BIOLOGICAL STUDIES ON THE CIGARETTE BEETLE, *Lasioderma serricorne* (F.) ON DIFFERENT BOTANICAL FOODS

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ABSTRACT: The cigarette beetle, *Lasioderma serricorne* (F.) is a serious economic insect pest of many stored products, spices and dried fruits. This work was carried out in the Laboratory of Plant Protection Department, Faculty of Agriculture, Zagazig University, Egypt, to study the effect of eight different botanical foods as insect diets (standard insect rearing diet, wheat germ, oat grains, cumin seeds, corn flakes, chamomile flowers, roselle flowers and fenugreek seeds) on some biological aspects of this insect, population growth after one and three months as well as percentage of weight loss. Also, the effect of the heavy insect infestation on certain chemical constituents of the tested foods as food moisture content, total carbohydrates, total proteins, ash, total fats and total fibers was determined and compared to control after three months of storage. The standard insect rearing diet and wheat germ were the best foods since the insect larval period was very short (14.45 and 15.36 days, respectively), while fenugreek was less preferred food as larval diet (30.55 days). Pupal period ranged from 7.18 to 11.81 days on wheat germ and corn flakes, respectively. The shortest complete developmental period was 30.67 days on wheat germ and the longest one was 53.21 days on fenugreek seeds. Values of the susceptibility index ranged from 3.03 to 8.08% for fenugreek seeds and wheat germ, respectively. The standard insect rearing diet and wheat germ were the best food kinds since they produced the highest mean progeny number after one and three months of storage (204.33, 151.67 and 3151.30, 4313.30 adults, respectively). Mean weight loss percentage ranged from 0.52 to 5.20% on corn flakes and oat grains after one month from insect infestation, respectively. However, it reached its maximum value (31.13%) on the standard insect rearing diet and minimum value on cumin seeds (1.23%) after three months. The highest relative weight loss per each adult insect was 23.75% on chamomile flowers and the lowest one valued 2.66% on corn flakes after one month of storage. After three months the value increased on corn flakes, standard insect rearing diet, roselle flowers and cumin seeds, while decreased on the other tested food kinds. A positive correlation was found between the heavy insect infestation on some foods and the chemical constituents as moisture content, total carbohydrate, total proteins, total fats, ash and total fibers. In contrast a negative one was recorded on the other foods. Positive correlation coefficients with all tested chemical constituents on sound and infested foods were detected by highly significant for total carbohydrates and total proteins as well as significant for total fats. The heavy insect infestation increased both the progeny number and the incurred weight loss and affected the chemical constituents of the different tested food kinds compared to control. All tested food kinds were infested by the cigarette beetle *L. serricorne* and no immune food was found free from the insect infestation with preferable some tested food kinds to the insect. Moreover, the heavy insect infestation after three months affected the chemical constituents of the tested food kinds.

Key words: Botanical foods, *Lasioderma serricorne* (F.), biological aspects, population growth, susceptibility index, weight loss, food chemical constituents.

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INTRODUCTION

The cigarette beetle, Lasioderma serricorne (F.) has gained a wide distribution through commerce and nowadays is found throughout the tropical and subtropical parts of the world. The adult beetle is small (2.0-3.7mm), reddish brown in color, and its head is retracted under the front part of the body. Distinguishing characteristics include the smooth elytra and serrate antennae (Croats, 1978). Cigarette beetles are slow flyers and can easily be spotted when flying. *L. serricorne* females oviposit directly onto the dried materials. The eggs are pearly white and elongated and hatch in 64-8 days. The larvae are 3 mm long, C-shaped, greyish white and thinly covered with fine brown hairs. When growth is completed, the larva transforms into an inactive pupa and emerges a fully developed beetle in about 7 days in summer and 14-18 days in the cooler weather conditions of spring and autumn. The complete life cycle of *L. serricorne* spans about 45-70 days, and 3-6 generations occur per year, depending on the food availability, as well as temperature and humidity (Edwards et al., 1980). Huge populations of *L. serricorne* can build up very quickly since a protected breeding pair can produce about 2000 offspring in four months (Howe, 1957).

The tobacco beetle, *L. serricorne* belongs to order: Coleoptera and family: Anobiidae, and is considered as one of the most serious economic insect pests of stored grain products (Runner, 1919; Ashworth, 1993; Shinoda and Fujisaki, 2001; Papadopoulou and Buchelos, 2002; Hori et al., 2011; Naveena et al., 2019), herbarium (Retief and Nicholas, 1988), foodstuffs, stored tobacco, cocoa, ground chili, paprika, cayenne pepper and spices (Powell, 1931; Blanc et al., 2006; Mahroof and Phillips, 2008), turmeric (Nischala and Prasad, 2017). Also, this insect infest and damage fenugreek, coriander, cumin, fennel, celery, carom and dried red chili (Chakma, 2014) and one of the most common insects that damage stored products such as dried and processed materials of animal origin, nuts, herbs, spices, grains and grain products (Boatseng et al., 2017). Therefore, the present work has been conducted to study the effect of eight different botanical foods on some biological aspects of *L. serricorne*, its progeny number and weight loss after one and three month of storage, as well as the changes in the chemical constituents of different tested foods due to insect infestation under the laboratory conditions were determined.

MATERIALS AND METHODS

Insect Rearing

The cultures of the cigarette beetle, *L. serricorne* were started using one hundred adult insects obtained from the stored grain insect pests Department, Plant Protection Research Institute, ARC, Dokki, Giza, Egypt. The insects were reared on a diet composed of wheat flour and dry yeast powder (95:5%), respectively within flat plastic dishes (35×18×25 cm) at the Department of the Plant Protection, Faculty of Agriculture, Zagazig University, Egypt. The rearing was carried out under controlled conditions at 28±2°C and 65±5% relative humidity within an electrical incubator. Cocoons appear and can be seen easily as small chambers on the sides of the petri dishes. The new progeny started to emerge after four weeks. Dishes were observed daily for adult emergence and adults less than 14 day old were collected for all tests. Males and females were separated during the pupal stage according to the characteristics described by Halstead (1963).

Eggs Collection

To collect large numbers of the insect eggs, many newly emerged adults were placed inside jam jars containing many pieces of black cloth (Fletcher, 1977; Yu, 2008). Folded in a zigzag form and fastened together with support of metal pins. The female prefers lay eggs within the black cloth either singly and/or in small random groups. Eggs were easily removed daily using fine camel hair brush and then were placed within small petri dishes for the experimental use as mentioned by the same previous author. Large numbers of eggs less than 1-day old were obtained for the biological studies and were incubated in petri dishes until cocoons formation.

Tested Food Kinds

Eight different botanical foods were selected as insect diet for *L. serricorne* growth and development. The common, scientific, family
names and the used parts of the selected foods were shown in Table 1. Foods were sterilized in a deep freezer at -18°C for two weeks to obtain foods free from any internal hidden pests. The tested foods were placed within the incubator for two weeks maintained at 28±2°C, 65±5 % RH to be equilibrated with the test conditions.

**Biology on Different Food Kinds**

**Incubation period**

Five replicates were used with fifty freshly laid eggs per each at the age of 0-18 hours. Each replicate was placed into a small plastic cup (1.5cm base diameter, and 0.7cm height) fastened within the center of a large glass petri dish (9cm in diameter). The inner rim of the larger petri dish contained a thin film of the larval food kind diet as a trap of any hatched larva (Chakma, 2014). All replicates were examined daily for eggs hatch to record the incubation period.

**Larval-pupal growth duration on different food kinds**

The hatched larvae were collected at less than 1-day old, used to infest groups of twenty five replicates of each food type. About 0.2g from each food type was placed into small plastic cup (2×5cm) and infested by one larva of the first instar. The cups covered with small holed plastic cover to allow air ventilation (Chakma, 2014). All replicates were incubated within an incubator at 28±2°C and 65±5% RH. The replicates were examined daily for observing the progress of larval development under a binocular microscope to record dates of the pre-pupal and pupal formation as well as adult emergence for calculating the larval, pre-pupal, pupal and complete developmental periods on each food kind.

**Food preference on different food kinds under non-free choice bioassay**

Five replicates were used from each food kind that mentioned above. Each replicate contained 30g which placed within a plastic cup (9×5 cm). Each replicate was infested with five pairs of *L. serricorne* newly emerged adults. The adults were allowed to oviposit for 10 days, and then removed. The cups were left undisturbed for further two weeks and then inspected daily for recording duration of the first generation. Progeny was removed daily and sex ratio was determined at the end of adult emergence. Sex ratio was determined by dividing the total number of males by the total number of females. The total number of progeny and the relative progeny percentage were calculated for each female. The suitability of the selected foods for insect growth was determined by calculating the susceptibility index (SI) according to equations mentioned by Howe (1971), Dobie (1974), Al-Dosari *et al.* (2002), Salama and Youssef (2004), Mohamed *et al.* (2019) as follows:

\[
\text{Susceptibility index (SI)} = \frac{\text{Log F1 (Total progeny number)}}{\text{Mean developmental period (day)}} \times 100
\]

**Population Growth and the Resultant Weight Loss from the Different Food Kinds**

Sixteen replicates from each food type were designed. Each one contained fifty grams of food kind placed into plastic jars. Eight plastic jars of each food kind were infested by three pairs of 0-1 day old adults. Four of them were stored for one month and the other for three months. Four plastic jars were left without infestation as control for each storage period (one and three months). All replicates were covered firmly with muslin cloth and fastened well by rubber bands and stored at laboratory condition (27–33°C and 60–75% RH).

After one month, all groups were inspected before appearance of the new progeny to remove all dead parent adults. Plastic jars of the first group, one month of storage were inspected daily for removing and counting the new progeny to prevent new females from laying more eggs.

All replicates of the various storage periods and the control were weighed at the end of each storage period to calculate the weight loss. Loss in weight was calculated after one and three months on the dry weight basis from the differences between the initial and final weight after subtracting the amount of moisture according to the method described by Moawad and Al-Ghamdi (2013) and Kemabonta *et al.* (2020). Moisture content was determined by
Table 1. Common, scientific and family names with the used parts of the tested food kinds

| No. | Common name           | Scientific name                     | Family name | Used part      |
|-----|-----------------------|-------------------------------------|-------------|----------------|
| 1   | Chamomile             | Matricaria chamomilla L.            | Asteraceae  | Flowers        |
| 2   | Cumin                 | Cuminum cyminum L.                  | Apiaceae    | Seeds          |
| 3   | Fenugreek             | Trigonella Foenum-graecum L.        | Leguminosae | Seeds          |
| 4   | Roselle               | Hibiscus sabdariffa L.              | Malvaceae   | Flowers        |
| 5   | Oat                   | Avena sativa L.                     | Poaceae     | Grains         |
| 6   | Wheat germ            | Triticum aestivum L.                | Gramineae   | Germ           |
| 7   | Corn flakes           | Zea mays L.                         | Gramineae   | Flakes         |
| 8   | Standard insect       | Triticum aestivum L. and            | Gramineae and Saccharomyces cerevisiae H. | Flour (95%) and dry yeast (5%) |

drying homogenous weighed samples of each food kind in the oven at 100°C for 24 hr. The weight of samples after drying was recorded for calculating mean weight loss percentage from the weight differences on the dry weight basis and relative weight loss percentage as compared with the total mean weight loss percentage of all foods. Mean weight loss caused by each insect was calculated by dividing the total gross weight loss by the total progeny number from each food kind.

\[
\text{Weight loss (\%)} = \left(\frac{\text{Initial dry weight} - \text{final dry weight}}{\text{Initial dry weight}}\right) \times 100
\]

Mean weight loss/adult (mg) = Weight loss (mg) \(\div\) Number of progeny

**Chemical Constituents of Different Infested Food Kinds**

After three months of storage, the chemical changes in the constituents of the infested and uninfested food kinds were determined. The percentages of moisture content, total carbohydrates, total proteins, ash, total fats and total fibers of both infested and uninfested foods were determined according to AOAC (2000).

**Statistical Analysis**

Data obtained were statistically analyzed by the analysis of variance (ANOVA) test by using SAS program (SAS, 2004). Simple correlation coefficient was calculated according to Hendy (1969) means comparison was done according to Duncan’s LSD (Duncan, 1955) at 5% probability level.

**RESULTS AND DISCUSSION**

**Biology of L. serricorne on Different Food Kinds**

Different developmental periods of *L. serricorne* were greatly influenced by food kinds as shown in Table 2. Incubation period had the same value 5.40 days on the tested foods. The tested food kinds high significantly influenced larval, pre-pupal, pupal and the complete developmental periods. The standard diet and the wheat germ were the best preferred foods for the larval period since the larvae spent the shortest periods (14.45 and 15.36 days), respectively. Fenugreek and chamomile were the less preferred foods of the larval period where was the longest periods 30.55 and 27.09 days, respectively.

As to the pupal period, wheat germ and the standard diet were the best preferred foods for pupal period where it was 7.18 and 7.72 days, respectively, while corn flakes and chamomile were less preferred foods of pupal period (11.81 and 11.45 days, respectively). The complete developmental period was shorter on the wheat
Table 2. Incubation, larval, pre-pupal, pupal and complete developmental periods of *L. serricorne* as influenced by different food kinds

| Food Kind      | Incubation period± SE (day) | Larval period± SE (day) | Pre-pupal period± SE (day) | Pupal period± SE (day) | Complete developmental period± SE (day) |
|----------------|-----------------------------|-------------------------|---------------------------|------------------------|----------------------------------------|
| Wheat germ     | 5.40±0.20                   | 15.36±0.20^a            | 2.72±0.30^d              | 7.18±0.30^f            | 30.67±0.24^g                          |
| Standard diet  | 5.40±0.20                   | 14.45±0.20^b            | 3.45±0.20^e              | 7.72±0.10^c^f          | 31.04±0.28^g                          |
| Oat grains     | 5.40±0.20                   | 17.18±0.20^c^f          | 2.81±0.20^f              | 8.18±0.40^d^f          | 33.58±0.33^f                          |
| Roselle flowers| 5.40±0.20                   | 20.91±0.20^c^f          | 4.36±0.20^d^f            | 8.64±0.20^d^f          | 39.31±0.41^c^f                        |
| Cumin          | 5.40±0.20                   | 22.27±0.40^d^f          | 5.36±0.30^e^f            | 9.45±0.40^c^f          | 42.95±0.34^d^f                        |
| Chamomile flowers| 5.40±0.20                   | 27.09±0.30^b^f          | 5.36±0.30^c^f            | 11.45±0.20^a^b         | 49.31±0.28^c^f                        |
| Corn flakes    | 5.40±0.20                   | 24.27±0.80^b^f          | 9.91±0.20^a^f            | 11.81±0.30^a^b         | 50.58±0.70^b^f                        |
| Fenugreek seeds| 5.40±0.20                   | 30.55±0.30^a^f          | 6.36±0.30^b^g^f          | 10.91±0.50^b^g         | 53.21±0.40^a^f                        |
| F. test        | *                           | *                       | *                         | *                      | *                                      |

Means in the same column followed by different letters are significantly different (at p<0.05) when analyzed using ANOVA and separated by Duncan test.

* = Significant difference.

germ than the standard diet (30.67 and 31.04 days, respectively) and longer on fenugreek than corn flakes (53.21 and 50.58 days, respectively).

Also, the obtained results in Table 2 show that the differences among the tested foods in respect to larval, pre-pupal, pupal and complete developmental periods were significant.

In addition, results of Table 2 classified the tested foods into two main groups. The first group included wheat germ, standard diet, oat grains and roselle flowers which were the most preferred foods of larval and pupal growth. The second group contains cumin seeds, corn flakes, chamomile flowers and fenugreek seeds as unsuitable foods for the larval and pupal growth. No completely immune food was found completely immune against the insect infestation.

The obtained results of the incubation period mentioned above are comparable with the results obtained by El-Halfawy (1977) who found that the incubation period was not affected by the diet on which the insect was bred. However they disagree with those recorded by Naveena et al. (2019) who indicated that the incubation period ranged from 7.0 to 9.9 days on dried yeast and cigar tobacco, respectively. Also, Al-Obaidy et al. (2019) mentioned that incubation period ranged from 6 to 10 days when the insect was reared on the baker’s yeast. In respect to larval and pupal periods, Ali et al. (1974) stated that larval periods were affected by kind of the larval food and were markedly retarded on ginger. Al-Obaidy et al. (2019) reported that larval period differed largely among the tested foods and ranged from 23.8 to 79.8 days on dried yeast and chewing leaf tobacco but on the rearing insect diet (composed of wheat flour and dried yeast) it reached 28.5 days and the pupal period was 7.7 days. Moreover, Naveena et al. (2019) stated that pupal period ranged from 7.3 to 14.7 days on the wheat flour admixed with dried yeast powder and chilli powder, respectively.

Results presented in Table 3 show that oat grains, wheat germ and corn flakes considered the most preferred foods and produced the highest F₁ progeny numbers of 316.50, 304.00 and 302.50 adults, respectively. Fenugreek seeds and roselle flowers produced the lowest progeny of 41.75 and 100.75 adults, respectively.
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Table 3. Mean progeny number, relative production, susceptibility index and sex ratio of *L. serricorne* on some different food kinds after one generation

| Food kind          | Mean number± SE of | Relative progeny (%)± SE / female | Susceptibility index (%)± SE | Sex ratio± SE |
|--------------------|--------------------|----------------------------------|------------------------------|---------------|
|                    | Male               | Female                          | Total progeny                | Total progeny / female |                      |
| Wheat germ         | 172.67±13.30^a     | 131.33±10.96^b                  | 304.00±23.51^a              | 60.80±4.70^a     | 17.65±1.45^a 8.08±0.12^a 1.32±0.05^a |
| Standard diet      | 100.00±10.26^d     | 154.00±5.34^b                   | 254.00±13.39^b              | 50.80±2.68^b     | 14.70±0.41^b 7.74±0.12^b 0.63±0.06^d  |
| Oat grains         | 150.75±9.80^ab     | 165.75±4.20^c                   | 316.50±8.30^c              | 63.30±1.66^c     | 18.37±0.53^c 7.45±0.09^c 0.91±0.07^cd |
| Roselle flowers    | 66.25±7.00^d       | 34.50±7.00^c                    | 100.75±11.40^d             | 20.15±2.28^d     | 5.87±0.71^d 5.06±0.21^e 1.94±0.48^d  |
| Cumin seeds        | 114.00±2.70^e      | 95.75±5.80^d                    | 209.75±8.40^d              | 41.95±1.68^e     | 12.19±0.60^e 5.41±0.09^d 1.20±0.07^ec  |
| Corn flakes        | 141.50±3.30^bc     | 161.00±6.80^e                   | 302.50±10.00^c             | 60.50±2.00^c     | 17.56±0.68^c 4.88±0.06^f 0.88±0.03^fcd |
| Chamomile flowers  | 118.00±9.10^a      | 101.25±7.70^c                   | 219.25±15.30^bc            | 43.85±3.10^bc    | 12.67±0.58^bc 4.74±0.10^f 1.17±0.06^bc  |
| Fenugreek seeds    | 24.50±2.50^f       | 17.25±2.30^d                    | 41.75±4.70^f               | 8.35±0.90^f      | 2.44±0.31^f 3.03±0.10^g 1.44±0.08^h  |
| F. test            | *                  | *                               | *                            | *              | *  |

Means in the same column followed by different letters are significantly different (at p<0.05) when analyzed using ANOVA and separated by Duncan test.

* = Significant difference.
SI= Susceptibility index.
Total progeny / female = total / (5 females)

Statistical analysis obviously cleared significant differences between all tested food kinds and all of the progeny number of males, females, total progeny per female, relative progeny production (%) per female, susceptibility index and sex ratio.

The relative progeny production (%) per female was increased on oat grains, wheat germ and corn flakes (18.37, 17.65 and 17.56%, respectively). Other foods showed lower percentages and fenugreek reached the lowest one (2.44%).

Values of susceptibility index (SI) differed among the tested foods. Wheat germ, the standard diet and oat grains were the most suitable foods (8.08, 7.74 and 7.45%, respectively). Fenugreek seeds which are not suitable food recorded the lowest value (3.03%).

Sex ratio of the progeny ranged from 0.63 to 1.94% for the standard diet and roselle flowers, respectively. From the above results, it could be concluded that tested food kinds affected the biological parameters of cigarette beetle.

### Weight Loss Percentage and the Mean Progeny Number from Different Food Kinds

The insect infestations by three pairs of *L. serricorne* after one month of storage to the eight tested foods are shown in Table 4. Standard diet produced the highest mean progeny number of (204.33 adults) and considered the most suitable and preferred food, while fenugreek seeds produced the lowest one (13.00 adults) and considered unsuitable food.

Oat grains and wheat germ suffered from the highest mean percentage of weight loss (5.20 and 4.23%, successively). The relative weight loss percentages reached its maximum (30.15 and 24.04%) on oat grains and wheat germ, respectively. Corn flakes, cumin and fenugreek seeds showed the lowest one of (3.11, 3.26 and 3.26%), respectively.

Significant differences were found among the tested foods in respect each of progeny number, mean weight loss percentage, relative weight loss percentage, mean weight loss per adult and relative weight loss per adult percentage after one month.
Table 4. Mean progeny number and weight loss of *L. serricorne* infestation from different food kinds after one and three months of storage

| Food kind       | Mean progeny No.±SE | Mean weight loss (%±SE) | Relative weight loss (%±SE) | Mean weight loss / adult (mg±SE) | Relative weight loss/adult (%±SE) |
|-----------------|---------------------|-------------------------|-----------------------------|---------------------------------|-----------------------------------|
|                 | One Month | Three Months | One Month | Three Months | One month | Three months | One month | Three months | One Month | Three months |
| Standard diet   | 204.33±10.59<sup>a</sup> | 3151.30±38.00<sup>b</sup> | 2.73±0.20<sup>c</sup> | 31.13±1.10<sup>d</sup> | 15.27±1.05<sup>e</sup> | 47.00±1.30<sup>f</sup> | 6.11±0.16<sup>g</sup> | 5.17±0.60<sup>h</sup> | 6.63±0.18<sup>i</sup> | 16.10±1.80<sup>j</sup> |
| Wheat germ      | 151.67±8.97<sup>b</sup> | 4313.30±102.10<sup>c</sup> | 4.23±0.07<sup>e</sup> | 12.91±0.48<sup>b</sup> | 24.04±0.48<sup>b</sup> | 19.29±0.52<sup>b</sup> | 13.05±0.74<sup>f</sup> | 1.34±0.02<sup>b</sup> | 14.15±0.62<sup>g</sup> | 4.18±0.05<sup>h</sup> |
| Oat grains      | 140.67±10.20<sup>b</sup> | 2401.00±43.00<sup>c</sup> | 5.20±0.21<sup>c</sup> | 11.52±0.66<sup>b</sup> | 30.15±1.01<sup>a</sup> | 17.41±1.00<sup>b</sup> | 17.64±0.81<sup>b</sup> | 2.17±0.07<sup>d</sup> | 19.12±0.54<sup>b</sup> | 6.75±0.18<sup>o</sup> |
| Corn flakes     | 106.33±8.67<sup>c</sup> | 143.67±11.30<sup>cd</sup> | 0.52±0.17<sup>e</sup> | 3.00±0.21<sup>c</sup> | 3.11±0.63<sup>c</sup> | 4.56±0.28<sup>e</sup> | 2.46±0.44<sup>e</sup> | 9.55±0.38<sup>e</sup> | 2.66±0.42<sup>g</sup> | 29.70±1.40<sup>a</sup> |
| Roselle flowers | 105.33±4.41<sup>c</sup> | 494.67±35.40<sup>d</sup> | 1.33±0.07<sup>d</sup> | 2.80±0.10<sup>d</sup> | 6.94±0.51<sup>d</sup> | 3.88±0.08<sup>cd</sup> | 5.37±0.13<sup>d</sup> | 2.45±0.17<sup>c</sup> | 5.84±0.26<sup>c</sup> | 7.65±0.59<sup>c</sup> |
| Chamomile flowers | 52.00±3.79<sup>d</sup> | 243.00±16.40<sup>e</sup> | 2.47±0.13<sup>e</sup> | 2.67±0.57<sup>cd</sup> | 13.85±0.78<sup>bc</sup> | 4.00±0.88<sup>e</sup> | 21.85±0.59<sup>b</sup> | 4.85±0.67<sup>a</sup> | 23.75±1.07<sup>b</sup> | 15.07±2.06<sup>b</sup> |
| Cumin seeds     | 113.67±8.45<sup>c</sup> | 234.67±26.35<sup>f</sup> | 0.60±0.10<sup>e</sup> | 1.23±0.07<sup>d</sup> | 3.26±0.40<sup>e</sup> | 1.88±0.13<sup>e</sup> | 5.21±0.58<sup>d</sup> | 2.45±0.17<sup>c</sup> | 5.64±0.59<sup>e</sup> | 7.64±0.52<sup>e</sup> |
| Fenugreek seeds | 13.00±1.53<sup>c</sup> | 51.67±7.80<sup>f</sup> | 0.60±0.10<sup>e</sup> | 1.37±0.15<sup>d</sup> | 3.26±0.40<sup>e</sup> | 2.00±0.23<sup>de</sup> | 20.48±0.48<sup>a</sup> | 4.17±0.16<sup>bc</sup> | 22.22±0.16<sup>a</sup> | 12.98±0.40<sup>b</sup> |

Means in the same column followed by different letters are significantly different (at p<0.05) when analyzed using ANOVA and separated by Duncan test.

* = Significant difference
After three months of storage the mean progeny varied significantly and ranged from 4313.30 to 51.67 on wheat germ and fenugreek seeds, respectively. The mean weight loss percent increased in all tested food kinds with increased the insect progeny. The standard diet suffered the highest mean weight loss percent (31.13%) followed by wheat germ (12.91%) and oat grains (11.52%) and the lowest ones were 1.23 and 1.37% on cumin seeds and fenugreek seeds, respectively after three months of storage.

For comparison between the relative weight loss percentage after one and three months of storage the maximum percentage after one month of storage were 30.15, 24.04 and 15.27% in case of oats grains, wheat germ and standard diet, respectively, while the minimum ones were 3.11, 3.26 and 3.26% with corn flakes, cumin seeds and fenugreek seeds, respectively. The relative weight loss decreased on different food kinds after three months except corn flakes where it was 3.11 and 4.56% after one and three months of storage, successively. This is properly due to higher increase of the progeny number and competition among insects for the available food amount.

The calculated weight loss (mg) per adult in corn flakes increased from 2.46 to 9.55 mg after one and three months because corn flakes produced lower progeny number after one month and each insect have a complete good chance to consume more food from the available amount without any individual competition.

The current results are similar to those of Howe (1957) who mentioned that growth rate of L. serricorne depended upon food types. The growth rate of the cigarette beetle may be largely affected by nutritional, quality and quantity of the tested foods. Butani (1984) recorded cigarette beetle as a major pest of coriander in storage. El-Din (2003) reported that coriander seeds were the most appropriate seeds for the cigarette beetle growth which showed three generations during the period from May to October. As to the weight loss, Hill (1983) found that L. serricorne caused serious damage and weight loss on many spices. Kohno and Ohinishi (1986) reported that the lower percentage of weight loss in fenugreek seeds is probably due to the presence of hard seed coats which represent a natural resistant factor for deposited eggs and the subsequent larval growth. Kant et al. (2013) mentioned that damage in fennel and cumin ranged between 50 to 60% and in coriander and ajowan from 40 to 50% and in dill from 30 to 40%. Therefore, a maximum annual loss was recorded in fennel seeds (58.02%) and the minimum was found in dill seeds (39.0%). The insect population growth was related with the damage potential which a maximum of 1,142 insects was produced from fennel seeds and a minimum of 902 insects from dill seeds. Chakma (2014) added that L. serricorne caused lower percentage of weight loss reached 1.6 and 5.4% after one and three months, respectively in fenugreek seeds. Many authors as Babarinde et al. (2008), Patra (2015) and Memon et al. (2017) mentioned that L. serricorne caused serious damage and weight loss on many spices as caraway, fennel, coriander, cumin, red chilli, dandicut chilli, turmeric and Saeed et al (2015) different tobacco types. Also, Memon et al. (2017) determined weight loss and damage caused by L. serricorne.

Chemical Changes in Different Food Kinds Caused by L. serricorne Infestation

The chemical changes in the constituents of different tested food kinds, after three months of infestation by L. serricorne were determined (Table 5). The studied chemical changes were moisture content, total carbohydrates, total proteins, ash, total fats and total fibers. The infestation by L. serricorne affected negatively the moisture content, total carbohydrates, ash and total fats and positively total proteins and total fibers on some food kinds. Contrast trend happened in other foods. The heavy infestation reduced the moisture content in most food kinds except wheat germ and the standard diet. This is probably due to that adult emergence makes the seeds naked and exposed for moisture loss. Total carbohydrates increased with increasing the insect infestation in oat grains, roselle flowers, fenugreek seeds, chamomile flowers and cumin seeds, from 48.29, 43.41, 33.59, 32.49 and 18.34% in uninfested food kinds to 67.10, 53.16, 44.38, 45.68 and 52.18% in infested foods, respectively. This value decreased in other foods as the standard diet, wheat germ and corn flakes.
Table 5. Changes in foods chemical constituents under infestation by *L. serricorne* after three months of storage

| Chemical constituent | Moisture content (%) | Total carbohydrates (%) | Total proteins (%) | Ash (%) | Total fats (%) | Total fibers (%) |
|----------------------|----------------------|-------------------------|-------------------|---------|----------------|------------------|
| Food kind            | Uninfested food      | Infested food           | Uninfested food   | Infested food | Uninfested food | Infested food    |
| Standard diet        | 1.73                 | 5.85                    | 74.39             | 72.94       | 12.79          | 11.99            |
| Wheat germ           | 4.96                 | 9.35                    | 34.60             | 31.55       | 32.72          | 30.68            |
| Oat grains           | 10.24                | 3.68                    | 48.29             | 67.10       | 19.22          | 16.22            |
| Roselle flowers      | 16.38                | 11.83                   | 43.41             | 53.16       | 10.93          | 12.71            |
| Chamomile flowers    | 11.86                | 4.34                    | 32.49             | 45.68       | 11.49          | 10.96            |
| Corn flakes          | 7.75                 | 4.19                    | 74.03             | 72.06       | 7.33           | 10.96            |
| Cumin seeds          | 10.79                | 6.59                    | 18.34             | 21.84       | 18.76          | 22.80            |
| Fenugreek seeds      | 10.81                | 9.72                    | 33.59             | 44.38       | 28.28          | 28.50            |

R1: Relation between chemical constituents and progeny number.
R2: Relation between chemical constituents and dry weight loss (%).
R3: Relation between chemical constituents and incomplete developmental period (day).
R4: Relation between sound and infested food kinds.

Total proteins content decreased with the heavy infestation in the standard diet, wheat germ, oat grains and chamomile flowers from 12.79, 32.72, 19.22 and 11.49% in uninfested foods to 11.99, 30.68, 16.22 and 10.96%, respectively but increased in roselle flowers, corn flakes, cumin seeds and fenugreek seeds. Ash increased after infestation in three tested foods as the standard diet, wheat germ, roselle flowers (2.74, 6.52 and 10.73%) and decreased in oats grains, chamomile flowers and corn flakes (2.11, 11.97 and 1.41%), respectively. The total fats were reduced after infestation with lower values compared to uninfested food except for corn flacks where the opposite case was found. The percent of total fibers differed between uninfested and infested foods which decreased in most food kinds but increased in wheat germ, oat grains and corn flacks to reach 4.88, 3.81 and 0.70%, respectively.

The correlation coefficients between chemical constituents in sound and infested foods and total progeny number, weight loss and the complete developmental period was shown in Table 5. The moisture content, ash and total fibers in sound foods affected negatively on the progeny number (R1= -0.691, -0.200 and -0.569%, respectively). Heavy infestation with longer storage period for three months and the resulted progeny number correlated positively with the moisture content, total proteins and total fats (R1= 0.046, 0.282 and 0.481%, respectively) but affected negatively on the total carbohydrates, ash and total fibers (R1= -0.094, -0.273 and -0.336%, respectively).
Percentage of dry weight loss caused by *L. serricorne* infestation affected negatively on moisture content, ash and total fibers (R²= -0.149, -0.406 and -0.424%, respectively). Total carbohydrates, total proteins and total fats in uninfested foods correlated positively with the weight loss. The insect infestation after three months and resulted dry weight loss correlated positively with total carbohydrates and total fats (R²= 0.383 and 0.009%, respectively). Dry weight loss after insect infestation correlated negatively with moisture content, total proteins, ash and total fibers (R²= 40.149, 40.406 and 40.424%, respectively). Total carbohydrates, total proteins and total fats in uninfested foods correlated positively with the weight loss. The insect infestation after three months and resulted dry weight loss correlated positively with total carbohydrates and total fats (R²= 0.383 and 0.009%, respectively). Dry weight loss after insect infestation correlated negatively with moisture content, total proteins, ash and total fibers (R²= 40.149, 40.406 and 40.424%, respectively). Total carbohydrates, total proteins and total fats affected negatively (R²= 40.238, 40.047 and 40.429%, respectively) and shortened the complete developmental period. Moisture content, ash and total fibers correlated positively with the growth period (R²= 0.343, 0.239 and 0.344%, respectively) in sound foods. Positive correlation coefficients with all tested chemical constituents on sound and infested foods were detected by highly significant for total carbohydrates and total proteins (R²= 0.783** and 0.960**), respectively as well as significant (R²= 0.673*) for total fats. The obtained results agree with the findings of Sinha (1984), Jood *et al.* (1996) and Sanchez-Marinez *et al.* (1997) who mentioned that moisture content increased by increasing the insect infestation. As to ash, Barney *et al.* (1991) found that the insect infestation on maize kernels induced increasing the food ash and Ahmedani *et al.* (2009) cleared that *Trogoderma granarium* (E.) infestation positively affected ash level. According total proteins, some authors such as Krzymanska and Goebiowska (1987), Sudhakar and Pandey (1987), Ahmedani *et al.* (2009) and Özkaya *et al.* (2009) recorded that total proteins increased with increasing the insect infestation period. In terms of fibers, Helaly (2015) stated that the maximum percentage of fibers was recorded after 8 months of infestation by *Ephestia kuehniella* (Z.). El-Sitiny (2016) added that both fibers and total carbohydrate increased by *Callosobruchus maculatus* F. infestation.

In the other hand the obtained results about negatively correlation between insect infestation on some foods and their tested chemical constituents are in particular agreement with the results obtained by Krzymanska and Goebiowska (1987), Jood *et al.* (1996) and Ghareeb (1998) who reported that insect infestation reduced fats on some foods. Helaly (2015) found that rice weevil effect negatively the fats content. In case of moisture content, Ghareeb (1998) recorded that insect infestation in wheat flour decreased by moisture content. Kailash and Tanjore (2006) and Singh *et al.* (2013) observed that insect infestation correlated negatively with the total proteins. In addition, Helaly (2015) stated that the infestation by *S. oryzae* reduced total carbohydrate and Sudhakar and Pandey (1987) added that this insect decreased ash in rice.

In conclusion, infestation by *L. serricorne* affected the chemical constituents as moisture content, total carbohydrates, total proteins, total fats, total fibers and ash. Also, it can be concluded that food kind affected the biology of the *L. serricorne* by decreasing or increasing some infestation parameters (progeny, growth and development).

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دراسات بيولوجية على خنفساء السجار


Lasioderma serricorne (F.)

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تعتبر حشرة خنفساء السجار من الأعشاب الاقتصادية الخطرة والتي تسبب العديد من المنتجات المخزون والتناول
والفاكهة المجففة. تم إجراء هذا البحث في معمل قسم وقاية النبات، كلية الزراعة، جامعة الزقاق، مصر، لدراسة تأثير
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 الذرة)، أثر الهيدروجين، أثر الكربون، بقور الحليب، وبيئة النباتة القياسية للحمرة (95% فقح + 5% خمرة جافة)
على بعض الخصائص البيولوجية للحمرة وعلى ظاهرة التثبيت وكذلك نسبة الفقد في الوصاية بعد شهر وثلاثة أشهر من
التخزين. بجانب دراستها تأثير الإصلاحية على بعض المكونات الكيميائية مثل نسبة كل من المحتوي الرئيسي للغدة،
الكربوهيدرات الكلية، البروتينات الكلية، الرماد، الدهن الكلوي والألغاز الكلية بعد ثلاثة أشهر من الإصلاح合いوقت وتلك
المكونات في الحمراء، البروتينات الكلية، الرماد، الدهن الكلوي والألغاز الكلية بعد ثلاثة أشهر من الإصلاحية
ومقارتها بتلك المكونات في الحمراء غير الزيتي، وجد أن البيئة الزيتية والشفطية اختلاف أن أن المكونات المساهمة لها بفضل أنواع الأغنية تسمى

حيث كانت فترة النمو البري قصيرة جداً (14.45 و15.36 يومًا على التوالي)، بينما كانت بذور الحليب الأغاني الأقل
تفضيلًا لنمو الزيت البري حيث وصلت فترة النمو البري لحالي شهر (30.55 يومًا)، وبداية فترة نمو الزيت البري
بين 7.18 و11.81 يومًا على كل من حتي النبات، وكون فلكين على حتي، وكانت أقل فترة نمو الحمرة 30.67 يومًا
على بذر الحليب، وقدرت فترات الت الثنائية لحريات الزيتية المسمكة، تفاوتت في بذر الحليب، وبيئة النباتة 
بين 8.03-0.8% على بذر الحليب، وبعدين النباتة على التوالي، وكانت بذور النباتة الأساسية وبيئة النباتة أصل أصل أنواع
الأغنية للحمرة حيث كان أعلى متوسط عدد لحريات النباتة هي 204.33 و151.67 حريات لكل كم 2.03 على بذر النباتة، ونسبة الفقد
الكامل على النباتة وأكثر من 50% على بذر النباتة، ونسبة الفقد على نباتة الأغنية للحمرة بعد ثلاثة أشهر من
التمكين ونسبة الفقد على نباتة الأغنية للحمرة بعد ثلاثة أشهر من الإصلاحية 31.13% على بذر النباتة 
والتمكين، ونسبة الفقد على نباتة الأغنية للحمرة 33.75% في أثر ال
المكونات أصل وأقل نسبة لها هي 26.6% في بذر النباتة، فلكين بعد شهرين من التنزيل، انخفضت هذه القيمة بعد ثلاثة سنوات
في معظم الأغنية ما دون فلكين. فلكين، بيئات النباتة الأساسية للحمرة، أثر الكربون، بذور الحليب، وبيئة النباتة
المسمكة بعد تأثير نباتة الأغنية للحمرة، وجد أرتياحًا موثقًا ببيئة النباتة المسمكة في بعض الأنوار المخزية
المكونات الكيميائية لها مثل المحتويات الرئيسيه، البروتينات الكلية، الدهن الكلوي،
ومقارنة على المجموع استندًا إلى أنواع الأغنية الأخرى، أدت إصلاحية الحمراء المبكرة لإعادة تنزيل النباتة، والذرو
في النباتة before on the التغييرات الكيميائية في المكونات الأغنية المختلفة للحمرة المختارة بالمختبر، والفجوة
أثرت الإصلاحية المبكرة في جودة النباتة ومشكلة الأنواع المختارة بالإضافة إلى ذلك فقد الإصلاحية المبكرة للحمرة للعوامل
المختلفة أثرت على المحتويات الكيميائية لأنواع الأغنية المختارة.

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