

ESSENTIAL OILS: AN ALTERNATIVE FOR REDUCING POST-HARVEST LOSSES OF FRESH BELL PEPPER

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ABSTRACT

Bell pepper is an important and nutritious vegetable worldwide. However, due to its high-water content and thin skin layer, its shelf life is short. This study was conducted to evaluate the effectiveness of three essential oils (rosemary, thyme, and lemon grass) as a postharvest treatment on the shelf-life of bell pepper fruits stored for 35 days at 8±1 °C. The findings demonstrated that thyme oil and rosemary oil treatments were the most effective in decreasing weight loss, decay, total yeast and mold counts, and preserving antioxidant capacity. Additionally, thyme oil treatment exhibited the highest antiradical scavenging activity and total phenolic compounds compared to other treatments. Lemon grass oil was the most effective treatment in preserving vitamin C and reducing the respiration rate. Thyme and rosemary treatments were superior in preserving antioxidant capacity in bell pepper fruits. In conclusion, rosemary, thyme, and lemon grass oils could be alternative applications to minimize microbial growth in bell pepper fruits during cold storage.

Additional keywords: *Capsicum annuum*, essential oils, postharvest, quality, shelf-life, storage ability

RESUMEN

Aceites esenciales: una alternativa para reducir las pérdidas postcosecha del pimiento fresco

El pimiento morrón es una hortaliza importante y nutritiva a nivel mundial. Sin embargo, debido a su alto contenido de agua y a su fina capa de piel, su vida útil es corta. Este estudio se realizó para evaluar la eficacia de tres aceites esenciales (romero, tomillo y limoncillo) como tratamiento postcosecha para la vida útil de pimientos almacenados durante 35 días a 8±1 °C. Los resultados demostraron que los tratamientos con aceite de tomillo y romero fueron los más eficaces para reducir la pérdida de peso, la descomposición, el recuento total de levaduras y mohos, y para preservar la capacidad antioxidante. Además, el tratamiento con aceite de tomillo mostró la mayor actividad antirradical y el mayor contenido de compuestos fenólicos totales en comparación con otros tratamientos. El aceite de limoncillo fue el tratamiento más eficaz para conservar la vitamina C y reducir la tasa de respiración. Los tratamientos con tomillo y romero fueron superiores en la conservación de la capacidad antioxidante de los pimientos. En conclusión, la aplicación de los aceites de romero, tomillo y limoncillo podrían ser alternativas viables para minimizar el crecimiento microbiano en los pimientos morrones durante el almacenamiento en frío.

Palabras clave adicionales: Aceites esenciales, calidad, capacidad de almacenamiento, *Capsicum annuum*, poscosecha, vida útil

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INTRODUCTION

As a member of the *Solanaceae* family, the bell pepper (*Capsicum annuum* L.) is considered one of the most widely consumed commercial vegetables globally, and its production is expanding worldwide, particularly in warm climate regions. Bell peppers are rich in bioactive

components, including vitamins, phenolics, and flavonoids (Ahamad *et al.*, 2024).

Bell peppers, on the other hand, are particularly susceptible to phytopathogens and exhibit a limited shelf life due to their elevated respiratory rate and high-water loss (Smith *et al.*, 2006). The shelf life of bell peppers is limited by rapid weight loss, shriveling, discoloration, and

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loss of glossiness. Various research efforts have been undertaken to extend the shelf life of bell peppers, exploring methods such as UV-C treatment, putrescine, spermidine, methyl jasmonate, calcium chloride, and melatonin (Wang *et al.*, 2018; Patel *et al.*, 2019; Castillejo *et al.*, 2022; Ma *et al.*, 2023). For many years, synthetic chemical fungicides, including thiabendazole, have been used to prevent or reduce fungal growth. Thiabendazole is frequently applied to harvested fruit through dipping or spraying. However, the presence of traces of this fungicide in fruit has been linked to liver injury and disturbances in thyroid hormone balance (López *et al.*, 2024). As a result, it is imperative to employ natural and harmless alternatives to combat phytopathology.

Essential oils serve a crucial function in safeguarding vegetables and fruits, as they possess insecticidal and antimicrobial properties (Ding and Lee, 2019). Essential oils have the potential to act as fumigants, suppressing postharvest decay and mold in fruits and grain crops due to their bioactivity in the vapor phase (Perumal *et al.*, 2017). One of the most important medicinal plants in the *Poaceae* family is lemon grass (*Cymbopogon citratus*), which is well-known for its effective antibacterial and insecticidal capabilities (Tawfeek *et al.*, 2021). Thyme essential oil and its chemical components, including thymol and carvacrol, have been documented to exhibit significant antifungal activity among plant oils (Abbaszadeh *et al.*, 2014). Additionally, rosemary (*Rosmarinus officinalis* L.) has been shown to inhibit various bacteria that contaminate vegetables (de Sousa *et al.*, 2012). This investigation aimed to assess the impact of thyme, rosemary, and lemon grass essential oils on the shelf life and quality of sweet peppers.

MATERIALS AND METHODS

Fruit samples. Fruits of *Capsicum annuum* L. (sweet pepper), variety Lirica RZ were harvested at 3/4 yellow color stage, from a private farm at El-Aiat district, Giza Governorate, Egypt and transported during one hour to the postharvest laboratory. Fruits with high quality (free from disorder, diseases, and insect infection) were kept for 35 days at 8 ± 1 °C and 95 % RH.

Gas chromatography-mass spectrometry

analysis (GC-MS). The GC-MS system (Agilent Technologies) outfitted with mass spectrometer detector (5977A) (Shimadzu, Kyoto, Japan) and gas chromatography (7890B) was utilized to evaluate the chemical compositions of the rosemary, thyme, and lemon grass. Hexane was used to dilute the samples (1:19, v/v). An HP-5MS column with dimensions of 30 m, 0.25 mm internal diameter, and 0.25 mm film thickness was installed in the GC. Helium was employed as the carrier gas in the analyses, with a flow rate of $1.0 \text{ mL}\cdot\text{min}^{-1}$, a split ratio of 1:10, an injection volume of 1 L, and the temperature program listed below 40 °C for one minute, increasing at $4^\circ\text{C}\cdot\text{min}^{-1}$ to 150 °C and holding for six minutes, and then increasing at $4^\circ\text{C}\cdot\text{min}^{-1}$ to 210 °C and holding for five minutes. Detector and Injector temperatures were maintained at 220 °C and 280 °C, correspondingly. Utilizing electron ionization (EI) at 70 eV, mass spectra were generated within an m/z range of 40–550, with a 3-minute solvent delay. Many components were identified by contrasting the spectrum fragmentation pattern with those found in NIST and Wiley Mass Spectral databases.

Free radical scavenging activity of essential oils utilizing DPPH. The free radical scavenging activity of the rosemary, thyme, and lemon grass essentials oils (acquired from La Vie Aromatherapy Company, 6th of October, City, Egypt), against 2,2-diphenyl-1-Picrylhydrazyl (DPPH) was measured following the approach of Awad *et al.* (2021). Essential oils EOs samples were first diluted in methanol ($50 \mu\text{L}\cdot\text{L}^{-1}$) before combined with a 4 mL DPPH solution (0.24 % in methanol). The control sample was created by combining an equal volume of methanol and DPPH solution. After thoroughly blending the mixture and allowing it to sit at ambient temperature in the dark for 30 minutes, the absorbance at 520 nm was established utilizing a spectrophotometer (UV-2401 PC, Shimadzu, Milan, Italy). The following equation determined each essential oil's capacity to scavenge free radicals.

Free radical scavenging (%) = $((A \text{ control} - A \text{ sample})/A \text{ control}) \times 100$

Where: A sample = absorbance of essential oil sample, and A control = absorbance of the control sample.

Emulsions preparation. The emulsion

solutions were prepared adhering to the methodology described previously (Rojas *et al.*, 2007). The essential oils were diluted in distilled water with 1 % (v/v) of either rosemary, thyme, or lemon grass before being emulsified with tween80 as an emulsifier (10 % of the volume of the essential oil).

Application of emulsions to sweet pepper fruits. Sorted sweet pepper fruits first washed with distilled water and air dried at room temperature. The fruits were immersed in the corresponding treatments for five min: T1= control (distilled water); T2 = rosemary essential oil emulsion (1 %); T3= thyme essential oil emulsion (1 %); and T4= lemon grass essential oil emulsion (1 %). During the immersion, the fruits were carefully agitated to promote uniform coating. After that, the fruits were dried for one hour in a sterile room (Laminar Flow Hood) to facilitate coating stabilization. Following the emulsion procedure, the fruits from each treatment that had been coated, were similarly packaged into carton boxes packages (37×27×10 cm) and kept for 35 days at 8±1 °C and 95 % RH. Fifty four fruits from every treatment were randomly picked and examined after 0, 7, 14, 21, 28, and 35 days of storage to assess changes in microbial count and physicochemical characteristics of the treated fruits. Addition to, six fruits were stored individually to measure weight loss%. The zero day transpires 12 hours post-treatment. The entire set of experiment was conducted twice, the research was conducted using a completely randomized design with six replications.

Physical parameters of sweet pepper

Weight loss and decay. Six fruits of every treatment and replication were individually tagged and weighed before storage, as well as on each sampling day during the storage period (7, 14, 21, 28, and 35 days), and the weight loss percentage was calculated. To calculate decay, nine sweet pepper fruits were visually inspected for deterioration from each treatment at each storage period. Mycelia development, obvious lesions, brown patches, and weakening of fruits were all regarded as signs of deterioration.

Respiration Rate. The fruits were kept in a glass jar 1470 ml and the jars were hermetically sealed for two hours. Three replications of each treatment (three fruits) were used to record the fruits respiration rates. The respiration rate was

measured as the ratio of carbon dioxide to oxygen by employing a carbon dioxide and oxygen analyzer (Model 902P, Quantek Instruments, Grafton, MA, USA) outfitted with an oxygen/carbon dioxide sensor PS-2110.

Fruit firmness and total soluble solid (TSS). Using force gauge with an 8 mm diameter cylindrical probe (model M4-200, MARK, Copiague, NY, USA), the firmness of sweet pepper fruits was evaluated for each treatment. The sample was manually squeezed to obtain juice after being crushed in a mortar. TSS in fruit juices from various treatments were measured utilizing a digital refractometer (model PR101, Co. Ltd., Tokyo, Japan).

Ascorbic acid and total phenolic compounds. Ascorbic acid content was assessed by titration technique. Ninety milliliters of 3 % oxalic acid (Nice Chemical LTD, Kerala, India) were used to homogenize 10 g of fruit tissue; after that, the samples were filtered utilizing Whatman paper (12 cm), the solution was titrated by using 2, 6-dichlorophenol indophenol (Qualikems, Gujarat, India), and it was implemented a modified Folin technique to assess the phenolic content of fruits (Ali *et al.*, 2024).

Antioxidant activity. The antioxidant activity of pepper fruit was assessed employing the modified methods of Ali *et al.* (2024). The fruit samples, weighing 6 g, underwent homogenization in 75 ml of methanol (80 %). The homogenized mixture was subsequently filtered utilizing a Whatman No.1 filter. A volume of 0.1 ml filtrate was mixed with 3.9 ml of a 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution at a concentration of 2.4 mg per 100 ml of methanol. Absorbance was determined at a wavelength of 520 nm.

Polyphenol oxidase analysis (PPO). The activity was measured utilizing a spectrophotometer and catechol (0.2 mm·L⁻¹) as a substrate. The increase of 0.001 per minute in absorbance at 420 nm for the reaction mixture at pH 7 and 25 °C is equal to one unit. mg⁻¹.min⁻¹ (Gawlik *et al.*, 2007).

Biological evaluation. These analyses were carried out twice for the count of total count of bacteria and molds & yeast. In each treatment, ten-fold serial dilutions were made. In order to establish the total number of bacteria and mold & yeast, at 35 and 28 °C using Nutrient Agar and Potato Dextrose Agar (PDA), respectively

(Eni *et al.*, 2010).

Statistical analysis. The experiment was statistically analyzed using the M. Stat program (Version 2.1, East Lansing, MI, USA) through a two-way analysis of variance (ANOVA) to examine the essential oils treatments and storage periods. LSD test was applied for mean separation at a 95 % confidence level. The findings were presented as means \pm standard error. SPSS software (version 14, Chicago, IL, USA) was utilized to perform Pearson correlation.

RESULTS AND DISCUSSION

Several compounds were identified in the three types of essential oils (rosemary, thyme, and lemon grass) (Table 1). In thyme oil, thymol was identified as the main component (45 %), followed by Alpha-terpinene (30.05 %) and paracymene (8.37 %). These outcomes are aligned with the studies of Abdolhossein *et al.* (2000), who demonstrated that the essential oil of thymus identified the following main components: p-Cymene (8.41 %), γ -Terpinene (30.90 %) and Thymol (47.59 %). Moreover, the predominant compounds found in lemon grass oil were geranial (40.32 %), followed by neral (39.05 %). These results are in line with Tzortzakis and Economakis, (2007), who reported that the Geranial and Neral are typically the dominant compounds (70–80 % of total oil). Meanwhile, rosemary oil contains 1,8-Cineole (38.32 %), alpha-pinene (12.22 %), camphor (12.15 %), and beta-pinene (8.95 %) as predominant compounds. The findings of Jiang *et al.* (2011) support the composition of rosemary oil, who identified the compounds found in it as 1,8-Cineole (26.54 %), α -Pinene (20.14 %) and Camphor (7.21 %), correspondingly.

Essential oils antiradical scavenging activity

The findings, Figure 1, indicate that thyme essential oil had the highest antiradical scavenging (78.7 %) compared to rosemary (55.0 %) and lemon grass (50.3 %). This result of thyme oil antioxidant is consistent with the studies of Pandur *et al.* (2022), who documented that it exhibits intense antioxidant activity, ranging from 50 % to over 90 % inhibition by DPPH, depending on the concentration used. Furthermore, Aljabeili *et al.* (2018) reported that thymol, carvacrol, and other phenolic compounds are also noted for their

synergistic effects, enhancing the total antioxidant activity of thyme oil. Previous studies (Mukarram *et al.*, 2021) showed that lemon grass oil can reduce DPPH radicals by 25 % to 58 %, depending on factors like how the oil is extracted, its concentration, and where the plant comes from. Our findings on rosemary's antioxidant activity are close to the results of Rašković *et al.* (2014), who documented that the scavenging inhibition of rosemary is 50 %. However, the oil's antioxidant activity can be attributed to the presence of phenolic compounds and other constituents, including α -pinene, 1,8-cineole (eucalyptol), and camphor, which are known for their potent antioxidant activity.

Weight loss. All treatments, including control samples, showed an increase in weight loss as storage time increased (Figure 2a). The enhanced transpiration from the fruit surface could be the cause of this weight loss over time (Pandiselvam *et al.*, 2022). The thyme treatment showed minimal weight loss compared to the control treatment (Figure 2b). Additionally, there was no notable difference between the control, rosemary, and lemon grass oils. The role of thyme oil in reducing weight loss might be attributed to its function as a semi-permeable membrane around the fruit's surface, which reduces transpiration and respiration. Our findings agree with earlier studies that showed thyme oil treatment reduced weight loss in strawberries (Guerreiro *et al.*, 2015) compared to untreated fruits.

Firmness. Storage period was the only factor that significantly affected pepper fruit firmness at 0.05 level. As storage time increased, the firmness value decreased (Figure 3). The breakdown of pectin and cell walls during the respiration process may be the cause of the reduction in firmness (Kawhena *et al.*, 2022).

Decay. The decay (%) significantly increased with prolonged storage periods across all emulsion treatments (Figure 4). Decay appeared after 21 days of storage in control and lemon grass treatments and increased until the end of the storage period (35 days). The onset of decay was delayed in thyme and rosemary treatments, appearing after 28 days of storage and increasing until the end of the storage duration. Thyme oil has been shown to inhibit decay (Sellamuthu *et al.*, 2013). The effect of thyme oil on reducing decay may be attributed to thymol, the primary

compound in thyme oil, which is known to mitigate decay in grapefruit (Olmedo *et al.*, 2023). The beneficial impact of rosemary on reducing decay percentages may be attributed to the

presence of certain compounds, including camphor and α -pinene, which have demonstrated antimicrobial efficacy (Soković and van Griensven, 2006).

Table 1. Identified volatile compounds of essential oils.

Compounds	Percentage of compounds in essential oils		
	Lemon grass	Rosemary oil	Thyme oil
Geranial	40.32	-	-
Neral	39.05	-	-
6-methyl•Hept•5-en-2-one	3.3	-	-
Geranyl acetate	2.82	-	-
Camphene	2.28	5.36	-
Geraniol	1.83	-	-
Caryophyllene(E-)	1.49	4.56	-
Pentyl propyl ketone	1.24	-	-
Linalool	1.2	0.54	-
Gamma-Cadinene	1.19	-	-
Isogeranial	0.79	-	-
(Z)-beta-Ocimene	0.43	-	-
Isoeugenol	0.4	-	-
alpha-Pinene	0.38	12.22	1.07
Limonene	0.35	1.36	-
Tricyclene	0.26	-	-
1.8 Cineole	-	38.32	-
Camphor	-	12.15	-
endo-Borneol	-	2.88	-
alpha-Terpineol	-	2.79	-
Bornyl acetate	-	2.55	-
Myrcene	-	1.28	-
gamma-Terpinene	-	1.02	-
Thymol	-	-	45.5
Alpha -Terpinene	-	0.55	30.05
para-Cymene	-	1.13	8.37
Carene < δ -2->	-	-	3.76
Caryophyllene	-	-	2.68
beta-Myrcene	-	-	1.53
alpha-Thujene	-	-	1.06
Cyclohexene, 1-methyl-4-(5-methyl-1-methylene-4-hexenyl)	-	-	0.78
Terpineol	-	-	0.47
Terpinen-4-ol	-	0.73	0.46
beta-Pinene	-	8.92	0.37
alpha-Phellandrene	-	-	0.033
D-Limonene	-	-	0.29
beta-Phellandrene	-	-	0.21

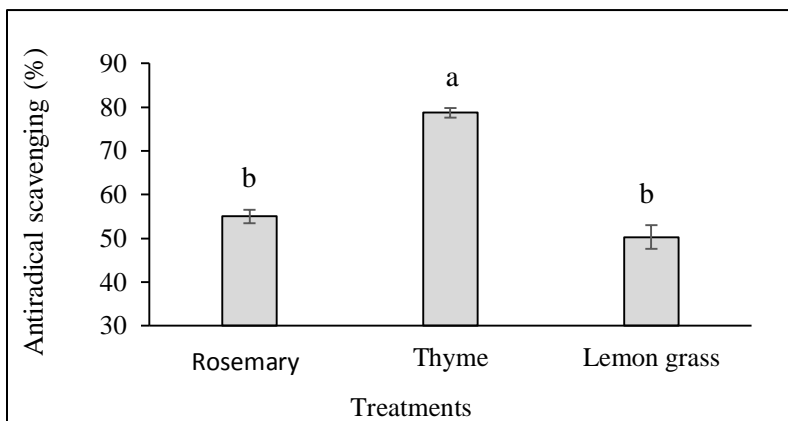


Figure 1. Antiradical scavenging (%) of rosemary, thyme, and lemon grass essential oils.

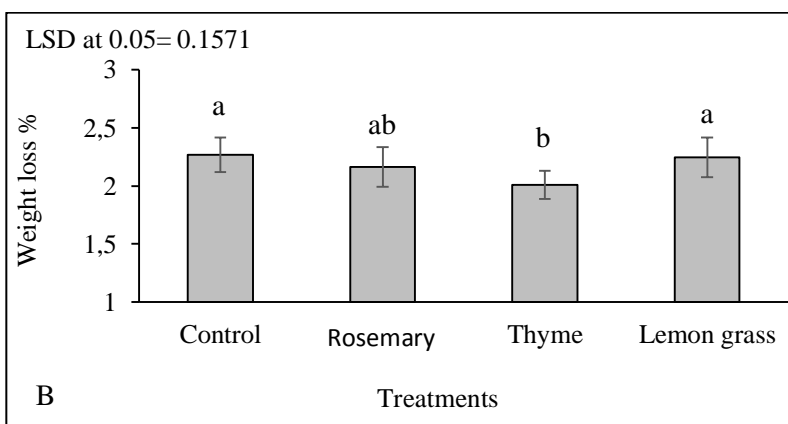
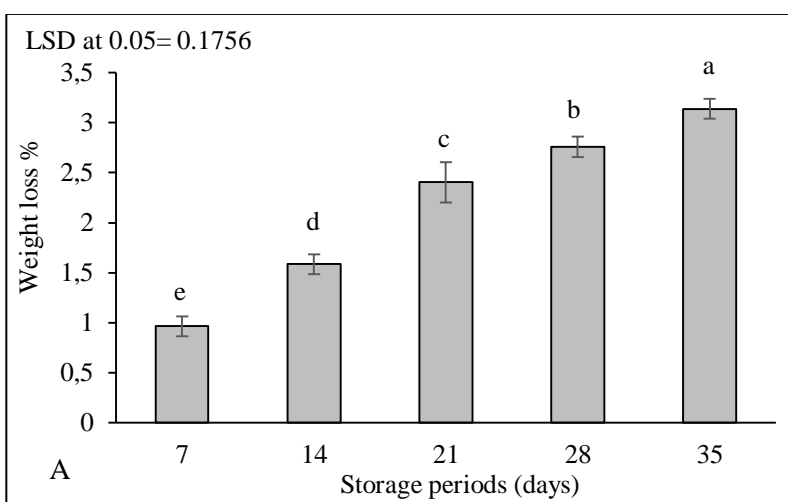


Figure 2. Effect of storage periods (A); essential oils' emulsions (B), on weight loss percentage of sweet pepper fruits for 35 days at 8° C.

Vitamin C. The retention of vitamin C increased across all treatments until day 28 of storage, followed by a slight decline (Figure 5). Fruits treated with rosemary oil exhibited higher vitamin C levels compared to other treatments

after 7 and 14 days of storage. The drop in vitamin C in the control fruits could be due to their higher respiration rate and spoilage compared to the treated fruits (Elsayed *et al.*, 2022).

Respiration rate. The respiration rate across all treatments demonstrated a gradual increase as the storage period extended (Figure 6a). The highest respiration rate was observed in untreated samples, while the lowest respiration rate was

observed in fruits treated with lemon grass essential oil (Figure 6b). In accordance with our research, it has been documented that essential oils have a positive effect on reducing the respiration rate in table grapes (Elsayed *et al.*, 2022).

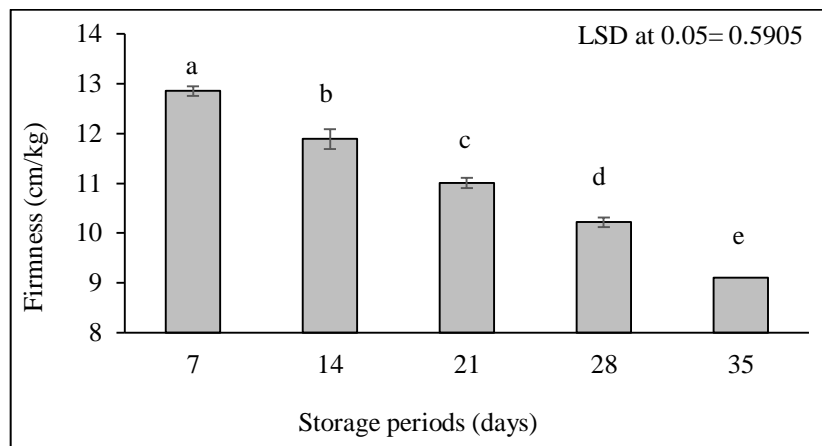


Figure 3. Effect of storage periods on firmness of sweet pepper fruits for 35 days at 8°C.

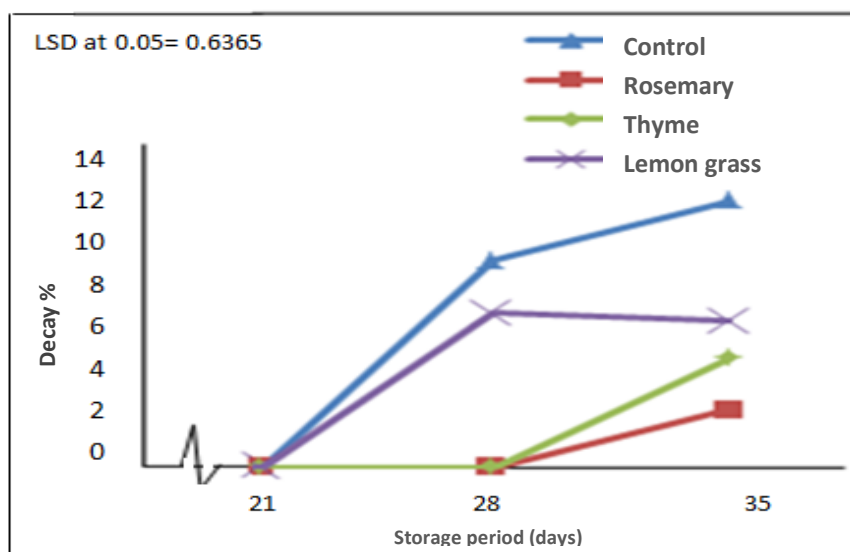


Figure 4. Influence of essential oils' emulsions and storage periods on decay % of sweet pepper fruits through storage for 35 days at 8°C.

Total phenolic compounds. Figure 7 demonstrates a notable reduction in total phenolic content across all treatments as storage duration increases. The reduction of phenolic compounds at the end of the storage period might be due to the increase in respiration rate and the deterioration of cell structure (Zhang *et al.* 2018). All treatments significantly conserved phenolic compounds compared to the control treatment at

0.05 level from 21 days of storage until the end of the storage period. This could be related to the inhibition of polyphenol oxidase activity, which helps preserve phenolic compounds (Khumalo *et al.*, 2017). Moreover, this may be related to the antioxidant properties of the essential oils used, which reduced the oxidation of phenolic molecules (Yang *et al.*, 2010).

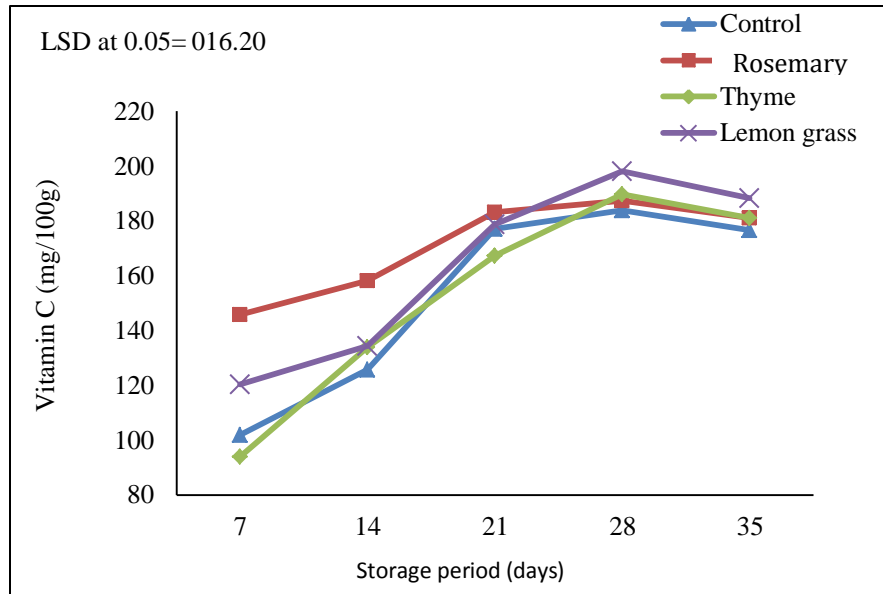


Figure 5. Influence of essential oils' emulsions and storage periods on vitamin C content of sweet pepper fruits through storage for 35 days at 8°C.

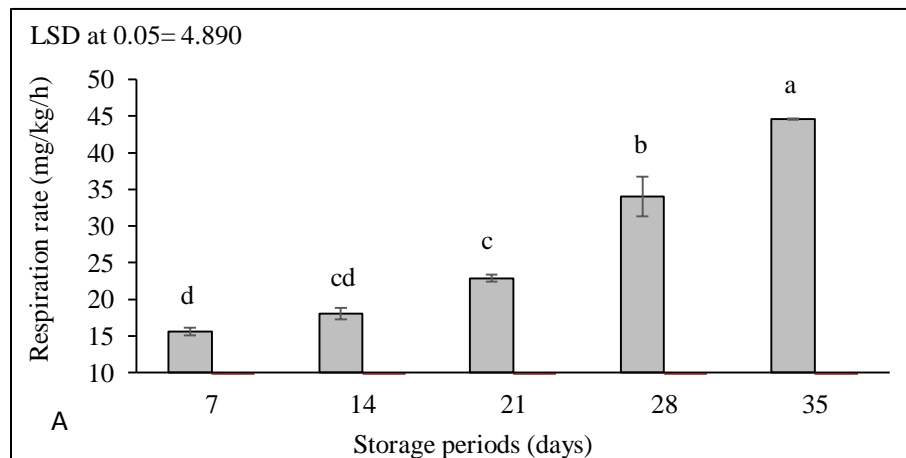
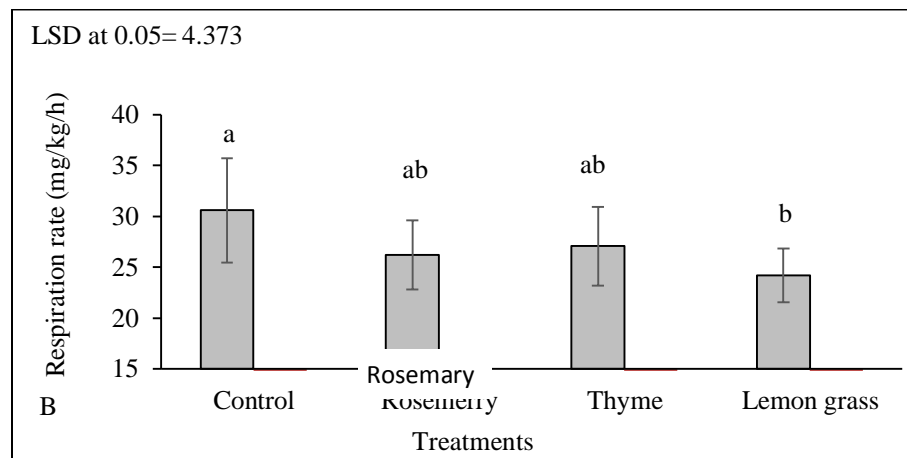


Figure 6. Impact of storage periods (A); essential oils' emulsions (B), on respiration rate of sweet pepper fruits for 35 days at 8° C.

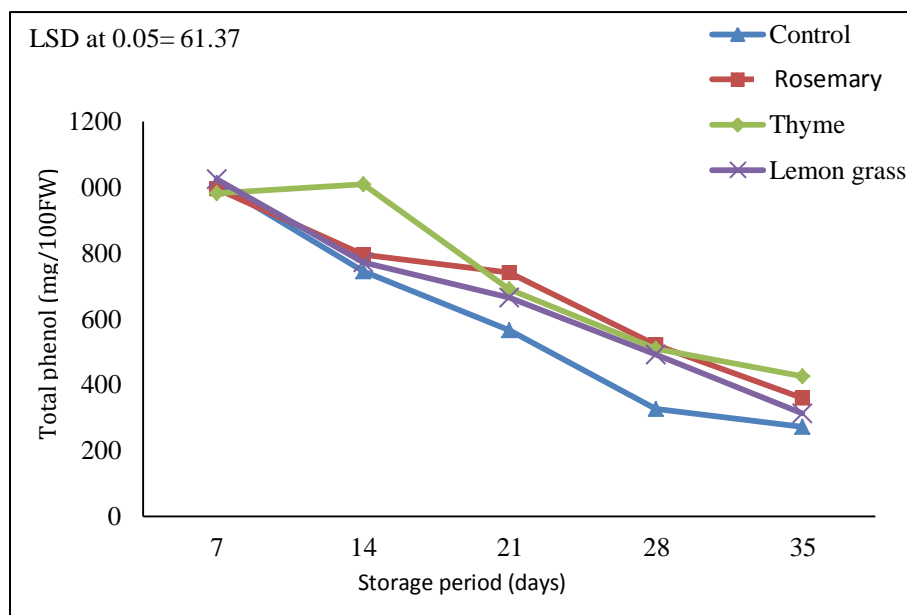


Figure 7. Impact of essential oils' emulsions and storage periods on total phenolic compounds of sweet pepper fruits through storage for 35 days at 8°C.

Antioxidant capacity. Antioxidant capacity decreased over the refrigerated storage periods (Figure 8). Nevertheless, the fruits exposed to all essential oils exhibited greater antioxidant capacity than those untreated. Additionally, thyme oil treatment had the greatest antioxidant capacity relative to the other essential oils. Enhancing the overall antioxidant capacity in essential oil-treated fruits may be linked to the relative quantities of antioxidant chemicals, notably polyphenols, introduced to pepper after applying essential oils (Martínez *et al.*, 2018). The decline in untreated fruits' antioxidant capacity at the storage period's conclusion may be attributed to senescence (Khumalo *et al.*, 2017).

Polyphenol oxidase. All treatments showed no activity of the PPO enzyme during the different storage periods (Figure 9). However, the control treatment exhibited a gradual increase in polyphenol oxidase activity over the storage period. The increased total phenolic content, antioxidant activity, and decreased PPO activity further demonstrate that thymol has potent anti-oxidation activity, postpones senescence, preserves cell integrity, and thereby prevents cell constituent mixing, which in turn inhibits pericarp browning (Khan *et al.*, 2021). The antioxidant activities of essential oils could be responsible for inhibiting polyphenol oxidase activity (Karimirad

et al., 2019).

Total count, yeast, and mold. Total count, yeast, and mold increased in all treatments over storage periods (Figures 10 and 11). The control treatment showed a higher total count and mold & yeast count compared to the other essential oil treatments, followed by rosemary and lemon grass, respectively. It has been documented that thyme oil inhibits the growth of various microbes, such as *Rhizopus stolonifer*, *Alternaria alternata*, *Botrytis cinerea*, and *C. gloeosporioides* (Sellamuthu *et al.*, 2013). The effect of the thyme oil treatment might be due to the role of the thymol compound in reducing decay and spoilage of many crops, such as grapefruit (Olmedo *et al.*, 2023). The antimicrobial effect of the treatments might be attributed to their role in reducing spore germination and mycelium growth by disrupting cellular metabolism (Juglal *et al.*, 2002)

Carvacrol and eugenol are examples of such volatile oils that cause the fungal cell plasma membrane to contract and rupture (Zhou *et al.*, 2018). These components may work by inhibiting the synthesis of ergosterol in the cell membrane, which damages and ruptures the membrane, allowing the internal substances of the fungal cell to leak out, ultimately resulting in cell death (Ma *et al.*, 2016).

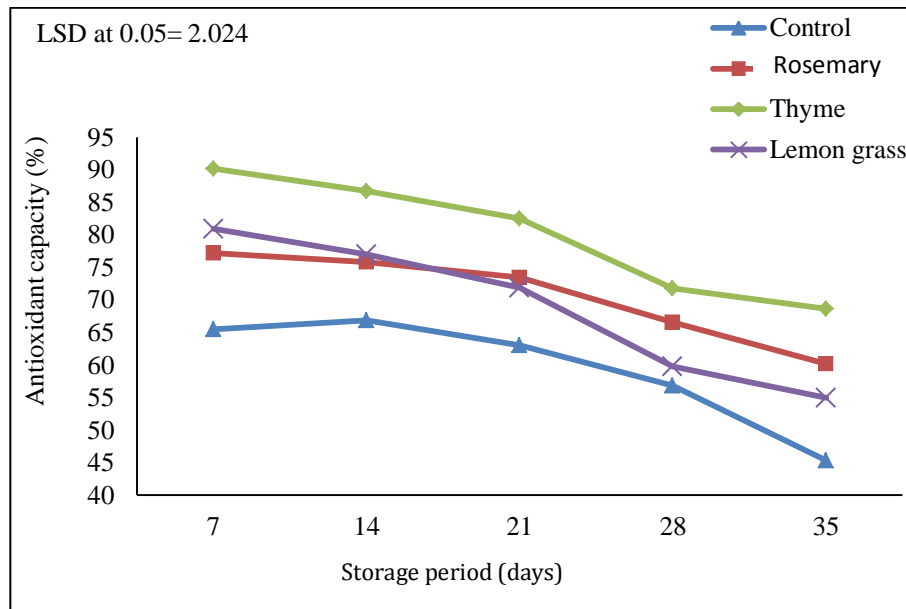


Figure 8. Impact of essential oils' emulsions and storage time on antiradical scavenging activity % of sweet pepper fruits through storage for 35 days at 8° C.

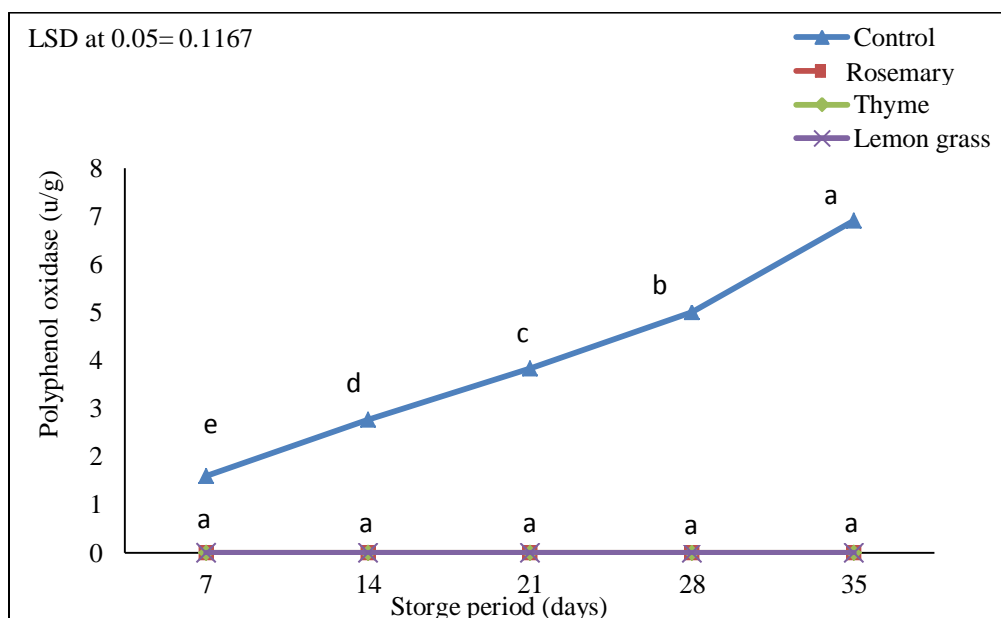


Figure 9. Impact of essential oils' emulsions on polyphenol oxidase of sweet pepper fruits for 35 days at 8°C. All treatments, but the control, overlap each other on the zero line.

Previous work has found that phenolic compounds are the main constituents of thyme oil (Ramezani *et al.*, 2016). The impact of thyme oil against the growth of certain microbes might be attributed to the considerable level of phenolic compounds in thyme

oil (Bagamboula *et al.*, 2004). These findings are consistent with previous studies that demonstrate the role of thyme oil in reducing microbial growth rates on various crops (Bill *et al.*, 2014).

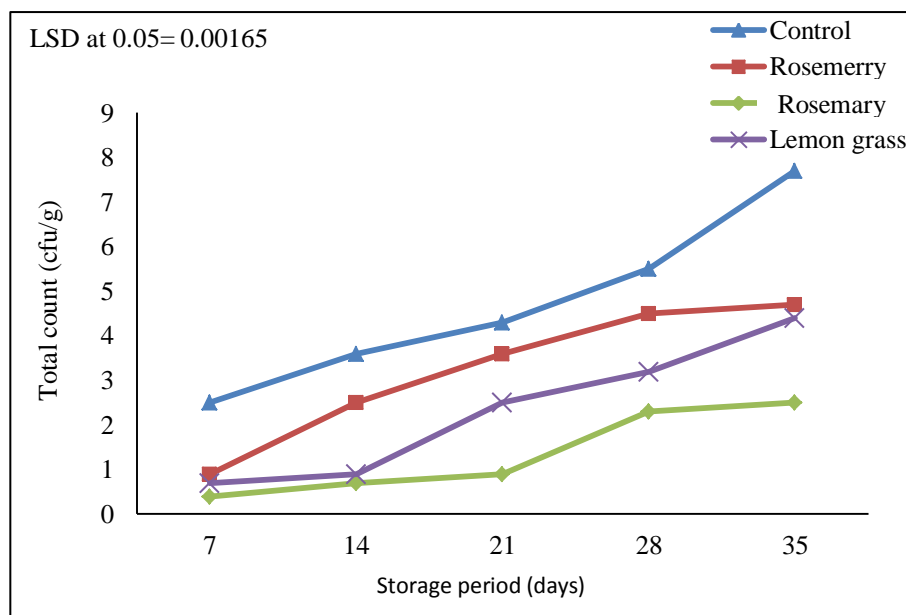


Figure 10. Influence of essential oils' emulsions and storage time on total count of sweet pepper fruits at 8°C for 35 days.

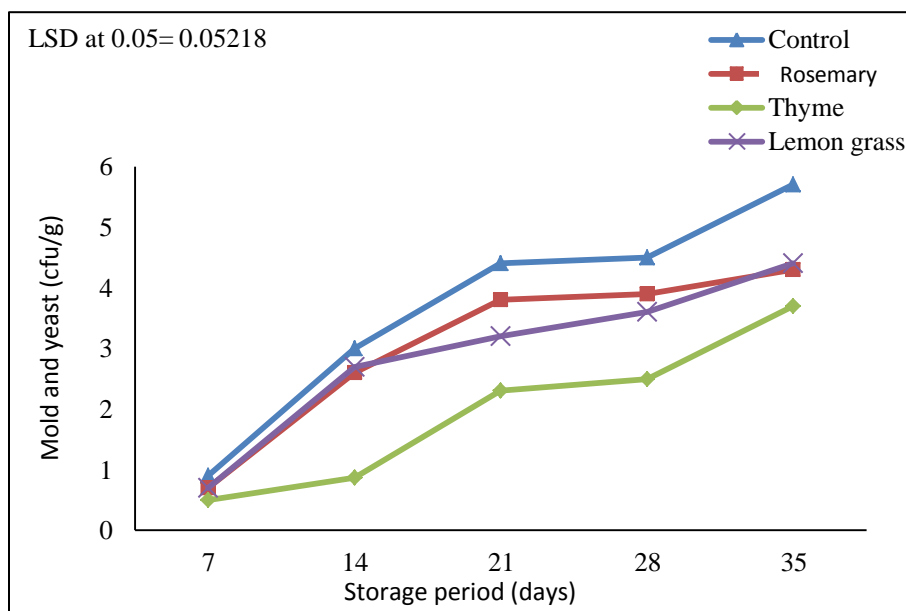


Figure 11. Impact of essential oils' emulsions and storage period on yeast and mold of sweet pepper fruits for 35 days at 8°C.

Correlation study. The correlation study confirmed a positive relationship between antiradical scavenging and fruit antioxidants, but a negative correlation with total count, mold, and yeast (Table 6). Weight loss percentage correlated positively with decay percentage, total count, mold and yeast, PPO activity, and respiration rate, while it correlated negatively with firmness, total phenolic compounds,

and antioxidant capacity. Fruit firmness was negatively affected by decay percentage, total count, mold and yeast, PPO activity, and respiration rate, whereas it was positively affected by total phenolic compounds. Both antioxidant capacity and total phenolic compounds had a negative effect on total count, mold and yeast, PPO activity, and respiration rate.

Table 6. Correlation coefficients among antiradical scavenging (AS) of oils, fruits weight loss (WL), firmness (F), decay (D). Total phenolic compounds (TP), total antioxidant (A), total count (TC), mold and yeast (MY), polyphenol oxidase (PPO) and respiration rate (RR).

	AS	WL(%)	F	D (%)	TP	A	TC	MY	PPO	RR
WL	-0.090									
F	-0.056	-0.753*								
D	-0.081	0.522**	-0.577**							
TP	0.116	-0.896**	0.771**	-0.644**						
A	0.489**	-0.690**	0.630**	-0.691**	0.796**					
TC	-0.410**	0.708**	-0.644**	0.668**	-0.782**	-0.914**				
MY	-0.343*	0.855**	-0.738**	0.594**	-0.912**	-0.827**	0.880**			
PPO	-0.120	0.322*	-0.369**	0.622**	-0.397**	-0.631*	0.730**	0.512**		
RR	0.140	0.785**	-0.707**	0.713**	-0.877**	-0.718**	0.722**	0.760**	0.438**	
Vit. C	-0.153	0.787**	-0.584**	0.335**	-0.785**	-0.543**	0.538**	0.745**	-0.850	0.609**

AS (%), WL (%), F (cm/kg), D (%). TP (md/100g), A (%), TC (cfu/g), MY: (cfu/g), PPO (u/g), Vit C (mg/100g) y RR (mg/kg/h)

CONCLUSION

This study aims to test the effect of various essential oil treatments (thyme, lemon grass, and rosemary) on physical and chemical parameters of bell pepper fruits during cold storage at 8°C for 35 days. Thyme oil was the most effective treatment in reducing weight loss compared to the control and other treatments. The control treatment showed the highest decay percentage, while the rosemary, thyme, and lemon grass treatments showed minimal decay. Using all essential oils on pepper fruits helped maintain vitamin C levels compared to the control. The most effective treatment for reducing respiration rates was lemon grass application. All treatments significantly conserved phenolic compounds and antioxidant capacity, with thyme oil treatment having the highest antioxidant capacity. All applications reduced the total count of mold and yeast compared to the control treatment.

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