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Utilizing Some Essential Oils to Extend the Shelf Life of Rashmiri and Khoshnawaty Grape Cultivars

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Abstract

The incidence of postharvest losses of table grapes causes economic damage along the food chain, especially in developing countries. To increase the shelf life of table grapes (*Vitis vinifera* L.) essential oils (EOs) of some plants (thyme, clove, rosemary, and cinnamon) were selected as packaging material, to coat the 200g of grape that packed in plastic clamshell containers, and estimate their effects on the physicochemical properties and decay incidence of two varieties of grapes (Khoshnawaty and Rashmiri) during cold storage at 4°C with 80–85% relative humidity for 45 days. The results show that in general, all EOs of the plants (thyme, clove, rosemary, and cinnamon) used in this study lead to reducing weight loss, rachis browning, delaying repining and maintaining firmness during storage, as well as maintained their chemical characteristics (pH, solid soluble content and total phenols) beside to reducing decay incidence in treated grapes with EOs compared to the control treatment. Among the EOs types used in this study, EOs of clove were the best in most of the studied parameters, followed by EOs of thyme and cinnamon. In comparison between the two cultivars of grapes used in the current study, the Khoshnawaty variety was more stable to most postharvest parameters (physical, chemical, and decay incidence) compared to the Rashmiri variety.

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Introduction

Grapes (*Vitis vinifera*) are considered one of the top-ranking fruit crops in Iraq. FAO data shows that in 2021, local grape production in Iraq was 427356 tonnes, grapes have high nutritional value due to their rich content of phenolic compounds, including flavonols, anthocyanins, hydroxycinnamic acids, and stilbenes (Ferreira *et al.*, 2016), which display a broad range of physiological properties, including antioxidant, anti-inflammatory, antimicrobial, cardio-protective, and vasodilator effects. However, grapes, as non-climacteric fruits with their thin pericarp and succulent flesh, are highly perishable; hence, 30% of the grape products were lost in the harvest season due to a lack of proper transport and postharvest handling, storage, and marketing. Grapes have a short shelf life due to firmness loss, berry drop, desiccation, discoloration, and fungal decay, resulting in high deterioration, especially during prolonged storage (Li *et al.*, 2023).

Fungi such as *Botrytis cinerea*, *Penicillium expansum*, *Rhizopus stolonifera,* and *Aspergillus niger* can colonize table grapes and cause a specific collection of symptoms inflicted on fruit that are referred to as black, gray, blue, and soft-rot mold, respectively (Sonker *et al*., 2016). To control the deterioration of the grapefruit during cold storage, $SO2$ is the most commonly used method. Despite its benefits in preventing stem browning and controlling decay, however, SO_2 coatings may negatively influence fruit appearance, sensory attributes, and excessive concentrations can interfere with normal respiration and moisture balance, which restricts their application in grape coating (Daniei-Swartiand *et al*, 2024). Moreover, using Chemical fungicides to control post-harvest decay was also restricted, due to the rising public concerns over the health and environmental risks involved with pesticide usage (Guerreiro *et al*., 2016; Hosseini *et al*., 2020). Hence, there is increasing scientific interest in developing alternative preservation strategies such as bio-based edible coatings and natural antimicrobial formulations that may provide more sustainable and consumer-acceptable solutions for maintaining grape quality during storage and distribution. (Guerreiro *et al*., 2016).

Coating with essential oil (EOs) has been developed to extend the shelf life of table grapes. They contain many bioactive compounds that play crucial role in preservation. The active compound of thyme are thymol and carvacrol; clove is eugenol; cinnamon is cinamaldehyde and rosemary are cinoel and camphur. They act as bioactive chemicals that make shield products when coated on fruits. This shield protects fruit by a semi-permeable barrier that inhibits postharvest fungal growth, lowers moisture loss, and improves the quality of food products (Gul *et al*., 2023). Using of natural materials like essential oil (EO) as a natural food-grade preservative is an innovative substitute for synthetic preservatives. EOs are Generally Recognized as Safe (GRAS), (Angane *et al.,* 2022).

To maintain grape quality and reduce gray mold, Elsayed *et al.,* (2022) successfully applied thyme, cinnamon, and oregano EOs on table grapes during cold storage at 2°C for 4 weeks. Whereas Lopes *et al*. (2023) used lemongrass and thyme for the same purpose. EOs can also demonstrate their action through food packaging; they can be combined with packaging material (EO-containing edible films). An active packaging system fortified with clove essential oil was applied by Luesuwan *et al*. (2021) to control fungal growth and improve post-harvest quality of table grapes during cold storage.

The aim of the study was to evaluate the possibility of improving fruit quality, preventing postharvest fungal deterioration, and increasing the shelf life of two cultivars of grapes (Khoshnawaty (white) and Rashmiri (black)) by coating them with essential oils from clove (*Syzygium aromaticum*), rosemary (*Salvia rosmarinus*), cinnamon *(Cinnamomum verum)*, and thyme *(Thymus vulgaris*).

Materials and Methods

1. Sampling

In 30 September 2024, two types of grapes: Khoshnawaty (white) and Rashmiri (black) were gathered from Sitak farms in the Sulaymaniyah Governorate -Iraq, and visually selected based on uniform colour, size, firmness, and the absence of mechanical damage or fungal infection. After washing with distilled water and dried they were distributed into five groups. The first group was used as a control (without any treatment), while the other four groups were immersed for 1 min in 1% solution of essential oils of the four selected plants (clove, rosemary, cinnamon, and thyme). After coating treatments, fruits were hung up, air-dried, and stored in Refrigerator room in Food science and quality control department at 4°C with 80-85% relative humidity. Each treatment contains 200 g of grapes used to evaluate fruit physicochemical properties and decay incidence at different cold storage times (0, 15, 30, and 45 days). All the assays were carried out in triplicate.

2. Physical Tests

2.1. Rachis Browning: Rachis browning was conducted according to Lichter *et al.* (2011), based on a 1–4 numerical scale which comprised four categories: healthy(0), slight (1 or 25%), moderate (2 or 50%), severe (3 or 75%), and completely browning (4 or 100%). A healthy rachis is defined as completely green; stem caps are brown in the slight category; in moderate browning, some of the lateral branches are affected, and with severe browning, the primary rachis is also affected, and the rachis is completely brown (100%) at the last degree of scale.

2.2.Weight Loss Percentages: To measure the percentage of weight loss, the initial weight at the harvest (zero time) was measured, and at the end of each storage period. Weight loss was expressed as a:

$$\text{Weight loss (\%)} = W0 - Wt / W0 \times 100$$

which W0: initial berry weight, *Wt*: weight at time (He *et al*., 2024).

2.3. Fruit Firmness: Randomly, 10 berry samples were chosen, and firmness was determined according to Sánchez-González *et al*. (2011) by measuring force at break (N) using a texture analyzer (CT3 Texture Analyzer, Brookfield-Ametek). The instrument was set to 500g trigger load and a 3.0 mm depth with a speed of 3.0 mm/ second. The firmness was expressed in Newtons (N). All parameters were determined at the beginning and at the end of the shelf life study were achived at College of Agriculture Engineering Scinces .

3. Chemical Tests

3.1. Effects of Essential Oils (EOs) on the pH of Grape Samples: It was measured by a pH meter (Testo 206, UK), which was calibrated with pH 4.0, 7.0, and 10.0.

3.2. The Total Soluble Solid Content (SSC): The SSC of grape juice was obtained using a refractometer (HANNA model HI96801, UK). After calibrating the instrument with distilled water, a few drops of the extracted solution were poured onto the glass plate, and the Brix refractometer was read.

3.3. Total Phenol: Total phenol (mg/100g) was performed according to Ranganna (2011) by taking 5 ml juice a vial and adding 25 ml ethanolic HCl (95% ethanol: 1.5 N HCl by 85:15) and store it for overnight at 4 °C. Then it filtered with watt man No. 1 and measured absorbance at 280 and 535 nm (UV-VIS spectrophotometer, Jenway-7205, UK) for total phenol.

4. Decay Incidence

Decay incidence of molds in grapes is a standard postharvest quality parameter, which is estimated by the percentage of infected berries (mold infection %) and microbial count, which is estimated by Fungal load measurement (CFU/g), which was conducted by the traditional plate method using potato dextrose agar at 25 °C for 5 days according to Batta (2006).

Statistical analysis

XLSTAT statistical analysis software (version 2019.2.2.59614) was used to analyze the data. Berry grape quality and phytochemical content data were subjected to a one-way analysis of variance. The impact of post-harvest storage was assessed using the same methodology. Three replicates were used for each measurement, which were given as mean values ± standard deviations. Data were subjected to a one-way (or two-way) analysis of variance (ANOVA) using where significant differences were found ($p<0.05$), mean comparisons were performed using Duncan's Multiple Range Test to separate the means.

Result and Discussion

1. The effect of EOs on Physical properties

1.1. Rachis Browning

In terms of visual appearance, the main effect of the different storage treatments was observed in rachis browning. Rachis browning was observed on the Rashmiri variety after one week**,** while the rachis stayed green in the Khoshnawaty variety for more than 10 days after storage (Table 1). This may relate to the genetic differences between the two cultivars that effect chlorophyll content. In the current study, all EOs treatments reduced rachis browning in comparison with the control; among them, clove and cinnamon coating treatments were the most effective in improving rachis quality during table grape postharvest. Other studies also showed the effects of EOs in reduced rachis browning (El-Abbasy *et al*., 2023; Lippi *et al.,* 2025). Rachis browning is considered the second most important postharvest problem of table grapes, after decay, since a green rachis is an indication of freshness, and hence, a brown rachis can be a major cause of consumer rejection and eventually fruit waste. The main reason for rachis browning is dehydration, because they do not have epidermis shield protection layers that usually protect berries from dryness (Lichter, 2006). Hence, preventing dehydration is an obvious target that is currently undertaken during storage as a part of rachis browning management, as well as reducing respiration and blocking the ethylene pathway appear to be promising approaches in this management. Using EOs coating reduces rachis browning through reducing the activity of polyphenol oxidase enzyme. Since there is a direct relationship between polyphenol oxidase enzyme activity and rachis browning in grapes. Inhibition or reduction of this enzyme activity, which is done by EOs, is a key strategy for reducing the browning of the grape rachis (Kaur *et al*., 2019). Some active compounds in the thymol and carvacrol for example have ability to intercat with active sites and decline the activity of PPO enzyme (El-Abassy *et al.,* 2026). Beside to this, EOs roles as antioxidant scavenging characters thet have ability to scavenging reactive oxygen (Romero *et al.,* 2022). Hence, it is necessary to maintain postharvest rachis quality by delaying the degradation of green pigments and the accumulation of brown compounds at the periderm and cortex tissues.

1.2. Water Loss or Shriveling

In the study, the weight loss of both grape varieties (Rashmiri and Khoshnawaty) increased significantly with increasing storage time (45-days); however, water loss in the Rashmiri variety was more than that of the Khoshnawaty cultivar (Table 1). The data shows that Rashmiri lost more weight than Khoshnawaty, it is likely because Rashmiri has a higher surface-area-to-volume ratio or a more permeable cuticle structure (Lara *et al*., 2014). Weight loss is an important determinant of postharvest life and fruit quality, since most fruits lose weight during storage owing to respiration and transpiration processes, which cause grape shriveling (Aloui *et al*., 2014). Variations in weight loss rates between cultivars are often attributed to the thickness of the cuticle, epidermis, and hypodermis, cultivars with a thicker, more robust cuticle layer typically exhibit lower dehydration rates as the cuticle serves as the primary barrier to water movement.Conversely, Khoshnawaty's superior weight retention might be linked to a more complex wax crystalline structure or thicker hypodermal cell layers that provide better mechanical resistance to moisture loss (Brizzolara *et al*., 2020). Regarding EOs treatments, all of them (clove, thyme, rosemary, and cinnamon) significantly up to 30 days of storage, then weight loss closely doubled in the last 15 days of storage. Among the EOs treatments used, clove oil was more efficient in reducing weight loss, followed by thyme. For grape preservation during cold storage with an effective control of water losses, Aloui *et al.* (2014) used grapefruit essential oil, and Gul *et al*. (2023) used lavender essential oil combined with sodium alginate, whereas Nano capsules containing EOs of *Thymus vulgaris* were applied by Piña-Barrera *et al*. (2019) for the same purpose. EOs are also used in reducing water loss and shriveling of other fruit, such as strawberries, as reported by Hosseini *et al.* (2020). This is due to the coating acting as a barrier, which reduces the transpiration and the respiration rate (metabolism) of fruits and subsequently increases their shelf life. EOs also form a hydrophobic cover on fruits and lower the dehydration process (Krishnan *et al.,* 2025). The utilized EOs layer likely decreased the permeability of the fruit epiderm tissue to water vapor, causing rise resistance to water transfer and as a result lower weight loss (Adhikary *et al.,* 2020) Recent advances in packaging and edible coating for shelf life enhancement in fruit crops.

1.3. Grape Firmness

The results in Table 1 show significant differences ($p<0.05$) between the effects of the four kinds of EOs used in this study on the firmness of the two cultivars of grape berry samples during cold storage for 45 days. All coating treatments used in this study were able to reduce the loss of grape firmness during cold storage; among them, Eo of thyme treatment had more firmness, followed by Eo of clove treatment. Grapes treated with Eo of thyme in the study of Dehestani-Ardakani and Mostofi (2019) also had more firmness than untreated ones. Using oregano and thyme EOs also reduces the loss of grape firmness during cold storage in the study of El-Abbasy *et al*. (2023). When water loss decreases in a sample, its firmness increases and vice versa. High water content in grapes increases the expansion pressure of the cells and rigidity of the fruit, and consequently increases their resistance to pressure. During storage, pectin in grapes, which is closely associated with the cell wall cellulose, is transformed into pectic acid by the action of pectinases and depolymerization from the cell wall; the texture becomes soft. If the transformation goes on to the stage of pectic acid formation, the texture would become softer, and the fruit would rot and lose its edible and commercial value. This may be considered as a factor that can makes sharp decrease in texture properties. Pressure resistance increased when the degree of maturity decreased (Defilippi *et al*., 2018).

Table 1. The variation of the effect of eos on physical properties (rach browning, weight loss%, and firmness) of grapes during cold storage

Treatment	Period (days)	Rach Browning (%)		Weight Loss (%)		Firmness (gm/cm^2)	
		Khoshnawaty	Rashmiri	Khoshnawaty	Rashmiri	Khoshnawaty	Rashmiri
Control	0	0.000^{e}	0.000^{e}	0.000^{p}	0.000^{p}	1369.400^{hijk}	792.600^{q}
	15	2.000^{c}	3.000^{b}	3.458^{l}	4.067^{jk}	1346.067^{k}	749.500^{st}
	30	4.000^{a}	4.000^{a}	6.492^{g}	7.507^{e}	1283.500^{l}	699.500^{v}
	45	4.000^{a}	4.000^{a}	8.708^{c}	10.205^{a}	1231.500^{m}	653.700^{w}

Cinnamon	0	0.000 e	0.000 e	0.000 p	0.000 p	1459.500 ab	779.333 qr
	15	0.000 e	2.000 c	2.896 m	2.138 o	1433.633 cd	765.333 rs
	30	2.000 c	3.000 b	3.610 l	3.804 kl	1424.533 cd	748.167 st
	45	3.000 b	4.000 a	7.526 e	9.247 b	1393.500 fgh	719.333 uv
Clove	0	0.000 e	0.000 e	0.000 p	0.000 p	1415.500 def	782.500 qr
	15	0.000 e	2.000 c	2.011 o	2.594 mn	1387.300 ghi	762.167 rs
	30	2.000 c	3.000 b	4.394 ij	3.411 l	1378.200 ghij	745.000 st
	45	3.000 b	4.000 a	7.611 e	6.839 fg	1358.700 jk	732.800 tu
Rosemary	0	0.000 e	0.000 e	0.000 p	0.000 p	1448.600 bc	882.333 n
	15	0.000 e	2.000 c	2.396 no	2.304 no	1426.500 cd	835.433 o
	30	3.000 b	4.000 a	4.095 jk	4.212 jk	1398.800 efg	818.000 op
	45	4.333 a	4.000 a	7.302 e	8.204 d	1366.600 ijk	766.167 rs
Thyme	0	0.000 e	0.000 e	0.000 p	0.000 p	1475.533 a	801.433 pq
	15	0.000 e	1.000 d	2.421 no	2.204 no	1448.500 bc	791.100 q
	30	3.000 b	3.000 b	4.714 i	5.895 h	1433.500 cd	794.667 pq
	45	4.000 a	4.000 a	7.212 ef	7.607 e	1418.500 de	745.333 st

**Note.* Values are expressed as means of three replicates (n = 3). a–^w Means within each column followed by different letters are significantly different based on Duncan's Multiple Range Test at the 5% probability level ($p < 0.05$).

2. The Effect of EOs on Chemical Properties

2.1. Grape pH

Table 2 shows the effect of coating four kinds of EOs that were used in this study on the chemical properties of the two cultivars (Rashmiri and Khoshnawaty) of grape samples during cold storage for 45 days. In general, pH of the samples decreses during cold storage in both cultivars. However, grapes treated with EOs reduced the decline in their pH compered to control. Among the selected EOs, clove and thyme used in the current study maintained acidity better than the other treatments in both study varieties. These results were close to the results of Divyashri *et al*. (2024), who state that coated grapes with Clove oil maintain acidity better than the other EOs treatments. Abd El-Khalek *et al.* (2023) also reported limited adverse change in pH during cold storage after thyme oil application. Coatings with clove EOs preserved physicochemical quality, including limiting pH drift in the study of Lakshan *et al*. (2024). Hence, EOs coating grapes *helps maintain acidity* and pH without large pH drift compared to untreated berries. Moreover, EOs can slow respiration besides their effect on organic-acid metabolism, which influences pH behavior. The effects of coating grapes with EOs on the pH can vary, depending on the type of EOs concentration, grape variety, and the method used in their application (Tovar *et al*., 2018).

2.2. Soluble Solid Content (SSC) of Grapes

In the current study, the SSC values (Table 2) in EOs coating treatments slightly increased in both cultivars (Rashmiri and Khoshnawaty) during storage; the increase in SSC was slower and less than that of the untreated grape (control treatment). EOs of clove had the highest effect in reducing the difference between the level of SCC at the beginning and end of storage time (19.55 to 20.50) °Brix compared to untreated samples (13 .85 to 16 .88) °Brix. These results are close to the study of Ceylan and Ünlü (2023), who found that Sage EOs treatment delayed the increase in SSC during storage. Divyashri *et al*. (2024) also found that coating with clove essential oil had a moderated SSC accumulation during storage, as the increase in SSC was slower than in uncoated grapes. In general ripening process lead to increasing SSC level in fruit during storage due to the metabolic activity continues as a result of fruit ripening, which leads to converting of insoluble compounds to soluble forms such as carbohydrates and organic acids (Guerreiro *et al*., 2016), or conversion of sucrose in grapes into glucose and fructose (Kambiranda *et al*., 2014). EOs coating treatments may slow SSC accumulation more than control, because EOs reduce respiration, delay ripening, and limit water loss, which in turn affects the SSC concentration and increase it.

2.3. Total Phenols

Table 2 shows that coatings with EOs have been reported to significant decrease ($p<0.05$) total phenols in the two selected grape cultivar in this study. These results are close to other studies (Šuput *et al*., 2023), which show a reduction in total phenol content during storage, which might be due to the formation of a semi-permeable barrier by Eo coating, reducing transpiration, thereby alleviating dehydration and oxidative stress, which led to decline of the berry's endogenous stress-induced synthesis of phenolic compounds. Total phenols are also reduce due to polyphenol oxidase enzyme activity, which can oxidize phenols over time (Šuput *et al.*, 2023), or the coating is not fully impermeable to gases, and some O_2 can penetrate and lead to oxidation of phenols. Moreover, longer storage time (45 days in this study) and higher temperatures can lead to phenolic loss. The difference in the effect of these EOs treatments on the total phenols in these cultivars of grapes during storage is due to the type of interaction between phenols and the substances present in EOs. The main phenolic constituents are: Eugenol in clove oil, carnosic acid and carnosol in rosemary oil, cinnamaldehyde in cinnamon oil, and thymol and carvacrol in thyme oil are considered the major bioactive compounds. The affinity between them may lead to the migration of phenolic molecules from the grape skin into the coating matrix, leading to EOs interacting chemically with these phenols, resulting in low levels of phenolic compounds in grape berries. However, EOs coatings may cause an increase in phenolic content in some studies (Rguez *et al*., 2025) by reducing oxygen diffusion and lowering the activity of polyphenol oxidase, which helps preserve phenolic stability during storage. Hence, the net effect of EOs coatings on total phenols depends strongly on the coating composition, the grape cultivar, and the storage conditions (temperature, time).

Table 2. Average Variation in pH, Soluble Solid Percentage, and Total Phenols of Grapes Treated with Volatile Oil Coatings Post -Harvest (n = 3)

Treatment	Period (day)	pH		SSC (°Brix)		T. Phenol (mg/100 gm)	
		Khoshnawaty	Rashmiri	Khoshnawaty	Rashmiri	Khoshnawaty	Rashmiri
Control	0	3.840 g	3.910 d	13.400 opq	19.900 fgh	210.148 f	293.553 b
	15	3.810 ij	3.880 ef	14.300 n	20.067 efg	169.690 h	196.557 g
	30	3.780 k	3.840 g	15.200 l	20.500 cde	100.426 l	171.653 h
	45	3.610 v	3.620 v	16.567 k	22.300 a	77.774 n	159.084 hij
Cinnamon	0	3.890 e	3.870 f	12.800 s	19.200 ij	210.148 f	310.207 a
	15	3.800 j	3.830 gh	13.367 pq	19.600 hij	144.419 k	204.125 fg
	30	3.760 l	3.820 hi	14.633 mn	19.867 fgh	89.427 lmn	144.550 k
	45	3.720 n	3.673 rst	15.200 l	20.700 bc	37.840 o	93.094 lm
Clove	0	3.970 ab	3.910 d	13.700 op	19.167 j	210.148 f	305.898 ab
	15	3.940 c	3.880 ef	13.100 qrs	19.633 ghi	148.086 jk	250.328 d
	30	3.910 d	3.830 gh	13.700 op	19.867 fgh	86.285 mn	194.479 g
	45	3.883 ef	3.803 ij	14.500 mn	20.500 cde	48.969 o	140.099 k

Rosemary	0	3.980 ^{a}	3.780 ^{k}	12.767 ^{s}	19.300 ^{ij}	210.148 ^{f}	301.588 ^{ab}
	15	3.960 ^{b}	3.740 ^{m}	13.400 ^{opq}	20.200 ^{def}	139.706 ^{k}	251.694 ^{d}
	30	3.920 ^{d}	3.707 ^{nop}	13.833 ^{o}	20.600 ^{cd}	94.534 ^{lm}	226.815 ^{e}
	45	3.670 st	3.690 ^{pqr}	14.900 ^{lm}	21.100 ^{b}	82.095 ^{mn}	162.619 ^{hi}
Thyme	0	3.780 ^{k}	3.710 ^{no}	12.267 ^{t}	19.200 ^{ij}	210.148 ^{f}	296.695 ^{b}
	15	3.710 ^{no}	3.683 ^{qrs}	12.900 ^{rs}	19.500 ^{hij}	139.444 ^{k}	275.298 ^{c}
	30	3.700 ^{opq}	3.670 st	13.267 ^{pqr}	19.867 ^{fgh}	94.796 ^{lm}	151.146 ^{ijk}
	45	3.660 ^{t}	3.640 ^{u}	13.833 ^{o}	20.200 ^{def}	43.863 ^{o}	145.467 ^{k}

*SSC: Soluble Solid Content, T. Phenol = Total Phenolic.
Values are expressed as means of three replicates (n = 3). a–^v Means within the same column followed by different lowercase letters are significantly different ($p < 0.05$) according to Duncan's Multiple Range Test.

2.4. Decay Incidence of Molds

In the present study, the decay incidence and mold count (Table 3) in all EOs treated grape was significantly ($p < 0.05$) lower than that of the control group, specifically, during the first 30 days of storage. The EOs maintained lower pH stability which likely contributed to a more resilient defense against mold. While the control group showed a sharp increase in mold infection (23.505%and 31.317%) and mold count (2640.000 cfu/gm and 19033.333 cfu/gm) in Khoshnawaty and Rashmiri respectivly by day 45. The differences between the various EOs treatments (Cinnamon, Clove, Rosemary, and Thyme) remained statistically marginal, indicating that all four EOs were similarly effective at suppressing decay during the mid-storage phase. Among them, EOs of cinnamon and thyme treatments had suppress decay in both cultivars (Rashmiri and Khoshnawaty). These results are close to previous studies (Divyashri *et al*., 2024; Luesuwan *et al*., 2021), who found that EOs of clove (Eugenol-rich) reduce decay in grapes stored at 4 °C. Kontaxakis *et al*. (2020) used EOs of oregano, thyme, and savory, that rich in carvacrol and thymol, to protect the grape berries from fungi attack. The severity area of infection per berryof the gray mold also showed a tendency to a reduction with the EOs of rosemary and mint (Gabal *et al*., 2019) and Cinnamon that is rich in cinnamaldehyde (Sukatta *et al*., 2008).

Table 3. Average Variation of the Mold Infection% and Mold and Yeast (cfu/gm) of Grapes Treated with Volatile Oil Coatings with Post-Harvest Treatments

Treatment	Period (day)	Mold Infection (%)		Mold count (cfu/gm)	
		Khoshnawaty	Rashmiri	khoshnawaty	Rashmiri
Control	0	0.000 ^{n}	0.000 ^{n}	23.333 ^{b}	16.667 b
	15	0.000 ^{n}	1.862 ^{m}	132.667 ^{b}	33.667 ^{b}
	30	18.194 ^{c}	6.800 ^{j}	1600.000 ^{b}	223.333 ^{b}
	45	23.505 ^{b}	31.317 ^{a}	2640.000 ^{a}	19033.333 ^{a}
Cinnamon	0	0.000 ^{n}	0.000 ^{n}	0.000 ^{b}	0.000 ^{b}
	15	0.000 ^{n}	0.000 ^{n}	10.000 ^{b}	13.000 ^{b}
	30	0.000 ^{n}	0.000 ^{n}	13.333 ^{b}	433.333 ^{b}
	45	7.473 ^{i}	11.200 ^{f}	23.333 ^{b}	846.667 ^{b}
Clove	0	0.000 ^{n}	0.000 ^{n}	0.000 ^{b}	3.333 ^{b}
	15	0.000 ^{n}	1.467 ^{m}	3.333 ^{b}	3.333 ^{b}
	30	0.000 ^{n}	2.394 ^{l}	6.667 ^{b}	10.000 ^{b}
	45	12.107 ^{e}	13.186 ^{d}	13.333 ^{b}	470.000 ^{b}

Rosemary	0	0.000 ^{n}	0.000 ^{n}	0.000 ^{b}	0.000 ^{b}
	15	0.000 ^{n}	0.000 ^{n}	6.667 ^{b}	3.333 ^{b}
	30	0.000 ^{n}	2.413 ^{l}	76.667 ^{b}	33.333 ^{b}
	45	9.692 ^{g}	11.297 ^{f}	25.000 ^{b}	823.333 ^{b}
Thyme	0	0.000 ^{n}	0.000 ^{n}	3.333 ^{b}	0.000 ^{b}
	15	0.000 ^{n}	0.000 ^{n}	23.333 ^{b}	3.333 ^{b}
	30	6.107 ^{k}	2.413 ^{l}	73.333 ^{b}	6.667 ^{b}
	45	8.000 ^{h}	6.283 ^{k}	120.000 ^{b}	13.333 ^{b}

* a–^n Means within the same column followed by different lowercase letters are significantly different ($p < 0.05$) according to Duncan's Multiple Range Test.

The findings suggest that EOs play an important role in plant defense mechanism against pathogenic microorganisms including fungi. They offer a promising natural alternative to synthetic fungicides for mitigating postharvest decay of table grapes during cold storage. EOs dissolve into the lipid layers of fungal membranes, which disrupt fungal cell membranes. EOs also inhibit spore germination by blocking the enzymes required for fungal spores to germinate. Since EOs are volatile, their vapors inhibit fungal development, also impair the metabolic functions of key pathogens, e.g., *Botrytis cinerea*, *Alternaria spp*, Penicillium spp, and *Aspergillus carbonarius* (Kontaxakis *et al*., 2020). Moreover, EOs create a semi-permeable barrier that reduces water loss and gas exchange, thereby physically blocking pathogens from contacting the berry surface (Luesuwan *et al*., 2021). They also may enhance the antioxidant capacity of the grape through their bioactive compounds, such as thymol, carvacrol, and eugenol, reducing oxidative stress and reinforcing cell wall integrity, preserving firmness, which makes the fruit less vulnerable to fungal attack. EOs components also suppress the enzyme produced by fungi and senescing fruit tissues (Polygalacturonase, Pectin methylesterase, and Cellulase) by binding to their active sites may inhibit enzyme activity and preserving the skin, that led to reduced pathogen entry points.

Conclusions

According to the obtained results, coating grapes with EOs of thyme, clove, rosemary, and cinnamon maintains the overall qualities of the treated fruit. The selected EOs lead to reducing weight loss or shriveling, rachis browning, delaying ripening, and maintaining firmness during storage, as well as maintaining their chemical characteristics (pH, SSC, and Total phenols) for a longer time than those of the control treatment. Additionally, reducing decay incidence in the treated grapes with EOs provides antifungal activity against mold growth on the table grapes. Among the types that were used in this study, the EOs of clove were the best in most of the studied parameters due the major active compounds including eugenol and thymol which provides both antimicrobial and antioxidant activities it s protective barrier effects. Based on these results, it can be concluded that the application of the EOS on the surface of the grape was effective in maintaining the postharvest quality and extending the shelf life of grapes.

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Conflict of interests

The authors declare that they have no conflict of interest.

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Author Contribution

First author writes the original draft, second, fourth, sixth, and seventh author, conceptualization, software, methodology, and third author, editing, writing, data Curation, and the fifth author, investigation, validation, writing–review the manuscript. All authors read and agree to the submission of the manuscript to the journal.

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