Food Preference of *Oryzaephilus Surinamensis* (Coleoptera: *Silvanidae*) to Different Types of Plant Products

Nurul Huda A*, Noor Amni M.

Department of Plant Science, Kulliyyah of Science, International Islamic University Malaysia, Jalan Sultan Ahmad Shah, Bandar Indera Mahkota, 25200 Kuantan, Pahang, Malaysia
*Corresponding author e-mail: anhuda@iium.edu.my

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Abstract:
Oryzaephilus surinamensis is one of the stored product insect that commonly found in Malaysia. The biological study through host range or food preferences of *O. surinamensis* is important for the development of sustainable management practice to control its infestation. The objective of this study was to identify the food preference of *O. surinamensis* to different plant products in relation to food type and moisture content. Twenty adult of *O. surinamensis* were exposed to three different group of food; dried fruits (date, raisin, apricot, fig), grain/cereals (rice, barley, oat grout, dried maize), and nuts (almond, ground nut, walnut, cashew nut) for 240h in laboratory Kulliyyah of Science, IIUM Kuantan. Moisture content in each food was also measured. It was found out that the most preferred food by *O. surinamensis* is oat groat of cereal grain group with medium level of moisture content. Further analysis on food moisture suggested that under current experimental conditions (temperature of 27°C and 64% relative humidity within 240h of exposure), food moisture content does not affect pest infestation and distribution.

Keywords: *Oryzaephilus surinamensis*, insect, food preference, moisture content

1.0. Introduction:

The development of world agriculture, trade, and then mechanization leading to even more extensive monocultures and consequently larger stores has worsen the problems with insect pests [1]. According to a study conducted by the International Food Policy Research Institute, about RM184.9 billion worth of crop production were destroyed annually by pest in Asia and stored product insects (SPI) have been identified as one of the pests that contributed to the losses [2]. They cause damages to stored products such as grains by directly feeding on the grain at some stages in their life cycle.

SPI that are commonly found in Malaysia include the cigarette beetle (*Lasioderma serricorne*), rice weevil (Sitophilus oryzae L.), sawtoothed grain beetle (*Oryzaephilus surinamensis L.*), and flour beetle (*Tribolium sp.*). They are normally grouped into two categories, for example rice weevil and lesser grain borer (*Rhyzopertha dominica F.*) are known as 'internal feeders' as they feed within the kernel. Meanwhile, sawtoothed grain beetle and flat grain beetle (*Cryptolestes sp.*) described as the 'external feeders' because they feed on grain dust and debris without entering the kernel. SPI can pose a huge threat in the entire supply chain especially in food processing facilities and warehouses because they usually spread and develop their colony in the food commodities. In fact, the most devastating damage that SPI can cause is commodities losses due to SPI contamination. In warehouses, stored products especially grains and nuts are stable when the temperature and moisture are below the level needed for germination. However, this condition is optimal for development and reproduction of insect pests. And due to their tiny size, SPI infestations can be difficult to detect in the initial stages. As a result, SPI may be ground together with the raw materials, packed and sold to the consumers. Usually, dried foods stored for considerable long periods before packing tend to become infested compared to food stored only for short periods.

Among all stored product pests, the sawtoothed grain beetle (*Oryzaephilus surinamensis*) is one of the most widespread pests and its infestation can originate at the manufacturing, storage or retail levels. The distribution of the beetle is significantly affected by various factors such as food availability, processing practices, temperature conditions in different areas, and interaction between species. They may occur in both food products in the pantry area as well as in other adjacent rooms. Foods that may be infested include cereals, flours, pastas, dried fruits, nuts, dries meats, candies, and other similar packaged goods [3]. The presence of the sawtoothed grain beetles in foodstuffs cause quantitative and qualitative losses by rendering the food unsalable or unpalatable [4].

The beetle's flattish form allows it to penetrate apparently tightly wrapped packages. Although the attack usually followed by the other insect's infestation such as rice weevil, loses caused by the sawtoothed grain beetles are often significant. The beetle is nearly omnivorous, so it is important to frequently update in detail of its feeding habits in order to establish suitable and sustainable control methods to reduce this pest infestation [5, 6]. Food product losses due to sawtoothed grain beetles infestation during storage are a serious problem particularly in the developing country such as Malaysia [7]. Although people were very well aware of the relationship between insects and stored products but the source of infestations was likely being poorly understood. The present biology investigations of this insect on various plant-based food products are informative and crucial for the development of sustainable management practices in reducing losses of postharvest product's handling and contamination in ways that increase efficiency and limit the use of energy and nonrenewable resources. It includes each stage in a product's handling after harvest such as cleaning, packaging, transportation, storage, preparation, and retail.

Unfortunately, such studies are mostly dated back in early half of the nineteenth century, and some have lack of comprehensiveness. Not all of the plant products are equally susceptible to this pest insect [8]. The host on which *O. surinamensis* choose to lay eggs and multiply can have a great influence on the developmental rate and on the number of offspring the beetle eventually produces which undeniably become a major factor for prevalent infestation. In response to this problem, this research aspired to provide more updated and more extensive data involving the biological study through host range or food preferences of *O. surinamensis* to different plant products in relation to food type and moisture content [9].

2.0. Materials and methods

2.1. Insect Culture (Mass-rearing)

The insects, *O. surinamensis* were sampled manually from infested stored grain such as rice and barley and were mass reared in the laboratory using modified method of which previously used wheat grains to culture *O. surinamensis*. Insects were reared in 300 ml containers, each containing 100 g of barley, rice grains, dried corn, and oat groat [9]. These cultures were chosen due to high content of carbohydrates same with wheat grains thus increases the population of the insect rapidly. Insects were allowed to mate and reproduce for a few generations (up to 3rd generation) in the laboratory under temperature of 27°C and 64% relative humidity. The cultures were then used for bioassay.

2.2. Food preference study

The study on food preference study of *O. surinamensis* was conducted by using modified methods [10, 11]. Five adults of O. surinamensis, of mixed sex and age, were taken from each culture and were placed in the plastic cup for bioassay. There are three groups of food were used in this study; dried fruits (date, raisin, apricot, fig), grain/cereals (rice, barley, oat groat, dried maize), and nuts (almond, ground nut, walnut, cashew nut). Fifteen gram of each food type were placed in a plastic cup without cover and randomly arranged inside a large closed container. Three large containers with lids were used in this experiments and each container contained different groups of food type as shown in Figure 1. Cup containing 20 individuals of O. surinamensis was placed in the middle of large container and insects were allowed to disperse. As precaution to avoid incident of pest infestation in the laboratory, the large container were placed inside rearing cage. Food preference of *O. surinamensis* to different type of host was accessed based on total number of beetles recorded in each cup at interval of 24h, 48h, 72h, 120h, and 240h (time of exposure) with six replications of experiment.

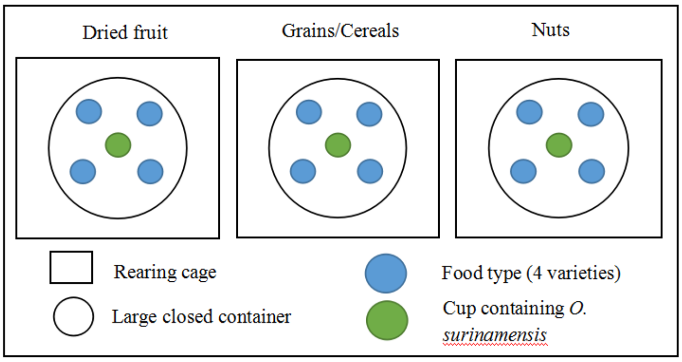

Figure 1. Treatments arrangements for food preference study of *O. surinamensis*.

2.3. Moisture Content Measurement

Thirty gram of each food types were weighed for initial weight (wet weight) using an analytical balance. After being weighed, each sample was put into a pocket made by paper with 10 cm x 10 cm measurement. Total of 48 samples were dried in the oven at 50°C for 3 days. After 3 days, the samples were took out from the oven and cooled at room temperature before weighting the final weight (dry weight). The moisture content of each food types were measured in four replications using modified method of [12]. Moisture content in food products were measured using following formula and expressed as a percentage (Equation 1):

$$\text{Moisture content} = \left[\frac{\text{Initial weight (g)} - \text{Final weight (g)}}{\text{Initial weight (g)}} \times 100\% \right]$$

2.4. Statisctical Analysis

All data were analyzed with software of IBM SPSS for Window®. Overall, data of insect recorded in food preferences study subjected to parametric test of analysis of variance (ANOVA). Interaction of food types and time of exposure on number of insect recorded was examined using two-way ANOVA but no significant interaction detected therefore further analysis of differences was conducted using one-way ANOVA. Meanwhile, relationship between moisture content in food types and insect preference were analyzed using Spearman's rho correlation for small sample size and simple linear regression analysis. Multiple mean comparisons were conducted using post-hoc test of Tukey's HSD.

3.0. Result and Discussion

There were three groups of food were used in this study; dried fruits (date, raisin, apricot, fig), grains/cereals (rice, barley, oat groat, dried maize), and nuts (almond, ground nut, walnut, cashew nut). Food preference of sawtoothed grain beetle to different type of host were accessed based on total number of beetles recorded in each cup containing food samples at interval of 24h, 48h, 72h, 120h, and 240h. However, there is no interaction ($F= 0.181$, $df= 8$) between the food group and time of exposure on the number of insect found in each cup containing food samples at $p> 0.05$.

Figure 2 shows number of individual (mean and standard error; mean ± SE) recorded in each group. In general, higher number of insect recorded in cup containing grains/cereals (3.27 ± 0.267), followed by dried fruits (2.69 ± 0.241) and nuts (2.49 ± 0.176). However, statistical analysis showed that the difference among groups was not significant ($F= 3.022$, $df= 2$) at $p= 0.05$. The graph also showed that higher number of individual recorded outside from the cups. This showed that, these insects also spend notable time venturing outside from host probably for mating.

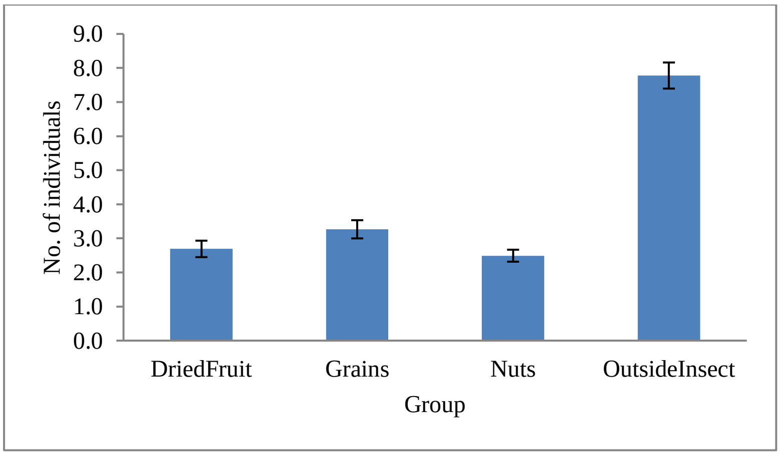

Figure 2. Number of insect (mean ± SE) recorded in three food groups and outside of the cups.

Meanwhile, when the analysis of variance (one-way ANOVA) was executed on 12 different food types, there was significant difference in number of insect recorded ($F= 6.183$, $df= 11$, $p= 0.000$). Oat groat have the highest mean (5.07 ± 0.599) of live insect compared to the rest of food type (Table 1). The lowest number of insect was recorded in rice (1.47 ± 0.257). Based on multiple mean comparisons (post-hoc test of Tukey's HSD), the 12 food types used in this experiment can be grouped into four homogeneous subsets (a, b, c and d) according to preferences shown by the insects. In this study, preference of the insect to certain food types is not fixed throughout the time of exposure. There was no significant effect of time on the number of insect recorded in all 12 food types ($F= 0.402$, $df= 4$, $p= 0.808$). The number of live insect decreased over the time of exposure as result of natural mortality (Table 2).

Table 1: Number of insect (mean ± SE) recorded in 12 different food types. Multiple mean comparisons were shown using post-hoc test of Tukey's HSD of ANOVA. Small letters indicated significant of mean at p< 0.05.

Food Type	Mean ± SE	Post-hoc test of significant
Fig	3.67 ± 0.399	bcd
Date	3.47 ± 0.703	abcd
Raisin	2.00 ± 0.336	ab
Apricot	1.63 ± 0.286	a
Barley	4.13 ± 0.602	cd
Rice	1.47 ± 0.257	a
Dried Maize	2.40 ± 0.334	abc
Oat Groat	5.07 ± 0.599	d
Ground Nut	2.60 ± 0.388	abc
Cashew Nut	2.73 ± 0.349	abc
Walnut	2.60 ± 0.278	abc
Almond	2.03 ± 0.385	ab

Table 2: Number of insect (mean ± SE) recorded according to time of exposure.

Time of Exposure (hour)	Live Insect	Dead Insect
24	3.15 ± 0.309	0.00 ± 0.000
48	2.74 ± 0.286	0.03 ± 0.020
72	2.78 ± 0.292	0.06 ± 0.034
120	2.74 ± 0.325	0.08 ± 0.047
240	2.68 ± 0.295	0.08 ± 0.033

Among three food groups, dried fruit showed the highest mean of moisture content percentage which is 11.14 ± 1.111(in %) as compared to the other two groups; grains and nut respectively (6.97 ± 0.104 and 3.40 ± 0.227). From analysis of variance using one-way ANOVA test, 12 different food types showed significant difference in moisture content, (F= 286.38; df= 11; p< 0.05) (Figure 3). Dried apricot has the highest moisture content percentage (15.08 ± 0.311) among all dried fruits. However, in date (*Mariami cultivar*) recorded low moisture almost similar as measured from ground nut. The lowest moisture content recorded from walnut (2.30 ± 0.140).

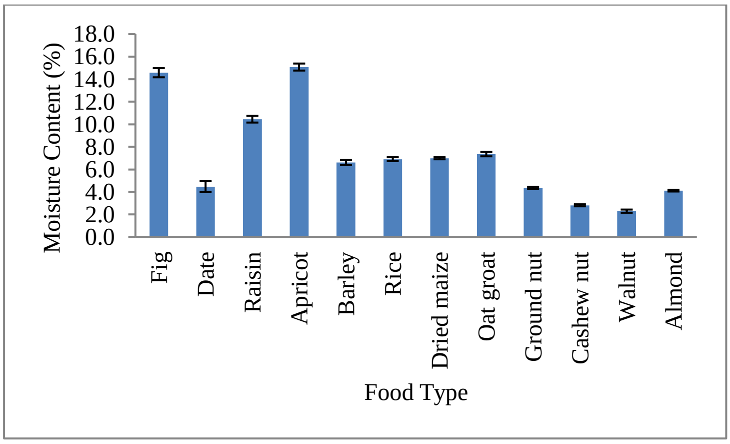

Figure 3. Moisture content (mean ± SE) recorded from 12 different food types in percentage.

In order to examine the relationship between moisture content and preferences of *O. surinamensis*, data insect from preference study (four replications) was analyzed with percentage of moisture content using Spearman's rho correlation for small sample size. However, there was no significant relationship between the variables at p< 0.05 even though the equation for single linear regression formed toward negative relationship with R2= 0.005 and B= - 0.039 (Figure 4).

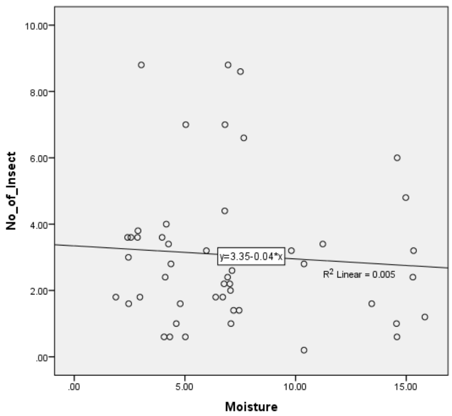

Figure 4. Single linear regression showed relationship of moisture contents with number of insect (preference) on 12 food types with equation of y= 3.35 - 0.04x, R2= 0.005.

In general, insect behavior is affected by the interaction of many different physical, chemical, and biotic factors in their environment [13]. These factors include light intensity, relative humidity, temperature, food availability, grain moisture content, size and variety, grain store design and construction materials, disturbance caused by insect density and the presence of other arthropod species including predators and parasitoids, vertebrates and disease micro-organisms [14-16]. Food preference is a single criterion in assessing the suitability of stored product pests to various food fractions. Nonetheless it can be valuable in determining the probability that an insect will choose a particular food product [11]. A majority of insect tested in this study showed a preference to grains/cereals as food source compared to dried fruits and nuts. This result supported the finding which mentioned that sawtoothed grain beetle is more frequently found on cereal products [17]. Besides, study on feeding habits and nutritional requirement of storage insects also discovered that *O. surinamensis's* suitability of food was largely depend on the presence of carbohydrate [18]. 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%) [19-21].

According to a findings stated, losses in cereal crops hold the largest share which was 53% on calorific basis since cereal grains such as wheat, rice, and maize are the most popular food crops in the world, and are the basis of staple food (energy source) in most of the developing countries [22]. Alternative explanation on insect preference on cereals is sawtoothed grain beetle prefers products higher in carbohydrates such as stored grains and cereal products as compared to their cousin, the merchant grain beetle (*O. mercator*) which was more often found on products with higher oil content, and as such is more often a problem in tree nuts and peanuts [16]. Meanwhile, dried fruits are relatively poor source of vitamins of the B-group, thus suggested that the requirements of *O. surinamensis* for these vitamins are not great as the number of insect recorded less in dried fruits [23].

The findings of this study also showed that oat groat recorded the highest mean of live insect compared to the rest of food type. Based on direct observation, oat groat produced slightly strong odors compared to other grains. It has been reported that food volatile has significant effect on behavioral activity of O. surinamensis during its invasion into stored product despite of small openings in the packaging materials [24]. Furthermore, it was found out that volatile components from oat has become a source of strong attractant that stimulates the aggregation and feeding behaviour of *O. surinamensis* in a few studies done [25-27]. However, volatile compound in oat groat has not been examined during this present study.

Meanwhile, the evaluation of relationship between moisture content in food and preference of the beetle shows that the former does not give any effect to the choices of diet among the beetles. Sawtoothed grain beetle showed high interest on cereal/grain food group which has intermediate percentage of moisture content as compared to dried fruit and nuts. However, a slight negatively linear relationship showed by regression analysis suggested that higher moisture content in food may become limitation factor for *O. surinamensis* infestation. According to a study, food with high moisture content deteriorates quickly with enhanced deterioration can be caused by microbes such as fungi [28]. This condition could be unfavorable for the insects to establish their population in the high moisture food. Meanwhile, low moisture content of the food might not be a sufficient resource of moisture or water to the insect even though it reduces the possibility of microbes' contamination. On the contrary, semi-dry varieties date palm was reported highly attractive to *O. surinamensis* as it provide high moisture and sugar as well as tender in flesh compared to dry varieties [29]. However, to ensure good storage, moisture content of plant products usually was set at the normal requirement for conservation to avoid pest damage as it may influence the effectiveness of insecticidal powders for storage management [30]. Therefore, moisture content in food might not be a good predictor for successful invasion of this pest in plant-based stored products.

In this study, the food preference of insect did not show consistency over the time of exposure since the number of living insect found varies in each interval. However, the number of insects decreased as result of natural mortality. According to a study, adult sawtoothed grain beetle can live on average 6 to 8 months at temperature of 30°C under optimum conditions [31]. Their life cycle (egg to adult) completed almost in 30 to 40 days [29]. However, during this study, laboratory conditions with lower temperature of 27°C and 64% relative humidity as well as disturbance from human (researcher activities) may provide less preferable conditions for insect to survive longer during experiment. Nevertheless, the study may have produced inadequate data or overestimated results due to the nature of experiment where only 20 insects used per food group. Separate experiment containers for each food group also could be a reason for imperceptible response by insect pest. Therefore, in future experiment, it will be wise to consider higher number of insect and more treatments (combination of different food groups) to reduce bias in any study of food-related behavior by *O. surinamensis*.

4.0. Conclusion

Insects' behaviors are generally affected by the interaction of many different physical, chemical, and biotic factors in their environment. In this study, it was found out that food type influenced the insect preferences and subsequently affected their life-history. The most preferred food by *O. surinamensis* was oat groat of cereal grain type with medium level of moisture content. The findings suggested that with current experimental conditions (temperature of 27°C and 64% relative humidity within 240h of exposure), food moisture content does not affect pest distribution. However, a slight negatively linear relationship showed by regression analysis suggested that higher moisture content in food may become limitation factor for *O. surinamensis* infestation.

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