J. of Plant Protection and Pathology, Mansoura Univ., Vol. 13 (2): 47 - 54, 2022

Journal of Plant Protection and Pathology

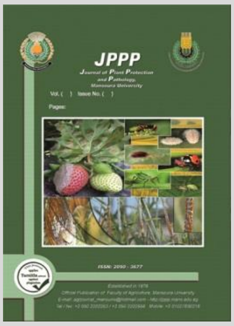
Journal homepage & Available online at: www.jppp.journals.ekb.eg

Protection of Stored Grain Products by Loading Garlic (*Allium sativum*) and Parsley (*Petroselinum crispum*) Essential Oils on Cork Disks

Cross Mark

Alzahraa A. Elmadawy[*] and A. F.Omar

Stored Product Pests Department, Plant Protection Research Institute (Sakha, Kafr El-Shiekh), Agricultural Research Center, Egypt



ABSTRACT

Stored products and commodities are more accessible to get plagued by stored pests during storage period that resulting in damage and losses to stored products. Overuse of insecticides in stored and commodities protection caused environmental risks and economic encumbrances. Therefore, natural products may offer an alternative new way of protection. In this study, garlic (*Allium sativum*) and parsley (*Petroselinum crispum*) essential oils that loaded on cork disks were investigated against larvae and adults of both the khapra beetles, *Trogoderma granarium* and red flour beetles, *Tribolium castaneum*. The chemical composition of garlic (*Allium sativum*) and parsley (*Petroselinum crispum*) essential oils revealed that 1,3,8-p-menthatriene was the primary ingredient (23.34 %) of parsley essential oil, alpha-Terpinene was a small ingredient (1.40 %) of parsley essential oil. While, diallyl disulfide (27.9 %), dialyl tetrasulfide was a minor component (1%) in garlic essential oil. Results showed that cork disks loaded with garlic oil more superior than those loaded with parsley oil against both adult and larvae of the khapra and red flour beetles. However, both tested stages of *T. castaneum* beetle were more tolerant than those of *T. granarium*. Also, there was a significant difference between concentrations of each essential oil loaded on cork disks and control treatment, indicating that both essential oils can decline the feeding of larval and adult stages during the exposure time. Finally, the essential oils loaded on disks may be an effective approach to protect stored products (wheat flour and grains) from *T. granarium* and *T. castaneum* infestation.

Keywords: Feeding, Essential oils, cork disks, stored products, *Trogoderma granarium*, *Tribolium castaneum*.

INTRODUCTION

Grains, cereals, and their industrial derivatives are among humanity's most important food sources. Grain and cereal production is expected to reach 2,765 million tonnes in 2020/21, according to estimates. (FAO, 2020). Stored products and commodities are more likely to become infested by stored pests during long storage periods (Mullen *et al.*, 2012). Stored pests and other bio-agents resulting in damage and losses to stored products ranged from 10 to 40% all over the world (Papachristos and Stamopoulos, 2002). Insect damage primarily impacts the product's quality, quantity, commercial, and agronomic qualities (Bell *et al.*, 1998). As a result, they must be safeguarded against pest infestation throughout production and storage in a methodical manner. Due to the overuse of insecticides with high doses, it became, exceedingly expensive, and it raised questions about human and environmental fitness, as well as insect resistance (Desneux *et al.*, 2007).

Order Coleoptera (beetles) and Lepidoptera (moths) involve the most harmful insect pests of stored products, which are worldwide distributed (Robertson, 2006). The khapra beetle, *Trogoderma granarium* (Everts), is one of these insects, which has been described as the world's most devastating insect pest of stored items and commodities (Lowe *et al.*, 2000; Mark *et al.*, 2010; Athanassiou *et al.*, 2019). That is because it feeds on a wide range of foods, such as stored cereals or related products and non-grain commodities (Degri and Zainab, 2013; Athanassiou et al., 2016; Kavallieratos et al., 2019). Besides, its larvae may fall under optional lethargy for several years and are tolerant to insecticidal treatments as mentioned by (Edde et al., 2012; Myers and Hagstrum, 2012; Athanassiou et al., 2015). Thus, it has attracted great attention after the attainment of the status of A2 quarantine organism due to its harmful larval stages (EPPO, 2011). On the other hand, the red flour beetle, *Tribolium castaneum* (Herbst) is one of the secondary pests of cereal grains that feed on a wide scope of stored product, flours, and other processed products which are among the most favored foods varieties for both the adults and neonates (Ramadan *et al.*, 2020).

Therefore, the strategy for the protection of such stored products and commodities should be based on Integrated Pest Management (IPM) principles by using combinations of varied methods (Trematerra and Fleurat-Lessard, 2015; Stejskal *et al.*, 2019). In the recent years, several research have been conducted in recent years to investigate the use of botanical sources such as essential oils and their bioactive chemical component as an alternative to synthetic insecticides (Rajendran and Srianjini, 2008). Research has shown that many plants extracts have recently been proven to have insecticidal effects and rapid degradation in addition to low toxicity to non-target organisms (Sha Sha *et al.*, 2010).

In this pattern, the European Union energizes a significant decrease in the utilization of compound pesticides, empowering the utilization of more eco-accommodating methodologies under the Integrated Pest Management (IPM) principles (Hillocks, 2012; Lucchi and Benelli, 2018). Many studies have been focused on the use of plant-derived materials as bio-insecticides, particularly essential oils (EOs). Plant extracts have recently been utilised to control a wide

[*] Corresponding author.
E-mail address: wza1841981@yahoo.com
DOI: 10.21608/jppp.2022.124365.1062

spectrum of insects on a variety of stored commodities, with varied treatment methods (Athanassiou *et al.*, 2014). It could provide effective alternatives or supplements to a synthetic insecticide with no side effects on the non-target organism (Isman, 2006; Dhifi *et al.,* 2016). Fumigations formulations are effective for indoor conditions and are commonly used to control the population of pests by vaporization of repellent chemicals (Ogoma *et al.,* 2012). The active compounds loaded on a carrier such a procedure specialized with rapid-acting have killing properties with repellent effects (Rozendaal, 1997). In this study, an attempt to develop a new approach for the management of stored product insects depending on loeading essential oil as biopesticide on cork disks as a carrier for slow release. In this study, cork disks act may affect as fumigation, repellent, or by contact upon the tested insect.

MATERIALS AND METHODS

Insect

Adult and larva stages of the Khabra, *Trogoderma granarium* Everts as well as the red flour beetles, *Tribolium castaneum* (Herbst) (Coleoptera: Dermestidae) used in bioassays were obtained from stock colonies maintained in the Sakha Agricultural Research Station's Stored Product Insects laboratory, Agriculture Research Center (ARC) Egypt. adults of *T. granarium* less than 24 hours old and larvae measuring 2–4 mm in length were used. (Athanassiou *et al.,* 2016) were used in the experiments. These stagdes were cultured on wheat grains at 30 °C, 65% relative humidity (RH) and continuous darkness.

Adults and larvae of *Tribolium castaneum* were raised on a cracked wheat grain and wheat flour mixture. Cracked grain was washed, sanitised, and placed in 400 g (30 percent wheat flour) glass jars with 100-200 adult beetles in each. Light: dark photoperiod of 16:8 light: dark photoperiod of 16:8 light: dark photoperiod of 16:8 light: dark photoperiod of 16:8 light: dark photoperiod of 16:8 light: dark photoperiod of 16:8 light: dark photoperiod of 16:8 light: the beetles (unsexed; 4-7 days old) were sieved out of the stock colony the next day and used in the studies.

Essential oil

Garlic (*Allium sativum*) and parsley (*Petroselinum crispum*) essential oils (Eos) were supplied by Hashem Brothers Company for Essential Oils and Aromatic Products (Kafr-Elsohby, Kalyoubeya, Egypt).

GC/MS analysis of the essential oils.

The chemical composition of the essential oils was determined using gas chromatography-mass spectrometry (GC/MS) with an HP column (60 m 0.25 mm, 0.25 m film thickness) on a model (HP5890-USA) (HP-5 ms). For 65.3 minutes, the temperature was 60 °C at the start and 250 °C at the end. The injector had a temperature of 240 degrees Celsius. The equipment software determined relative percentage quantities from the overall area of the peaks. According to Wiley 275. L, the chemicals were identified by comparing mass spectra data with those stored in a computer library (Swigar and Silverstein, 1981) and (Adams, 1995). All analysis steps were carried out in the laboratory of Hashem Brothers Company, Egypt.

Carrier disks

Carrier disks used for tested essential oil were made manually from a cork sheet with equal size 2.0 cm in diameter and 0.1 cm in thickness.

Bioassays

Preparation of essential oil concentration

Serial concentrations for both tested essential oil (EOs) were obtained by dilute 1ml of crude oil in 100 ml acetone to obtain standard solution then, (2.5, 5, 7.5, 10, and 12.5) mg/ml were prepared from the standard solution of garlic and parsley oil. After preparation of the required concentration, disks were treated separately by the targeted concentration of each essential oil. After that, 10 gm of wheat grain were introduced in a small jar then treated disks were put over the grain then exposed to ten adults of *Trogoderma granarium* for each concentration. The same was done for *T. granarium* larva. Each concentration replicated three times.

For *Tribolium castaneum* and its larval, we used the same procedure instead of replacing the wheat grain in the above experiment with cracked wheat, an additional series of disks were prepared without any treatment and served as controls. All jars were placed in incubators set at 30°C±5 and 65%±1 r. h. Mortality counts were recorded after 2, 5, and 7 days from treatment and corrected by Abbott's formula, (1925).

Antifeedant activity

To determine the effeciency of the tested essential oil on the vitality of the tested insects, antifeedant activity was estimated according to Shukla *et al.,* (2011). To calculate the antifeeding action of the EO, the percentage of weight loss of the whole and cracked wheat for both experiments was determined by estimating the difference between the initial weight at the beginning of the experiment, and the final weight in the end of the experiment for both control and treated samples, the feeding deterrent index (FDI) was calculated according to the following formula:

(FDI, %) equation $$\mathbf{FDI = \frac{C-T}{C} * 100}$$

Where C = weight loss of the wheat grains in control sample and T= weight loss in treated samples.

Statistical analysis

Data were analyzed by one-way ANOVA followed by the Least Significant Difference test for mean separation at 0.05 probability level. The experiments were performed in triplicate, data presented are the mean ± SE. The lethal concentration for 50% mortality (LC50) was determined by log-probit analysis (Finney, 1971), and the data were analyzed by determining chi-square values and degrees of freedom. The analysis of data was performed using SPSS program version 24.0 for Windows (SPSS Inc., IBM Corp.).

RESULTS AND DISCUSSION

Chemical composition tested essential oils

The major components of tested essential oils are summarized in Table (1). A total of 33 components were identified for parsley essential oil, the major constituents were Trimethyl bicylo (13.01%), Beta pienen (8.28%), Beta myrcene (3.93%), Beta phellandrene (3.81%),1,3,8-p-menthatriene (23.34%), Benzodioxole (11.67%), Apiol (12.72%) and Benzofuran (7.87%). Whereas the minor constituents were cavicol (2.51 %), Benzene-methyl (2.06 %) and Alpha-Terpinene (1.40%).

Where in (Table 2) a total of 42 components were identified for garlic essential oil, the major component were, dimethyl disulfide (1.4%), diallyl sulfide (9.5%), allyl methyl disulfide(8.3%), dimethyl trisulfide (2.9%), diallyl disulfide(27.9%), allyl (Z)-1 propenyl disulfide(2.2%), allyl (E)-1-propenyl disulfide (3.7%), allyl methyl trisulfide (17.7%), 4-Methyl-1,2,3-trithiolane(1.2%), 2-Vinyl-4H-1,3-dithiine(1.8%), diallyl trisulfide (16.8%) and diallyl tetrasulfide (1%).

Table 1. The main component of parsley (*Petroselinum crispum*) essential oil analyzed by gas chromatography-mass spectrometry (GC-MS).

Compounds	Percent Composition %	Molecular formula	Retention time (min)
Trimethyl bicylo	13.01	$C_{10}H_{16}$	6.20
Beta pienen	8.28	$C_{10}H_{16}$	7.52
Beta myrcene	3.93	$C_{10}H_{16}$	7.97
Beta phellandrene	3.81	$C_{10}H_{16}$	9.31
1,3,8-p-menthatriene	23.34	$C_{10}H_{14}$	12.85
Benzodioxole	11.67	$C_7H_6O_2$	30.05
Apiol	12.72	$C_{12}H_{14}O_4$	36.02
Benzofuran	7.87	C_8H_6O	12.08

Table 2. The main component of *Garlic (Allium sativum)* essential oil, analyzed by gas chromatography-mass spectrometry (GC-MS).

Compounds	Percent Composition%	Molecular formula	Retention time (min)
Dimethyl disulfide	1.4	$C_2H_6S_2$	12.32
Diallyl sulfide	9.5	$C_6H_{10}S_2$	14.25
Allyl methyl disulfide	8.3	$C_4H_8S_2$	15.26
Dimethyl trisulfide	2.9	$C_2H_6S_3$	16.13
Diallyl disulfide	27.9	C6H10S2	18
Allyl (Z)-1-propenyl disulfide	2.2	$C_4H_8S_2$	18.21
Allyl (E)-1-propenyl disulfide	3.7	$C_6H_{10}S_2$	18.33
Allyl methyl trisulfide	17.7	$C_4H_8S_3$	18.96
4-Methyl-1,2,3-trithiolane	1.2	$C_3H_6S_3$	19.21
2-Vinyl-4H-1,3-dithiine	1.8	$C_6H_8S_2$	20.23
Diallyl trisulfide	16.8	$C_6H_{10}S_3$	21.68
Diallyl tetrasulfide	1	C6H10S4	25.66

Essential oils toxicity against *Trogoderma granarium* and *Tribolium castaneum* adults.

In the present study *A. sativum* and *P. crispum,* essential oils exhibited strong insecticidal activity against both *T. granarium* and *T. castaneum* adults with a significant difference between treated concentrations along the test period.

Results in Fig (1,2) showed that the mortality percentage positively correlated with concentration rate under all treatment concentrations. Results demonstrate that *A. sativum* oil showed high efficiency than *P. crispum* oil against khapra beetle and red flour beetles along the test period. Where Mortality of *T. granarium* with the highest concentration recorded (60, 63.33, and 90 %) after 2, 5, and 7 days compared to (46.6, 50, and 73.3 %) in parsley respectively for the same concentration and investigation period.

In the same trend mortality of *T. castaneum* was recorded at the highest concentration of garlic (76.66, 76.66, and 90%) after 2, 5, and 7 days compared to (13.33, 36.66, and 60 %) in parsley respectively for the same concentration and investigation period. These results indicate that garlic essential oil had superiority over parsley oil with the adult of the two tested insects.

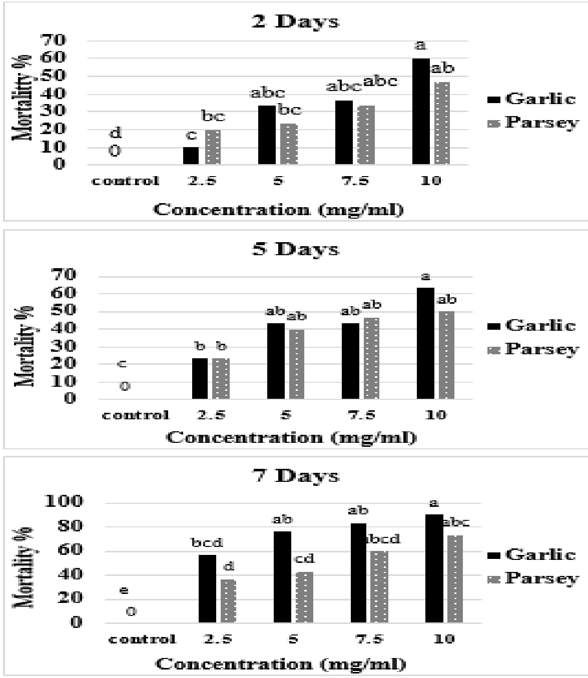


Fig. 1. Mortality percentage of garlic essential oil (*Allium sativum*) and parsley essential oil (*Petroselinum crispum*) against *Trogoderma granarium* adults after different exposure period.

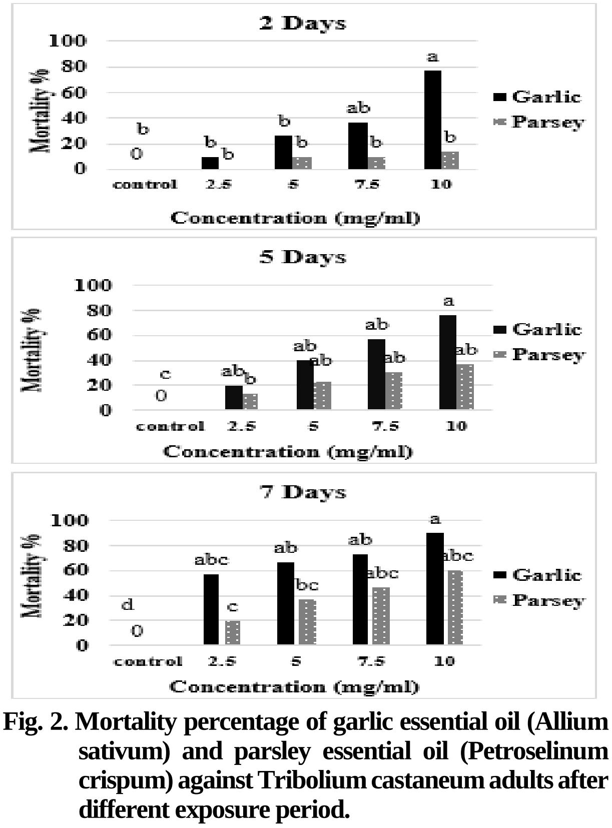


Fig. 2. Mortality percentage of garlic essential oil (Allium sativum) and parsley essential oil (Petroselinum crispum) against Tribolium castaneum adults after different exposure period.

Essential oils toxicity against *Trogoderma granarium* and *Tribolium castaneum* larvae.

For *T. granarium T. castaneum* larvae, results in Fig (3, 4) showed that the mortality percentage also positively correlated with concentration under all treatment with a significant difference between treated concentrations along the test period.

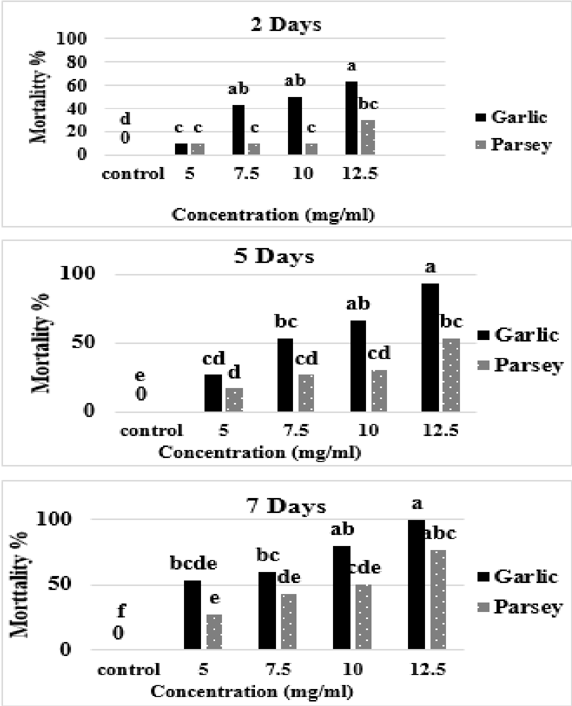


Fig. 3. Mortality percentage of garlic essential oil (Allium sativum) and parsley essential oil (Petroselinum crispum) against Trogoderma granarium larvae after different exposure period.

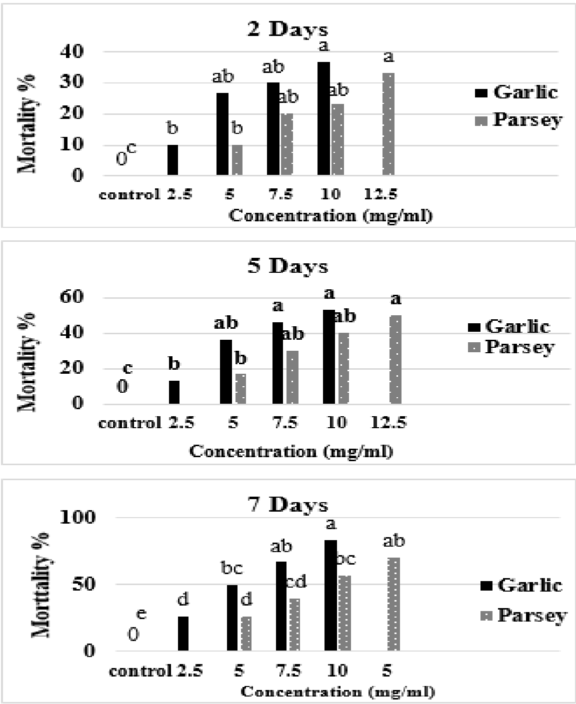


Fig. 4. Mortality percentage of garlic essential oil (Allium sativum) and parsley essential oil (Petroselinum crispum) against Tribolium castaneum larvae after different exposure period.

Where mortality of *T. granarium* larvae with the highest concentration recorded (63.33, 93.33, and 100 %) after 2, 5, and 7 days compared to (30, 53.33, and 76.66 %) in parsley respectively for the same concentration and investigation period. On the other hand mortality of *T. castaneum* was recorded at the highest concentration of garlic (36.66, 53.33, and 83.33%) after 2, 5, and 7 days compared to (33.33, 50, and 70 %) in parsley respectively for the same concentration and investigation period. These results also demonstrated the high efficiency of *A. sativum* oil over *P. crispum* oil against larvae of both khapra beetle and red flour beetles along the test period.

Comparative resistance of both adult and larva of *Trogoderma granarium and Tribolium castaneum* against tested essential oil.

Results documented in the Tables (3 and 4) compare between adults and larvae of *T. granarium* and *T. castaneum* adults according to LC_{50} of garlic essential oil. Results indicated that there are significant differences between the two insects wherein Table (3) LC_{50} recorded (8.67, 7.66 and 0.896 mg/ml) and (7.81, 6.49, and 1.658 mg/ml) for the adult of *T. granarium* and *T. castaneum* after 2,5 and 7 days of exposure respectively indicating high tolerance of *T. castaneum over T. granarium.* The same results were observed for both insect larvae after 2 and 5 days. Where LC_{50} was (10.06 and 7.49 mg/ml) compared to (12.52 and 8.64 mg/ml) for *T. granarium* and *T. castaneum* respectively while after 7 days of exposure there was no significant difference between both larvae recording 5.47 mg/ml for *T. granarium* and 5.306 mg/ml for *T. castaneum.*

Table 3. Comparative toxicity between *Trogoderma granarium* and *Tribolium castaneum* adults by garlic (*Allium sativum*) essential oil LC_{50} value.

Tested insect	Time (d)	LC_{50} Value (mg/ml)	Confidence Interval 95 %		Slope value	Chi-Square (X^2)
			Lower	Upper		
Trogoderma granarium	2 day	8.67 a	7.29	11.39	1.56	1.59
	5 days	7.66 a	5.80	11.54	0.970	1.083
	7 days	0.896 c	0.72	1.12	0.132	0.361
Tribolium castaneum	2 day	7.81 a	6.82	9.16	1.98	1.89
	5 days	6.49 b	5.24	7.83	1.32	0.089
	7 days	1.658 c	1.32	2.073	0.222	0.765

Values in the row followed by the same letters are not significantly different (P > 0.05) according to ANOVA and Duncan multiple-comparison tests.

Table 4. Comparative toxicity between *Trogoderma granarium* and *Tribolium castaneum* larvae by garlic (*Allium sativum*) essential oil LC_{50} value.

Tested insect	Time (d)	LC_{50} Value (mg/ml)	Confidence Interval 95 %		Slope value	Chi-Square (X^2)
			Lower	Upper		
Trogoderma granarium	2 day	10.06 b	8.78	11.94	1.87	3.25
	5 days	7.49 d	6.24	8.46	1.91	1.33
	7 days	5.47 e	4.38	6.84	1.27	3.94
Tribolium castaneum	2 day	12.52 a	9.33	43.60	1.356	1.104
	5 days	8.64 c	6.99	12.58	1.25	1.59
	7 days	5.306 e	3.81	6.47	1.103	0.116

Values in the row followed by the same letters are not significantly different (P > 0.05) according to ANOVA and Duncan's multiple-comparison tests.

For parsley, essential oil results in Tables (5 and 6) showed that there are significant differences between the two tested insects. Where results in Table (5) LC_{50} recorded (11.24, 9.103 and 5.57 mg/ml) and (18.68, 13.11 and 8.037 mg/ml) for *T. granarium* and *T. castaneum* adult after 2,5 and 7 days of exposure respectively, indicating high tolerance of *T. castaneum* over *T. granarium*. The same results were observed for both insect larvae after 2 and 5 days. Where LC_{50} was, (19.16 and 12.60 mg/ml) compared to (16.61 and 12.22 mg/ml) for *T. granarium* and *T. castaneum* respectively. For seven days of exposure treatment, there was no significant difference in LC_{50} value between both larvae recording 8.88 mg/ml for *T. granarium* and 9.05 mg/ml for *T. castaneum*. These results indicate that *T. castaneum* insect is more tolerant than *T. granarium* insect for both adults and larvae.

Table 5. Comparative toxicity between *Trogoderma granarium* and *Tribolium castaneum* adults by Parsley (*Petroselinum crispum*) essential oil LC_{50} value.

Tested insect	Time	LC_{50} Value (d) (mg/ml)	Confidence Interval 95 %		Slope value	Chi-Square (X^2)
			Lower	Upper		
Trogoderma granarium	2 day	11.24 c	8.64	34.23	1.175	0.235
	5 days	9.103 d	6.59	35.85	0.837	0.723
	7 days	5.57 f	2.82	7.50	0.736	0.263
Tribolium castaneum	2 day	18.68 a	14.94	23.35	2.189	2.213
	5 days	13.11 b	9.49	16.39	1.287	0.166
	7 days	8.037 e	6.37	11.55	1.127	0.206

Values in the row followed by the same letters are not significantly different (P > 0.05) according to ANOVA and Duncan's multiple-comparison tests.

Table 6. Comparative toxicity between *Trogoderma granarium* and *Tribolium castaneum* larvae by Parsley (*Petroselinum crispum*) essential oil LC_{50} value.

Tested insect	Time	LC_{50} Value (d) (mg/ml)	Confidence Interval 95 %		Slope value	Chi-Square (X^2)
			Lower	Upper		
Trogoderma granarium	2 day	19.16 a	13.95	23.95	1.99	1.99
	5 days	12.60 c	10.55	20.12	1.66	0.797
	7 days	8.88 e	7.29	10.55	1.48	0.995
Tribolium castaneum	2 day	16.61 b	12.66	20.76	1.727	0.250
	5 days	12.22 d	10.18	20.07	1.527	0.165
	7 days	9.05 e	7.35	10.96	1.399	0.013

Values in the row followed by the same letters are not significantly different (P > 0.05) according to ANOVA and Duncan's multiple-comparison tests.

Antifeedant activity

Results represented in Fig (5) illustrate the weight loss at the end of the experiment of whole and cracked wheat results from the feeding of both *T. granarium* and *T. castaneum* adult and larvae.

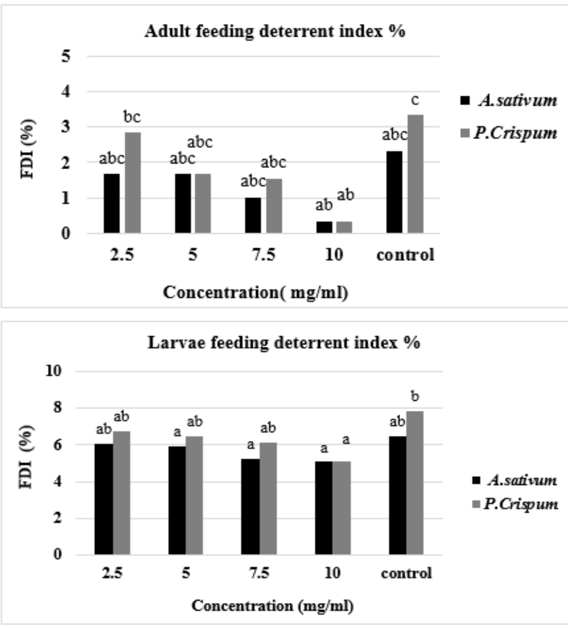


Fig. 5. Anti-feedent effect of garlic (*Allium sativum*) Parsley (*Petroselinum crispum*) essential oil against adult and larvae of *Trogoderma granarium* and *Tribolium castaneum*.

Where results showed that there is a significant difference between concentration and control treatment for both essential oil garlic (*A. sativum*) and parsley (*P. crispum*) indicating that both essential oils can suppress insect and larva feeding during the test period.

Discussion

Plant extracts include wide categories of promising components such as essential oils (EOs) to be used for developing novel, effective, and environmentally alternatives to pesticides (Stevenson *et al.*, 2017; Pavela *et al.*, 2019). EOs are being increasingly used due to their availability, cost-effectiveness, non-toxic to humans, nature, and limited development of resistance to target insects (George *et al.*, 2014). The chemical composition of *P. crispum* analyzed by GC–MS in (Table 1) agrees with earlier studies from different regions all over the world with some differences in component percentage due to climate change and environmental factors. In addition, the chemical constituents of *A. sativum* EO in Table (2) are in agreement with those of Satyal *et al.* (2017) and Mossa *et al.* (2018) who reported that *A. sativum* EO from various cultivated areas has shown specific resemblance, but quantitative differences in component concentrations. Previous components belonging to monoterpenes have been investigated to have a strong fumigant action against insects that attacks stored products (Bett *et al.*, 2016; Zhang *et al.*, 2016).

Results of the present study have demonstrated that natural plant botanicals tend to control *T. granarium* and *T. castaneum* population in stored commodities. Garlic and parsley have proved to be an effective botanicals against *T. granarium* and *T. castaneum* when applied on cork surface as a carrier with the superiority of garlic over parsley (Figs. 2 and 3). Earlier research has documented that EOs have the efficacy to use as grain protectants (Campolo *et al.*, 2018). These findings are following earlier studies where garlic essential oil loaded on coated polyethylene glycol (PEG) in the size of the nanoparticles has been proved to be insecticidal activity against *T. castaneum* (Yang *et al.*, 2009). Lu *et al.* (2013) reported that the active component of *A. sativum* essential oil has significant fumigation toxicity against different developmental stages of *T. castaneum*. In the same trend, Bortolucci *et al.*(2015), and Mansour *et al.* (2015) reported that parsley essential oil has insecticidal activity in some arthropods also, in parallel with our results. Massango *et al.* (2016) reported that *P. crispum* essential oil has low fumigation toxicity against *Callosobruchus maculatus*. Our findings revealed that the immediate larval mortality was lower than adult mortality almost at all treatments. Feroz (2020) revealed that both EOs of *Cymbopogon citratus* and *Cinnamonum camphora* were highly effective against populations of fifth instar larvae . Several studies are in line with our finding where Janaki *et al.* (2018) showed that *T. granarium* adults were highly susceptible to the EO of *Cyperus rotundus* that causing 94% repellence after 2 h of exposure when applied on filter paper. Also Tayoub *et al.* (2012) and Nenaah (2014) reported that EOs of different plant extracts exhibited strong fumigant and repellent activities against adults and second instar larvae of *T. granarium* after the different exposure periods. Estenial oil of *Tanacetum vulgare* caused complete mortality to *T. castaneum* larvae but less to adults at

1000 ppm after one week post-exposure (Kavallieratos *et al.,* 2021). Essential oils with repellent activity are volatile, requiring a physiologically acceptable carrier for their administration. In the present study, we developed garlic and parsley oil-based vaporizer formulations by loading these oils on cork disks to diminish the toxicity associated with these chemicals and slow-release up to 7 days. This formulation act by both technique direct contact to tested insect or by repellent action, repellent is a substance that acts locally or at a distance to prevent insects from biting its target. The repellent provides a vapor barrier of the loading substance to prevent insects from coming into contact with the target Legeay *et al.,* 2018). Regnault-Roger *et al. (*1993) reported that the volatile terpenes and phenolic compounds in EOs exhibit neurotoxic effects on insects through several mechanisms, such as the inhibition of acetylcholinesterase, octopamine, and gamma-aminobutyric acid (GABA) or through interactions with gustatory receptors (GRs) or olfactive receptors (ORs) as also reported by da Silva and Ricci-Júnior (2020). The encapsulation and microencapsulation of oil offers a promising new alternative to allow its slow release as well as to ensure that the active compounds these techniques had proven to be effective for use as controlled release in the control of agricultural pests (Senhorini *et al.,* 2012).

For the deterrent effect of tested essential oils, the antifeedant activity test indicated that Garlic (*A. sativum*) and parsley (*P. crispum*) EOs had greater signs to protect wheat grains from*T. granarium* and *T. castaneum* infestation. The study shows great similarity with the earlier studies of Rajkumar *et al.* (2019) and Sousa *et al.*(2015) who stated that *P. crispum* essential oil exhibited feeding and growth inhibitory effects against armyworm, *Pseudaletia unipuncta*. Athanassiou *et al.* (2014) reported that various essential oils have a negative impact on biological advantages like repellency, growth inhibition, and/or progeny or oviposition deterrence upon *Callosobruchus maculatus.* Garlic essential also reported in previous studies to have an antifeedant effect where Abdel-Hakim *et al*. (2021) mentioned that *A. sativum* essential oil leads to high mortality (100%) to *Sesamia cretica* larvae by inhibiting the larval feeding through making the food unpalatable or acting directly on the chemosensilla of the larvae leading to feeding deterrence.

CONCLUSION

Our findings show the negative impacts of Garlicand parsley EOs that loaded in cork disks as grain protectants against both larvae and adults of *T. granarium* and *T. castaneum*. In addition, to their impact as antifeedant agent, both reduced the losses in wheat weight during the experiment. Further research is still needed on the possible ecotoxicological effects as well as on the development of highly stable and effective formulations of such disks and loading efficiency of such carriers to be used in real-world applications alternative to conventional insecticide.

REFERENCES

Abbott, W. S. (1925). A method for computing the effectiveness of an insecticide. Journal of Economic Entomology 18, 265-267.

Abdel-Hakim, E. A., S. S Ibrahim and N. Y. Salem (2021). Effect of garlic and L]lemongrass essential oils on some biological and biochemical aspects of corn stem borer *Sesamia cretica* larvae (Lepidoptera: Noctuidae) during diapausing phase. In *Proceedings of the Zoological Society* 74(1): 73-82.

Adams, R. P. (1995). Identification of essential oil components by gas chromatography/mass spectroscopy. Allured Publishing Co., Carol Stream, IL javascript:void.

Athanassiou, C. G., N. G. Kavallieratos, and M. C. Boukouvala (2016). Population growth of the khapra beetle, Trogoderma granarium Everts (Coleoptera: Dermestidae) on different commodities. J. Stored Prod. Res. 69, 72–77.

Athanassiou, C. G.; N. G. Kavallieratos; M. C. Boukouvala; M. E. Mavroforos; and C. D. Kontodimas (2015). Efcacy of alpha-cypermethrin and thiamathoxam against Trogoderma granarium Everts (Coleoptera: Dermestidae) and Tenebrio molitor L. (Coleoptera: Tenebrionidae) on concrete. J. Stored Prod. Res. 62, 101–107.

Athanassiou, C. G.; T.W. Phillips; and W. Wakil (2019). Biology and control of the khapra beetle, Trogoderma granarium, a major quarantine threat to global food security. Annu. Rev. Entomol. 64, 131-148.

Athanassiou, C. G.; P. U. Rani; and N. G. Kavallieratos (2014). The use of plant extracts for stored product protection. In: Singh D. (ed.) Advances in plant biopesticides. Springer, New Delhi, pp 131–147.

Bell, A., O. Mück; and H. Schneider (1998). La protection intégrée des denrées stockées est une affaire rentable! GTZ, Eschborn, Germany, 42 pp.

Bett, P. K.; A. L. Deng ; J. O Ogendo; S. T. Kariuki ; M. Kamatenesi-Mugisha ; and J. M. Mihale (2016). Chemical composition of *Cupressus lusitanica* and *Eucalyptus saligna* leaf essential oils and bioactivity against major insect pests of stored food grains. Ind. Crops Prod. 82: 51–62.

Bortolucci, W. C.; J. E. Gonc¸alves; J. Camilotti; L. Ferarrese; O. S. Takemura; and R. P. Junior (2015). Essential oil of parsley and fractions to in vitro control of cattle ticks and dengue mosquitoes. J. Med. Plants Res. 9, 1021–1030.

Campolo, O; G. Giunti; A. Russo; V. Palmeri; and L. Zappalà (2018). Essential oils in stored product insect pest control. J. Food Qual. 2018, 6906105.

Da Silva, M. R. M. and E. Ricci-Júnior (2020). An approach to natural insect repellent formulations: From basic research to technological development. Acta tropica, 105419.

Degri, M. M.; and J. A. Zainab (2013). A study of insect pest infestations on stored fruits and vegetables in the northeastern Nigeria. Int. J. Sci. Nat. 4, 646–650.

Desneux, N.; A. Decourtye; and J. M. Delpuech (2007). The sublethal effects of pesticides on benefcial arthropods. Annu. Rev. Entomol. 52, 81–106.

Dhifi, W.; S. Bellili; S. Jazi ; N. Bahloul; and W. Mnif (2016). Essential oils' chemical characterization and investigation of some biological activities: a critical review. Medicines 3 (25): 2-16.

Edde, P. A.; M. Eaton; S. A. Kells; and T. W. Phillips (2012). Biology, behavior, and ecology of pests in other durable commodities. In: Hagstrum, D.W., Phillips, T.W., Cuperus, G. (Eds.), Stored Product Protection. Kansas State University, Manhattan, KS, pp. 45–62.

EPPO, (2011). EPPO Standards: EPPO A1 and A2 lists of pests recommended for regulation as quarantine pests. Pharm. Manag. PM 1/2 (20) (Paris, France).

FAO, (2020). *Situaci´ on Alimentaria Mundial* (Accessed September 23, 2020) http://www. fao.org/ worldfoodsituation /csdb/es/.

Feroz, A. (2020). Efficacy and cytotoxic potential of deltamethrin, essential oils of Cymbopogon citratus and Cinnamonum camphora and their synergistic combinations against stored product pest, *Trogoderma granarium* (Everts). J. Stored Prod. Res., 87, 101614.

Finney, D. J. (1971). Probit Analysis, Cambridge: Cambridge University Press.

George, D. R.; R. D. Fin; K. M. Graham; and O. A. Sparagano (2014). Present and future potential of plant-derived products to control arthropods of veterinary and medical significance. Parasit. Vectors 7, 28..

Hillocks, R. J. (2012). Farming with fewer pesticides: EU pesticide review and resulting challenges for UK agriculture. Crop Prot.. 31, 85–93.

Isman, M. B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annu. Rev. Entomol. 51, 45-66.

Janaki, S.; N. Zandi Sohani; L. Ramezani; and A. Szumny (2018). Chemical composition and insecticidal efcacy of *Cyperus rotundus* essential oil against three stored product pests. Int. Biodeterior. Biodegrad. 133, 93–98.

Kavallieratos, N. G.; A. Skourti ; E. P. Nika ; P. Mártonfi; E. Spinozzi; and F. Maggi (2021). Tanacetum vulgare essential oil as grain protectant against adults and larvae of four major stored-product insect pests. J. Stored Prod. Res., 94, 101882.

Kavallieratos, N. G. and M. C. Boukouvala (2019). Efcacy of d-tetramethrin and acetamiprid for control of *Trogoderma granarium* Everts (Coleoptera: Dermestidae) adults and larvae on concrete. J. Stored Prod. Res. 80, 79–84.

Legeay, S.; N. Clere ; V. Apaire-Marchais ; S. Faure ; and B. Lapied (2018). Unusual modes of action of the repellent DEET in insects highlight some human side effects. Eur. J. Pharmacol. 825, 92–98.

Lowe, S.; M. Brone; S. Boudjelas ; and M. De Poorter (2000). 100 of the World's Worst Invasive Alien Species. A Selection from the Global Invasive Species Database. Hollands Printing Ltd, Auckland, New Zealand.

Lu, Y.; J. Zhong; Z. Wang; F. Liu; and Z. Wan (2013). Fumigation toxicity of allicin against three stored product pests. J. Stored Prod. Res. 55, 48-54.

Lucchi, A. and G. Benelli (2018). Towards pesticide-free farming? Sharing needs and knowledge promotes Integrated Pest Management. Environ. Sci. Pollut. Res. 25, 13439 –13445.

Mansour, S. A.; A. Z. El-Sharkawy; and N. A. Abdel-Hamid (2015). Toxicity of essential plant oils, in comparison with conventional insecticides, against the desert locust, *Schistocerca gregaria* (Forska˚l).Ind Crops Prod 63, 92–99.

Mark, A. C.; D. L. Severtson ; C. J. Brumley ; A. Szito ; R. G. Foottit ; M. Grimm; K. Munyard ; and D. M. Groth (2010). A rapid non-destructive DNA extraction method for insects and other arthropods. J. Asia Pac. Entomol. 13, 243-248.

Mossa, A. T. H.; S. I. Afia ; S. M. Mohafrash; and B. A. Abou-Awad (2018). Formulation and characterization of garlic (*Allium sativum* L.) essential oil nanoemulsion and its acaricidal activity on eriophyid olive mites (Acari: Eriophyidae). Environmental Sci. Poll. Res. 25(11): 10526-10537.

Mullen, M. A.; J. M. Vardeman; and J. Bagwell (2012). Insect-resistant packaging. In: Hagstrum, D.W., Philips, T.W., Cuperus, G. (Eds.), Stored Product Protection. Kansas State University, Manhattan, Kansas, USA, pp. 135–142.

Myers, S. W. and D. W. Hagstrum (2012). Quarantine. In: Hagstrum, D.H., Phillips, T.W., Cuperus, G. (Eds.), Stored Product Protection. Kansas State University, Manhattan,KS, pp. 297–304.

Nenaah, G. E. (2014). Chemical composition, insecticidal and repellence activities of essential oils of three *Achillea* species against the Khapra beetle (Coleoptera: Dermestidae). J. Pest. Sci. 87, 273–283.

Ogoma, S. B.; H. Ngonyani ; E. T. Simfukwe ; A. Mseka ; J. Moore ; and G. F. Killeen (2012). Spatial repellency of transfluthrin-treated hessian strips against laboratory-reared *Anopheles arabiensis* mosquitoes in a semi-field tunnel cage. Parasit. Vectors 5, 54. Papachristos, D. P. and D. C. Stamopoulos (2002). Repellent, toxic and reproduction inhibitory effects of essential oil vapours on *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae). J. Stored Prod. Res. 38, 117-128.

Pavela, R.; F. Maggi; R. Iannarelli; and G. Benelli (2019). Plant extracts for developing mosquito larvicides: from laboratory to the feld, with insights on the modes of action. Acta Trop. 193, 236–271.

Rajendran, S. and V. Srianjini (2008). Plant products as fumigants for stored product insects control. J. Stored Prod. Res. 44, 126-135.

Rajkumar, V.; C. Gunasekaran ; I. K. Christy ; J. Dharmaraj ; P. Chinnaraj ; and C. A. Paul (2019). Toxicity, antifeedant and biochemical efficacy of *Mentha piperita* L. essential oil and their major constituents against stored grain pest. Pesticide Biochemistry and Physiology 156, 138-144.

Ramadan, M. M.; A. A. Abdel-Hady; R. N. C. Guedes ; and A. S. Hashem (2020). Low temperature shock and chill-coma consequences for the red flour beetle (*Tribolium castaneum*) and the rice weevil (*Sitophilus oryzae*). J. Therm. Biol. 94, 102774. .

Regnault-Roger, C.; A. Hamraoui ; M. Holeman ; E. Theron ; and R. Pinel (1993). Insecticidal effect of essential oils from mediterranean plants upon *Acanthoscelides obtectus* say (Coleoptera, Bruchidae), a pest of kidney bean (*Phaseolus vulgaris* L.). J. Chem. Ecol. 19, 1233–1244.

Robertson, G. L. (2006). Food packaging: Principles and practice. Taylor and Francis Group, Boca Raton, FL, USA: CRC Press.

Rozendaal, J. A. (1997). Vector control: Methods For Use By Individuals and Communities. World Health Organization, Geneva.

Satyal, P.; J. D. Craft; N. S. Dosoky; and W. N. Setzer (2017). The chemical compositions of the volatile oils of garlic (*Allium sativum*) and wild garlic (*Allium vineale*). Foods 6(8): 63.

Senhorini, G. A.; S. F. Zawadzki; P. V. Farago; S. M. W. Zanin ; and F. A. Marques (2012). Microparticles of poly (hydroxybutyrate-co-hydroxyvalerate) loaded with andiroba oil: Preparation and characterization. Mater. Sci. Eng. C 32, 1121–1126.

Sha Sha, C.; H. Jin Fen H; and H. Zhi Long (2010). Composition of essential oil of Chinese Chenopodium ambrosioides and insecticidal activity against maize weevil: Sitophilus zeamais. Pest Manag. Sci.67, 714-718.

Shukla, R.; P. Singh; B. Prakash; A. Kumar; P. K. Mishra; and N. K. Dubey (2011). Efficacy of essential oils of Lippiaalba (Mill.) N.E. Brown and *Callistemon lanceolatus* (Sm.) sweet and their major constituents on mortality, oviposition and feeding behavior of pulse beetle, *Callosobruchus chinensis* L. J. Sci. Food Agric. 91, 2277–2283.

Sousa, R. M. O. F.; J. S. Rosa; L. Oliveira; A. Cunha; and M. Fernandes-Ferreira (2015). Activities of Apiaceae essential oils and volatile compounds on hatchability, development, reproduction and nutrition of Pseudaletia unipuncta (Lepidoptera: Noctuidae). Ind. Crops Prod. 63, 226-237.

Stejskal, V.; T. Vendl ; Z. Li ; and R. Aulicky (2019). Minimal thermal requirements for development and activity of stored product and food industry pests (Acari, Coleoptera, Lepidoptera, Psocoptera, Diptera and Blattodea): a review. Insects10, 149.

Stevenson, P. C.; M. B. Isman; and S. R. Belmain (2017). Pesticidal plants in Africa: a global vision of new biological control products from local uses. Ind. Crops Prod. 110, 2–9.

Swigar, A. A. and R. M. Silverstein (1981). Monoterpenes. Aldrich Chemical Company Publ., Inc, Milwaukee, Wisconsin, USA, 130.

Tayoub, G.; A. Abu Alnaser; and I Ghanem (2012). Toxicity of two essential oils from *Eucalyptus globolus* Labail and *Origanum syriacum* L. on larvae of khapra beetle. Int. J. Med. Arom. Plants 2, 240–245.

Trematerra, P. and F. Fleurat-Lessard (2015). Food industry practices affecting pest management. Stewart Postharvest Rev. 12, 1–7.

Yang, F. L.; X. G. Li; F. Zhu; and C. H. L. Lei (2009). Structural characterization of nanoparticles loaded with garlic essential oil and their insecticidal activity against *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). J. Agri. Food Chem. 57, 10156-10162.

Zhang, Z.; T. Yang; Y. Zhang; L. Wang; and Y. Xie (2016). Fumigant toxicity of monoterpenes against fruitfly, *Drosophila melanogaster*. Ind Crops Prod 81, 147–151.

حماية منتجات الحبوب المخزنة بتحميل كل من زيتي الثوم (أليوم ساتيفم) والبقدونس (بيتروسيلينيم كريسبيم) العطريه على أقراص فلين

الزهراء عبدالعاطى المعداوى و أحمد فايز عمر

قسم افات الحبوب والمواد المخزونه، معهد بحوث وقاية النباتات بسخا ، مركزالبحوث الزراعية

المنتجات والسلع المخزنة أكثر عرضة للإصابة بالآفات أثناء التخزين. تم فحص التركيب الكيميائي لزيوت الثوم والبقدونس العطرية ، تم أيضًا تقييم تأثير التركيزات المختلفة للزيوت العطرية المختبرة (المحملة على أقراص) على *Trogoderma granarium* و *Tribolium castaneum* (الحشرة الكاملة واليرقات) لدقيق القمح والحبوب. أظهرت النتائج أن ١،٣،٨-ف منثرين كان المكون الأساسي (٢٣,٣٤٪) من زيت البقدونس العطري. بينما كان Alpha-Terpinene مكونًا صغيرًا (١,٤٠٪) من زيت البقدونس العطري. على الجانب الأخر، كان المكون الرئيسي لزيت الثوم العطري هو ثنائي كبريتيد ثنائي الأليل (٢٧,٩٪). بينما كان Dilyl tetrasulfide مكونًا ثانويًا (١٪) في زيت الثوم العطرى. علاوة على ذلك ، خلال فترة الاختبار ، كانت الأقراص المحمله بزيت الثوم العطرى اكثر تاثيرمن زيت البقدونس العطرى ضد خنافس الخبرا وخنافس الدقيق الأحمر. أيضًا ، مع فحص الحشرات البالغة ، تفوق زيت الثوم العطري على زيت البقدونس العطري. خلال فترة الاختبار ، تفوق االأقراص الحمله بزيت الثوم على أقراص زيت البقدونس فى التأثير على يرقات خنافس الخبرا وخنافس الدقيق الأحمر . بينما من ناحية أخرى ، فإن *T. castaneum* أكثر تحملاً لكل من الحشرات الكاملة واليرقات من *.T. granarium* . من ناحية أخرى ، لكل من زيوت الثوم والبقدونس العطرية المحملة على أقراص ، مما يشير إلى أن كلا الزيوت العطرية يمكن أن تقلل من تغذية الحشرات واليرقات خلال وقت الاختبار. أخيرًا ، كانت الزيوت العطرية الموضوعة على الأقراص طريقة فعالة لحفظ المنتجات المخزنة (دقيق القمح والحبوب) ضد خنافس الخبرا وخنافس الدقيق الأحمر

كلمات المفتاح : الزيوت العطرية ، الديسكات ، المنتجات المخزونة