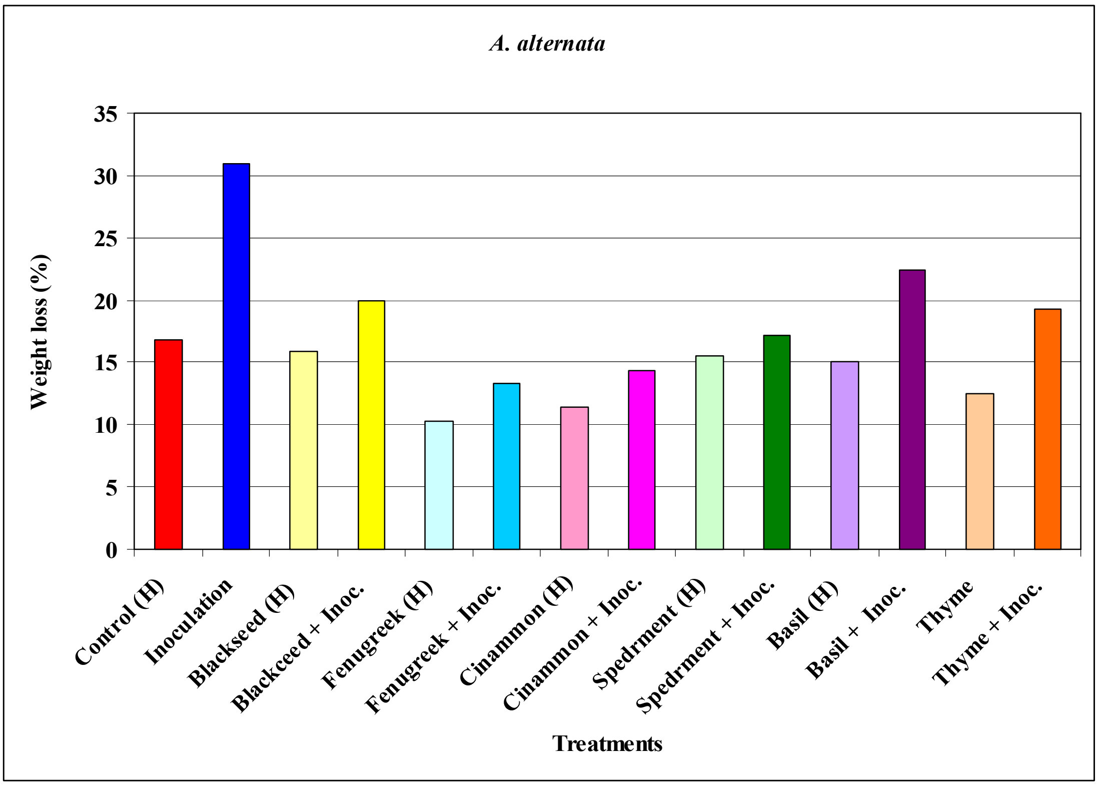
Treatment	Color L*,a*,b*	*Alternaria alternata* Storage days			*Botrytis cinerea* Storage days		
		15	30	45	15	30	45
	L*	24.33	22.61	20.22	24.64	22.70	21.29
Control healthy	a*	13.80	11.66	10.64	15.22	13.29	12.30
	b*	10.07	9.47	8.37	11.70	10.00	9.43
	L*	23.47	21.84	19.65	22.21	21.00	20.32
Inoculated (Inc.)	a*	10.75	9.28	8.61	14.40	11.81	12.71
	b*	10.52	9.20	7.76	8.50	7.20	6.79
	L*	25.13	23.71	22.82	19.70	18.54	17.55
Black seed	a*	15.24	13.77	11.70	10.66	9.33	8.15
	b*	13.82	11.62	9.88	10.35	9.25	7.21
	L*	20.27	19.57	17.85	23.19	21.10	20.26
Black seed + Inc.	a*	15.45	13.50	12.47	15.05	13.50	12.43
	b*	10.33	8.68	6.74	13.20	10.50	8.61
	L*	19.55	17.20	16.17	23.50	21.50	20.66
Fenugreek	a*	12.07	10.40	8.41	14.20	13.25	12.61
	b*	10.52	7.82	6.68	10.35	9.44	8.54
	L*	24.55	23.60	22..36	21.40	20.07	18.75
Fenugreek + Inc.	a*	14.20	13.27	11.49	11.70	11.00	10.31
	b*	13.51	11.44	10.56	9.29	8.13	6.97

Table 6–b. Effect of cinnamon and spearmint essential oil treatments on color changes of inoculated cherry tomato fruits with (*Alternaria alternata* and *Botrytis cinerea*) stored under (MA) conditions

Treatment	Color L*a*b*	*Alternaria alternata*			*Botrytis cinerea*		
		Storage days			Storage days		
		15	30	45	15	30	45
Control healthy	L*	24.80	21.95	20.29	20.80	19.95	18.78
	a*	10.65	9.32	8.48	17.40	10.34	9.70
	b*	10.70	9.40	8.82	9.82	9.90	7.40
Inoculated (Inc.)	L*	20.40	18.21	17.36	23.50	20.40	18.70
	a*	10.33	9.50	9.23	12.23	11.04	10.43
	b*	8.10	7.33	6.50	9.84	9.80	7.24
Cinnamon	L*	24.20	22.50	21.47	24.20	21.48	20.30
	a*	11.40	11.01	9.24	12.15	10.19	12.04
	b*	10.03	9.90	9.79	11.19	9.06	8.13
Cinnamon +Inc.	L*	20.22	20.00	18.80	22.32	20.00	19.64
	a*	13.74	12.11	11.84	14.34	13.24	9.65
	b*	9.13	7.11	6.19	9.22	8.55	8.11
Spearmint	L*	24.44	20.50	21.40	20.82	18.21	17.36
	a*	15.33	14.20	14.15	11.24	9.45	8.76
	b*	10.70	9.01	9.06	11.24	8.19	7.12
Spearmint + Inc.	L*	21.50	20.18	19.81	17.80	17.00	16.22
	a*	11.70	10.25	9.13	9.32	8.29	7.16
	b*	9.18	8.02	7.31	9.30	7.55	6.31

Table 6-c. Effect of basil and thyme essential oil treatments on color changes of inoculated cherry tomato fruits with (*Alternaria alternata* and *Botrytis cinerea*) stored under (MA) conditions

Treatment	Color L*a*b*	*Alternaria alternata* Storage days			*Botrytis cinerea* Storage days		
		15	30	45	15	30	45
	L*	24.67	22.53	20.54	20.48	18.83	17.29
Control healthy	a*	14.64	12.73	11.65	10.20	9.40	8.84
	b*	9.53	8.59	8.45	10.03	9.35	8.24
	L*	19.82	16.30	14.83	21.53	19.72	18.19
Inoculated (Inc.)	a*	11.50	10.80	11.40	14.35	13.15	12.64
	b*	9.11	9.40	7.50	8.73	7.40	6.47
	L*	22.43	20.48	21.53	25.83	22.83	21.97
Basil	a*	10.50	9.42	9.35	14.11	12.46	9.98
	b*	9.25	9.00	8.72	10.50	9.98	9.83
	L*	21.97	20.73	19.84	21.55	19.73	19.18
Basil + Inc.	a*	13.52	12.70	12.46	11.40	10.65	9.73
	b*	10.42	9.55	8.54	10.35	8.54	7.52
	L*	22.53	20.40	19.17	19.44	17.19	16.47
Thyme	a*	14.25	13.00	12.75	9.24	9.01	7.98
	b*	9.50	8.03	7.61	8.20	7.50	6.20
	L*	24.83	22.40	20.98	22.71	20.77	19.76
Thyme + Inc.	a*	15.20	13.19	12.99	17.42	15.44	14.68
	b*	11.45	10.50	9.23	12.53	11.57	8.04



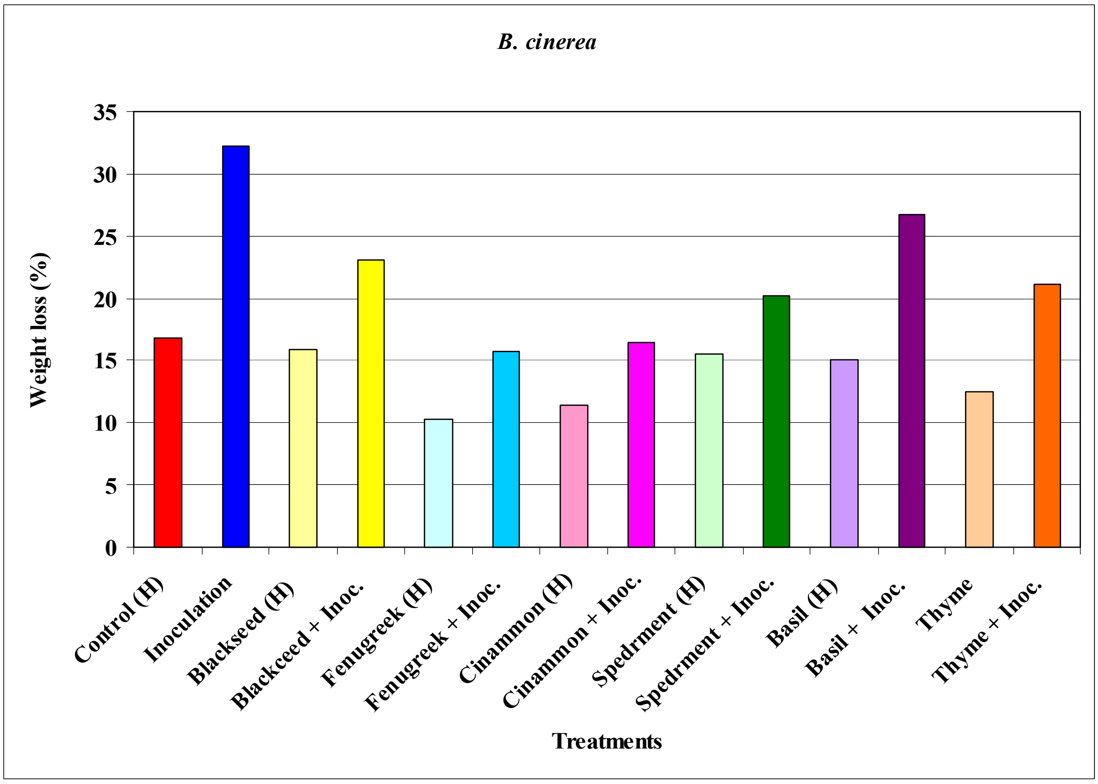
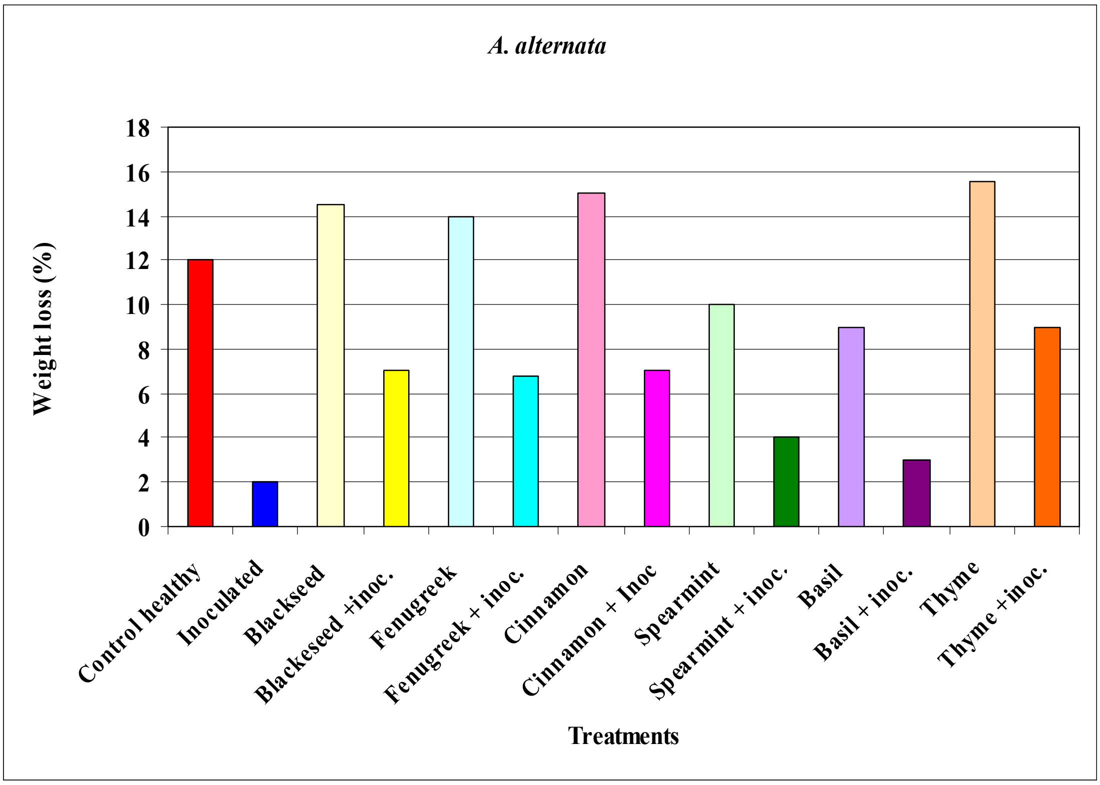


Fig. 1. Weight loss of cherry tomatoes uncoated (control) or coated with different essential oils and non or inoculated with fruit spoilage pathogens

H. = Healthy



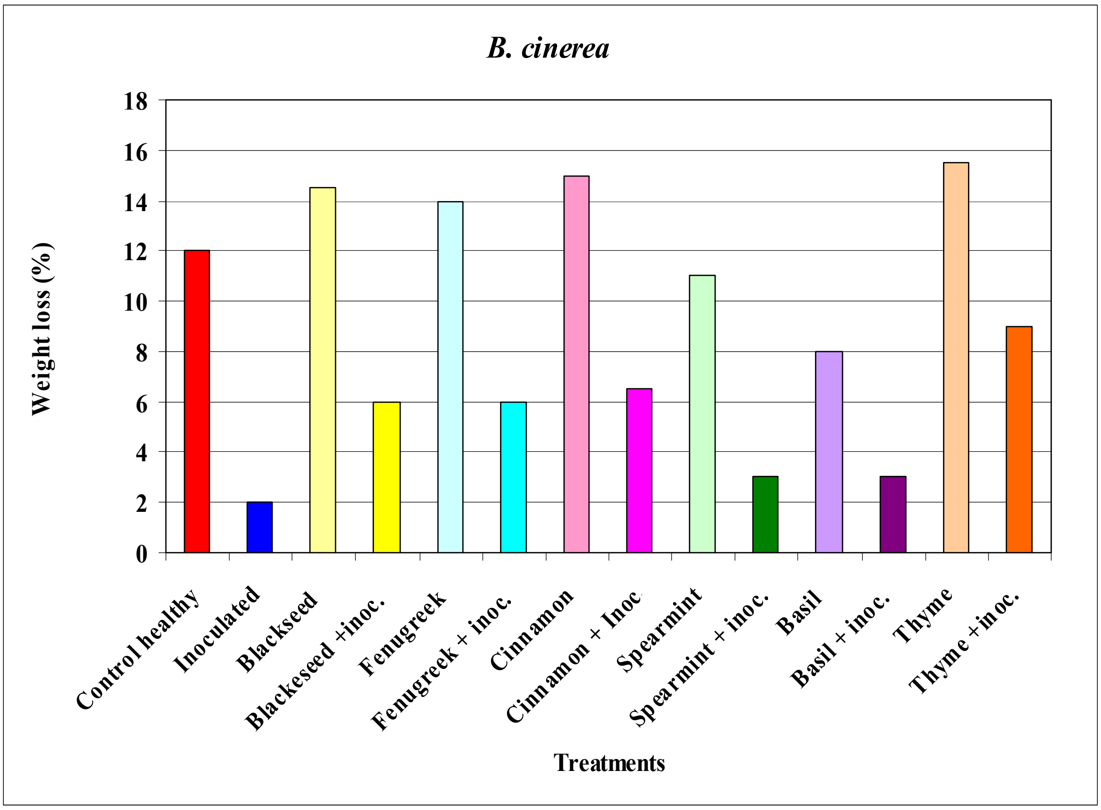


Fig. 2. Shelf life (days) of cherry tomatoes influenced by combined effect of essential oils coating, spoilage pathogens inoculation and storage conditions

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مردود معاملة ثمار الطماطم الشيري ببعض الزيوت النباتية الطيارة علي مقاومة أعفان الثمار وإطالة عمر الثمرة وتحسين صفات الجودة أثناء التخزين

شيماء محمد رأفت[١] - محمد إبراهيم أبوزيد[٢] - محمد رضا أحمد تهامي[٢] - حامد محمد محمد الهادي عريشة[٣]

١- الحجر الزراعي المصري - الإسماعيلية - مصر

٢- قسم أمراض النبات - كلية الزراعة - جامعة الزقازيق – مصر

٣- قسم البساتين - كلية الزراعة - جامعة الزقازيق – مصر

تعد سلامة الغذاء أهم مشكلة تواجه الخضروات والفواكه الطازجة، والحفاظ على جودة ثمار الطماطم الشيرى تعد كاشفة للمردود الاقتصادى لها، عوملت ثمار الطماطم الشيرى (السليمة أو المحقونة بفطرى عفن ثمار الطماطم ألترناريا الترناتا وبوتريتس سينيريا) تحت ظروف التخزين فى الجو المعدل (١٢%ك أ٢ + ٦% أ٢) والمبرد (٧°م ± ١ ورطوبة نسبية ٩٠% ± ٣) ببعض الزيوت النباتية الطيارة لنباتات حبة البركة، الحلبة، القرفة، النعناع، الريحان والزعتر بتركيز ١٠%، حيث توصلت النتائج إلى خفض معدل حدوث عفن ثمار الطماطم المعاملة، انخفضت صفات جودة الثمار المصابة وغير المعاملة بالزيوت النباتية متأثرة بطول فترة التخزين ماعدا الثمار المعاملة بالزيوت حيث أبطأت من معدل إنخفاض جودة الثمار مثل الصلابة، المواد الصلبة الذائبة، الفقد فى الوزن، درجة الحموضة، السكريات، ومضادات الأكسدة (فيتامين ج، الليكوبين، الفينولات) مقارنة بالثمار غير المعاملة. كما لوحظ أن أعلي معدلات تغير لون الثمار كان فى معاملة المقارنة وكذا معاملة الثمار المحقونة بالفطريات وغير المعاملة بالزيوت، وعليه أوضحت النتائج أن الزيوت النباتية الطيارة لعبت دوراً هاماً فى زيادة مقاومة الثمار للعفن مع إطالة عمر الثمار وكذا تقليل تدهور صفات جودتها، كما أنها تعد كمضاد ميكروبى يحمى الثمار الطازجة خلال التخزين.

المحكمون :

١- أ.د. محمود رزق الله عسران أستاذ ورئيس قسم أمراض النبات – كلية الزراعة – جامعة سوهاج.

٢- أ.د. هاني محمد السعيد محمد أستاذ أمراض النبات المتفرغ – كلية الزراعة – جامعة الزقازيق.