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PROTECTIVE ROLE OF ESSENTIAL OILS AGAINST POSTHARVEST DECAY AND PHYSIOCHEMICAL PROPERTIES OF MANGO (*MAGNIFERA INDICA*) FRUIT AT ROOM TEMPERATURE

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ABSTRACT

Postharvest fungal spoilage of vegetables and fruits during their storage period is a cause of huge loss in overall production. An active organic molecule from a natural product bears great potential in order to substitute synthetic fungicides. For example, the essential oils extracted from natural sources which are formed as a secondary metabolite in an aromatic plant. In this study, the effect of three essential oils including coriander oil, cinnamon oil and yellow mustard oil on quality and shelf life of stored mango fruit at room temperature (33+3"C; RH 63-76°/e) was studied. Among the essential oils, cinnamon oil at the concentration of 1000 g/L showed minimum postharvest losses in both fruits as compared to other two essential oils (Yellow mustard oil, coriander), control set and I % K-sorbate. Cinnamon oil successfully maintained the quality of mango fruit, showed least weight loss and decay percent during storage of ten days. Least changes in quality attributes including total soluble solids (TSS), total titratable acidity (TTA), pH, ascorbic acid content and polyphenol content were observed in cinnamon oil treated fruits.

Key words: Cinnamon oil, decay percent, polyphenol, shelf life, *Magnifera indica*

INTRODUCTION

Fruit are very fragile and sensitive to storage condition, and the major cause of postharvest losses is generally because of physiological deterioration, physical injury, pathophysiological injury and pathological breakdown (Feliziani *et al*., 2016). With increasing buyer call for best quality fruit with health benefits combined with attractive appearance, and good taste (He and Giusti, 2010). Moreover, thanks to greater access of knowledge and technology, consumers have developed conscious of health and safety concerning the handling of vegetables and fruit (Habiba *et al.*, 2019). Also, the effectivity of chemical treatments to cope with pathogens of agricultural commodities has negative growth with the appearance of resistant strains (Abd-alla and Haggag, 2013). Novel trends have been arisen to design and discover substitutes which can control postharvest diseases, giving primacy to preventive methods for decay having minimal impact on both human health and environment (Habiba *et al.,* 20l7; 2019). As these compounds drives purely from nature so are these considered to be safe for consumer and eco-friendly due to which their use over the years has increased in agriculture. Essential oils are rich in hydrophobic compounds containing volatile aromatic molecules produced by plants including ketones, phenolic components, aldehydes, sesquiterpenes and terpenes (Sivakumar and Bautista-Banos, 2014). Since the medieval times, essential oils have been broadly utilized for antiviral, antiparasitical, bactericidal, insecticidal, corrective and restorative applications, particularly these days in rural, pharmaceutical, fungicidal, corrective, food businesses and clean (Bakkali *et al*., 2008) .These extracted oils known to be effective against a far reaching limits of postharvest infections of organic products (Hammer *et al.,* 1999) and affectionate ruining microbes (Tajkarimi *et al.,* 2010). Usage of basic oils has received increasingly significance since they are assumed as being biologically more secure and progressively satisfactory to the general network (Janisiewicz and Korsten, 2002). The potential impact of utilizing fundamental oils by showering or plunging organic products for controlling postharvest sicknesses has been accounted for by a few agents (Kanherkar *et al.,* 2007). Basic oils (EO) have fungicidal and insecticidal exercises against some central plant pathogens (Kanherkar *et al.,* 2007).

Climatic conditions of Pakistan ranges from temperate to tropic where 40 different types of vegetables and 21 kinds of fruits are grown (Raja and Khokhar, 1993). Citrus and mango of Pakistan are most favorite and well-known commodities due to their exceptional f1avor and high production rate. Large quantity of mango and citrus fruits are exported to Middle East, Europe, China and Japan. Pakistan is also ranked among top 13 citrus producing countries (Raja and Khokhar, 1993). Mango *(Magnifera Indica*) is one of the top five fruit in the whole world which can be produced in a widespread range of climates that ranges from dry subtropical to wet tropical (Solgi and Ghorabanpour, 2014). 1.7 million tons of mangoes occupied by an area of 151.5 thousand hectares are produced in Pakistan ranks 5th in the list of mango producing countries (Maqbool and Malik, 2008). Pakistan's mango industry is unable to meet the international market requirements due to improper management of pest control and diseases (MSDS) (Rajwana *et al.,* 2011). Most prevalent postharvest diseases observed in mango fruits includes *Botryodiplodia theobromae*, *Alternaria alternata*, *Colletotrichum gloeosporioides* and *Phomopsis mangiferae* (Syed *et al.,* 2014). The use of some essential oils purely extracted from plants like orange oil (*Citrus sinensis*), basel oil (*Ocimum basilicum*), mustard oil (*Brassica juncea* L.) and lemon oil (*Citrus medica*) has been reported to reduce postharvest diseases caused by *Colletotrichum gloeosporioides* Penz. in mango fruits (Solgi and Ghorbanpour, 2014).

The present report describes the scope of essential oils for controlling postharvest diseases in stored mango fruit. Impact of these essential oils on important properties of fruits like weight loss pH, Total Titrable Acidity (TTA), Total Soluble Solid (TSS) and amount of phenols and decay percentage of fruits is also addressed.

MATERIALS AND METHODS

Sample Collection

Fresh and healthy fruit, mango *(Magnifera indica)* were purchased from supermarket (Metro, Karachi).

Application of essential oils for minimizing the postharvest losses in mango Fruit

l% calcium hypochloride solution was used to sterilized fruits surface for 2-3 minutes and then rinsed with disinfected water to contain any unwanted effect of calcium hypochloride. By mixing 0.05% Tween 20 with distilled water for the concentration of 1000 µg/L of each essential oil was used as surfactant. After sterilizing surface of fruit, fruits were immersed in the above prepared suspension of essential oils for three minutes. Fruits were air dried and kept in a fruit baskets made of porous plastic and was enclosed by using sheet of polyethylene. Total of four samples of individual treatment and fruit per sample were three in number for each experiment. Mango fruit was closely observed for any change during the study period and following physiochernical characteristics were studied after every fifth day of storage for a period of ten days.

Weight loss

AOAC Guideline (1994) was used for the calculation of weight loss in mango.

Weight loss = W1-W2/W1 x 100

Where:

W1 is the weight of the mango fruit on the day of experimentation

W2 is the weight of the mango fruit on the subsequent days of storage

Fruit firmness

In order to check the firmness of Fruit we used a penetrometer (PC E-PTR 200) using 8 mm cross head and firmness was measured in Newton, two points of their cheeks were taken to measurements of mango (Abbasi *et al.,* 2009).

Brix content (TSS)

A refractometer (Atago Co., Tokyo, Japan) like the one used in AOAC (1994) was employed to determine the TSS content of each fruit.

PH

For the determination of the pH of the (fruit) samples, standard method as per description of AOAC (1994) was followed.

Titratable acidity

Acid base titration was used to measure titratable acidy. A 0.1 N sodium hydroxide was used to titrate 5 mL of each fruit juice with the addition of few drops of phenolphthalein to indicate endpoint. Results were recorded in % citric acid just like AOAC method 1994.

% citric acid = Volume x N x Wmeq x 100/Y

Where:

Volume = volume(mL) of sodium hydroxide solution used

N= 0.1 N NaOH

Wmeq = 0.064 for citric acid

Y = weight of sample (g /mL)

Ascorbic acid content (AA)

Amount of AA was recorded in mg/L and was determined with the help of refelectqaunt test strips specified for AA in refrectometer as per Neocleous and Vasilakakis (2005).

Total phenolic content Estimation (TPC)

Total phenols in mango juice were found out via Folin-Ciocalteu method as described by Chandini *et al*. (2005). In short, juice samples were centrifuged at 1007xg for 15 min. 10 microliter of supernatant was used. Sample was diluted to 100 mL using distilled followed by addition of two milliliters of 2 % Na_2CO_3 and left it for 2 mins. 100 mL of Phenol reagent (50 % Folin-Ciocalteu) was added after incubation for 2 minutes and kept it in a dark room for thirty minutes. With the help of spectrophotometer, at 720 nm wavelength absorbance was recorded with reference to blank and phenolic content (mg/g GAE) was noted.

Decay percent (DP)

Visual observations were made to determine the deterioration percent of the mango fruit. Following formula was applied to calculate the deterioration percent of mango fruit.

Decay percent = No of decayed fruit/Total number of fruit x 100

Data Analysis

A software, CoStat, CoHort, CA, U.S.A. were used to make comparison among the treatments and between various time intervals. We treated Data to two-way ANOVA. In comparison to means of treatment the follow up of ANOVA include least significant difference (LSD) at ($p<0.05$).

RESULTS

The experiment was terminated at ten days since most of mangoes were deteriorated and observation was not possible at fifteen days. Weight loss was observed in all treatments including untreated (control) with the increasing storage period (Table 1). Least loss in weight was recorded in fruits treated with cinnamon oil (8.95 %) compared to control (23.31%) on tenth day of storage period. Results for the effect of treatment on firmness are presented in Table 2. Data shows decrease in firmness with time both in control and treated group. However maximum fruit firmness was exhibited by fruits treated with cinnamon oil (2.05 N) on tenth day of study compared to control set (1.41 N). The total soluble solid content increased with storage time as depicted in Table 3. Gradual increase in total soluble contents was observed in fruits treated with cinnamon oil followed by other EO and control sets. pH shows increasing trend in treated and non-treated mango fruits noteworthy variation in pH was observed in control set and treatments as shown in Table 4. In this study total titratable acidity ranged from 0.91 - 0.21 during storage of ten days at room temperature as shown in Table 5. Polyphenol content of mango juice increased with the increase in storage period as shown in Table 6. Control set showed minimum level of poly phenol content on tenth day of study as compared to treated fruits. The highest polyphenols content on the tenth day of storage was observed in cinnamon oil (1.765mg GA). Maximum fruit decay was found in control set whereas least percent decay of mango fruit was detected in cinnamon oil treated fruits compared to other treatments and control sets (Fig.1). Mangoes of control set showed maximum anthracnose followed by positive control and coriander oil, whereas cinnamon oil treated mango showed less infection.

Table 1. Effect of essential oils on percent weight loss of mango fruit stored at 33±3ºC with relative humidity in the range of 63-76%.

Treatments	**0 D**	**5 D**	**10 D**
Control	0±0	10.24±1.15	23.31±4.12
1% K sorbate	0±0	8.77±0.25	20.23±2.72
Coriander oil	0±0	8.76±0.87	21.24±2.75
Cinnamon oil	0±0	8.32±0.22	18.95±2.89
Yellow mustard oil	0±0	8.85±1.07	19.99±2.39
$LSD_{0.05}$ = Treatment[1] = 1.493			Days[2] = 1.156

[1]Mean values in column showing differences greater than LSD values are significantly different at $p < 0.05$.
[2]Mean values in rows showing differences greater than LSD values are significantly different at $p < 0.05$.

Table 2. Effect of essential oils on firmness of fruit (N) of mango fruit stored at 33±3ºC with relative humidity in the range of 63-76%.

Treatments	0 D	5 D	10 D
Control	3.26±0.205	2.27±1.18	1.41±0.06
1% K sorbate	3.26±0.205	2.47±0.05	1.72±0.26
Coriander oil	3.26±0.205	2.65±0.05	1.32±0.55
Cinnamon oil	3.26±0.205	2.08±0.11	2.05±0.58
Yellow mustard oil	3.26±0.205	2.22±0.53	1.43±0.11
$LSD_{0.05}$ = Treatment[1] = 0.345			Days [2] = 0.267

[1]Mean values in column showing differences greater than LSD values are significantly different at $p < 0.05$.
[2]Mean values in rows showing differences greater than LSD values are significantly different at $p < 0.05$.

Table 3. Effect of essential oils on total soluble solids (%) content of mango fruit stored at 33±3ºC with relative humidity in the range of 63-76%.

Treatments	**0 D**	**5 D**	**10 D**
Control	22.6±4.76	23.35±1.80	27.9±2.91
1% K sorbate	22.6±4.76	23.4±1.76	26.8±1.16
Coriander oil	22.6±4.76	25.25±2.36	27.8±1.09
Cinnamon oil	22.6±4.76	24.25±1.47	24.45±3.26
Yellow mustard oil	22.6±4.76	23.1±0.47	27.25±3.77
$LSD_{0.05}$ = Treatment[1] = 2.71			Days[2] = 2.10

[1]Mean values in column showing differences greater than LSD values are significantly different at $p < 0.05$.
[2]Mean values in rows showing differences greater than LSD values are significantly different at $p < 0.05$.

Table 4. Effect of essential oils on pH of mango fruit stored at 33±3ºC with relative humidity in the range of 63-76%.

Treatment	0 D	5 D	10 D
Control	4.68±0.16	5.06±0.42	5.44±0.75
1% K sorbate	4.68±0.16	5.29±0.40	5.33±0.50
Coriander oil	4.68±0.16	5.42±0.28	5.62±0.41
Cinnamon oil	4.68±0.16	5.12±0.13	5.27±0.38
Yellow mustard oil	4.68±0.16	5.12±0.11	5.18±0.45
$LSD_{0.05}$ = Treatment[1] = 0.296		Days[2] = 0.229	

[1]Mean values in column showing differences greater than LSD values are significantly different at $p < 0.05$.
[2]Mean values in rows showing differences greater than LSD values are significantly different at $p < 0.05$.

Table 5. Effect of essential oils on total titratable acidity (% citric acid) of mango fruit stored at 33±3ºC with relative humidity in the range of 63-76%.

Treatments	0 D	5 D	10 D
Control	0.91±0.05	0.27±0.00	0.23±0.02
1% K sorbate	0.91±0.05	0.23±0.02	0.21±0.03
Coriander oil	0.91±0.05	0.26±0.04	0.21±0.02
Cinnamon oil	0.91±0.05	0.34±0.02	0.25±0.03
Yellow mustard oil	0.91±0.05	0.29±0.03	0.25±0.01
$LSD_{0.05}$ = Treatment[1] = 0.031		Days[2] = 0.024	

[1]Mean values in column showing differences greater than LSD values are significantly different at $p < 0.05$.
[2]Mean values in rows showing differences greater than LSD values are significantly different at $p < 0.05$.

Table 6. Effect of essential oils on poly-phenol content (%mg of GA) of mango fruit stored at 33±3ºC with relative humidity in the range of 63-76%.

Treatments	0 D	5 D	10 D
Control	3.16±0.17	2.27±0.25	1.29±0.13
1% K sorbate	3.16±0.17	1.95±0.58	1.42±0.09
Coriander oil	3.16±0.17	2.39±0.64	1.56±0.10
Cinnamon oil	3.16±0.17	2.60±0.35	1.76±0.47
Yellow mustard oil	3.16±0.17	2.81±0.34	1.60±0.33
$LSD_{0.05}$ = Treatment[1] = 0.26		Days[2] = 0.20	

[1]Mean values in column showing differences greater than LSD values are significantly different at $p < 0.05$.
[2]Mean values in rows showing differences greater than LSD values are significantly different at $p < 0.05$.

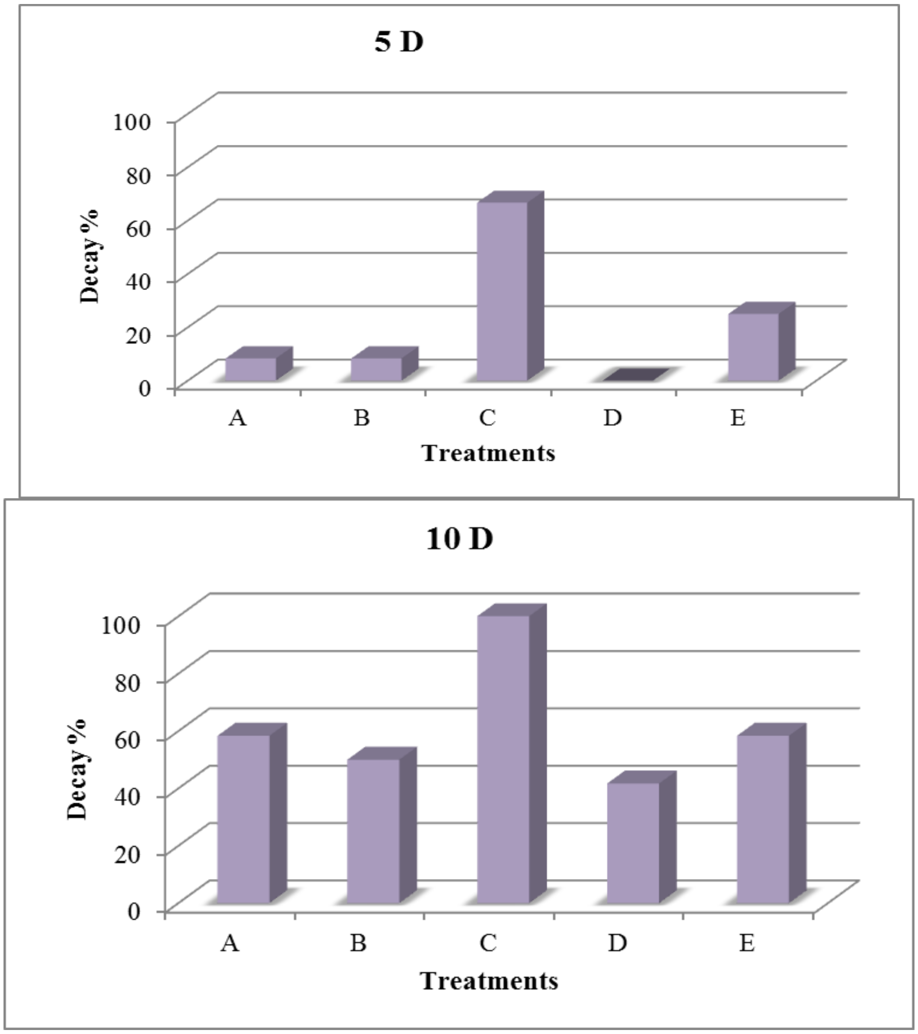

Fig.1. Effect of essential oils on the percent decay of mango fruit stored at 33±3ºC with relative humidity in the range of 63-76%.

A = Control D = Cinnamon oil
B = 1 % K-sorbate E= Yellow mustard oil
C = Coriander oil

$LSD_{0.05}$ = Treatment[1] = 16.084, Days[2] =12.459

[1]Mean values of bar in graph for treatment showing differences greater than LSD values are significantly different at $p<0.05$

[2]Mean values of bar at different days in graph showing differences greater than LSD values are significantly different at $p<0.05$.

DISCUSSION

Essential oils are used to control or cop with fungal rotting of fruit and vegetables thus served as the potential and eco-friendly method of decreasing and controlling postharvest losses of fruits and vegetables. This method has shown effectivity in minimizing the urge for manmade chemical fungicides, thereby conforming to consumer predilections, organic needs and decreasing environmental hazards. Essential oils are famous natural pesticides having bio-regulatory, antimicrobial and antioxidative attributes (Caccioni and Guizzardi, 1994). Bishop and Thornton (1997) have reported the antimicrobial effect of essential oils and their constituents on postharvest pathogens. Physical benefits of application of these organic oils as postharvest treatments have been manifested. Various applications such as dipping, spraying and fumigation were used to control postharvest decay was tested in samples of cherries, apples, citrus fruit, peaches, cabbages and avocados (Sellamuthu *et al.*, 2013). Essential oils can be spray as a vapor to decrease cost, as fumigation requires less oil and labor in postharvest handling (Wuryatmo *et al*., 2003). The gaseous phase application for postharvest not only reduces the chances of contamination in original organoleptic attributes of fruits but it also mitigates the risk of phytotoxic effects on fruit skin. The volatile components of few of the aromatic plants like geranium, lemongrass, clove, lime, lemon, tea tree, red thyme, basil savory, and caraway are well-known for their antifungal assets. Reports have demonstrated that essential oils enhanced the storage period of fruits and vegetables by controlling their fungal decay (Oyourou *et al.,* 2013; Shao *et al.,* 2013).

In this study the postharvest decay of mango fruit was successfully minimized by using suspension of essential oils during storage. Significant results were observed in cinnamon oil as compared to other essential oils and control sets. These stated results are firmly backed with the fact that the essential oils have shown antimicrobial, bio-regulatory and antioxidant characteristics (Vaughn and Spencer, 1991). Furthermore, results followed the findings of Wilson *et al.,* (1997) stating that fungi-toxic compounds of plants origin like essential oils can be utilize for the control of postharvest disease in fruits and vegetables. The fungistatic and fungitoxic property of cinnamon oil might be the core reason behind the least postharvest fungal decay during studies (Maqbool *et al.,* 2010). This difference in inhibitory effect of essential oil treatments might be due to variation in their fungicidal activity which depends upon its solubility and capacity to interact with cytoplasmic membrane (Tripathi and Shukla, 2007). Cinnamon oil in different concentrations not only delayed the onset of anthracnose in banana fruits but also proved to be successful in retaining fruit freshness during initial two weeks of storage (Maqbool *et al.*, 2010). This inhibitory effect of essential oils on postharvest fungal diseases might also be due to inhibitory behavior of essential oils on fungal enzyme production like pectinase and cellulase during disease development (Abd-Alla and Haggag, 2013). Essential oils of antimicrobial properties might be due to aromatic constituents and presence of OH groups which can alter the hydrogen bond of enzymes in microorganism (Farag *et al.,* 1989). The hydrophobic nature empowers compounds to enters the membrane lipid of fungal cell and mitochondria resulting in structural disturbance (Plaza *et al.,* 2004). Phenolic compound of essential oil has been reported for their antimicrobial potential. The phenolic compounds intermingle with membrane protein and alter permeability of microbial cell thus resulting in structural deformation of cell which causes loss of macromolecules from interior (Rattanapitigorn *et al.,* 2006). Shelef (1983) suggested that phenolic components in the essential oils target cell wall of pathogen and disrupt cell membrane permeability thus limiting the respiration rate. The conjugations of essential oils with phenolic compounds that are accumulated in some plants affect pathogen growth (Plotto *et al.,* 2002). The potential of oregano, clove, thyme and cinnamon oil was evaluated against *P. digitatum* and *P. italicum* on citrus fruit by Plaza *et al.* (2004). Essential oil from *Eupatorium cannabinum* contains antifungal property against *Colletotrichum gloeosporioides* and *Botryodiplodia theobromae* the casual agents of anthracnose and stern end rot in mango (Dubey *et al.*, 2007). The application of essential oils also have been enormously reposed to contain postharvest diseases along with the overall quality retention and enhancement of fresh commodities (Alikhani *et al*., 2014).

Soluble solids content and firmness are basic quality highlights for many fruits. Our observations and results demonstrated that the essential oils had major impact on firmness of stored mango fruit. Tzortzakis (2007) indicated that utilization of normal antifungal mixes on sweet cherry stockpiling expanded natural product firmness. Organic product stability on fruits and grapes was influenced by eugenol, thymol, or menthol fumes while acetaldehyde vapors-treated avocado postponed natural product softening (Pesis *et al.,* 1998). Absolute dissolvable solids content may check sugar substance of mango and kinnow and apparently of sweetness (Magwaza and Opara, 2015). TTA can be a significant tool in forecasting taste while assessing the fruit quality (Harker *et al.*, 2002). We observed that the total soluble solids of cinnamon oil treated fruits increased gradually as compared to control treatments and other two essential oil treatments. Our findings are in accordance with the findings of Tzortzakis (2007) who found increased total soluble solids in tomatoes and strawberries treated with oil vapors of cinnamon and eucalyptus. The total titratable acidity decreases during storage in both treated and non-treated fruits. However, cinnamon oil treated fruits showed slightly higher titratable acidity in comparison to other treatments at the closing period of storage. Lowering of total acidity content might be due to cellular activity in which organic acid enter Krebs cycle to achieve energy for fixing the membrane (Taiz and Zeiger, 2002). Results reported by Anthony *et al.,* (2003) states that ripened banana fruit treated with essential oils of *cymbopagon nardus, ocimum basilicum* and *cymbopagon nardus* had no effect on total soluble solids content during storage. Furthermore, Ju *et al.* (2000) has stated that TSS and TTA of pears sprayed with emulsions of plant oils were well-maintained and the efficacy of essential oils showed direct relationship with the concentration of essential oil used. Our results are the same as those reposed by Wang (2003), according to wang observations the raspberries treated with essential oils increased the acidity during storage. In our study, vitamin C of kinnow fruit were considered high in treated fruits as compared to control set (untreated). Our findings agree with the findings of Fatemi *et al.*, (2011) who observed that ascorbic acid concentration in citrus was increased by thyme and peppermint oil treatments @ l000ppm. Low oxygen concentration is reducing vitamin C wastage in fruit are well acknowledged and reviewed by Lee and Kader (2000). Furthermore, deprivation of ascorbic acid is augmented by many reasons like chilling injury, water loss, mechanical injuries and increased storing period (Sablani *et al.,* 2006; Lee and Kader, 2000). Tzortzakis *et al.* (2011) stated that vitamin C concentration in tomato fruit wasn't different but inclined to extend during storage of fruit. High level of antioxidant provides protection against free radicals and subsequently contributing in the preclusion of various progressive ailments. Lowering of ethylene is due to decreased in respiration, hindered maturation and senescence is principal to maintain vitamin C at highest levels. During this study the phenolic content in treated and non-treated fruits was high. The phenolic compounds of essential oil might be the reason for their effective antimicrobial activity (Nuchas and Tassou, 2000). Phenolics are secondary metabolites of plants which promote the antioxidant potential of many fruit and thus plays a significant part in preventing oxidation reactions, which are associated with multiple non-communicable diseases in human (Karakaya and Tas, 2001). Other studies also reported the induced resistance due to increased total phenolic content and Vitamin in tomato fruit treated with essential oils (Tzortzakis *et al.*, 2011; Rousos *et al.,* 2013). Content of phenols play a significant part in plants defense and resistance against intrusion of microorganisms (Beckman, 2000).

CONCLUSIONS

This study has shown that the essential oils applied to healthy fruits can decrease and minimize the potential post-harvest losses thus keeping the fruit quality at acceptable level. Additionally, essential oils can be vital in controlling the compositional changes, including TSS, pH, TTA, ascorbic acid content and polyphenol content with minimum weight loss in stored fruit.

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