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Study of the contact effect of stearic acid on *Trogoderma granarium* Everts, 1898 (Coleoptera: Dermestidae) in the laboratory

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Abstract. *Sabit FA, Abdullah MA, Elhadeeti SAK. 2025. Study of the contact effect of stearic acid on* Trogoderma granarium *Everts, 1898 (Coleoptera: Dermestidae) in the laboratory. Asian J Agric 9: 185-190.* The hairy grain beetle, *Trogoderma granarium* Everts, 1898 is a hazardous pest that infests grains and causes great losses in the stores. Stearic acid is a suitable alternative to synthetic insecticides and a safe option to prevent infestation. The current experiment was conducted to investigate the effects of stearic acid on the adult, larval, pupal, and egg stages of *T. granarium*, through the direct treatment of stearic acid on beetle adults, larvae, pupal and eggs stages at exposure times of 5, 10, and 15 hours and concentrations of 20, 40, 60, and 80 ppm. Adult mortality rates varied, with the lowest value at 20 ppm concentration and exposure time of 5 hours being 46.66%, and the highest mortality (100.00%) was at 80 ppm and 15 hours. Larvae mortality rates varied between concentrations, with the highest rates at 80 ppm and 15 hours of exposure time, which reached 93.33%, and the lowest was 26.66% at 5 ppm and 5 hours. The lowest mortality rate of the pupal stage was 14.45% at 20 ppm concentration and 5 hours (exposure time), while the best results were 80.00% at 80 ppm concentration and 15 hours (exposure time). The finding showed that the optimal concentration for controlling *T. granarium*, the egg was 80 ppm stearic acid and an (exposure time) of 15 hours, resulting in the most significant egg damage of 61.54%. The study concluded that stearic acid has a positive lethal impact on *T. granarium* in different stages.

Keywords: Direct effect**,** stearic acid, *Trogoderma granarium*

INTRODUCTION

It is well acknowledged that grain crops like wheat, have high levels of carbohydrates, proteins, and fats. Therefore, people consider it as one of their staple food and tend to store or consume it in times of need (Gadimov et al. 2009). Insect infestations can damage or destroy products, resulting in losses of up to millions of dollars to producers and retailers annually (Demissie et al. 2008). Post-harvest insects migrate for mates, food, and shelter (Tyagi et al. 2019). Insect pests infest stored products from harvest through storage, processing, transportation, and retail and consumer, enabling researchers to identify potential weak points in storage that contribute to increased insect damage (Abdullah et al. 2023).

The hairy grain beetle *Trogoderma granarium* Everts, 1898 (khapra), which belongs to the Dermestidae family, Coleoptera order, and is among the most critical and dangerous insect pests that infest stored products, represents a major and continuous threat (Sabit and Ali 2020; Al-Saffar and Augul 2022; Hameed et al. 2023). Moreover, this species is considered the most crucial quarantine insect of stored products in various parts of the world in tropical and subtropical regions, such as Australia, Russia, and the USA (Kavallieratos et al. 2019; Zhao et al. 2021). It is one of the world's 100 most dangerous invasive species because its larvae can survive in severe conditions (Al-Saffar and Augul 2022). Like many storage pests, *T. granarium* has been transferred to other parts of the world in recent centuries through international trade, although adults do not fly. The khapra insect (*T. granarium*) is now distributed in more than 40 countries in Asia, the Middle East, Africa, and Europe. In Iraq, there are 31 species of stored product insects recorded, 16 genera, 8 families, and 2 orders of insects spread in most parts where grain is stored; the top rank is *T. granarium* (Khalique et al. 2018).

Larvae of *T. granarium* are considered much more harmful than adult beetles concerning control methods (Athanassiou et al. 2015). The larvae feed on whole stored products including cereal crops such as wheat, barley, rice, and other food products. Infestation can be heavy, with weight losses of 5-30%; in extreme infestations, it can be 73% globally (Singh et al. 2017). Damaged grains cause a significant loss in weight, germination, and value of damaged grains, mainly at severe infestation (Rajput et al. 2015).

The management of the khapra insect is based mainly on synthetic chemical pesticides (Abdullah et al. 2024; Haitham et al. 2022). The continuous use of insecticides to manage warehoused product insects has resulted in high environmental risks for humans and animals (Ali and Ali 2016; Almamoory and Al-Mayaly 2018). Hence, alternative management methods have been used for the control of *T. granarium*, such as the application of ozone, temperature, plant extracts, and fatty acids in its control (Sabeat 2017; Abdul Hadi and Al-Khazraji 2021; Hadi and Sabit 2023; Sabet and Sabr 2023).

Also, fatty acids have been applied lately to manage insect infestations. They have been extensively used, particularly oleic and linoleic acids, as they have been developed to have suitable pesticidal properties (Rahuman et al. 2008). *Polytrichastrum formosum* hexane extracts showed the highest lethal activity reaching 70.33% against *Sitophilus granarius* (C.Linnaeus, 1758). Contact toxicity effects using a single dose of palmitic, lauric, and myristic acids showed that the highest mortality rate (53.34%) was achieved using the myristic acid among the other tested pure fatty acids; lauric and palmitic acids were 4.32 and 17.75%, respectively (Abay et al. 2013). A study by Salinas-Sánchez et al. (2020) showed that ethyl acetate fraction of *Serjania schiedeana* Schltdl. (Sapindaceae) stems eradicated 78% at 10,000 ppm with an LC_{50} value of 6,008 ppm in 72 h against adults of *Melanaphis sacchari* (Zehntner, 1897). Commercial fatty acids and b-sitosterol have better aphicidal activity, with mean insecticidal concentrations ranging from 1,000 to 3,000 ppm in 72 h. The chemical analysis of the *S. schiedeana* extract showed that methyl palmitate is the main compound (38.6%). A study by Salinas-Sánchez et al. (2021) showed that a leaves fraction of *Ricinus communis* L eradicated 92% at 10,000 ppm, with an LC50 value of 1,427 ppm in 72 h against *Sipha flava* (Forbes, 1884) (Hemiptera: Aphididae). The chemical analysis revealed that linoleic acid is the primary compound in the active fraction (84.5%); in comparison, commercial linoleic acid at a concentration of 2,500 ppm had mortality and LC_{50} value of 85% and 1,181 ppm at 72 h after treatment, respectively. A study by Cantrell et al. (2011) showed that the fatty acids of *Jatropha curcas* L. seed oil have activity as mosquito repellent against *Aedes (Stegomyia) aegypti* (Linnaeus, 1762) (Diptera: Culicidae) at a concentration of 20 nmol/cm^2.

In another study to estimate the effectiveness of fatty acids in the laboratory on the larvae of the *Earias insulana* (Boisduval, 1833) revealed that oleic acid and stearic acid affected more than linoleic acid at different concentrations the survival time of larvae and pupae reducing it to 18.93 and 10.19 days respectively compared to the other acids tested (Moustafa et al. 2018). A study by Aquilar-Marcelino et al. (2022) revealed that stearic and palmitic fatty acids were active against *M. sacchari* by fumigation of particles at rates of 74 and 63%, respectively, at 2500 ppm concentration and 72 hours exposure time. A recent study by Hadi and Sabit (2023) that evaluated the efficiency of fumigation using two fatty acids as a natural and safe alternative to synthetic pesticides in management eggs and pupa of *T. granarium*, the results showed that treating the insect eggs with fumes resulted in high rates of inhibition of egg hatching (Hadi and Sabit 2023). The effect of fatty acids on insect mortality involves physical and chemical disruption of the insect's protective barriers, leading to insect's death by suffocation, dehydration, or cell damage. It is often used alone or combined with other ingredients to enhance effectiveness (Bernklau et al. 2016). This study aimed to evaluate the effectiveness and efficiency of stearic acid by contact method as an accepted and harmless alternative to chemical pesticides in managing the larval, pupal, and adult stages of the hairy grain beetle *T. granarium*.

MATERIALS AND METHODS

Insect rearing

The beetle, *T. granarium* was obtained from infested grains in the warehouse insect laboratory – at the University of Baghdad. The beetles were placed in a containers made of sterilized plastic with a capacity of 500 mL. Insects were fed on wheat grains of the Ibaa 99 variety, and the new eggs deposited, adults, larvae, and pupae were separated carefully for further experiments. The insect rearing and experiments were carried out in the laboratory of the plant protection department, which is affiliated with Agricultural Engineering Sciences College/Baghdad University. New wheat grains were frozen at a temperature of -20°C for (14) days to ensure they were free from pests infestation, they were then placed in an incubator at 35 ± 1°C and 65 ± 5 (humidity). 3 g of KOH compound was placed in water (100 mL) in a tightly sealed glass container to stabilize the humidity.

Preparation of stearic acid concentrations

The stearic acid concentrations were prepared by putting 1 mL of 99% (ethanol) in a 1000 mL container and dissolving 20 microliters of stearic acid inside it using a microliter device and completed it to a volume of 1000 mL by adding distilled water in which fatty acid to the solvent ratio solution became (20) parts per million. Other concentrations (40, 60, and 80 ppm) were prepared, and the comparison treatments (ethanol and water) were prepared using a similar procedure.

Bioevaluation by contact with stearic acid on *T. granarium*

The different stages of *T. granarium* (eggs, larvae, pupae, and adults) were sprayed with a small hand sprayer at a capacity of 20 mL and at a distance of 15 cm from the dish at a rate of 1 mL/dish to ensure the homogeneity of the solution for all dishes (three replicates, 10 individuals from each stage for every replicate) for the different treatments and stages in addition to the control treatment (only treated with ethanol and water). All dishes were placed in the incubator under the indicated conditions (35 ± 1°C t and 65 ± 5 h). The mortality data were recorded every 5 hours and for 15 hours and corrected using (Abbott 1925) formula.

Statistical analysis

Experiments were designed according to Complete Randomized Design (CRD) (Shaaban and Al-Mallah 1991). Data were subjected to a one-way ANOVA of insect mortality, and statistical analysis was conducted using GenStat software at a significant level of $p>0.05$.

RESULTS AND DISCUSSION

Direct effect of stearic acid application on adults of *T. granarium*

Table 1 shows stearic acid's effect on *T. granarium* adults at concentrations of 20, 40, 60, and 80 ppm and exposure time of 5, 10, and 15h. The means of adult mortality percentages at 20, 40, 60, and 80 ppm concentration reached 58.88, 71.55, 79.00, and 91.11% respectively. The effect of exposure time (5, 10, and 15 h) had a mortality rate of 61.91, 79.17, and 84.33% respectively. The lowest mortality rate was 46.66% at 20 ppm and 5h, and the best results were 100.0% at 80 ppm and 15h.

Increasing concentration increases the mortality rate significantly in the adult stage of *T. granarium* (Table 1). However, the exposure time of 5 hours had a significantly lower mortality rate than that of 10 and 15 hours. The synergistic effect of the concentration and the exposure time had a more significant impact on the insect.

Direct effect of stearic acid on *T. granarium* larvae

Table 2 shows stearic acid's effect on larvae of *T. granarium* at concentration of 20, 40, 60, and 80 ppm and exposure time of 5, 10, and 15h. The larvae mortality percentages at concentration of 20, 40, 60, and 80 ppm were 36.66, 52.22, 67.78, and 76.66%, respectively. At the same time, three exposure times resulted in mortality rates of 45.83, 58.33, and 70.83%, respectively. The lowest mortality rate (26.66%) was obtained at the concentration of 20 ppm and the exposure time of 5h, and the highest mortality was 93.33% at the concentration of 80 ppm and at the exposure time of 15h. The lowest percentage of larvae mortality was obtained at a concentration of 20 ppm and exposure time 5h, which reached 26.66%, and the highest rate was 93.33% at 80 ppm and 15h exposure time.

The results showed that mortality percentage of 60 and 80 ppm concentration was not significantly different. However, the treatment of 20 and 40 ppm had a lower mortality percentage significantly than 60 and 80 ppm. The increasing exposure time increased significantly mortality percentage of the larvae. The synergistic effect of the concentration and exposure time treatments might had a greater impact on the larvae mortality rates.

Direct effect of stearic acid on *T. granarium* pupae

Table 3 shows the effect of stearic acid on the pupal stage of *T. granarium* at concentration of 20, 40, 60, and 80 ppm and exposure time of 5, 10, and 15h. The results showed that the highest mortality rate was 80.00% at concentration of 80 ppm and 15h as exposure time. The pupal mortality percentages at concentration of 20, 40, 60, and 80 ppm were 19.19, 29.08, 31.44, and 63.26% respectively, while their mortality rate at the three exposure time reached 25.75, 38.37, and 50.78% respectively. The lowest mortality was 14.45% at the concentration of 20 ppm and at the exposure time of 5h, and the highest mortality was 80.00% at the concentration of 80 ppm and at the exposure time of 15h.

The mortality percentage of 80 ppm was significantly higher than the other treatments in the pupae. However, the mortality rates for the 40 and 60 ppm treatments were not significantly different. Increasing exposure time increases the mortality percentage significantly. The inreaction of exposure time and concentration were all significant except for the interaction at the concentration of 40 ppm and exposure time of 10h, and the synergistic effect of the interaction treatments between concentration and exposure time was more influential on the mortality percentages.

Direct effect of stearic acid on *T. granarium* eggs

Table 4 shows the effect of stearic acid on the *T. granarium* egg stage at concentration of 20, 40, 60, and 80 ppm and exposure time of 5, 10, and 15h. The lowest rate of egg hatching inhibition was recorded at the concentration 20 ppm and exposure time 5h reaching 17.34%, while the highest rate was recorded at 80 ppm and exposure time 15h, namely 61.54%. The percentage inhibition means of the egg hatching at the four concentration reached 25.04, 33.7, 49.5, and 53.94% respectively, while the effect of exposure time at 5, 10, and 15 h on egg-hatching inhibition were 30.26, 40.30, and 51.07%, respectively.

The egg-hatching inhibition of the treatment of 60 and 80 ppm was not significantly different but significantly higher than that of 20 and 40 ppm. The egg hatching inhibition of exposure time of 5 and 10 hours was not significantly different but increasing exposure time of 15 hours increased egg-hatching inhibition significantly. The synergistic effect of the concentration and exposure time was more influential in the percentage of egg-hatching inhibition.

Table 1. Direct effect of stearic acid application on *T. granarium* adults

Concentration (ppm)	Mortality percentage			Mean
	Time (hour)			
	5	10	15	
20	46.66e	63.33d	66.66c	58.88d
40	60.00d	73.33c	81.33b	71.55c
60	67.66c	80.00b	89.33a	79.00b
80	73.33c	100.0a	100.0a	91.11a
Mean	61.91d	79.17b	84.33b	---
L.S.D (0.05)	Concentration 8.36 time 7.59 Concentration × time 14.07			

Table 2. Direct effect of stearic acid on *T. granarium* larvae

Concentration (ppm)	Mortality percentage			Mean
	Time (hour)			
	5	10	15	
20	26.66e	36.66e	46.66d	36.66
40	40.00e	53.33d	63.33c	52.22d
60	53.33d	70.00b	80.00b	67.78b
80	63.33c	73.33b	93.33a	76.66b
Mean	45.83e	58.33c	70.83c	---
L.S.D (0.05)	Concentration 9.41 time 7.95 Concentration × time 15.02			

Table 3. Direct effect of stearic acid on *T. granarium* pupae

Concentration (ppm)	Mortality percentage			Mean
	Time (hour)			
	5	10	15	
20	14.45	20.00e	23.11e	19.19e
40	20.22e	28.13d	40.00d	29.08d
60	25.00d	38.89d	60.00b	31.44d
80	43.34c	66.44b	80.00a	63.26b
Mean	25.75e	38.37d	50.78c	---
L.S.D (0.05)	Concentration 9.66 time 8.38 Concentration × time 15.87			

Table 4. Direct effect of stearic acid on *T. granarium* eggs

Concentration (ppm)	Mortality percentage			Mean
	Time (hour)			
	5	10	15	
20	17.34e	23.11e	34.67d	25.04e
40	20.22e	31.77d	49.11b	33.7c
60	37.55d	52.00b	58.94a	49.5b
80	45.94c	54. 33b	61.54a	53.94b
Mean	30.26c	40.30c	51.07b	---
L.S.D (0.05)	Concentration 7.92 time 6.86 Concentration × time 12.39			

Discussion

The lethal efficacy of fatty acids on some insects including *T. granarium,* has been studied previously (Abdullah and Muhammad 2005; Moustafa et al. 2018; Aquilar-Marcelino et al. 2022). This study evaluates the lethal effect of stearic acid against *T. granarium* stages in warehoused wheat grains.

The findings showed that stearic acid could control *T. granarium* at all its stages including adults, larvae, pupae, and eggs. All concentration of stearic acid were lethal and caused high rates of mortality for the adults at all exposure time. This result may be due to the penetration of stearic acid through the insect body wall, interfering with their metabolic processes and finally causing insect death (Peng et al. 2020; Kaczmarek et al. 2022). Fatty acids act as a deterrent for many insect species, making them less likely to feed or reproduce in areas where stearic acids are present. Additionally, stearic acids have been shown to disrupt the reproductive systems of certain insects, further impacting their population dynamics (Ferdous et al. 2021).

Stearic acid showed a high effect in causing the death of the larval and pupal stages of *T. granarium*, also it was effective at all of the concentration and exposure time. It destroys the exoskeleton of insects by covering the exoskeleton, which protects the insect externally and regulates humidity. Stearic acid can clog pores and disrupt normal physiological processes, including breathing through the spiracles, causing dehydration, suffocation, and ultimately, the insect˒s death (Kaczmarek and Bogus 2021).

Stearic acid showed high rates of egg-hatching inhibition at all its concentration and exposure time. It may be due to the ability of the fatty acid vapor to enter the egg and disturb its protoplasm, which has a deleterious effect on the respiratory and nervous parts (Hadi and Sabit 2023). After that, it affecting the growth and development of the embryo. It also can damage the embryo muscle tissue, resulting in loss the ability to breathe and, finally, embryo death. It can act as growth regulator that affects the progression of some biological processes for the embryo˒s growth and development, such as affecting the metabolism in the eggs, which thwarts the partial or total embryo formation (Mahgoub and El-Sisi 1997).

These findings agree with previous studies indicating the efficacy of fatty acids including stearic acid to control insects. Stearic acid is commonly used as an insecticide ingredient, effectively targeting many pests (Eldesouky et al. 2019). The mortality control rate of stearic acid is significant, as it is highly toxic to a wide range of insect species. Its action involves suffocating insects by enveloping their respiratory systems, ultimately resulting in death (Ibrahim 2020). In addition, stearic acid exhibits long-lasting effects, protecting against infestations by a range of insect pests (Ibrahim 2020). It is a valuable tool in both agricultural and domestic treatments. Its unrefined properties provide a reliable solution for managing insect-related problems with minimal environmental impacts (Aider et al. 2016; Aguilar-Marcelino et al. 2022). Stearic acid can affect metabolic rates and stress responses, impacting insect survival (Blomquist and Ginzel 2021; Refaey et al. 2022). It can have a toxic effect on insects by disrupting cell membranes, interfering with enzymes, and altering metabolic processes within the insect, leading to the collapse of critical cellular functions, which affects insect survival (Shah et al. 2023).

There is a positive relationship between the increase in concentration, exposure time and percentage rates mortality of adults, larvae and pupae and egg hatching inhibition (Prathiksh 2020; Siddiqui et al. 2022). Therefore, stearic acid can be considered as natural product promising potential source of safer alternative means with promising potential as a safer alternative to control *T. granarium* and different agricultural pests.

In conclusion, our results show that stearic acid is effective against all stages of *T. granarium* and can be considered an environmentally friendly alternative to the frequent use of synthetic traditional chemical insecticides within the concentrations and periods indicated in the integrated pest management plan. This study can inform decision-making processes regarding pest management strategies and implementing preventive measures in field and warehouse environments.

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