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GROWTH AND DEVELOPMENT OF *Oryzaephilus surinamensis* (L.) (COLEOPTERA: SILVANIDAE) IMMATURE STAGES ON SOME FOOD KINDS

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ABSTRACT: The saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.) is an important pest of many stored product foods. The effect of insect infestation on four various of whole food kinds as semi-dry date, dry date fruits, white sesame and reddish yellow sesame seeds as well as four food kinds of crushed seeds (chickpea, corn, rice and groundnut) as compared with standard diet (wheat flour, crushed wheat and dry yeast powder at 5:5:1, respectively) was investigated in the laboratory of Plant Protection Department, Faculty of Agriculture, Zagazig University, Egypt. Insect parameters on the tested food kinds as regards to resistance were duration of developmental stages, number of F_1 progeny, growth index and weight loss (%) after one month of storage. All tested parameters were significantly affected by food kinds except the duration of pupal stage in whole foods. The shortest mean insect complete developmental period was 19.85 days on standard diet, while the longest one was 29.18 days on whole reddish yellow sesame seeds and 35.05 days on crushed groundnut. Values of the growth index (GI) increased from 3.22 to 3.76 on whole reddish yellow sesame seeds and crushed chickpea, respectively compared to 4.64 on standard diet. The wet weight loss (%) ranged from 0.50 and 0.67% in whole sesame seeds (white and reddish yellow) and crushed groundnut, suscessively compared to11.17% in standard diet. The relative wet weight loss (%) in whole seeds reached its minimum (1.94%) in each of whole white and reddish yellow sesame seeds and reached its maximum (43.23%) in standard diet, while in crushed foods, the lowest value was 3.16% in crushed groundnut as compared with the standard diet which recorded the highest percent 52.76%. All tested foods either whole or crushed were infested with *O. surinamensis* and no completely immune food was found free from the insect infestation but the insect preferred crushed foods and some foods than another.

Key words: Whole and crushed food kinds, *Oryzaephilus surinamensis* (L.), developmental period, progeny, weight loss (%), Growth index.

INTRODUCTION

The saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae) is one of the key stored grain pests which occurs worldwide **(Rossiter *et al.*, 2001; Hashem *et al.*, 2012)**. This insect is considered as a secondary feeder and infest various stored product commodities such as cereals, millets, flour, oil seeds, confectionaries, dried meat and fruits, bran and nuts *etc.*, (**Bowditch and Madden, 1997; Barnes, 2002**). The infestation by this insect pest causes huge damage such as weight decrease, broken seed surface, broken germ, broken endosperm, and contamination (**Busvine, 1980; Robinson, 2005; Beckel *et al.*, 200; Leelaja *et al.*, 2007**). The saw-toothed grain beetle is a very small insect and has a strong

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ability to move and hide in many places in storage warehouses, making it difficult to be controlled by chemical control since and it has built up resistance to several insecticides (**Greening *et al*., 1974; Heather and Wilson, 1983; Wallbank and Collins, 2003**). A little information is known about growth and development of *O. surinamensis* in other food kinds. For that the present investigation screened the insect growth and development on various stored food kinds either whole or crushed for developing management practices and attempting to obtain a basic information for the future pest management strategies. The studied biological parameters were incubation period, duration of larval, pupal and complete developmental periods, progeny number, growth index and wet as well dry weight loss (%) from the tested whole and crushed food kinds.

MATERIALS AND METHODS

Insect Rearing

The adults of the saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.) were obtained from the Stored Grain Insect Pests Department, Plant Protection Research Institute, A.R.C., Dokki, Giza, Egypt. The stock cultures were set up by introducing about three hundred adults of this insect in glass jars of 2kg capacity, half filled with sterilized artificial diet. The insect diet was composed of (standard diet) wheat flour, crushed wheat and dry yeast powder at 5:5:1, respectively according to the method described by **Leelaja *et al*. (2007) and Kolar Aulicky *et al*. (2017)**. The jars were tightly covered with muslin cloth, held in place by rubber bands and the adults were left to oviposit for two weeks, then removed by sieving. The glass jars were labeled and kept within an electrical incubator adjusted at 29±1^{O}C and 65±5% RH in the laboratory of Plant Protection Department, Faculty of Agriculture, Zagazig University, Egypt.

Eggs Collection

The eggs of *O. surinamensis* were obtained by placing about 500-1000 adult beetles in one half-kg glass jar containing about 500g of the rearing medium which was mentioned before according to the method of **Eliopoulos (2019).** After 24hr, eggs and adults were separated from the crushed wheat and received through US standard sieves of 212-710mm to remove the eggs from the dust by using an 85- mesh (pore size 180µm) standard sieve (**Leelaja *et al*., 2007**). The eggs were placed within small Petri dishes for the experimental use. Large numbers of eggs of 0-1 day old were obtained for use in the biological studies of the present study.

Tested Foods

Nine different food kinds (whole and crushed) that are commonly found in stores of grain products were bought from the local supermarkets. The effect of insect infestation by this insect on five various whole food kinds: semi-dry date (Siwa date), dry date (commercial date), white and reddish yellow sesame seeds (**Ministry of Agriculture, 2016**) from Shandaweel 3 and Giza 32 cultivars, respectively, and on four crushed food kinds (corn, rice, chickpea and groundnut) as compared with standard diet was tested. All food kinds were sterilized in a deep freezer at –18 ^{O}C, for two continuous weeks to kill any hidden strange insect stages and then conditioned for two weeks at 29±1 ^{O}C and 65±5% RH to be equilibrated with the test conditions.

Duration of the Different Developmental Stages of *O. surinamensis* on the Tested Food Kinds

Three replicates of fifty eggs 0-1 day old that deposited by F_1 emerged females from each food kind were incubated at constant conditions of 29±1 ^{O}C and 65±5 % RH. Daily observations were made until eggs hatching and then the number of hatched larvae was counted to calculate the incubation period and hatchability percentage. Newly hatched *O. surinamensis* larvae of 0-4hr old were obtained. About 0.2g from each food kind was put in a clear penicillin glass bottle (2×4.5cm) and infested by one newly hatched larva. Each bottle was covered with small holed plastic cover (**Chakma, 2014**). Twenty replicates for each food kind were made. All replicates were kept at constant conditions mentioned above. Daily observations were made to observe the progress of the larval development and calculating the larval, pupal and complete developmental periods in each replicate of the tested food kinds and means were calculated.

Population Growth of *O. surinamensis* on the Tested Food Kinds

Twenty grams of each food kind was put in a plastic bottle (5.30×8cm), each bottle was infested with fifty eggs (0-1day old) and covered with muslin cloth and kept under open laboratory conditions (32.63 ^{O}C and 44.79% RH) as averages. Each food kind was replicated five times. All these bottles were covered with a very minute holed cover plastic to prevent escape the beetles. All replicates were kept at above laboratory conditions until adult emergence. The mean developmental period and progeny number as well as the reduction (%) of progeny and growth index were calculated. Growth index was calculated according to the equation of **Howe (1971)**, **Al-Dosari *et al.* (2002) and Mohamed *et al.* (2019)** by dividing adult emergence (%) by the total developmental period.

Wet and Dry Weight Losses (%) on Tested Food Kinds by the Infestation with *O. surinamensis*

Eight replicates from each food kind were made. Each replicate contained twenty grams of each food kind and placed into plastic jars (5.50×8 cm). Four plastic jars of each food kind were infested, each by fifty eggs of *O. surinamensis* (0-2 days old) and the last four jars were left uninfested as control. These jars were stored for one month. All these jars were covered well with muslin cloth, held firmly in place by rubber bands and stored under open laboratory conditions with averages 33.38 ^{O}C and 44.89% RH. After two weeks, all insects were removed and adult progeny as well as number of larvae and pupae were counted after one month of storage. All replicates plus the control were weighed to calculate the weight difference. The dry weight loss (%) was calculated as mentioned before after subtracting the moisture content from each food by the oven method according to the equation of **(El-Sayed *et al,* 2005**). Ten grams of each food kind was weighed initially (wet weight) then, the samples dried in the oven at 90-100ºC for continuous 24 hr. After this period (24 hr.), these samples reweighed again to calculate weight differences on the dry weight basis and relative weight loss (%) was calculated in respect with the total mean weight loss (%) of the foods.

Statistical Analysis

The obtained data was analyzed by analysis of variance (ANOVA) using Proc ANOVA in SAS (**Anonymous, 2003**) and means were separated by the least significant difference (LSD) at 5% probability level ($p \leq 0.05$) in the same program.

RESULTS AND DISCUSSION

Duration of the Different Developmental Stages of *O. surinamensis* on the Tested Food Kinds

Data in Tables 1 and 2 show effect of some whole and crushed food kinds on the duration of *O. surinamensis* developmental stages, respectively.

As regards whole food kinds in Table 1, the observed incubation period of the deposited eggs by F_1 females emerged from each food kind was lasted longer on whole white sesame seeds (4.04 days) and standard diet (4.00 days), while it was shorter in semi-dry date (3.00 days). The percent of eggs hatchability was 100.00% on the standard diet, while it was a minimum (70.00%) on whole reddish yellow sesame seeds.

The maximum larval period reached 20.95 days on whole reddish yellow sesame seeds, while it was minimum (11.10 days) on standard diet. The maximum pupal period was 5.05 and 4.90 days on whole semi-dry date and whole white sesame seeds, while the minimum one was 4.70 days on dry date. The highest larval-pupal period was 25.80 days were recorded on whole reddish yellow sesame seeds, while the shortest one was 15.85 days on standard diet. The longest complete developmental periods were 29.14 and 29.18 days on whole white and reddish yellow sesame seeds, respectively, while the shortest one was 19.85 days on standard diet. Dates either dry or semi-dry showed intermediate values. All durations of the different developmental stages of *O. surinamensis* were significantly affected by the whole food kind except the duration of pupal stage which varied insignificantly.

Table 1. Effect of some whole food kinds on the duration of the developmental stages of *O. surinamensis* at constant conditions of 29±1ºC and 65±5% RH

Whole food kind	Mean±SE of					
	Incubation period (day)	Eggs hatchability (%)	Larval period (day)	Pupal period (day)	Larval-Pupal period (day)	Complete developmental period (day)
Standard diet	$4.00\pm0.00_{a}$	$100.00\pm0.00_{a}$	$11.10\pm0.19_{c}$	$4.75\pm0.00_{a}$	$15.85\pm0.19_{c}$	$19.85\pm0.19_{c}$
Semi-dry date	3.00±0.00c	$83.33\pm1.92_{b}$	$13.90\pm0.04_{b}$	$5.05\pm0.04_{a}$	$18.95\pm0.04_{b}$	$21.95\pm0.04_{b}$
Dry date	$3.71\pm0.17_{ab}$	$83.33\pm1.92_{b}$	$14.45\pm0.08_{b}$	$4.70\pm0.04_{a}$	$19.15\pm0.07_{b}$	$22.86\pm0.07_{b}$
Reddish yellow sesame seeds	$3.38\pm0.18_{bc}$	$70.00\pm0.00_{c}$	$20.95\pm0.10_{a}$	$4.85\pm0.03_{a}$	$25.80\pm0.10_{a}$	$29.18\pm0.10_{a}$
White sesame seeds	$4.04\pm0.03_{a}$	$83.33\pm1.92_{b}$	$20.20\pm0.11_{a}$	$4.90\pm0.03_{a}$	$25.10\pm0.11_{a}$	$29.14\pm0.11_{a}$
F. test	*	*	*	NS	*	*
LSD 0.05	0.60	8.14	0.95	0.39	0.97	0.97

Means in the same column followed by different letters are significantly different at 5% probability level.

* = Significant means. NS= Non-significant means.

Table 2. Effect of some crushed food kinds on the duration of the developmental stages of *O. surinamensis* at constant conditions of 29±1ºC and 65±5% RH

Crushed food kind	Mean±SE of					
	Incubation period (day)	Eggs hatchability (%)	Larval period (day)	Pupal period (day)	Larval-pupal period (day)	Complete developmental Period (day)
Standard diet	$4.00\pm0.00_{b}$	$100.00\pm0.00_{a}$	$11.10\pm0.19_{d}$	$4.75\pm0.02_{bc}$	$15.85\pm0.03_{c}$	$19.85\pm0.03_{c}$
Corn	$4.09\pm0.03_{a}$	$86.67\pm3.85_{a}$	$11.40\pm0.03_{d}$	$4.60\pm0.03_{c}$	$16.00\pm0.03_{c}$	$20.09\pm0.03_{c}$
Rice	$4.00\pm0.00_{b}$	$70.00\pm3.33_{b}$	$13.10\pm0.05_{c}$	$4.95\pm0.01_{ab}$	$18.05\pm0.04_{b}$	$22.05\pm0.04_{b}$
Chickpea	$4.00\pm0.00_{b}$	$66.67\pm1.92_{b}$	$14.35\pm0.04_{b}$	$4.60\pm0.03_{c}$	$18.95\pm0.04_{b}$	$22.95\pm0.04_{b}$
Groundnut	$4.00\pm0.00_{b}$	$66.67\pm1.92_{b}$	$25.90\pm0.18_{a}$	$5.15\pm0.02_{a}$	$31.05\pm0.17_{a}$	$35.05\pm0.17_{a}$
F. test	*	*	*	*	*	*
LSD 0.05	0.06	14.09	1.08	0.28	1.05	1.05

Means in the same column followed by different letters are significantly different at 5% probability level.

* = Significant means.

The present data showed that all tested whole foods supported the insect growth but at various degrees. The tested food kinds could be arranged descendingly on the basis of its suitability as food for *O. surinamensis* growth as follows: standard diet> semi-dry date> dry date> white sesame seeds> reddish yellow sesame seeds. This insect needs special food-essentials that might not found in sesame seeds. As well as sesame seeds contain high oil content which probably hinder and prolong the insect growth duration.

According to the effect of crushed food kinds as clearly shown in Table 2, the duration of immature stages of *O. surinamensis* resulted from deposited eggs by F_1 females emerged from each food kind varied significantly among tested food kinds. The incubation period was 4.09 days on crushed corn compared with the standard diet and other tested crushed foods which recorded the same period of 4.00 days. The maximum of eggs hatchability was 100.00% on standard diet, while it was a minimum (66.67%) on both crushed chickpea and groundnut.

The maximum of larval period was longer (25.90 days) on crushed groundnut and shorter (11.10 days) on standard diet. The maximum pupal period was 5.15 days on crushed groundnut compared to 4.60 days on both crushed corn and chickpea. The highest larval-pupal period was 31.05 days on crushed groundnut, while the lowest one was 15.85 days on standard diet. The insect essentials are mainly proteins, vitamin B and organic salts. The differences in the chemical composition of the tested foods might be the main cause of differences in the larval and pupal periods**.**

The complete developmental period recorded the longest period of 35.05 days was occurred on crushed groundnut and the shortest one of 19.85 days on standard diet. Generally, all of the aforementioned biological parameters of *O. surinamensis* varied significantly among the tested crushed food kinds as corn, rice, chickpea and groundnut compared to standard diet.

Data in the present study show that all tested food kinds either whole (semi-dry date, dry date, white and reddish yellow sesame seeds) or crushed (corn, rice, chickpea and groundnut) and standard diet were suitable for growth of *O. surinamensis*. The development and growth of *O. surinamensis* immature stages varied among whole or crushed tested food kinds as compared with standard diet. Standard diet was the highest preferable food for *O. surinamensis* growth, while whole white or reddish yellow sesame seeds and crushed groundnut seeds were the lowest preferable foods. The tested foods either whole or crushed affected significantly incubation, larval, pupal and complete developmental periods of the tested insect except the duration of pupal stage on whole food kinds, which varied insignificantly.

In this respect, these results agree with the findings of many authors such as **Throne *et al.* (2003**) who added that the development of *O. surinamensis* is a very complex issue due to several factors, such as the food kinds and dietary requirements. **Hill (2008)** recorded that saw-toothed grain beetle is more frequently found on cereal products. **Klys and Przystupinska (2015)** stated that the saw-toothed grain beetle is found in a broad range of products from cereals and flour to dry fruits and oil seeds. This is corresponding with the fact that cereals have being classed as carbohydrate-rich foods, as they are composed of approximately 75% carbohydrate as compared to nuts 15.3% and dried fruits 70% **(McKevith, 2004; Hernández-Alonso *et al.*, 2017)**. Better performance was expected in dry fruits and nuts rather than on oil and legume seeds, which are usually more unsuitable substrates for polyphagous pest species such as the saw-toothed grain beetle (**Rees, 2004; Nurul and Amni, 2019)** indicated that the most preferred food to *O. surinamensis* is oat groat of cereal grain compared to dried fruits (date, raisin, apricot, and fig) and nuts (almond, ground nut, walnut, cashew nut). **Erifili *et al*. (2020) and Nika *et al*. (2020**) reported that *O. surinamensis* failed to develop on semolina and cracked wheat. **Awadalla *et al.* (2021**) recorded that the plasticity found in *O. surinamensis* survival caused the ability of this pest to develop in different diets.

Concerning the duration of eggs hatching, larvae, pupae and the total developmental stages, the current data show significant differences among the tested whole or crushed foods in all biological parameters except the pupal period on whole foods, which varied insignificantly.

As regards the incubation period, **Jacob and Fleming (1989)** stated that incubation period of *O. surinamensis* eggs was 6.6 days. In contrast, **Astuti *et al*. (2018)** and **Awadalla *et al.* (2021)** reported that the insect of *O. surinamensis* feeding on substrates exhibited insignificant effect on egg incubation time.

For larval period all whole or crushed foods were suitable foods for *O. surinamensis* larval

growth except crushed groundnut and whole sesame seeds either white or reddish yellow were the least suitable foods. Standard diet followed by crushed corn was the most suitable foods for larval growth.

The present results are in harmony with those obtained by **Jacob and Fleming (1989)** who found that larval period of *O. surinamensis* was 21.5 days. **Astuti *et al*. (2018)** mentioned that analysis of larvae results with the various food kinds indicated a significant difference. The average larval period on floured black rice was shorter (13.38 days), while it was longer (17.42 days) on whole grain of red rice. **Nika *et al.* (2020)** recorded that the larval period varied significantly among the different tested commodities. The larval period was significantly longer (20.3 days) when *O. surinamensis* fed on whole oat flakes and 19.2 days on whole barley flour compared with 16.6 days on maize flour or cracked maize (17.2 days). **Awadalla *et al.* (2021**) demonstrated that the longest larval periods were observed on legumes followed by oilseeds and dry fruits.

Regarding pupal period, the current data show that the pupal duration varied insignificantly among the tested whole food kinds. Similar results were obtained by **Nika *et al.* (2020)** who mentioned that the tested commodities did not affect the pupal development, which ranged between 4.6 and 4.7 days. Also, **Awadalla *et al.* (2021)** recorded that the feeding substrates affected insignificantly the length of the pupal period of *O. surinamensis*. In contrast, results of the previous authors disagree with the current data which show significant differences on the pupal period of *O. surinamensis* among the tested crushed food kinds.

In case of the total developmental period of the insect from egg to adult, the present data show that complete developmental period (CDP) was shortened on the standard diet and other starchy foods as rice and corn which rich in carbohydrates compared to other oily seeds as whole sesame seeds and crushed groundnuts. Many results were obtained by some researchers such as **Beckel *et al*. (2007)** who recorded that the mean total period from egg to adult for development of *O. surinamensis* was about 35 days. **Govindaraj *et al.* (2014)** found that complete developmental period of *O. surinamensis* was 39.1 and 37.5 days on intact wheat and rice kernels, respectively. Also, it ranged between 24.10 and 24.66 days on black rice and floured red rice **(Astuti *et al*., 2018)** and between 30.33 and 41.33 days on wheat germ and rice flour, succesively (**Hussain *et al.*, 2020).** Moreover, **Nika *et al.* (2020)** stated that the complete developmental period of *O. surinamensis* was 18.3 days on cracked barley.

Population Growth of *O. surinamensis* on the Tested Food Kinds

The productivity and growth index of *O. surinamensis* on some whole and crushed food kinds are presented in Tables 3 and 4, respectively.

With respect to effect of whole food kinds on the productivity and growth index of *O. surinamensis* was obviously exhibited in Table 3, the maximum mean developmental period was 29.00 days in whole reddish yellow sesame seeds, while the minimum one was 21.00 days in standard diet. The highest mean progeny number was 48.67 adults from the standard diet, while the lowest one was 46.67 adults from whole reddish yellow sesame seeds. The percent of adult emergence was 97.33% on standard diet, while it was 93.33% on whole reddish yellow sesame seeds. The highest reduction of progeny percentage was 6.67% on whole reddish yellow sesame seeds, while the lowest one was 2.67% on standard diet. The highest value of the growth index was in standard diet (4.64) and the lowest one (3.22) recorded in whole reddish yellow sesame seeds compared to other foods.

As concerns the productivity and growth index of *O. surinamensis* on some crushed foods, data of Table 4 show that the maximum mean developmental period was 28.00 days on crushed groundnut, while the minimum one was 21.00 days on standard diet. The mean progeny number was 48.67 adults on both standard diet and crushed groundnut, while the lowest one was 46.33 adults on crushed chickpea. The percentage of adult emergence reached 97.33% from standard diet and crushed groundnut, while it reached the lowest percentage (92.67%) on crushed chickpea. The

Table 3. The productivity and the growth index of *O. surinamensis* on some whole food kinds under laboratory conditions at 32.63 ^{O}C and 44.79 %RH

Whole food kind	Mean±SE of				
	MDP (day)	Progeny No.	Adult emergence (%)	Reduction of progeny (%)	Growth index (GI)
Standard diet	$21.00\pm0.33_{d}$	$48.67\pm0.19_{a}$	$97.33\pm0.38_{a}$	$2.67\pm0.38_{c}$	$4.64\pm0.06_{a}$
Semi- dry date	$25.00\pm0.33_{bc}$	$48.33\pm0.19_{ab}$	$96.67\pm0.38_{ab}$	$3.33\pm0.38_{bc}$	$3.87\pm0.05_{bc}$
White sesame	$27.00\pm0.33_{ab}$	$48.00\pm0.00_{ab}$	$96.00\pm0.00_{ab}$	$4.00\pm0.00_{bc}$	$3.56\pm0.04_{c}$
Dry date	$24.33\pm0.51_{c}$	$47.67\pm0.19_{b}$	$95.33\pm0.38_{b}$	$4.67\pm0.38_{b}$	$3.93\pm0.09_{b}$
Reddish yellow sesame	$29.00\pm0.33_{a}$	$46.67\pm0.19_{c}$	$93.33\pm0.38_{c}$	$6.67\pm0.38_{a}$	$3.22\pm0.04_{d}$
F. test	*	*	*	*	*
LSD 0.05	2.05	0.94	1.88	1.88	0.33

Means in the same column followed by different letters are significantly different (at p≤0.05). * = Significant means.

Table 4. The productivity and growth index of *O. surinamensis* on some crushed food kinds under laboratory conditions at 32.63 ^{O}C and 44.79 %RH

Crushed food kind	Mean±SE of				
	MDP (day)	Progeny No.	Adult emergence (%)	Reduction of progeny (%)	Growth index (GI)
Standard diet	$21.00\pm0.33_{c}$	$48.67\pm0.19_{a}$	$97.33\pm0.38_{a}$	$2.67\pm0.38_{c}$	$4.64\pm0.06_{a}$
Groundnut	$28.00\pm0.33_{a}$	$48.67\pm0.19_{a}$	$97.33\pm0.38_{a}$	$2.67\pm0.38_{c}$	$3.48\pm0.05_{d}$
Rice	$23.67\pm0.19_{b}$	$48.33\pm0.19_{ab}$	$96.67\pm0.38_{ab}$	$3.33\pm0.38_{bc}$	$4.08\pm0.03_{b}$
Corn	$22.00\pm0.33_{c}$	$47.33\pm0.19_{bc}$	$94.67\pm0.38_{bc}$	$5.33\pm0.38_{ab}$	$4.31\pm0.07_{b}$
Chickpea	$24.67\pm0.19_{b}$	$46.33\pm0.19_{c}$	$92.67\pm0.38_{c}$	$7.33\pm0.38_{a}$	$3.76\pm0.03_{c}$
F. test	*	*	*	*	*
LSD 0.05	1.56	1.05	2.10	2.10	0.27

Means in the same column followed by different letters are significantly different (at p≤0.05). * = Significant means.

reduction of progeny percentage was 7.33% on crushed chickpea and 2.67% on both standard diet and crushed groundnut. The highest value of growth index was 4.64 on standard diet and the lowest one was 3.48 on crushed groundnut and 3.76 on crushed chickpea.

The standard diet, crushed corn and rice were the best foods due to their higher values of the growth index compared with other tested foods.

Data in the present study are in accordance with those obtained by **Astuti *et al*. (2018)** who stated that the complete developmental period of *O. surinamensis* showed a significant difference among the floured foods. It was shorter (24.10 days) on floured black rice and longer (51.92 days) on floured white rice compared with the remaining treatments.

In case of effect of food kinds on the progeny production of *O. surinamensis* and growth index, the data obtained are partially confirmed

by the findings of **Beckel *et al.* (2007)** who mentioned that different levels of wheat kernels-milling grades affected the progeny production of *O. surinamensis*. The diets of cereal grains as wheat produced the highest progeny number of *O. surinamensis* compared to the whole wheat grains as well as the millet food grains favors a rapid population increase. Oat groat recorded the highest mean of live insect compared to the rest of food type (**Sahito *et al.*, 2017)**. **Awadalla *et al.* (2021**) mentioned that the highest survival and adult emergence were recorded on fruits and nuts, except raisin, but significantly lower than when fed on legume seeds, including soybean.

Wet and Dry Weight Loss (%) Due to Growth of *O. Surinamensis* Eggs on some Food Kinds after one Month of Storage

The results presented in Tables 5 and 6 determine weight loss (%) from growth of *O. surinamensis* eggs on some whole and crushed food kinds after one month of storage, respectively.

In respect to weight loss (%) on some whole food kinds in Table 5, the highest percentages of wet and dry weight loss were 11.17 and 13.16 % in standard diet, alternatively. The lowest percentage of wet and dry weight losses was 0.50 and 2.00% in whole white sesame seeds as well as 0.50 and 2.02% in whole reddish yellow sesame seeds, respectively. The maximum percentage of the relative wet weight loss was 43.23% in standard diet, while the minimum one (1.94%) was the same value in each of whole white and reddish yellow sesame seeds. The maximum and minimum percentages of relative dry weight loss showed a comparatively similar trend. The mean progeny number was 48.00 adults from each of standard diet and white sesame seeds, while the lowest one was 21.33 adults from dry date. The maximum percentage of relative progeny number showed a similar figure (27.64%) on standard diet and whole white sesame seeds, while the minimum percentage of relative progeny number was 12.28% on dry date. The highest pupae number was 4.33 pupae and the maximum percentage of relative pupae number was 38.22% in semi- dry date. The highest larvae number was 20.00 larvae in dry date. The highest total number of individuals was 48.33 individuals in semi- dry date, while the lowest one was 45.33 individuals in dry date. The maximum and minimum percentages of relative total individuals number were 20.36 and 19.10% in semi- dry date and dry date, successively.

As regards weight loss (%) due to growth of *O. surinamensis* eggs on certain crushed food kinds after one month of storage in Table 6, the highest and lowest wet weight loss (%) were 11.17 and 0.67% on standard diet and crushed groundnut, respectively. The relative wet weight loss (%) was 52.76 and 3.16% on the same food kinds which mentioned before, consecutively. The percent dry weight loss was 13.16 and 2.36% in standard diet and crushed groundnut. The maximum relative percentage of dry weight loss was 43.71% in standard diet, while the minimum one was 7.84% in crushed groundnut. The progeny number ranged between 22.33 and 48.00 adults from crushed groundnut and standard diet, suscessively. The relative progeny percent was 24.66% in standard diet, while it was 11.47% in crushed groundnut. The highest pupae number was 7.00 in crushed groundnut. The relative total individuals (%) ranged between 20.48 and 19.49% in crushed rice and crushed groundnut, respectively.

The present results of weight loss are partially agree with the findings obtained by some authors such as **Busvine (1980), Trematerra and Sciarretta (2004), Robinson (2005), Beckel *et al.* (2006) and Leelaja *et al.* (2007)** who recorded that *O. surinamensis* causes damage such as weight decrease, broken seed surface, broken germ, broken endosperm, and contamination. **Metwally *et al.* (2007)** mentioned that date weight loss caused by *O. surinamensis* reached 4.5 g/kg after one month post storage. **Hussain (2008)** added that weight loss of Firihi date infested by *O. surinamensis* was 12.47% after one month of storage. **Moawad and Al-Ghamdi (2013)** showed that the highest rate of the weight loss in the tested date cultivars caused by infestation of saw–toothed grain beetle was for Barhi followed by Barni Al Madina, Rushodia and Sukari which ranged between 62.7 to 43.7%, while the least weight loss (11.6 and 21.5%) was recorded with Deglet Noor and Ajwa after six months of storage, respectively. Moreover, **Astuti *et al.* (2018)** added that the huge losses in cereals reached 53% in cereal foods because wheat, rice

Table 5. Wet and dry weight loss (%) from some whole food kinds due to growth of *O. surinamensis* eggs after one month of storage under laboratory conditions at 33.38 ^{O}C and 44.89% RH

Whole food kind	Mean±SE of											
	Wet weight loss (%)	Relative wet weight loss (%)	Dry weight loss (%)	Relative dry weight loss (%)	Progeny no.	Percent of relative progeny no.	Pupae no.	Percent of relative pupae No.	Larvae No.	Percent of relative larvae No.	Total individuals No.	Percent of relative total individuals No.
Standard diet	11.17±0.38$_{a}$	43.23±1.49$_{a}$	13.16±0.81$_{a}$	30.39±2.09$_{a}$	48.00±0.67$_{a}$	27.64±0.38$_{a}$	0.00$_{b}$	0.00$_{b}$	0.00$_{c}$	0.00$_{b}$	48.00±0.67$_{a}$	20.22±0.28$_{a}$
Semi-dry date	5.00±0.73$_{c}$	19.35±2.81$_{c}$	13.00±0.54$_{a}$	30.02±1.23$_{a}$	31.33±2.69$_{b}$	18.04±1.55$_{b}$	4.33±0.51a	38.22±4.49a	12.67±2.12b	24.21±4.05$_{a}$	48.33±0.19$_{a}$	20.36±0.08$_{a}$
White sesame	0.50±0.00$_{d}$	1.94±0.00$_{d}$	2.00±0.16$_{b}$	4.62±0.42$_{fb}$	48.00±0.58$_{a}$	27.64±0.33$_{a}$	0.00$_{b}$	0.00$_{b}$	0.00$_{c}$	0.00$_{b}$	48.00±0.58$_{a}$	20.22±0.24$_{a}$
Reddish yellow sesame	0.50±0.00$_{d}$	1.94±0.00$_{d}$	2.02±0.00$_{b}$	4.66±0.00$_{b}$	25.00±0.67$_{bc}$	14.40±0.38$_{bc}$	3.00±033$_{a}$	26.48±2.94$_{a}$	19.67±0.51$_{a}$	37.58±3.22$_{a}$	47.67±0.38$_{ab}$	20.09±0.16$_{ab}$
Dry date	8.67±0.59$_{b}$	33.55±3.01$_{b}$	13.13±0.72$_{a}$	30. 32±2.14$_{a}$	21.33±0.51$_{c}$	12.28±0.29$_{c}$	4.00±0.58$_{a}$	35.30±5.09$_{a}$	20.00±0.00$_{a}$	38.21±2.54$_{a}$	45.33±0.19$_{b}$	19.10±0.08$_{b}$
F. test	*	*	*	*	*	*	*	*	*	*	*	*
LSD 0.05	2.46	10.69	2.98	7.96	7.22	4.16	2.05	18.07	5.31	14.07	2.44	1.03

Means in the same column followed by different letters are significantly different (at p≤0.05). * = Significant means.

Table 6. Wet and dry weight loss (%) from some crushed food kinds due to growth of *O. surinamensis* eggs after one month of storage under laboratory conditions at 33.38 ^{O}C and 44.89% RH

Crushed food kind	Mean±SE of											
	Wet weight loss (%)	Relative wet weight loss (%)	Dry weight loss (%)	Relative Dry weight loss (%)	Progeny No.	Percent of relative progeny No.	Pupae No.	Percent of relative pupae No.	Larvae No.	Percent of relative larvae no.	Total individuals No.	Percent of relative total individuals No.
Standard diet	11.17±0.38$_{a}$	52.76±1.82$_{a}$	13.16±0.81$_{a}$	43.71±2.99$_{a}$	48.00±0.67$_{a}$	24.66±0.34$_{a}$	0.00$_{b}$	0.00$_{b}$	0.00$_{d}$	0.00$_{d}$	48.00±0.67$_{a}$	20.34±0.35$_{a}$
Rice	1.17±0.10$_{c}$	5.53±0.45$_{C}$	2.84±0.18$_{c}$	9.43±0.63$_{bc}$	47.33±0.84$_{a}$	24.31±0.43$_{a}$	1.00±0.33$_{b}$	7.32±2.44$_{b}$	0.00$_{d}$	0.00$_{d}$	48.33±0.69$_{a}$	20.48±0.37$_{a}$
Corn	4.33±0.25$_{b}$	20.45±1.20$_{b}$	6.84±1.23$_{b}$	22.72±0.88$_{b}$	39.67±0.19$_{b}$	20.38±0.10$_{b}$	0.00$_{b}$	0.00$_{b}$	7.67±0.19$_{b}$	27.72±0.70$_{b}$	47.33±0.19$_{a}$	20.06±0.10$_{a}$
Chickpea	3.83±0.67$_{b}$	18.09±3.18$_{b}$	4.91±0.59$_{bc}$	16.31±1.99$_{bc}$	37.33±1.26$_{b}$	19.18±0.65$_{b}$	5.67±0.38$_{a}$	41.48±2.82$_{a}$	3.33±0.51$_{c}$	12.03±1.84$_{c}$	46.33±0.51$_{a}$	19.63±0.27$_{a}$
Groundnut	0.67±010c	3.16±0.45d$_{c}$	2.36±0.10$_{c}$	7.84±0.37$_{c}$	22.33±1.26$_{c}$	11.47±0.65$_{c}$	7.00±0.33$_{a}$	51.21±2.44$_{a}$	16.67±0.96$_{a}$	60.25±3.48$_{a}$	46.00±0.33$_{a}$	19.49±0.18$_{a}$
F. test	*	*	*	*	*	*	*	*	*	*	NS	NS
LSD 0.05	2.02	9.55	3.90	9.19	5.10	2.62	1.49	10.87	2.70	9.75	2.82	1.49

Means in the same column followed by different letters are significantly different (at p≤0.05). * = Significant means. NS=Non- significant means.

and corn are the most popular foods to *O. surinamensis*. **Syarifah *et al.* (2018)** stated that saw-toothed grain beetles produce a serious problem to food products during storage particularly in the developing countries. **Taain *et al.* (2019)** recorded that the highest percentage of weight loss was in the fruits of the Bream cultivar. **Hussain *et al.* (2020)** reported that *O. surinamensis* caused the highest weight loss (%) on corn flour (13.73%) after one generation followed descendingly without significant differences with wheat germ (11.01%), complete wheat flour (7.00 %), while rice and pass flours were recorded minimum (%) of 4.36 and 4.05 % without significant differences, respectively. **Awadalla *et al.* (2021**) found that the losses in fruits and nuts were higher, particularly on almonds and cashew. They added that larval development was inversely correlated to survival and adult emergence, but positively correlated to substrate loss.

In conclusion, all tested diets either whole or crushed were suitable for the growth of *O. surinamensis*. The kind of food affected directly the duration of the various insect stages and these crushed foods yielded the largest progeny within the shortest periods of development and the highest values of the weight loss (%). The present data provides us with information that could help in developing management practices to stop this insect infestation and minimizing storage losses caused by *O. surinamensis*.

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نمـو وتطـور الأطـوار غيـر الكـاملـة لخنفسـاء السـورينـام علـى بعض الأنـواع الغذائيـة

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تُعتبر حشرة خنفساء السورينام من أهم الآفات الحشرية الخطيرة التي تُهاجم العديد من المنتجات الغذائية المخزونة. تم دراسة تأثير الإ صابة الحشرية على أربعة أنواع مختلفة من الأغذية الكاملة مثل ثمار التمر النصف جاف، تمرجاف، بذورالسمسم البيضاء والصفراء المحمرة بالإضافة إلى أربعة أنواع من الأغذية المجروشة (حمص، ذرة، أرز وفول سوداني) بالمقارنة ببيئة التغذية القياسية (دقيق قمح، قمح مجروش وخميرة بيرة جافة بنسبة 5: 5 :1، على التوالي) في معمل قسم وقاية النبات، كلية الزراعة، جامعة الزقازيق، مصر. كانت فترات نمو الأطوار المختلفة، عدد الذرية الناتجة للجيل الأول، مؤشر النمو والنسبة المئوية للفقد في الوزن بعد شهر من التخزين هي المعايير الحشرية المُتخذة كمقياس للمقاومة. تأثرت كل المعايير المختبرة تأثراً معنوياً بنوع الغذاء ماعدا فترة طور العذراء في الأغذية الكاملة. كان أقل متوسط لفترة نمو الأطوار غير الكاملة 19.85 يوماً علي بيئة التغذية القياسية، بينما كانت أطول فترة نمو 29.18 يوماً علي البذور الكاملة للسمسم الأصفر المحمر و35.05 يوماً على مجروش الفول السوداني. زادت قيم مؤشر النمو من 3.22 إلى 3.76 على بذور السمسم الصفراء المحمرة ومجروش الحمص، على الترتيب بالمقارنة بالقيمة 4.64 علي بيئة التغذية القياسية، وكذلك تراوحت نسبة الفقد في الوزن الرطب من 0.50 و0.67% في البذور الكاملة للسمسم (الأبيض والأصفر المحمر) ومجروش الفول السوداني، على الترتيب بالمقارنة ببيئة التغذية القياسية التي كانت 11.17%، كانت أقل نسبة للفقد في الوزن الرطب النسبي في البذور الكاملة للسمسم الأبيض والأصفر المحمر (1.94%) ووصلت لأعلي قيمة لها في بيئة التغذية القياسية (43.23%)، بينما في الأغذية المجروشة كانت أقل نسبة 3.16% في مجروش الفول السوداني بالمقارنة ببيئة التغذية القياسية والتي سجلت أعلى نسبة (52.76%). وقد لوحظ أنّ كل أنواع الأغذية المختبرة سواء كانت كاملة أو مجروشة أُصيبت بخنفساء السورينام ولم يلاحظ وجود أي أغذية منيعة تماماً وخالية من الإصابة بالحشرة ولكن الحشرة تفضل الأغذية المجروشة وبعض الأغذية عن الأخرى.

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