Journal of Food Safety ISSN 0149-6085

IMPROVING POSTHARVEST QUALITY OF TABLE GRAPE CV. "RISH BABA" USING *THYMUS KOTSCHYANUS* AND *CARUM COPTICUM* ESSENTIAL OILS

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Accepted for Publication July 15, 2010

doi:10.1111/j.1745-4565.2010.00276.x

ABSTRACT

The antifungal activity of different concentrations of *Thymus kotschyanus* and *Carum copticum* essential oils (0, 100, 200, 300, 400 and 500 μL/L) on mycelial growth of *Botrytis cinerea* and *Penicillium digitatum* under *in vitro* condition were investigated. Also, the preservative property of various concentrations of these essential oils (0, 250 and 500 μL/L) to maintenance quality parameters of "Rish Baba" table grape were studied. Chemical compositions of the essential oils were also determined by gas chromatography–mass spectrometry analysis. Major compounds found in essential oils from *T. kotschyanus* and *C. copticum* were carvacrol (28.54%) and thymol (63.18%), respectively. The results of *in vitro* assay showed that *T. kotschyanus* and *C. copticum* essential oils in 300–500 μL/L concentration completely inhibited the mycelial growth of *B. cinerea* and *P. digitatum*. Also, at the end of the storage period, all the applied concentration of essential oils reduced disease severity compared to control fruit. The application of essential oil did not affect the berry shrinkage and rachis browning. However, essential oil treatment showed high preservative effect on weight loss, appearance, flavor, berry browning, total soluble solids (TSS), titrable acidity (TA) and TSS/TA of treated fruits. Therefore, essential oils may be used as an alternative for the synthetic chemicals for control of postharvest phytopathogenic fungi, and in turn to fulfill consumer requirements for more natural and healthy fruits.

PRACTICAL APPLICATIONS

Postharvest disease of perishable fruits such as table grape renders heavy losses during transit and storage. Use of chemical fungicides such as SO_2 generator pads are basic means of controlling postharvest diseases of table grape. Public awareness about chemical residues in food and interest to use of organic crops intended search to find a new safe alternatives to synthetic fungicides. The main reason for examine the possibility use of essential oils are they plant origins, safe, no side-effect and their acceptability for consumers. Consequently, recently the interest to use of essential oils to preserve of fruits and vegetables has increased. The goal of this research was to examine the possibility use of *T. kotschyanus*, *C. copticum* essential oils to maintain postharvest quality of table grapes.

INTRODUCTION

Postharvest fungal decay limits the storage period and marketing life of table grape. *Botrytis cinerea* Pers. Fr. and *Penicillium digitatum* are regarded as the major agents of postharvest losses in table grapes in most regions of world (Droby and Lichter 2007).

Control of the postharvest fungal decay of table grape is most commonly achieved by application of synthetic fungicides such as SO_2 (Crisosto *et al.* 1994). Although SO_2 application had an excellent effect on extending the postharvest life of table grapes, its use has been reduced. Because SO_2 has numerous hazards on human health, environment pollution and phytotoxicity properties on table grapes such as bleaching of berries and off-flavor (Romanazzi *et al.* 2007). Also, the interest of people to consume organic fruits urged the researchers to find new alternative fungicides without any hazards on human, environment and phytotoxicity efficacy, as well as to limit or eliminate synthetic chemical fungicides (Tripathi and Dubey 2004; Valero *et al.* 2006).

In the recent years, the reports about the investigation of antifungal activity of animal- and plant-derived substances such as chitosan, plant extract and essential oils for control of phytopathogenic fungi in horticulture crops were increased (Romanazzi *et al.* 2007; Tripathi *et al.* 2008). The use of biologically based compounds in plant extracts may be an alternative to currently used chemical fungicides to control postharvest losses because they virtually constitute a rich source of bioactive chemical groups (Soylu *et al.* 2006; Valero *et al.* 2006).

Essential oils are volatile compounds from aromatic plants that are widely used in foods, cosmetics and pharmaceuticals. Essential oils represent a small fraction of a plant's composition but confer the characteristic for which aromatic plants are used in the pharmaceutical, food and fragrance industries. Essential oils have a complex composition, containing from a few dozen to several hundred constituents, especially hydrocarbons (terpenes and sesquiterpenes) and oxygenated compounds (alcohols, aldehydes, ketones, acids, phenols, oxides, lactones, acetalse, ethers and esters) that derive from the secondary metabolism of plants (Pourmortazavi and Hajimirsadeghi 2007; Araus *et al.* 2009).

Extensive works are carried out around the world in investigation of antimicrobial property of essential oils under *in vitro* condition (Viuda-martos *et al.* 2007; Yahyazadeh *et al.* 2008; Abdolahi *et al.* 2010a) but the antifungal activity of essential oils or their constituents for elongation the shelf life of fruits and vegetables were reported in the literature (Ranasinghe *et al.* 2005; Valero *et al.* 2006; Lee *et al.* 2007; Tripathi *et al.* 2008). The antifungal activity of the essential oils of *C. copticum*, *Foeniculumn vulgare* and *Carum carvi* was evaluated *in vitro* and *in vivo* conditions against the growth of *Alternaria alternata* and *Penicillium digitatum*, two postharvest pathogens of tomato fruits (Abdolahi *et al.* 2010b).

Essential oils as phytocompounds are expected to be far more advantageous than synthetic compounds, as they are easily decomposable, nonenvironmental pollutants and posses no residual or phytotoxic properties (Bishop and Thornton 1997). With respect to this topic, the present contribution was aimed at the investigation of the possibility use of essential oils extracted from *T. kotschyanus* and *C. copticum* as a new strategy for increasing the storage life of table grape without use of chemicals.

MATERIALS AND METHODS

Plant Material and Essential Oils

Bunches of table grapes (*Vitis vinifera* L. cv. Rhish Baba) were harvested from commercial vineyards and selected for uniformity in size, appearance, ripeness and the absence of physical defects.

The aerial parts of thyme (*Thymus kotschyanus* L.) at flowering stage and ajowan (*C. copticum* L.) fruits at ripening stage were harvested, air-dried and then submitted to hydrodistillation in a Clevenger-type apparatus for 3 h. The extracted essential oils dried over anhydrous sodium sulfate and stored at 4C until use and analysis.

Essential Oil Analysis

Gas chromatography (GC) analyses were performed using a Shimadzu GC-9A gas chromatograph equipped with DB-5 fused silica column (30 m × 0.25 mm; film thicknesses 0.25 μm). Oven temperature was held at 60C for 5 min then programmed to 210C at a rate of 3C/min. Injector and detector flame ionization detector (FID) temperatures were 300C and 280C, respectively. Helium was used as carrier gas with a linear velocity of 32 cm/s. Percentages were calculated by electronic integration of FID peak areas without the use of response factor correction. GC/mass spectrometry (MS) analyses were carried out on a Varian 3400 GC/MS system equipped with a DB-5 fused silica column (30 m × 0.25 mm; film thicknesses 0.25 μm); oven temperature program was 60–210C at a rate of 3C/min, transfer line temperature 240C, carrier gas helium with a linear velocity of 31.5 cm/s, split ratio 1/60, ionization energy 70 eV; scan time 1 s; mass range 40–340 amu.

The constituents of the oils were identified by calculation of their retention indices under temperature-programmed conditions for identification of individual *n*-alkanes (C6-C24) and the oil on DB-5 capillary column. Compounds were made by comparison of their mass spectra with those of the internal reference mass spectra library (NIST 98 and Wiley 5.0), with authentic compounds or with those reported in the literature (Davies 1990; Adams 2001). Quantitative data were obtained from FID area percentages without the use of correction factors.

Treatment of Bunches with Essential Oils

Six uniform grape bunches (200–250 g) sprayed with different concentrations of *T. kotschyanus* and *C. copticum* essential oils (0, 250 and 500 μL/L). Then they placed in plastic boxes with polyethylene cover and stored in cold storage (0–1C and 90% RH) for 3 months. Each treatment was replicated four times with six clusters per replicate.

Evaluation of Fungal Decay on Sprayed Bunches

Fungal decay was assayed in 30-days intervals and scored by using the following scoring system: (0) bunch without rots; (1) 1–5% of rotted berries; (2) 6–10% of rotted berries; (3) 11–25% of rotted berries; (4) 26–50% of rotted berries; (5) 51–75% of rotted berries; and (6) more than 75% of rotted berries (Nigro *et al*. 2006).

Evaluation of Quality Parameters on Treated Fruits

At the end of the storage period, boxed grapes from each treatment were removed from storage, and overall visual appearance, berry and rachis color were evaluated. The overall visual appearance of the grapes was evaluated for intensity on a 9-point scale: (1) extremely poor or soft in case of texture; (3) poor or soft; (5) moderate; (7) good; and (9) excellent. Berry and rachis browning development were evaluated on a 5-point intensity scale of damage by using the following scoring system: (1) none; (2) slight; (3) moderate; (4) severe; and (5) extreme. (Artés-hernández *et al*. 2004). Berry shrinkage of fruits was evaluated on a 5-point scale: (1) very shrinkage; (2) low shrinkage; (3) normal (medium); (4) smooth; and (5) very smooth (Bourne 1980).

Weight loss was calculated by weighting the fruit at harvest and reweighing at the end of the storage period. Weight loss percentage was calculated as the percentage of loss from the initial weight. At the end of storage period plus 2 days at 20C, flavor analysis to compare the quality of treated and control table grapes was carried out by 10 trained panelists. A questionnaire was used to record the data; each judge evaluated five berries for each treatment for flavor analysis, on a scale of 1–5 (ranked), where (1) very low; (2) low; (3) medium; (4) high and (5) very high (Valero *et al*. 2006).

A random sample of berries (10 berries) was sampled per replicate, juiced, and filtered to get a clear sample. Total soluble solids content (TSS) was determined by means of digital refractometer (Atago Co. Ltd., Tokyo, Japan), and results were expressed in °Brix. Titrable acidity (TA) content was determined with phenolphthalein as indicator using 0.1 mol/L NaOH and expressed as mmol H^+ per 100 g fresh weight. Total soluble solids/titrable acidity (TSS/TA) was expressed as the ratio between TSS and TA.

Test Pathogens

Botrytis cinerea and *P. digitatum* were isolated from infected table grape fruits and identified in the Plant Pathology Department, Faculty of Agriculture, Urmia University. These fungi were grown on Potato Dextrose Agar (PDA) medium at 25C. A 4–7-day-old culture of each fungus was used in bioactivity tests.

Assessment Antifungal Activity of Essential Oils Under *In Vitro* Condition

The antifungal activity of essential oils against *B. cinerea* and *P. digitatum* were tested by poison food medium method. Different concentrations of essential oils (0, 100, 200, 300, 400 and 500 μL/L) were added aseptically to sterile molten PDA medium (≈45C) containing Tween 80 (0.5%, v/v). The resulting media were immediately dispensed (20 mL) into sterilized Petri plates (9 cm). A mycelial disk of 5 mm diameter of the test pathogens were taken from the 4–7-day-old cultures, with the help of a sterilized cork borer, and was placed at the center of the Petri plates. In the controls, water and Tween 80 were used instead of essential oils. Inoculated Petri plates were incubated at 25C in darkness and observations were recorded on the seventh day, by which time the growth of the controls would have reached the edge of the plate. Each treatment was replicated four times, and the fungitoxicity of essential oils was measured in terms of percentage mycelial growth inhibition (MGI %) calculated by the following formula:

$MGI (\%) = ((dc - dt)/dc) \times 100$, where dc and dt represent mycelial growth diameter in control and treatment Petri plates, respectively.

Statistical Analysis

Statistical analyses of the data were performed using the MSTATC statistical software (Freed *et al*. 1991) using completely randomized design (CRD) with four replicates. Data were subjected to analysis of variance, and mean differences were established by Tukey's test ($P < 0.05$).

RESULTS AND DISCUSSION

The results of GC and GC/MS analysis of the essential oils of *T. kotschyanus* and *C. copticum* are presented in Table 1. The numbers of compounds were identified in the essential oils of *T. kotschyanus* and *C. copticum* were 9 and 24, respectively.

TABLE 1. THE QUALITY AND QUANTITY (%) OF TESTED ESSENTIAL OILS

Component	RI*	*T. kotschyanus*	*C. copticum*
α-thujene	936	–	0.21
α-pinene	942	1.46	0.09
Camphene	950	3.27	–
Sabinene	963	2.35	0.61
β-pinene	987	1.56	0.33
Myrcene	999	2.91	–
α-terpinene	1022	0.68	–
ρ-cymene	1035	11.45	21.4
Limonene	1040	7.1	–
β-phellandrene	1043	–	0.02
(Z)-β-Ocimene	1047	0.67	–
γ-terpinene	1061	14.66	13.8
Cis-sabinene hydrate	1065	2.01	–
Trans linalool oxide	1076	0.42	–
linalool	1107	1.2	–
Trans pinocarveol	1149	0.6	–
Terpinene-4-ol	1174	3.16	–
ρ-cymene-8-ol	1182	0.92	–
α-terpineol	1199	2.9	0.18
Thymol	1311	3.31	63.18
Carvacrol	1332	28.54	–
E-caryophyllene	1416	2.57	–
β-bisabolene	1510	0.29	–
Spathulenol	1570	0.46	–

* Retention indices.

The sample of *T. kotschyanus* contains carvacrol (28.54%) followed by γ-terpinene (14.66%), ρ-cymene (11.45%) and limonene (7.1%). Many studies on chemical composition of *T. kotschyanus* essential oils from different regions have been carried out. The published results reveal that major volatile constituents obtained from the aerial parts of *T. kotschyanus* are thymol, carvacrol, ρ-cymene, γ-terpinene, β-caryophyllene, etc. (Sefidkon and Dabiri 1999; Sefidkon *et al.* 1999). Nickavar *et al.* 2005 identified that thymol (38.6%), carvacrol (33.9%), γ-terpinene (8.2%) and ρ-cymene (7.3%) were the major constituents *T. kotschyanus* oil.

The major components of the essential oil of *C. copticum* fruits in our study were thymol (63.18%), ρ-cymene (21.4%) and γ-terpinene (13.8%). In two other reports, major components of the oil were reported as thymol (35.4% and 49.0%), γ-terpinene (28.6% and 30.8%) and ρ-cymene (29.2% and 15.7%) with no carvacrol (Khajeh *et al.* 2004; Lucchesi *et al.* 2004). However, in other reports from India, the major compounds were reported as ρ-cymene (41.98%) carvacrol (45.20%) and thymol (0.48%) (Srivastava *et al.* 1999). Due to the significant difference between the amount of thymol and carvacrol in different reports about thymol and carvacrol chemotypes, we suggest that the chemical variations for *C. copticum* from different regions should be regarded as chemodemes, and we speculate that there are two different chemotypes of *C. copticum* – thymol chemotype and carvacrol chemotype. In addition, these chemical differences can be most probably explained by the variability of the plant subspecies, plant genotype, organ of plant, geographical origin, season, environmental, agronomic conditions, extraction method and storage condition of plant and essential oils (Marotti *et al.* 1992; Suhr and Nielsen 2003).

In this study, we preferred to use essential oils extracted from *T. kotschyanus* and *C. copticum* plants instead of pure compounds of essential oils such as thymol (main component of *C. copticum* oil) and carvacrol (main component of *T. kotschyanus* oil(because it was emphasized in several papers that mixtures of all components available in the essential oils, due to the existence of synergistic efficacy within all components of essential oils, showed higher biological activities compared with pure components (Edris and Farrag 2003; Bagamboula *et al.* 2004; Rota *et al.* 2008).

The results of this study showed that essential oil treatment had a good inhibitory effect on weight loss and berry browning (Fig. 1, Tables 2 and 3). In a previous study, Valero *et al.* (2006) tested the effect of thymol and eugenol on quality parameters in table grapes. They found that the percentage of weight loss in thymol- and eugenol-treated table grapes were lower than controls, and they stated that thymol and eugenol treatment reduced the dehydration process in treated fruits. Loss of weight in fruits and vegetables during storage is caused by water exchange between the internal and external atmospheres, the transpiration rate being accelerated by cellular breakdown (Woods 1990). Thus, the higher fungal decay of untreated fruits would lead to tissue disruption and, in turn, be responsible for the higher weight loss reported when compared to oil-treated fruits. Also, the inhibitory effect of essential oils on the reduction of weight loss in treated fruits could be related to the lipophilic property of essential oils and the creation of an oily layer on berries and suppression of weight loss. Dehydration in fruits and decomposition of chlorophylls by polyphenoloxidase (PPO) enzyme are important factors in berry browning (Vial *et al.* 2005). The effectiveness

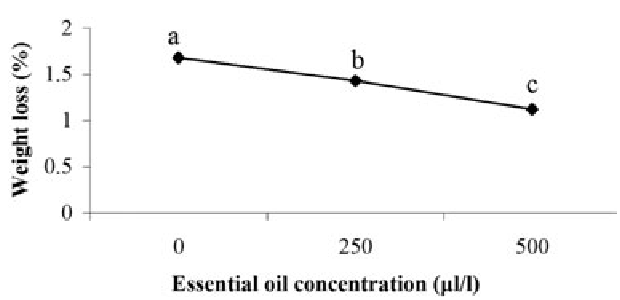

FIG. 1. EFFECTS OF DIFFERENT CONCENTRATION OF ESSENTIAL OILS ON WEIGHT LOSS (%) IN BUNCHES OF "RISH BABA" TABLE GRAPE
Means of treatments with the same letter are not significantly different according to Tukey's multiple comparison tests ($P < 0.05$).

TABLE 2. MEANS SQUARES FOR THE VARIANCE OF THE EFFECTS OF ESSENTIAL OILS ON DISEASE SEVERITY AND QUALITY PARAMETERS OF OIL-TREATED BUNCHES

Significance	Disease severity	Weight loss (%)	appearance	Berry browning	Rachis browning	Berry shrinkage	Flavor	TSS	TA	MI
EO	**	**	ns	ns	ns	ns	ns	ns	ns	ns
Con	**	*	ns	**	ns	ns	**	*	**	**
EO * Con	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

*, ** and ns: Significant at $P < 0.05$, $P < 0.01$and not significant, respectively.
EO: Essential oil, Con: Essential oil concentration. TSS: Total Soluble solids, TA: Titrable acidity and MI: Maturity index.

of essential oils in the reduction of berry browning may be related to their inhibitory effect on PPO activity and/or their efficacy in the reduction of weight loss in fruits.

The evaluation of quality parameters of treated fruits at the end of the storage period showed that essential oil treatment had a positive preservative effect on the level of flavor and appearance of treated fruits when compared with the controls (Tables 2 and 3). Essential oils are mixtures of volatile compounds, mainly constituted by monoterpenes and sesquiterpenes and their oxygenated derivatives, together with aliphatic aldehydes, alcohols and esters – 90–95% of the whole oil. A large percentage of the volatile fraction is composed by terpenes, which make little contribution to the flavor or fragrance of the oil, and the oxygenated fraction is highly odoriferous and mainly responsible for the characteristic flavor (Roldàn-Guiérrez *et al.* 2009). Therefore, with respect to the topic that the oxygenated fraction of essential oils tested in our study were high, we can speculate that the good flavor of oil-treated bunches, when compared to the controls, could be related to oxygenated compounds.

In addition, with increase of essential oil concentration the changes of TSS and TSS/TA increased and TA decreased (Fig. 2, Tables 2 and 3). Serrano *et al.* (2005) reported that sweet cherry fruits treated with essential oil constituents such as eugenol, thymol and menthol showed benefits in terms of reduced weight loss and maintenance of fruit firmness when compared to controls. However, sweet cherries treated with eucalyptol garnered an off-flavor. Some workers stated that cinnamon, clove and eucalyptus essential oils did not change the quality parameters of banana and strawberry fruits (Ranasinghe *et al.* 2005; Tzortakis 2007). The reason(s) for this being effective/ineffective have not been determined.

The evaluation of disease severity on clusters showed that during the storage period, disease severity on clusters increased (Table 2 and Fig. 3), but at the end of the storage period, essential oil treatments showed high reducer effects on disease severity and with the increase in essential oil concentration, disease severity decreased (Table 3), although the essential oils did not have differences between them (Table 2). These results were in accordance to a study by Reddy *et al.* (1998) who found that essential oil extracted from *T. vulgaris*, which contain a high percentage of thymol, showed a high inhibitory effect on the growth of *B. cinerea* and *R. stolonifer* on strawberry fruits. The potential use of essential oils extracted from *T. vulgaris* against alternaria rot on cherry tomato and *Zingiber officinale* on gray mold rot on table grape was affirmed previously (Feng and Zheng 2007; Tripathi *et al.* 2008). In addition, the antifungal properties of some constituents of essential oils such as eugenol, thymol, menthol and carvacrol as natural, alternative fungicides to the control of postharvest pathogens in table grape (Valverde *et al.* 2005; Valero *et al.* 2006; Guillén *et al.* 2007; Martínez-romero *et al.* 2007), sweet cherry (Serrano *et al.* 2005), apricot and plums (Liu *et al.* 2002) were documented.

Assessment of the antifungal activity of *T. kotschyanus* and *C. copticum* essential oils by using the poison food medium method showed that both essential oils showed high antifungal activity against *B. cinerea* and *P. digitatum*. Essential oils completely inhibited the mycelial growth of both fungi at ≥300 μL/L (Table 4). These results agreed with the report of Yahyazadeh *et al.* (2008) that showed that *T. vulgaris* and *Eugenia caryophyllata* essential oils completely inhibited *P. digitatum* growth at 600 μL/L, and stated that *E. caryophyllata* essential oil leads to a large alternation in the morphology of fungi. In addition, it seems that the sensitivity of *P. digitatum*

TABLE 3. EFFECT OF VARIOUS CONCENTRATIONS OF ESSENTIAL OILS EXTRACTED FROM *T. KOTSCHYANUS* AND *C. COPTICUM* ON DISEASE SEVERITY AND QUALITY PARAMETERS OF OIL-TREATED BUNCHES OF "RISH BABA" TABLE GRAPES THAT MEASURED AT THE END OF STORAGE PERIOD

Concentration (μL/L)	Disease severity (%)	Appearance	Berry browning	Flavor	TA	TSS/TA
Control (0)	89†	1‡	3.66†	5‡	3.31†	33.35‡
250	62‡	3.33†	2.33‡	7†	2.92§	39.67†
500	60‡	3.66†	2.16‡	7†	3.08‡	38.06†

The means followed by same symbol in each column are not significantly different according to Tukey's multiple comparison tests ($P < 0.05$).

TABLE 4. EFFECT OF T. KOTSCHYANUS AND C. COPTICUM ESSENTIAL OILS ON MYCELIAL GROWTH INHIBITION PERCENT (MGI%) OF B. CINEREA AND P. DIGITATUM UNDER *IN VITRO* CONDITION

	B. cinerea		*P. digitatum*	
Concentration (μL/L)	*C. copticum*	*T. kotschyanus*	*C. copticum*	*T. kotschyanus*
Control (0)	0‡‡	0‡‡	0‡‡	0‡‡
100	43.7††	49.63¶	30.79¶	25.83††
200	76.67‡	71.11§	77.61‡	45.99§
300	100†	100†	100†	100†
400	100†	100†	100†	100†
500	100†	100†	100†	100†

The means followed by same symbol in each column are not significantly different according to Tukey's multiple comparison tests ($P < 0.01$).

to essential oils was more than *B. cinerea*; this agreed with other reports that showed that *Aspergilus flavus* and *A. niger* have different sensitivities to *T. vulgaris* essential oil (Viuda-martos *et al*. 2007).

The antimicrobial activities of several essential oil-bearing plants used today as seasoning agent in foods and beverages have been recognized for centuries. Major components with antimicrobial activity found in plants are phenolic compounds, terpenes, aliphatic alcohols, aldehydes, ketons, acids and isoflavonoids (Farrag *et al*. 1989). It is shown that the essential oils with high levels of eugenol, thymol and carvacrol as phenolic compounds are usually strong antimicrobials. There is overwhelming consensus that aromatic and phenolic compounds exert their antimicrobial effect in the cytoplasmic membrane by altering its structure and function. The loss of the differential permeability character of the cytoplasmic membrane is frequently identified as the cause of cell death (Sikkema *et al*. 1995). The antimicrobial effect of phenolic compounds could be related to their concentrations. At low concentration, phenols affected enzyme activity, especially of those enzymes associated with energy production, and denaturated proteins at higher concentrations (López-malo *et al*. 2006). The concentration of volatile terpens carvacrol (28.54%) in *T. kotschyanus*, thymol (63.18%) and ρ-cymene (21.4%) in *C. copticum* essential oils were high; hence, the result can be that the antifungal activity of *T. kotschyanus* and *C. copticum* essential oils and their capacity on the reduction of fungal disease severity can be related to phenolic components available in essential oil. Also, the antimicrobial activity of these oils can be attributed to the presence of an aromatic nucleus and phenolic OH group that is known to be reactive and to form hydrogen bonds with active sites of target enzymes (Farrag *et al*. 1989).

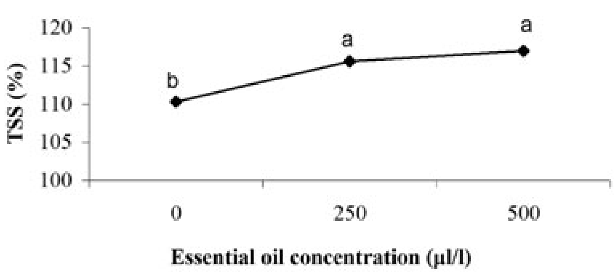

FIG. 2. EFFECTS OF DIFFERENT CONCENTRATION OF ESSENTIAL OILS ON TSS (%) IN BUNCHES OF "RISH BABA" TABLE GRAPE
Means of treatments with the same letter are not significantly different according to Tukey's multiple.

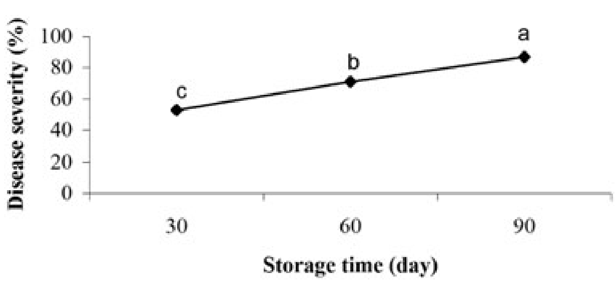

FIG. 3. CHANGES OF DISEASE SEVERITY (%) IN BUNCHES OF "RISH BABA" TABLE GRAPE IN STORAGE PERIOD
Means of treatments with the same letter are not significantly different according to Tukey's multiple comparison tests ($P < 0.05$).

CONCLUSIONS

The results of our study made it clear that the essential oils from *T. kotschyanus* and *C. copticum* have inhibitory effect on the mycelial growth of tested pathogens under *in vitro* and *in vivo* conditions, and essential oils could be used as a new tool to control of postharvest diseases of table grapes, since these essential oils are "generally recognized as safe" products, but further studies are needed to investigate the best essential oils and application method for the treatment of table grapes.

ACKNOWLEDGMENTS

This study was supported by Biotechnology Institute of Urmia University, Urmia, Iran. Project No: 007/z/86

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