Toxicity of Five Plant Oils to Adult Tribolium castaneum (Coleoptera: Tenebrionidae) and Oryzaephilus surinamensis (Coleoptera: Silvanidae)

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Toxicity of five plant oils to adult Tribolium castaneum (Coleoptera: Tenebrionidae) and Oryzaephilus surinamensis (Coleoptera: Silvanidae)

Fatehia Gharsan1*, Nihad Jubara1, Lamya Alghamdi1, Zahraa Almakady1, and Eisha Basndwh1

Abstract

Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae) and Oryzaephilus surinamensis (L.) (Coleoptera: Silvanidae) cause extensive damage to many stored products, thereby reducing their nutritional and economic value. However, controlling these pests with insecticides can have an impact on the environment as well as on human health. Thus, it is important to identify more environmentally safe compounds, such as plant oils, that can be used as an alternative means of pest control. In this study, we investigated the toxicity of 5 plant oils isolated from lavender (Lavandula angustifolia Mill., Lamiaceae), onion (Allium cepa L., Amaryllidaceae), flax (Linum usitatissimum Mill., Linaceae), caraway (Carum carvi [Lindl.] H. Wolff, Apiaceae), and brown galangal (Cyperus fuscus, or saad L., Cyperaceae) for use on the stored-products insect pests T. castaneum and O. surinamensis. The efficacy of these oils was evaluated at concentrations of 1, 2, 3, and 4 μL per mL and at an exposure time of 24 h. Results indicated that O. surinamensis was more susceptible to plant oils than T. castaneum, which showed a greater resistance to these natural products. Results also revealed that caraway and lavender oils were the most toxic of all treatments rendered for T. castaneum, with 50% lethal concentration (LC50) values of 1.2 and 2.4 μL per mL, respectively. The onion and lavender oils displayed the highest efficacy on O. surinamensis with insect mortality reaching 100% with onion oil and an LC50 value for lavender oil of 0.6 μL per mL. These results suggest that onion, lavender, and caraway oils are potentially promising and environmentally acceptable alternatives for the control of T. castaneum and O. surinamensis.

Key Words: biopesticides; lavender; onion; flaxseed; caraway; saad

Resumen

Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae) y Oryzaephilus surinamensis (L.) (Coleoptera: Silvanidae) causan daños extensos a muchos productos almacenados, lo que reduce su valor nutricional y económico. Sin embargo, el control de estas plagas con insecticidas puede causar problemas ambientales y de salud. Por lo tanto, es necesario identificar compuestos más seguros para el medio ambiente, como los aceites vegetales, que se pueden usar como un medio alternativo de control de plagas. En este estudio, investigamos la toxicidad de 5 aceites vegetales aislados de lavanda (Lavandula angustifolia Mill., Lamiaceae), cebolla (Allium cepa L., Amaryllidaceae), lino (Linum usitatissimum Mill., Linaceae), alcaravea (Carum carvi [Lindl.] H. Wolff, Apiaceae) y galingale marrón (Cyperus fuscus, o saad L., Cyperaceae), para su uso contra las plagas de insectos de productos almacenados, T. castaneum y O. surinamensis. Se evaluó la eficacia de estos aceites a concentraciones de 1, 2, 3 y 4 μL para mL y con un tiempo de exposición de 24 horas. Los resultados indicaron que O. surinamensis es más susceptible a los aceites vegetales que T. castaneum, que mostró una mayor resistencia a estos productos naturales. Los resultados también revelaron que los aceites de alcaravea y lavanda fueron el tratamiento más tóxico para T. castaneum, con valores de concentración letal del 50% (CL50) de 1.2 y 2.4 μL para mL, respectivamente. Los aceites de cebolla y lavanda mostraron la mayor eficacia en O. surinamensis, con una mortalidad de insectos que alcanzó el 100% con aceite de cebolla y un valor de CL50 para el aceite de lavanda de 0.6 μL para mL. Estos resultados sugieren que los aceites de cebolla, lavanda y alcaravea son alternativas potencialmente prometedoras y ambientalmente aceptables para el control de T. castaneum y O. surinamensis.

Palabras Clave: bioplaguicidas; lavanda; cebolla; semilla de lino; alcaravea; saad

Agricultural crops are the most important food source for millions of people worldwide. However, in most cases, grains are not used immediately after harvesting, but instead are stored for the next season or exported to other countries. The loss of grain yield during storage can be attributed to many factors, and among those, insect pests are the most important cause of loss because they reduce the quality of the stored grain (Jayakumar et al. 2017). Unchecked growth of human population has led to numerous and very serious problems, including food shortage. Globally, Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae) and Oryzaephilus surinamensis (L.) (Coleoptera: Silvanidae) are the 2 most important stored-grain pests, damaging 10 to 40% of all stored agricultural crops (Al Qahtani et al. 2012). These beetles feed on grains, dried fruits, flour, sugar, candies, tobacco, and many other plant products intended for human consumption, as well as dried meat (Bilal et al. 2015).

Currently, the intensive use of chemicals for the control of stored-products pests has resulted in serious problems, including pest resistance to insecticides, environmental contamination, the presence of
unacceptable pesticide residues in foods, and lethal effects on non-
target organisms (White & Leesch 1995; Jovanovic et al. 2007; Lu et
al. 2011). Botanical insecticides have long been used as alternatives to
synthetic insecticides for insect pest management because botanicals
pose little threat to the environment or to human health (Isman 2006;
Ahmad et al. 2013). Many previous studies have demonstrated the ef-
fectiveness of plant oils to control stored-products insects. Magd El-Din
(2001) evaluated the efficacy of 3 essential oils to control 3 stored-
product insects, among which caraway seed oil demonstrated high
toxicity to both insect eggs and adults. Plant oils comprise complex
mixtures of monoterpenes, sesquiterpenes, and aromatic compounds
(Nattudri et al. 2017), and may act as contact insecticides, antifeed-
ants, repellents, or fumigants (Jayakumar et al. 2017).

Essential oils are interesting natural plant products that possess
various biological activities, among other qualities. These materials
rapidly degrade under ambient air temperature and moisture, and are
readily broken down by detoxification enzymes. These features are
important for their use as biopesticides, because a rapid breakdown
means less persistence in the environment (i.e., lower residual effects),
and reduced risks to non-target organisms. Although natural enemies
are sensitive to direct contact with such materials, predators and para-
sitoids that attack the product 1 to 2 d after treatment application are
not affected by the toxins (Isman 2006).

In this study, we evaluated the effectiveness of 5 types of plant oils
on T. castaneum and O. surinamensis. These plant oils were selected
based on prior knowledge regarding their effective toxicity to control
similar pests (Magd-El-Din 2001; Al-Jabr 2006; Lopez et al. 2008; Ger-
minara et al. 2017). These oils also are relatively inexpensive and read-
ily available in most countries.

Materials and Methods

PLANT OILS

Pure plant oils were obtained from Diar Almadina Company in Jed-
dah, Saudi Arabia (Table 1). We evaluated 4 concentrations of these oils
(1, 2, 3, and 4 µL per mL) diluted in acetone, that was used as a solvent
because of its rapid evaporation.

INSECT REARING TECHNIQUE

Tribolium castaneum and O. surinamensis were collected from infes-
ted products obtained from a local market in Albaoha City, Saudi Ara-
bia, and reared under laboratory conditions at 27 °C, 70 ± 5% relative
humidity, and 12:12 h (L:D) photoperiod. Yeast and flour (5:100 g) were
used as food for the insects that were maintained in jars covered with
muslin cloth fastened with rubber bands. One- to 3-wk-old adults were
collected and used for bioassays (Madkour et al. 2013).

CONTACT TOXICITY BIOASSAY

As a bioassay, we used the thin film technique described by Iwu-
uala et al. (1981). One mL of each concentration of the plant oils was evenly
spread over the bottom of a Petri dish. Petri dishes used for control
treatments were treated with 1 mL of acetone. Mature adults were ex-
posed to a thin film of plant oils for 24 h, when mortality was recorded
following adjustment with Abbott’s (1925) formula. Four replicates of
10 adults were used for each concentration treatment.

STATISTICAL ANALYSIS

The data were analyzed using 1-way analysis of variance (ANOVA),
followed by Tukey’s honest significant difference (HSD) test. Differences
were considered significant at P < 0.05. The LC 50 values (oil concentra-
tion high enough to kill 50% of the insects) were calculated using
Probit analysis (Finney 1964).

Results

The insecticidal activity of lavender, onion, flaxseed, caraway, and
saad oils tested on T. castaneum are listed in Table 2 and depicted in
Figures 1 to 5, respectively. The data indicated that caraway oil was the
most toxic of the oils evaluated, causing a mortality rate of 50% at the
lowest concentration (1 µL per mL) and 95% mortality at the highest
concentration (4 µL per mL), with LC 50 value of 1.2 µL per mL.
For insects treated with lavender oil for 24 h, mortality was 30% at a
concentration of 1 µL per mL and 70% at 4 µL per mL. Onion oil was
less potent than the 2 aforementioned oils, causing only 5% mortality
at a concentration of 1 µL per mL and 90% mortality at 4 µL per mL.
Flaxseed and saad oils showed similarly low toxic effects, with LC 50
values of 4.5 and 4.24 µL per mL, respectively. Results clearly indicated
that insect mortality increased with increasing oil concentration. Thus,
plant oils can be ranked as follows according to their toxicity to control
T. castaneum: caraway > lavender > onion > saad > flaxseed.

Insecticidal activity of the 5 plant oils examined on O. surinamen-
is are listed in Table 3, and those of lavender, flaxseed, caraway, and
saad oils are depicted in Figures 6 to 9, respectively. Onion oil caused
100% insect mortality at all concentrations that were examined. The
LC 50 value was 0.6 µL per mL for lavender oil, which caused 65% mor-
tality at a concentration of 1 µL per mL and 90% mortality at 4 µL per
mL, after a 24 h exposure. Insects treated with saad oil exhibited 60% morta-
ality at a concentration of 1 µL per mL and 90% mortality at 4 µL per
mL, with an LC 50 value of 0.77 µL per mL. Caraway oil caused 100% in-
sect mortality highest at the concentration, with an LC 50 value of 0.81 µL
per mL. Flaxseed oil caused 55% and 95% mortality in insects treated
at 1 and 4 µL per mL, respectively, and produced an LC 50 value of 1 µL
per mL. Based on these results, plant oils were ranked in the following
order according to their toxicity for O. surinamensis: onion > lavender
> saad > caraway > flaxseed.

Discussion

The results of this study demonstrated that the toxicity of the 5 se-
lected plant oils varied depending on the oil concentration and target

Table 1. Plant oils used in bioassays and source of essential oil.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Plant family</th>
<th>Plant part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lavender</td>
<td>Lavandula angustifolia</td>
<td>Lamiaceae</td>
<td>Flowers</td>
</tr>
<tr>
<td>Onion</td>
<td>Allium cepa</td>
<td>Amaryllidaceae</td>
<td>Bulbs</td>
</tr>
<tr>
<td>Flaxseed</td>
<td>Linum usitatissimum</td>
<td>Linaceae</td>
<td>Seeds</td>
</tr>
<tr>
<td>Caraway</td>
<td>Carum carvi</td>
<td>Umbelliferae</td>
<td>Seeds</td>
</tr>
<tr>
<td>Saad (Brown galingale)</td>
<td>Cyperus fuscus</td>
<td>Cyperaceae</td>
<td>Seeds</td>
</tr>
</tbody>
</table>
insect species. Caraway, lavender, and onion oils were most effective in controlling *T. castaneum* and *O. surinamensis*. These findings are consistent with the results of previous studies that have investigated the toxic effects of plant oils on these 2 insects (Al-Jabr 2006; Mondal & Khalequzzaman 2006; Ahmed et al. 2009; Lu et al. 2011; Hamed et al. 2012; Madkour et al. 2013; Iijeke & Ogungbite 2014; Aref & Farashiani 2015; Khanzada et al. 2015). These studies indicated that edible plant oils affect the developmental stages of *T. castaneum*, resulting in low adult emergence and pest fecundity in grain treated with plant oils. Talukder et al. (1998) demonstrated that the toxic effects of plant oils are due to the presence of oleic, linoleic, and palmitic acids, and alkalis that may block insect tracheae, thereby inhibiting respiration during contact or fumigation tests. Yoon et al. (2011) showed a repellent effect of lavender oil for the spotted lantern fly, *Lycorma delicatula* (White) (Hemiptera: Fulgoridae) (also referred to as “spot clothing wax cicada” or “Chinese blistering cicada” in the literature) and established that linalool (a monoterpene) was the most effective constituent present in this oil. Similarly, Lucic et al. (2015) demonstrated the toxic effects of the lavender plant parts and essential oil on 3 stored-wheat pests, including *T. castaneum*. Other studies have concluded that plant

### Table 2. Mortality of *Tribolium castaneum* adults exposed to different concentrations of plant oils.

<table>
<thead>
<tr>
<th>Plant oil</th>
<th>Concentration (µL per mL)</th>
<th>SD</th>
<th>Mortality (%) (mean ± SE)</th>
<th>Slope function (S ± SE)</th>
<th>LC50 (µL per mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lavender</td>
<td>1 11.54</td>
<td></td>
<td>30 ± 5.77 a</td>
<td>1.50 ± 0.13</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>2 5.77</td>
<td></td>
<td>45 ± 2.88 a</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>3 5.77</td>
<td></td>
<td>45 ± 2.88 ab</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 0.00</td>
<td></td>
<td>70 ± 0.00 c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onion</td>
<td>1 5.77</td>
<td></td>
<td>5 ± 2.88 a</td>
<td>4.5 ± 0.05</td>
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</tr>
<tr>
<td></td>
<td>2 5.77</td>
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<td>15 ± 2.89 b</td>
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<tr>
<td></td>
<td>3 17.32</td>
<td></td>
<td>45 ± 8.66 c</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 11.54</td>
<td></td>
<td>90 ± 5.77 d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flaxseed</td>
<td>1 0.00</td>
<td></td>
<td>10 ± 0.00 a</td>
<td>2.03 ± 0.11</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>2 5.77</td>
<td></td>
<td>25 ± 2.88 b</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 0.00</td>
<td></td>
<td>25 ± 2.88 b</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 5.77</td>
<td></td>
<td>55 ± 2.88 c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caraway</td>
<td>1 11.55</td>
<td></td>
<td>50 ± 5.77 a</td>
<td>2.56 ± 0.09</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>2 0.00</td>
<td></td>
<td>60 ± 0.00 a</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>3 9.67</td>
<td></td>
<td>80 ± 4.84 b</td>
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<tr>
<td></td>
<td>4 5.77</td>
<td></td>
<td>95 ± 2.88 c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saad</td>
<td>1 11.55</td>
<td></td>
<td>10 ± 5.77 a</td>
<td>2.23 ± 0.09</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>2 0.00</td>
<td></td>
<td>20 ± 0.00 b</td>
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<tr>
<td></td>
<td>3 5.77</td>
<td></td>
<td>25 ± 2.88 c</td>
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<tr>
<td></td>
<td>4 11.54</td>
<td></td>
<td>60 ± 11.54 d</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Means within each plant oil followed by different letters are significantly different (*P* < 0.05; 1-way ANOVA and Tukey’s HSD test).
essential oils from the family Linaceae, including lavender oil, may cause feeding inhibition, repellence, and insecticidal action to control various insect pests (Papachristos & Stamopoulus 2004; Gonzalez-Coloma et al. 2006). Furthermore, Magd-El-Din (2001) demonstrated that caraway oil exhibited a high toxicity for Tribolium confusum Jacquetin du Val (Coleoptera: Tenebrionidae) and other pests. Fang et al. (2010) found that the essential oil of C. carvi showed a strong toxicity in controlling Sitophilus zeamais (Motschulsky) (Coleoptera: Curculionidae) and T. castaneum with (R)-carvone and D-limonene being the principal toxic constituents for these 2 insects.

Several studies have demonstrated that plant extracts can be more effective in controlling pest insects than individual active compounds, owing to natural synergism, that also may delay the development of insecticide resistance (Yoon et al. 2011; Bilal et al. 2015). In this study, O. surinamensis was found to be more susceptible to the toxic effects of the oils, whereas T. castaneum was more resistant, as previously reported by Al-Jabr (2006). Interestingly, in the present study we found that A. cepa oil was highly toxic to O. surinamensis; however, other studies that investigated the effect of A. cepa oil on insect pests did not report similar results (Tunaz et al. 2009; Denloye 2010).

In conclusion, the results of the present study indicate that onion, lavender, and caraway oils are promising alternatives for the control of T. castaneum and O. surinamensis in stored products. Synthetic insecticides cause adverse effects on the environment, including pest resistance, pollution, and toxicity to non-target organisms. Plant essential oils are less likely to elicit pest resistance and are less toxic to the environment. However, further studies are needed to evaluate the cost of these oils and their effectiveness in controlling a wider range of insect pests.

**Acknowledgments**

The authors would like to thank Fatimah Alzahrani for her assistance during the preparation of the manuscript.

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**Table 3. Mortality of Oryzaephilus surinamensis adults exposed to different concentrations of plant oils.**

<table>
<thead>
<tr>
<th>Plant oil</th>
<th>Concentration (µL per mL)</th>
<th>SD (mean ± SE)</th>
<th>Mortality (%) (mean ± SE)</th>
<th>Slope function (S ± SE)</th>
<th>LC50 (µL per mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lavender</td>
<td>1 5.00</td>
<td>65 ± 2.50 a</td>
<td>1.28 ± 0.17</td>
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<td></td>
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<td>3 5.77</td>
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<td>4 0.00</td>
<td>90 ± 0.00 d</td>
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<tr>
<td>Onion</td>
<td>1 0.00</td>
<td>100 ± 0.00 a</td>
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<td></td>
<td>2 0.00</td>
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<td>4 0.00</td>
<td>100 ± 0.00 a</td>
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<tr>
<td>Flaxseed</td>
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<td>2.41 ± 0.10</td>
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<td>3 5.77</td>
<td>85 ± 8.66 c</td>
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<tr>
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<td>4 5.77</td>
<td>95 ± 2.88 d</td>
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<td></td>
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<tr>
<td>Caraway</td>
<td>1 5.77</td>
<td>65 ± 2.88 a</td>
<td>2.41 ± 0.10</td>
<td>0.81</td>
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<td>100 ± 0.00 d</td>
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<td></td>
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<tr>
<td>Saad</td>
<td>1 23.09</td>
<td>60 ± 11.55 a</td>
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<td>0.77</td>
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<td>70 ± 5.77 b</td>
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</tbody>
</table>

Means within each plant oil followed by different letters are significantly different (P < 0.05; 1-way ANOVA and Tukey’s HSD test).
References Cited


