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Original article

Effect of peppermint leaf extract and peppermint oil on the flour beetle *Tribolium castaneum* (Coleoptera: Tenebrionidae)

Nane yaprağı ekstresi ve nane yağının Kırmızı un böceği *Tribolium castaneum* (Coleoptera: Tenebrionidae) üzerindeki etkisi

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ABSTRACT

The red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae), is among the global storage pests that lead to the deterioration of grains and stored products. A series of laboratory experiments were conducted to evaluate the efficiency of different concentrations of *Mentha piperita* L. (Lamiaceae) oil and leaf methanol extracts against the rust-red flour beetle in the different instars. The results of the present study showed that the mint, *M. piperita*, oil treatments at all concentrations used (8%, 10%, or 12%) were significantly effective, resulting in remarkable individual mortality of *T. castaneum* third instar larvae and adult mortality compared to the treatment of the peppermint methanol leaf extract at the highest concentration. Peppermint oil showed insecticidal effect against the third instar larvae of the red flour beetle, especially where sprayed at the highest concentration of 12%. The post-treatment results after seventh days showed 94% adult mortality and 82% mortality in the third instar of larvae. This study confirmed the possibility of using mint essential oil at relatively low concentrations as environmentally friendly product in controlling the rust-red flour beetle *T. castaneum*.

INTRODUCTION

The red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae), is one of the most well-known agricultural pests in the field of food and grain storage (Pinto et al. 2020). It feeds on a variety of foodstuffs, such as grains, cereals, pulses, and other products, diminishing the quality of agricultural products and undermining food safety (Amoura et al. 2021, Uritu et al. 2018). Its presence can lead to significant economic losses, spoilage of stored goods, and a reduction in product quality and storability (Pavela 2015). Several methods have been developed to control this pest, including the use of traditional chemical pesticides (Aktar et al. 2009). However, concerns about the environmental and health impacts of these pesticides, as well as the potential for the development of pesticide resistance, have reasonably increased the importance of seeking safe and effective alternatives to control this pest (Stejskal et al. 2015). *Mentha piperita*, commonly known as peppermint, is considered one of the most widespread garden plants (Mamadalieva et al. 2020). It is used in food and as a repellent for most types of insects and some other pests due to its active compounds and volatiles (Salehi et al. 2018, Uritu et al. 2018). Mint extract and essential oil combine an attractive aroma with potential effects on insects. Natural peppermint compounds are believed to have the ability to affect the sensing and communication systems of insects (Mishra et al. 2012), which may lead to reduced mating, egg production, and thus limit the insect's reproduction (Lu et al. 2012, Regnault-Roger et al. 2012). In addition, some compounds in mint have been reported to affect the hormonal and developmental systems of the insect, enhancing the chances of controlling their populations (Kumar et al. 2011). This study aims to evaluate the effect of mint *Mentha piperita* leaf extract and essential oil on different life stages of the red flour beetle *T. castaneum* and assess their attractiveness and repellent potential as a biological solution for controlling this pest.

MATERIALS AND METHODS

Insect rearing

Adult *T. castaneum* insects used in this experiment were collected from flour samples purchased from three different local retail markets. The culture was maintained in the laboratory in the Department of Plant Protection, Faculty of Agriculture, University of Kufa. Fifty pairs (males and females) of the insect were isolated and distributed into 2-liter glass breeding bottles, covered with pieces of milling cloth, and tied with rubber bands. The insects were fed on wheat flour free of insect infestation. The bottles were incubated at 26±2 °C and a relative humidity of 70±4%. The colony was constantly renewed, with careful renewal every 2-4 weeks, to obtain different larval stages and adults for subsequent experiments. The insect was identified as the rusty-red flour beetle *T. castaneum* according to the Natural History Museum and Research Center/University of Baghdad. Adults were starved for 24 hours before starting the experiments.

Isolating the insect at different life stages

The first larval instar was collected by placing pairs of adults in a plastic dish while monitoring the first instar larvae. Successive molts and the larval size were observed. Based on these observations, the different larval stages were isolated until the pupal stage and then adulthood. To control the movement of the adults during examination, they were immobilized by anesthetizing them through freezing for one minute (Arakane et al. 2004).

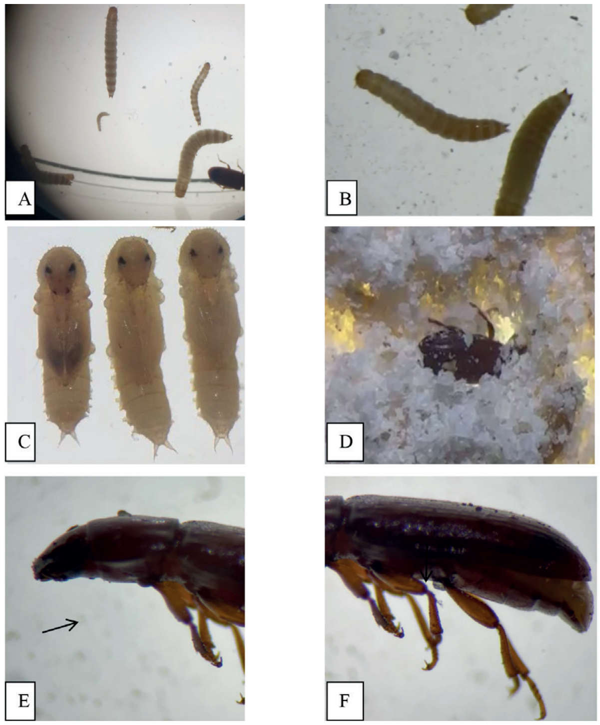

Figure 1. Different life stages of the red flour beetle *Tribolium castaneum* reared in the laboratory; A) Insect larvae at different instar ages, B) The 3rd instar larvae, C) Developed insect's nymphs, D) Adult insect digging and feeding in the flour, E and F) Adult insect's anterior.

Methanol leaf extract of peppermint (Mentha piperita)

Fresh mint plants were collected from a farm located in the south of Najaf province, Iraq, and then washed with running tap water. After washing, the mint leaves were left in the laboratory for seven days until completely dry. The dried leaves were cut, ground by hand, and stored in black polythene bags. A total of 100 g of the acquired powder was extracted by adding 0.5 liter of 70% methanol (MeOH) for 48 hours at room temperature. The methanol was then evaporated using a rotary evaporator at 30–40 °C to obtain the crude extract.

Essential oil of peppermint

A 100 g of dried plant material with 500 ml of water were subjected to hydro distillation for 4 hours using the Clevenger apparatus. The essential oil was separated and stored in a refrigerator at 4 °C for further analysis. To compare the effect of selected plant extracts and essential oils with conventional insecticides as positive control, Deltamethrin (Decis® 2.5EC) was chosen.

Bioassays

Spray method: Adults, pupae, and 3rd instar larvae were sprayed with 3 ml solutions of the mint extract (dissolved in methanol) or mint essential oil (dissolved in water) using a hand sprayer after calibration to ensure homogenous coverage. Insects were left for 15 minutes and then transferred to Petri dishes containing white flour supplemented with brewer`s yeast at 30 °C. Five biological replicates were used, each consisting of 10 insects. Survival was monitored daily for 7 days. To obtain 1% solution treatments, 0.5 ml of the tested materials and 1 ml of soap liquid were placed in a glass flask and filled to 50 ml.

Repellent / attractive effect

The repellent and attractive effects of *M. piperita* extract and oil were tested at different concentrations using a Chemotropometer (Figure 2). The test was conducted by placing a piece of cotton at the entrance to the opening of the tube containing the concentration of the extract or oil to be tested, while another piece of cotton containing only sterile distilled water was placed in the other hole. Ten adults were inserted for each replicate, with three replicates per concentration. The box was closed to prevent light from reaching the adults. The adults were allowed to move for 15 minutes, after which the box was opened, and the number of adults moving towards or away from the cotton treated with the extract or oil was recorded. The rate of attraction and repulsion was calculated as follows:

Attraction (%)=(No.insects directed to substance)/(Total No.of insects) x100

Repellence (%)=(No.insects opposit to substance)/(Total No.of insects) x100

Figure 2. Chemotropism device used in testing the repulsive and attractive properties of mint essential oil and mint methanol leaf extract

Experimental design and data analysis

All experiments were repeated twice, and data were subjected to Analysis of Variance (ANOVA) using GenStat package 2009, (12th edition) version 12.1.0.3278 (www.vsni.co.uk). Waller-Duncan's multiple range test was used for means separation wherever appropriate. The experiments were conducted using a Completely Randomized Design (CRD) with five replications. Means were compared for the least significant difference (LSD) using Duncan's multiple range test at 95% of confidence ($P \leq 0.05$).

RESULTS

The results of GC-MS analysis of peppermint leaf methanol extract

The results of the GC-MS analysis of alcoholic mint extract showed that there are ten active substances that recorded the highest estimated peaks for the compounds: Oxime-, methoxy-pheny ($C_8H_9NO_2$) with an area of 45.02 and a retention time of 4.169 min, Cyclotrisiloxane, hexamethyl ($C_6H_{18}O_3S$) with an area of 34.67 and a retention time of 6.566 min., Cyclotetrasiloxane, octamethyl ($C_8H_{24}O_4Si_4$) B with an area of 3.56 and a retention time of 9.249, Hexadecanoic acid, methyl ester ($C_{17}H_{34}O_2$) with an area of 1.72 and a retention time of 21.125 min, and Tetraacetyl-d-xylonic nitrile $C_{14}H_{17}NO_9$) with an area of 2.04 and a retention time of 21.713 min (Table 1).

The results of GC-MS analysis of peppermint essential oil

On the other hand, the results of the GC-MS analysis of peppermint oil showed that 15 compounds of active substances were recorded (Table 2). The most abundant compounds that recorded the highest estimated peaks were: 5-methyl-2-(1-methyl ethyl-trans) ($C_{10}H_{20}O$) with an area of 23.23 and retention time of 4.124 min, Cyclohexanol ($C_{20}H_{26}O$, and $C_{20}H_{26}O$) with an area of 47.50 and a retention time of 8.739 min, Menthyl acetate ($C_{11}H_{22}O$) with an area of 11.59 and a retention time of 10.678 min, beta-ylangene ($C_{15}H_{24}$) with an area of 3.61 and a retention time of 13.101 min, and Tetraacetyl-d-Caryophyllene oxide ($C_{15}H_{24}O$) with an area of 0.34 and 16.052 min retention time (Table 2).

Effect of spraying peppermint oil on flour beetle larvae

The results (Figure 3) indicate that peppermint oil showed a clear antibiotic effect against the third instar larvae of the red flour beetle, especially at the highest concentration of 12%, while the lower concentrations of 8%-10% of the oil were in most cases less than or equal to the effect of spraying with the control treatment (water and soap). It is noted that the higher concentration led to a mortality rate of more than 80% from the first day, compared to less than 10% mortality where using 10% oil spraying treatments, which generally recorded relatively higher mortality rates or close to those recorded when using oil at a higher concentration 8%.

Table 1. GC-MS analysis of the active compounds in peppermint leaf GC-MS analysis of peppermint leaf methanol extract

No.	R.t (min)	Nursery area	Molecular formula	M.W(g/mole)	Area %
1	3.710	Glycine-N,N-bis(methylenephosphonic acid) 113289 002439-99-8	$C_4H_{11}NO_8P_2$	263.08 g/mol	1.84
2	4.169	Oxime-, methoxy-phenyl-_ 24837 1000222-86-6	$C_8H_9NO_2$	151.16 g/mol	45.02
3	4.731	11H-Dibenzo[b,e][1,4]diazepin-11-one, 5,10-dihydro-5-[3-(-methylamino) propyl]- 128388 013450-70-9	$C_{13}H_{10}N_2O$	210.23 g/mol	2.88
4	6.566	Cyclotrisiloxane, hexamethyl- 79619 000541-05-9	$C_6H_{18}O_3Si_3$	222.46 g/mol	34.67
5	6.809	1H-Trindene, 2,3,4,5,6,7,8,9-octah ydro-1,1,4,4,9,9-hexamethyl- 129526 055682-87-6	$C_{21}H_{30}$	282.4629 g/mol	4.83
6	7.423	2-Aminononadecane 130243 031604-55-4	$C_{19}H_{41}N$	283.5 g/mol	1.92
7	9.249	Cyclotetrasiloxane, octamethyl- 141484 000556-67-2	$C_8H_{24}O_4Si_4$	296.61 g/mol	3.56
8	10.141	Arsenous acid, tris(trimethylsilyl) ester 178799 055429-29-3	$C_9H_{27}AsO_3Si_3$	342.49 g/mol	1.53
9	21.125	Hexadecanoic acid, methyl ester 119400 000112-39-0	$C_{17}H_{34}O_2$	270.5 g/mol	1.72
10	21.713	Tetraacetyl-d-xylonic nitrile 178849 1000130-04-4	$C_{14}H_{17}NO_9$	343.29 g/mol	2.04

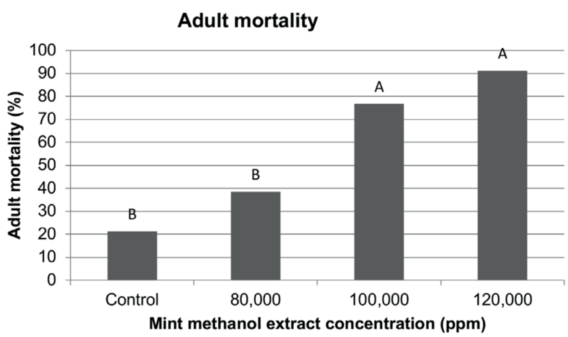

Figure 3. Effect of spraying with mint oil at different concentrations on the adults mortality red flour beetle *Tribolium castaneum*. Bars with different letter are significantly different according Fisher LSD grouping (P≤0.05)

Effect of spraying with mint oil on flour beetle adults

As for the effect of spraying with peppermint oil on adult insects (Figure 5), the results showed that the effect of the oil increased on insect mortality with increasing concentration used, as the concentrations differed significantly (P≤0.05). The concentration of 8% generally recorded the lowest mortality rate from the first day to the seventh day, which ranged from 35% -to 42%, while the 10% concentration led to a significantly higher mortality rate than the previous concentration, as it recorded a mortality rate that ranged from 68% -to 75%. This is compared to the higher concentration (12%), which recorded a mortality rate in insect adults on the first day, which exceeded 85% and ended on the seventh day with a percentage of 94%, which differed significantly (P≤0.05) from the effect of the two lower concentrations of 10% - 8% of the mint oil (Figure 4).

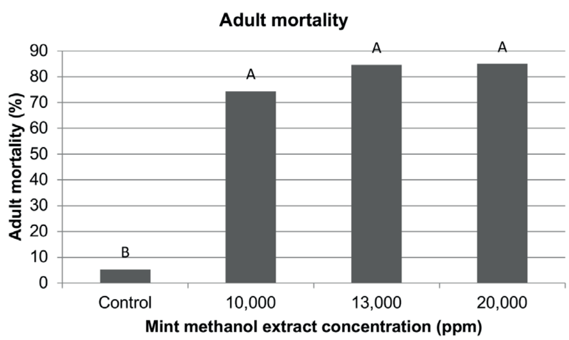

Figure 4. Effect of spraying with mint leaf methanol extract at different concentrations on the adults mortality red flour beetle *Tribolium castaneum*. Bars with different letter are significantly different according Fisher LSD grouping (P≤0.05)

Table 2. GC-MS analysis of the active compounds in peppermint essential oil

No.	R.t (min)	Compounds	Molecular formula	M.W(g/mole)	Area %
1	5.623	D-Limonene 15682 005989-27-5	$C_{10}H_{16}$	136.23 g/mol	1.12
2	6.999	Cyclohexanol, 5-methyl-2-(1-methy lethyl)-, (1.alpha.,2.alpha.,5.alph a.)- 28381 000491-02-1	$C_{10}H_{20}O$	156.26 g/mol	0.36
3	7.440	Butanal, 3-hydroxy- 2033 000107-89-1	$C_4H_8O_2$	88.11 g/mol	0.30
4	8.124	Cyclohexanone, 5-methyl-2-(1-methy lethyl)-, trans- 26912 000089-80-5	$C_{10}H_{18}O$	154.25 g/mol	23.23
5	8.349	Cyclohexanone, 5-methyl-2-(1-methy lethyl)-, trans- 26912 000089-80-5	$C_{10}H_{18}O$	154.25 g/mol	5.50
6	8.739	Cyclohexanol, 5-methyl-2-(1-methyl ethyl)- 28342 001490-04-6 Cyclohexanol, 5-methyl-2-(1-methyl ethyl)-, (1.alpha.,2.beta.,5.alpha .)-(.+/-.) 28387 015356-70-4	$C_{20}H_{26}O$ $C_{10}H_{20}O$	282.4 g/mol 156.26 g/mol	47.50
7	10.046	2-Cyclohexen-1-one, 3-methyl-6-(1-methylethyl)- 25293 000089-81-6	$C_{10}H_{18}O$	154.25 g/mol	0.43
8	10.357	1-Decanol 29593 000112-30-1	$C_{10}H_{22}O$	158.28 g/mol	1.54
9	10.678	Menthyl acetate 59498 000089-48-5	$C_{12}H_{22}O_2$	198.30 g/mol	11.59
10	11.456	Cyclohexane, 1-ethenyl-1-methyl-2- (1-methylethenyl)-4-(1-methylethyl idene)- 64474 003242-08-8	$C_{15}H_{24}$	204.35 g/mol	0.17
11	12.495	(-)-.beta.-Bourbonene 64360 005208-59-3	$C_{15}H_{24}$	204.35 g/mol	1.25
12	12.824	photocitral B 25079 006040-45-5	$C_{10}H_{16}O$	152.23 g/mol	0.35
13	13.110	beta.-ylangene 64294 1000374-19-1	$C_{15}H_{24}$	204.35 g/mol	3.61
14	13.309	1,6-Cyclodecadiene, 1-methyl-5-met hylene-8-(1-methylethyl)-, [S-(E,E)]- 64463 023986-74-5	$C_{15}H_{24}$	204.35 g/mol	0.94
15	13.560	1,6-Cyclodecadiene, 1-methyl-5-met hylene-8-(1-methylethyl)-, [S-(E,E)]- 64463 023986-74-5	$C_{15}H_{24}$	204.35 g/mol	0.27
16	13.707	1H-Cyclopropa[a]naphthalene, 1a,2, 3,5,6,7,7a,7b-octahydro-1,1,7,7a-t etramethyl-, [1aR-(1a.alpha.,7.alp ha.,7a.alpha.,7b.alpha.)]- 64579 017334-55-3	$C_{15}H_{24}$	204.35 g/mol	0.62
17	14.140	Spiro[4.5]dec-7-ene, 1,8-dimethyl-4-(1-methylethenyl)-, [1S-(1.alpha .,4.beta.,5.alpha.)]- 64504 024048-44-0	$C_{15}H_{24}$	204.35 g/mol	0.25
18	14.572	1,6-Cyclodecadiene, 1-methyl-5-met hylene-8-(1-methylethyl)-, [S-(E,E)]- 64463 023986-74-5	$C_{15}H_{24}$	204.35 g/mol	0.38
19	16.052	Caryophyllene oxide 77539 001139-30-6	$C_{15}H_{24}O$	220.35 g/mol	0.34
20	21.116	Hexadecanoic acid, methyl ester 119400 000112-39-0	$C_{17}H_{34}O_2$	270.5 g/mol	0.26

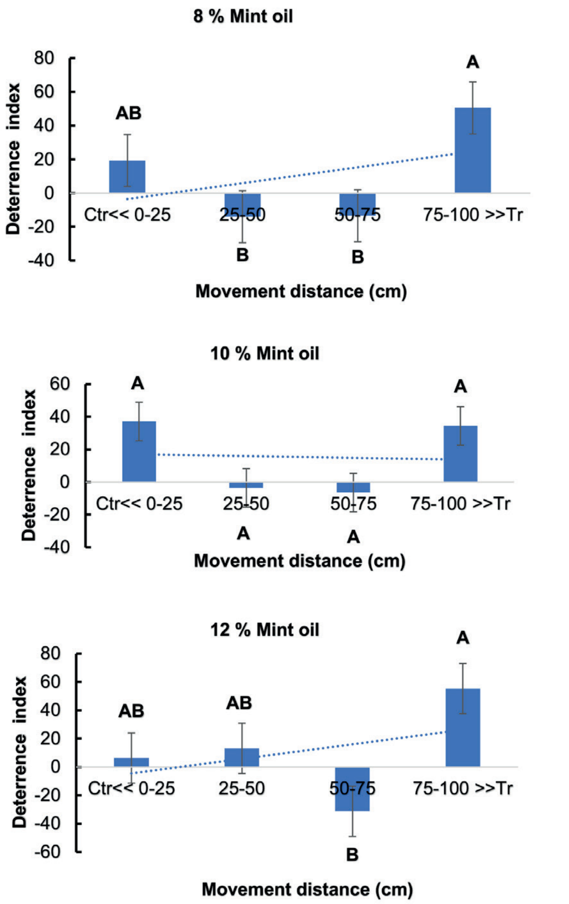

Figure 5. Peppermint *Mentha piperita* oil repellent/attractive effect on the red flour beetle *Tribolium castaneum* adults. The mint oil was used at three concentrations 8, 10, and 12% respectively

Peppermint oil repellent/attractive effect on the red flour beetle adults

In testing the repellent/attractive effect of peppermint oil on adult insects of the red rusty flour beetle, the results generally showed that peppermint oil exhibited a repellent effect towards the insect, especially at high concentrations. The repulsion rate of peppermint oil at the lowest concentration of 8% differed significantly from the attraction rate after 15 minutes of treatment. However, the results showed that sometimes the repellent/attractive effect of peppermint oil was not clear in the repulsion/attraction test, which did not differ between them at the concentration of 10% (Figure 5). On the other hand, the 12% concentration treatment recorded high significant differences between the rates of attraction/repulsion of the insect adults. Where the largest number was recorded in the direction opposite to the oil treatment with a percentage of expulsion (Figure 5).

The results showed that the effect of the methanolic mint leaf extract was somewhat similar in its repellent effect to that recorded in peppermint oil on the insect, especially at the higher concentration of the extract (15%). It was found that at a low concentration of the extract, the distribution of insects at a distance of 10-50 cm did not differ between them, while the insect concentration was large towards the control (Figure 6). The repellency rate also increased at the distance closest to the control 25-50 cm, and a significantly low repellency rate was recorded at distances of 50-100 cm, although the repulsion towards the treatment was mathematically higher than the average distance of 50-75 cm (Figure 6). However, it was found that the repellence to the adult insects was significant at the higher concentration of the 20% extract, which recorded a significant repellency at the end tube spot compared to all other distances (0 - 75 cm) of the scale (Figure 6).

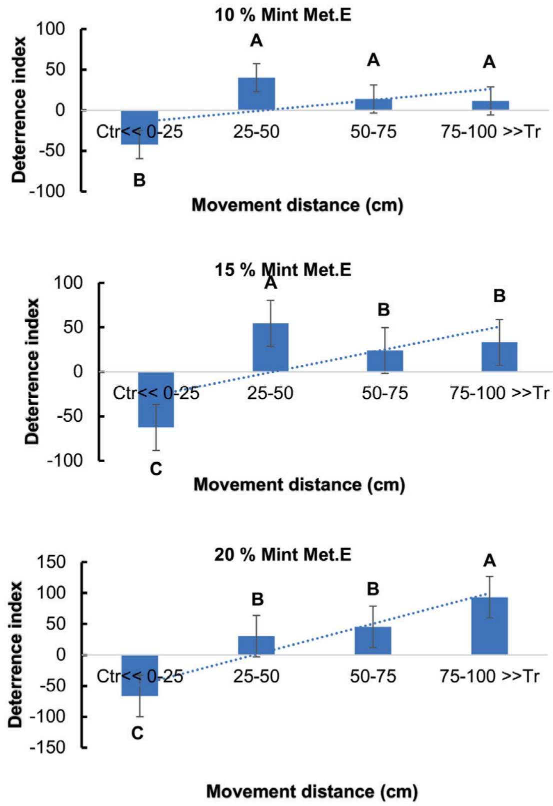

Figure 6. Peppermint *Mentha piperita* methanol extract (Mint Met.E) repellent/attractive effect on the red flour beetle *Tribolium castaneum* adults. The mint extracts were used at three concentrations 10, 15, and 20% respectively

DISCUSSION

The results obtained in this study agree with previous results in testing the efficacy of plant extracts from four plants: *Melissa officinalis*, *Thymus vulgaris*, *Mentha piperita* and *Rosmarinus officinalis*. Mint was the second-best treatment, leading to mortality in juveniles with a rate higher than 50% in *T. castaneum* juveniles and a lower rate in *T. granarium* juveniles, compared to higher levels of mortality using *R. officinalis*. Peppermint extract also recorded a similar effect on adult females with a mortality rate higher than 70%, but its effect was much lower on *T. granarium* adults, with a higher effect than *Thymus vulgaris* and *Melissa officinalis*, but a lower effect than *Rosmarinus officinalis* (Panezai et al. 2019). Damage to food products and stored grains can be considered an ongoing problem in all regions of the world and is more serious in developing countries (Stejskal et al. 2015). In general, stored grains are often affected by insect infestations that accompany crops stored in large warehouses or retail stores. The damage resulting from stored grain pests is estimated at approximately 10-40%, not only through the consumption of stored grains and materials, but also in reducing the quality of the stored product and making it unfit for human consumption or a significant reduction in its marketing value (Lefèvre and Fady 2016). The anti-inflammatory effect of peppermint oil on warehouse insects is often due to the nature of the oily fats, which interfere with their content of active substances to influence basic metabolism and physiological-biochemical processes, which may affect the behavior of the treated insects (Linsley 1944). In general, the anti-insect effect of peppermint oil has been the subject of many studies, most of which were directed towards combating insects of the order Coleoptera (Kumar et al. 2011). On the other hand, although vegetable oils are environmentally friendly and harmless to humans, the treatment of stored food products and grains must be accompanied by controls and consideration to remove the effect of the oil to a level that does not affect the stored food material and does not reduce the commercial properties of the material (Golob 1997). Sometimes, the presence of insect pests of stored materials, including rice weevils, corn weevils, red and similar rusty flour beetles, and other insects, is considered the determining factor for the survival of the crop with good economic quality (Keskin and Ozkaya 2013), since in these cases the specific damage to the stored material is more severe than the damage caused by quantitative loss (Kumar et al. 2011). Natural peppermint compounds have the ability to affect the sensing and communication systems of insects (Mishra et al. 2012), which may lead to reduced mating and egg production, and thus limit the reproduction of this pest (Regnault-Roger et al. 2012). It was also reported that some compounds in mint may affect the hormonal and developmental systems of insects, enhancing the chances of controlling them (Kumar et al. 2011). The study of Lee et al. (2002) indicated the effectiveness of *M. piperita* oil when used in relatively low concentrations (LD_{50}: 25.8 µl/l) against the red rusty flour beetle *T. castaneum*. This confirmed previous results in the study (Mishra et al. 2012). When using it on *S. oryzae*, it was found that mint oil used by evaporation or contact differed in its impact on the main warehouses insects *T. castaneum*, *Lasiooderma serricorne* and *Liposclis bostrychophiva* where a high mortality rate with low concentrations was recorded on *T. castaneum* by vaporization, which was LD_{50}: 18.1 µl/l (Pang et al. 2020). Mint is known for its active compounds such as menthol, methyl acetate, and menthone, possessing antibacterial (Fazal et al. 2023), antifungal (Abdelli et al. 2016), and insect-repellent properties (Kumar et al. 2011). The results of the study implicitly agreed on the effect of the *Mentha* spp. on *T. castaneum*, which was found to be relatively less sensitive compared to the *C. maculatus* insect, which showed a higher sensitivity to vegetable oil. Similar results recorded in the effect of methanolic mint extract of from peppermint, which recorded a death rate of 70% in insect food treatment after a period of 7 days of treatment in laboratory plastic vessels (Saljoqi et al. 2006). The study conducted by Negahban et al. (2007) was indicated that the insecticidal activity of vegetable oils varied with insect species, concentrations of the oil and exposure time. The results showed higher mortality rates in *C. maculatus* than in *S. oryzae* and *T. castaneum*. At 444 ml/L air the mortality was 100% after 12 h for *T. castaneum*. Based on their experimental study in a controlled laboratory environment, Atay et al. (2024) reported that the essential oil of *Mentha piperita* L. (Lamiaceae) has the potential to control two important stored product pests, *Tribolium castaneum* (Herbst, 1797) (Coleoptera: Tenebrionidae) and *Sitophilus granarius* (Linnaeus, 1758) (Coleoptera: Dryophthoridae).

The study included evaluating the effectiveness of peppermint oil and peppermint leaf extract (methanol) against different stages of the red rusty flour beetle. The study showed that treatments of *Mentha piperita* oil at all concentrations under study, when sprayed on the insect, were significantly effective in causing high mortality rate in *T. castaneum* adults. On the other hand, it was found that spraying with methanol mint leaf extract also led to a clear mortality rate in insect adults, but with less efficiency than mint essential oil treatments. The peppermint oil and methanol extract of mint leaves showed a moderate to high repellent effect on insect adults, which fluctuated depending on the concentration used and the period post-treatment.

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Author's Contributions
Authors declare the contribution of the authors is equal.

Statement of Conflict of Interest
The authors have declared no conflict of interest.

ÖZET

Kırmızı un böceği *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) depolanan tahılların ve gıda ürünlerinin hem kalitesini hem de miktarını etkileyen olumsuz bir faktör olarak dikkate değer bir öneme sahiptir. Bu çalışmada, kırmızı un böceği zararlısını çevre dostu doğal materyaller kullanarak kontrol etme olasılığını araştırmak amacıyla, nane yağı ve alkollü (metanolik) nane ekstraktının Kırmızı un böceğinin farklı aşamalarına karşı etkinliğini değerlendirmek üzere bir dizi laboratuvar deneyi yapılmıştır. Bu çalışmanın sonuçlarına göre, %8, %10 ve %12'lik konsantrasyonlardaki nane *Mentha piperita* L. (Lamiaceae) yağının uygulamalarının, tüm dozlarda Kırmızı un böceği mortalitesi üzerine önemli bir etkiye sahip olduğu tespit edilmiştir. Sprey yöntemiyle yapılan uygulama sonucu ölüm oranı üçüncü larva döneminde %36'dan %80'e, ergin evrede ise %40'tan %94'e çıkmıştır. Nane yaprağı metanol ekstraktının en yüksek konsantrasyonda (13000 ppm) uygulanması, 7 günlük uygulama sonrası larva ölümlerinin %87'ye varan oranda artmasına neden olmuştur. Nane yağı, özellikle en yüksek konsantrasyonda (%12) uygulandığında, kırmızı un böceğinin üçüncü dönem larvalarına karşı önemli insektisidal etki göstermiştir. Ancak, nane uçucu yağının %8 ve %10'luk daha düşük konsantrasyonları kontrole göre önemli bir farklılık ortaya çıkarmamıştır. Bu çalışmanın sonuçları, Kırmızı un böceğine verilen yemde nane yağı arttıkça larva ölüm oranının arttığını, özellikle %12'lik en yüksek konsantrasyonda, 3. dönem larvalarda %82 ve yetişkinlerde %95 ölüm oranı kaydettiğini gösterdi. Bu çalışma, Kırmızı un böceğinin (*T. castaneum*) kontrolünde çevre dostu bir ürün olarak nane esansiyel yağının nispeten düşük konsantrasyonlarda kullanılmasının mümkün olabileceğini ortaya koymuştur.

Anahtar kelimeler: esansiyel yağı, nane, metanolik ekstraktlar, Tribolium castaneum, kırmızı un böceği

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