

## Effect of Mint and Rosemary Aromatic Oil Extracts on the Mortality of the Stored Date Pest *Ephestia cautella* (Walker)

Sarah Ali Hamid\*, and Aseel Kemal Abdul Hussein\*

Department of Biology, Faculty of Education for Women, University of Kufa, Najaf, Iraq

\*Corresponding author; email: saraha.ismail@student.uokufa.edu.iq; aseelk.alwaily@uokufa.edu.iq

### Abstract

*Ephestia cautella* is one of the most common insect pests of stored dates, causing quantitative and qualitative losses. Therefore, this research aimed to evaluate the insecticidal effect of oil extracts from peppermint (*Mentha piperita*) and rosemary (*Rosmarinus officinalis*) against different larval instars of the date moth under laboratory conditions, to promote botanicals as a safe and environmentally friendly alternative for managing insect pests. This study was conducted in the Advanced Laboratory of Entomology at the Faculty of Education for Women, University of Kufa, during 2024-2025. The academic year showed the contact and digestive effects of both oil extracts at concentrations of 2.5%, 5%, 7.5%, and 10% on the mortality of second- and fourth-instar larvae of *E. cautella*. The results showed high efficacy of the tested plant oil extracts in causing mortality across both larval instars. The contact effect of mint extract was slightly more effective against second-instar larvae than fourth-instar larvae across all treatments, with mortality reaching 100% in most treatments and concentrations, except at 2.5%, where it recorded 80% mortality for second-instar larvae. With rosemary extract, mortality percentages among fourth-instar larvae were higher under contact than under digestive treatment at all concentrations. Most contact treatments achieved 100% mortality, even at the 10% concentration. Digestive treatments resulted in an 80% mortality rate of second-instar larvae and a 50% mortality rate of fourth-instar larvae. These results demonstrate the potential of peppermint and rosemary oil extracts as effective botanical insecticides for controlling the date moth.

**Keywords:** aromatic oils, biopesticide, fruit, larval mortality, moth, post-harvest

### Introduction

Dates (*Phoenix dactylifera* L.), one of the world's most important strategic crops, are highly nutritious, rich in natural sugars, fiber, and antioxidants, and are important for enhancing human health (Al-Karmadi & Okoh, 2024). Dates also play an essential role in global food security because they can grow in harsh conditions such as drought and salinity, helping them withstand climate change. Dates are also of great economic importance as they are a major source of income to many producing countries and help stimulate global trade and the food industry (Sporchia et al., 2023). Iraq is known for its staple crop, dates, which have been associated with the civilizations of Mesopotamia for thousands of years and have formed an integral part of the population's diet. The date palm sector in Iraq is an important economic sector, providing broad employment opportunities, improving farmers' incomes, and contributing to national agricultural production (Al-Karmadi & Okoh, 2024). Dates also help achieve local food security through their storability and the essential nutrients they contain, which can be relied upon under almost all conditions. Furthermore, the cultivation of date palms in Iraq is characterized by its development under difficult conditions and its contribution to agricultural and rural development (Sporchia et al., 2023). Many pests and diseases attack date palm trees in Iraq, including several insects, mites, and fungi. Depending on the kind and severity of the infestation, the damage varies. In mild infestations the vigor of trees is slightly reduced

and fruits are not significantly deteriorated and losses in yield do not exceed 10% each season; in moderate infestations damage to fronds and fruits is clearly visible, the loss of yield reaches 10%—30% and the size and market value of fruit declines; in severe infestations substantial damage is done to the tissues, loss of yield may exceed 50% and there is decline and shortening of the life of trees unless proper control steps are taken. Some of these pests attack different parts of the tree, while others attack only fruits (Al-Bakr, 1972; Al-Janabi, 2011; Wu et al., 2023).

The most dangerous pest insect of stored dates in Iraq is also the most prevalent among *Ephestia*, making it an obvious candidate for concerted control efforts. In other words, economic damage results from their reproduction and multiplication during storage. Packaging techniques are one method for controlling this pest, along with chemical fumigants such as phosphine gas, methyl bromide, and carbon tetrachloride (Munera-Echverri, 2024). Meanwhile, packaging is one of the few fumigants used for packaged dates due to the dates' resistance to chemical pesticides. Alternative solutions are increasingly being researched, including using natural plant products that contain secondary metabolites (Al-Khafaji, 2004; Moutassem & El-Baz, 2024)

Human interest in medicine, aromatic, and poisonous plants dates back to the instinctive quest for remedies to relieve pain and suffering from local plants. With awareness of medicine, demand for medicines has increased significantly in recent years. Medicines have two main sources: first, active substances extracted from medicinal plants; second, chemically manufactured compounds (Nebié & Ouédraogo, 2024).

Advances in analytical methods enabled the detection of active ingredients, herbs, and their extraction or synthesis, later giving rise to a gradual displacement of traditional herbal therapy by tablets and drinks, either containing active herbal components or inorganic chemicals. Expected to be more effective because they were concentrated forms of active ingredients; meanwhile, comparative studies proved compounds sometimes work better when

coming directly from whole herbs and plants (Múnera-Echeverri et al., 2024). By the grace of God, in plants are foods, medicines, and healing; so many benefits when properly used in proper amounts, but they can become harmful to human health with overuse.

At present, medicinal plants and biologically active compounds play a leading role in agriculture, industry, and daily life through their use in pharmaceuticals. Modern studies are increasingly focused on identifying key plant components, their effects as medicines or remedies for diseases, and their applications in the food industry (Abada, 2023; Achoura, 2007; Khanata, 2014; Su & Zhang, 2024).

Aromatic medicinal plants produce strongly scented or flavored compounds and are widely used as food flavorings, natural preservatives, and sources of bioactive metabolites. Their essential oils contribute to food quality and sensory appeal and have demonstrated antibacterial and antioxidant properties, supporting their use in food and medicinal applications (Giuliano & Fabbri, 2024; Prieto et al., 1999).

Essential oils also have significant potential as pesticides and repellents. Their efficacy against public health, stored-product, and agricultural pests has been increasingly documented in the literature (Isman & Machial, 2006). In addition, essential oil-based insecticides have recently entered the U.S. market, with active ingredients derived from rosemary, clove, thyme, and peppermint, all of which show notable pesticidal activity (Aqeel et al., 2024; El-Shafei et al., 2022).

## Materials and Methods

### Raised Insect Collection

Dates infested with the date moth *E. cautella* were obtained from a warehouse in Najaf Governorate and transferred to the Advanced Laboratory of Insect Studies for Postgraduate Studies, Department of Biology, College of Education for Women, Kufa University. They were raised in plastic boxes on artificial food, composed of 405 g groats, 60 g glycerin, 30 g

date molasses, and 5 g instant yeast. These quantities were measured by a sensitive balance and mixed to prepare a diet for the date moth. The boxes were covered with muslin and fastened with rubber bands to prevent the escape of insects. The insects were maintained at room temperature ( $28 \pm 2$  °C), with a relative humidity of  $55 \pm 5\%$  and a photoperiod of 8 hr light and 16 hr dark. The colony was observed for its continuity and to obtain the required larval instars for subsequent laboratory experiments (Al-Tariq, 2014; Hamid, 2002).

### Plants for Oil Extraction

*Mentha piperita* (mint) and *Rosmarinus officinalis* (rosemary) were obtained from local markets in Najaf Governorate (Table 1).

### Essential Oil Extraction

The weight of both mint and rosemary plants was measured by using a sensitive balance. The essential oils were extracted separately from each plant by using the Clevenger apparatus (30 g of plant powder is placed in the device with 250 ml of water, heated on an electric heater to a temperature between 40 °C and 50 °C). The extraction takes about four to five hr; approximately three milliliters of oil are obtained from thirty grams of each plant per extraction, yielding about six milliliters in total. The extractions were repeated many times throughout the study. The oils obtained are kept in tightly closed jars at 4 °C until use (Enas & Ashwaq, 2025).

Four concentrations of the oils (2.5%, 5.0%, 7.5%, and 10%) were prepared in 100 ml of distilled water with 0.5 ml/L of liquid soap as an emulsifier, which showed no harmful effects

on insect development. The solutions were stirred by using a magnetic stirrer for 20 min. Distilled water was used in the control treatment. The extraction and preparation were done in the laboratories of the Department of Agriculture, Najaf governorate.

### Contact Effect of Mint and Rosemary Oils on *Ephestia cautella* Instars

Ten second-instar larvae were collected using a soft brush and placed in clean, sterilized Petri dishes. Each group of 10 larvae was sprayed from a distance of 10 cm with one concentration of essential oil, with one replicate per concentration. After treatment, the larvae were transferred to Petri dishes containing artificial diet. For each dish, the larval instar, oil treatment, and date of experiment were recorded. Control larvae were sprayed only with distilled water. All dishes were kept in an incubator at  $28 \pm 2$  °C and  $55 \pm 5\%$  relative humidity. Larval mortality was recorded daily for five days. Fourth-instar larvae were treated in the same way, and their stage was determined based on average larval length (Abdul, 2001).

### Digestive Effect of Mint and Rosemary Oils on *E. cautella* Instars

The same method used to determine larval age in the contact-effect experiment was applied here. Each essential oil was mixed thoroughly with artificial food at concentrations of 2.5%, 5.0%, 7.5%, and 10%. Ten second-instar larvae were placed in each petri dish containing treated food, with three replicates per concentration. Three dishes containing untreated food that had been sprayed with distilled water served as the control group. Mortality was recorded five

**Table 1**

*Names of Local and Scientific Plants Used in the Study*

Part from which the oil is extracted	Scientific name	Plant local names
Leaves	<i>Mentha piperita</i>	Mentha
Leaves	<i>Rosmarinus officinalis</i>	Rosmarinus

days after treatment under the same incubation conditions as in the contact experiment. Fourth-instar larvae were treated in the same manner (Jbilou et al., 2006).

### Statistical Analysis

The experiment was conducted in a factorial arrangement of two factors: oil concentration (0%, 2.5%, 5%, 7.5%, and 10%) and larval instar (second and fourth). The mortality data were analyzed using analysis of variance to test for differences among treatments. Where differences existed among means, means were compared using the least significant difference at 5% probability level. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA, 2016) (Al-Rawi & Khalaf, 2000).

## Results and Discussion

### Contact Effects of Mint and Rosemary Oils on *Ephestia cautella* Instars

Table 2 and Figure 1 show a clear contact effect of peppermint (*Mentha piperita*) oil on *E. cautella*, with total mortality increasing at higher concentrations. For second instar larvae, mortality was 100% at the two highest concentrations, 5% and 7.5%, while for fourth instar larvae, mortality was 100% at all tested concentrations. The lowest mortalities were recorded at a concentration of 2.5%-100% for the second instar and 80% for the fourth instar. Most deaths occurred on the first day after application; hence, most deaths happened on the first day, and this difference between initial death and subsequent daily deaths is statistically significant.

**Table 2**

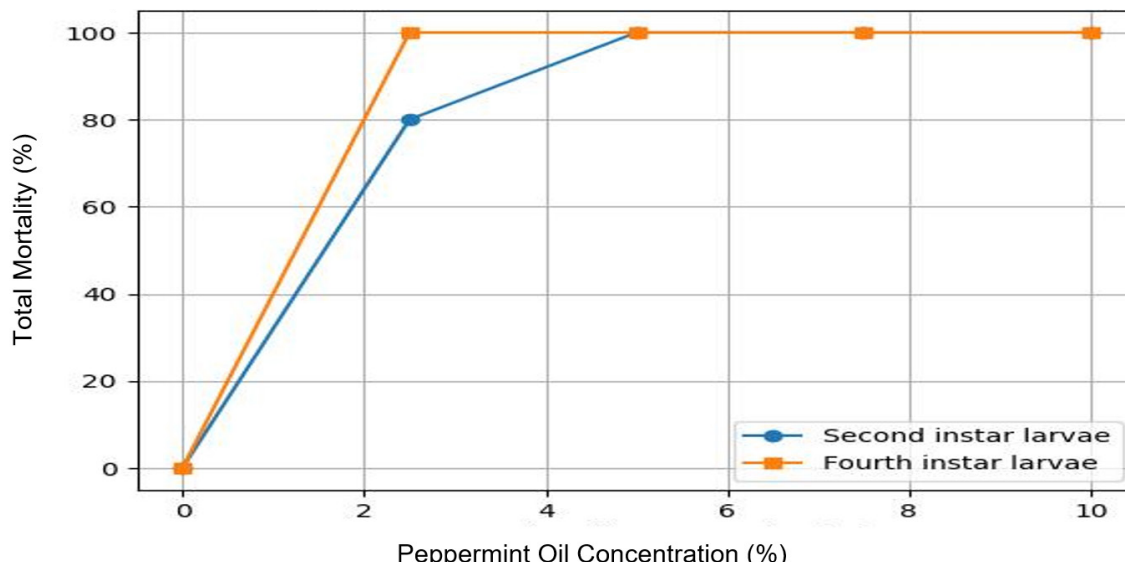
*The Contact Effect of Peppermint Oil on the Mortality of the Second and Fourth Larval Instars of Ephestia cautella*

Larvae stage	Concentrations (%)	Mortality rates (%)					LSD <i>P</i> < 0.05	Total mortality (%)
		Day 1	Day 2	Day 3	Day 4	Day 5		
Second instar larvae	control	0	0	0	0	0	-	0
	2.5	80	0	0	0	0	7.2	80
	5	100	0	0	0	0	11.2	100
	7.5	100	0	0	0	0	11.2	100
	10	100	0	0	0	0	11.2	100
	LSD <i>P</i> < 0.05	12.3	-	-	-	-	-	12.5
Fourth instar larvae	control	0	0	0	0	0	-	0
	2.5	60	20	20	0	0	9.2	100
	5	100	0	0	0	0	11.2	100
	7.5	100	0	0	0	0	11.2	100
	10	100	0	0	0	0	11.2	100
	LSD <i>P</i> < 0.05	12.2	3.4	3.4	-	-	-	12.5

*Notes.* The LSD values at the bottom of the columns show a comparison of the effects of different concentrations on the same day. The LSD column, positioned vertically on the right side of the rows, indicates the minimum significant difference required to evaluate changes in mortality across days within the same concentration. Dashes ( - ) indicate time points where statistical variance was zero due to total larval mortality in preceding intervals.

**Figure 1**

**Contact Toxicity of Peppermint Oil on Total Mortality (%) of the Second and Fourth-instar Larvae of *Ephestia cautella***



Tests have also been carried out on peppermint oil against beneficial insects. Two aphid predators, *Adalia bipunctata* and *Coccinella septempunctata*, were exposed to peppermint oil vapor, yielding LC50 values of 0.62 ml/L and 0.67 ml/L at 21 °C for 24 hr, respectively (Atay et al., 2023; Catani et al., 2023). Peppermint oil showed moderate toxicity to the beneficial parasitoid *Cotesia glomerata* but was much less toxic than dichlorvos (LD50 = 0.3 mg/pc) (Naftaly, 2024).

At essential oil concentrations of 1%, 2%, 4%, and 8%, the incubation period, hatching duration, and hatchability percentage were significantly affected. Maximum ovicidal activity was observed at 8% concentration, where peppermint oil extended the incubation period to 15 days; the control treatment took 6.67 days to hatch, with a hatchability of 5.07%. In comparison, rosemary oil took 13.67 days to develop, with a hatchability of 5.33%, while chamomile took 9.67 days and had the highest hatchability at 32.45%. (Farag & Sakla, 2019; Gospodarek & Kaczmarek, 2024). Table 3 and Figure 2 show the contact effect of rosemary oil on second and fourth-instar larvae. Total mortality increases significantly with higher

concentrations, reaching 100% at 5%, 7.5%, and 10%. The lowest mortality rate is 60% at 2.5% in both instars. As in peppermint oil, the highest mortality was recorded on the first day of treatment.

The major compounds of rosemary oil are effective against a wide range of pests, particularly stored-product pests (Shaaya et al., 1997). Miresmailli et al. (2006) found that 1,8-cineole and alpha-pinene are the most toxic components to the two-spotted spider mite *Tetranychus urticae* Koch. Camphor is also one of the main constituents of rosemary oil; Isikber et al (2006) reported high toxicity of camphor. High mortality rates involving populations of *Ephestia cautella* treated with German chamomile essential oil have been reported by Ayvaz et al. (2010).

### **The Digestive Effect of Aromatic Oils on the Death of Date Moth Larvae**

Table 4 and Figure 3 present the results of peppermint (*Mentha piperita*) oil as a digestive effect on mortality in second and fourth-instar larvae. Total mortality increased with increasing concentration; hence, a direct relationship

**Table 3**

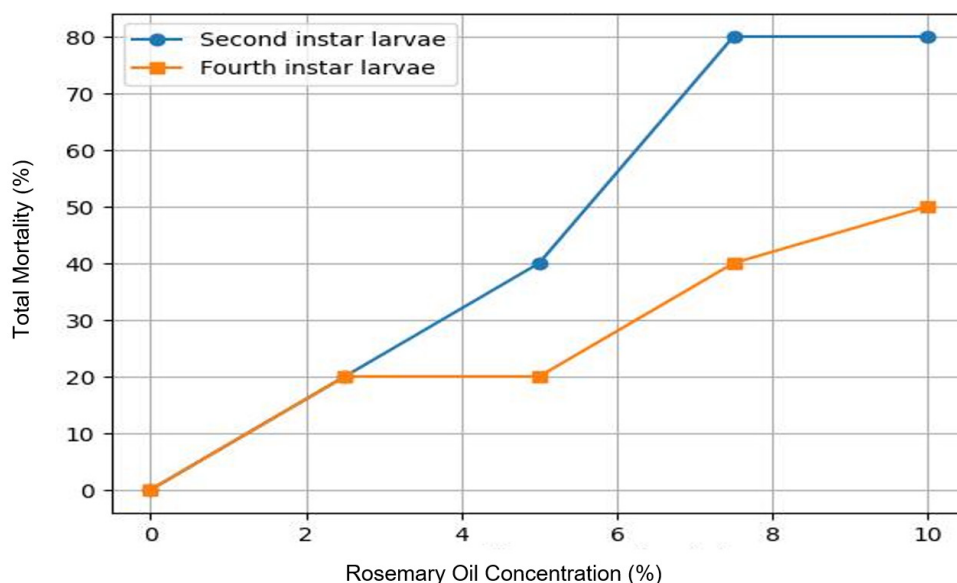
*The Contact Effect of Rosemary Oil on Mortality of the Second and Fourth Larval Instars of Ephestia cautella*

Larvae stage	Concentrations (%)	Mortality rates (%)					LSD $P < 0.05$	Total mortality (%)
		Day 1	Day 2	Day 3	Day 4	Day 5		
Second-instar larvae	control	0	0	0	0	0	-	0
	2.5	40	20	0	0	0	5.2	60
	5	40	20	40	0	0	5.4	100
	7.5	80	20	0	0	0	9.2	100
	10	100	0	0	0	0	11.2	100
	LSD $P < 0.05$		11.6	3.6	5.2	-	-	
Fourth- instar larvae	control	0	0	0	0	0	-	0
	2.5	40	20	0	0	0	5.2	60
	5	60	40	0	0	0	7.4	100
	7.5	100	0	0	0	0	11.2	100
	10	80	20	0	0	0	9.2	100
	LSD $P < 0.05$		11.6	5.2	-	-	-	

*Notes.* The LSD values at the bottom of the columns show a comparison of the effects of different concentrations on the same day. The LSD column, positioned vertically on the right side of the rows, indicates the minimum significant difference required to evaluate changes in mortality across days within the same concentration. Dashes ( - ) indicate time points where statistical variance was zero due to total larval mortality in preceding intervals.

**Figure 2**

*Contact Toxicity of Rosemary Oil on Mortality of the Second and Fourth Larval Instars of Ephestia cautella*



between total mortality and concentration is observed. The highest total mortality was 10% for both instars, while the lowest was 0 % for both stages. Most deaths occurred within the first day after treatment application. There were significant differences in daily mortalities among second instars at concentrations of 2.5%, 7.5%, and 10%, as well as among fourth instars at concentrations of 7.5% and 10%.

Menthone, a major constituent of peppermint oil, has been reported as a natural pesticide (Jyotsna et al., 2024). In addition to menthone, other peppermint oil components have shown selective toxicity toward mites while remaining relatively safe for bees. For example, one compound was reported to be 19 times more toxic to the tracheal mite *Acarapis woodi* than to honey bees (*Apis mellifera*) at LC50 and 5.7 times more toxic at LC90, indicating a wide safety margin despite some toxicity to bees (Ellis

& Baxendale, 1997). Peppermint oil has also shown strong insecticidal activity against red flour beetle populations. Reported LC50 values ranged from 0.76 to 20.4 ml/100 ml across the first to fifth instars, while adult mortality was observed at LC50 values of 3.04 and 3.21 ml/100 ml after 24 and 48 hr of exposure, respectively. In addition, 90% mortality was recorded in first instars at 4 ml/100 ml, whereas no effect was observed on eggs (Jyotsna & Ramesh, 2024; Khalil et al., 2024; Mackled et al., 2019).

Table 5 and Figure 4 show the effect on digestibility at different concentrations in both the second and fourth instars. Total mortality increased directly with concentration. The highest mortality of 50% and 80% was recorded at a 10% concentration for the second and fourth instars, respectively, while the lowest mortality of 20% was observed at a 2.5% concentration for both instars. Most deaths occurred within one

**Table 4**

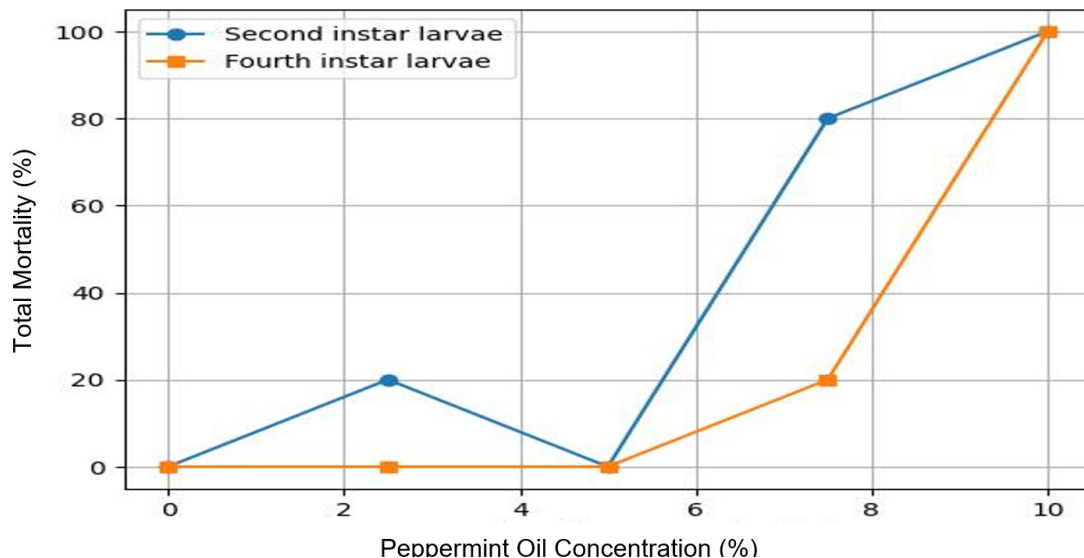
*The Digestive Effect of Peppermint Oil on the Mortality of the Second and Fourth Larval Instars of Ephestia cautella*

Larvae stage	Concentrations (%)	Mortality rates (%)					LSD $P < 0.05$	Total mortality (%)
		Day 1	Day 2	Day 3	Day 4	Day 5		
Second-instar larvae	control	0	0	0	0	0	-	0
	2.5	20	0	0	0	0	3.4	20
	5	0	0	0	0	0	-	0
	7.5	40	20	20	0	0	5.2	80
	10	100	0	0	0	0	11.2	100
	LSD $P < 0.05$	11.5	3.4	3.4	-	-		11.6
Fourth-instar larvae	control	0	0	0	0	0	-	0
	2.5	0	0	0	0	0	-	0
	5	0	0	0	0	0	-	0
	7.5	20	0	0	0	0	3.4	20
	10	40	40	20	0	0	5.4	100
	LSD $P < 0.05$	5.2	5.4	3.2	-	-		11.2

*Notes.* The LSD values at the bottom of the columns show a comparison of the effects of different concentrations on the same day. The LSD column, positioned vertically on the right side of the rows, indicates the minimum significant difference required to evaluate changes in mortality across days at the same concentration. Dashes ( - ) indicate time points where statistical variance was zero due to total larval mortality in preceding intervals.

**Figure 3**

*Digestive Toxicity of Peppermint Oil on Total Mortality (%) of Second and Fourth Instar Larvae of Ephestia cautella*



**Table 5**

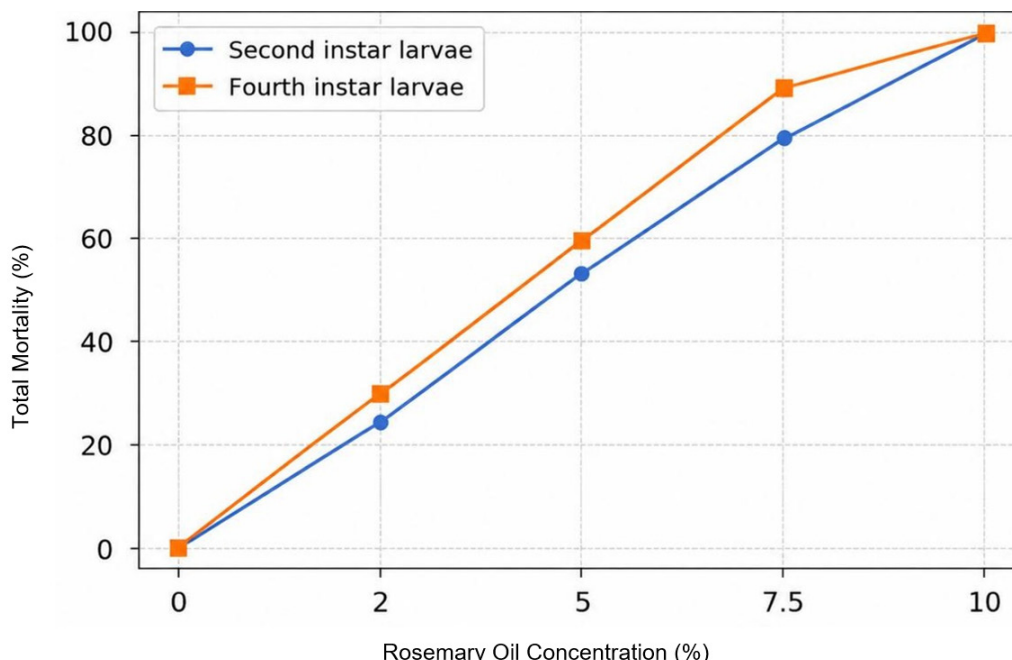
*The Digestive Effect of Rosemary Oil on the Mortality of the Second and Fourth Larval Instars of Ephestia cautella*

Larvae stage	Concentrations (%)	Mortality rates (%)					LSD $P < 0.05$	Total mortality (%)
		Day 1	Day 2	Day 3	Day 4	Day 5		
Second-instar larvae	control	0	0	0	0	0	-	0
	2.5	20	0	0	0	0	3.4	20
	5	20	20	0	0	0	3.2	40
	7.5	20	20	20	20	0	3.4	80
	10	40	20	20	0	0	4.1	80
	LSD $P < 0.05$	4.1	3.6	3.2	3.4	-		9.6
Fourth- instar larvae	control	0	0	0	0	0	-	0
	2.5	20	0	0	0	0	3.4	20
	5	20	0	0	0	0	3.4	20
	7.5	20	20	0	0	0	3.2	40
	10	40	10	0	0	0	4.2	50
	LSD $P < 0.05$	4.1	3.1	-	-	-		5.5

*Notes.* The LSD values at the bottom of the columns show a comparison of the effects of different concentrations on the same day. The LSD column, positioned vertically on the right side of the rows, indicates the minimum significant difference required to evaluate changes in mortality across days within the same concentration. Dashes ( - ) indicate time points where statistical variance was zero due to total larval mortality in preceding intervals.

**Figure 4**

*Digestive Toxicity of Rosemary Oil on Total Mortality (%) of Second and Fourth Instar Larvae of Ephestia cautella*



day after treatment, except in the case of the fourth instar at a 7.5% concentration, where two days tied statistically for first place. Most deaths occur within a day after treatment; the difference between the first days is not significant.

The toxic activity of rosemary oil against stored-product pests has been well documented. Wild rosemary essential oils were more toxic than cultivated types. For example, *T. confusum* adults showed 90% mortality at 6.5 g/L, while *Sitophilus granarius* mortality reached 93.93% after 96 hr at 20 µl/L air (Sabbour & El-Aziz, 2019). GC-MS analysis revealed that L-camphor, 1,8-cineole, L-borneol, and bornyl acetate are the main components of rosemary oils. Toxicity tests indicated that rosemary oils were more effective against *T. granarium* than *T. castaneum*, with LC50 values for wild and cultivated rosemary oils against *T. castaneum* adults of 65.5 µl/L air and 180 µl/L air, respectively (Khalil et al., 2024).

### Conclusions

This study proves the high effectiveness of peppermint (*Mentha piperita*) and rosemary

(*Rosmarinus officinalis*) essential oils in causing mortality among second and fourth-instar larvae of *Ephestia cautella*. The results also show that contact treatments are more effective than ingestion treatments, particularly at higher concentrations. Peppermint oil shows the highest lethality, reaching 100% mortality at most concentrations except 2.5%, while rosemary oil achieves 100% mortality at 5%, 7.5%, and 10%. Generally, the two control instars were more sensitive in their second instar than in their fourth; a clear dose-dependent relationship was observed, with maximum mortality on day one of treatment, indicating that these oils act as natural insecticides. Therefore, this research supports the use of both peppermint and rosemary as safe, environmentally friendly alternatives to pesticides for controlling stored-product pests. Peppermint and rosemary oils are recommended for use in date storage facilities, preferably through contact application and incorporation into IPM programs to minimize reliance on chemical pesticides. Further field-trial studies under commercial storage conditions are required to determine effective concentration and economic

thresholds. More research is also needed on other stored product pests for which they can be applied successfully; identification work aimed at optimizing extraction should take place simultaneously with long-term assessments of quality parameters and consumer safety.

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