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Ecofriendly Control for Stored-Product Pest, *Oryzaephilus surinamensis* (Order: Coleoptera, Family: Silvanidae)

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Abstract

Dates are considered one of the most important foods consumed in Arab countries. Dates are commonly infested with the sawtoothed grain beetle, *Oryzaephilus surinamensis*. Consequently, the date yield, quantity, and quality (economic value and seed viability) are negatively affected. This study was designed to investigate the effectiveness of air evacuation as eco-friendly and safe control method against adult *O. surinamensis*. Insects were obtained from the infested date purchased from a private store in sakaka city, Aljouf region, Saudi Arabia. Air evacuation (using a vacuum pump) and food deprivation were applied to *O. surinamensis*, and insect mortality was observed daily in comparison with the control group (administered both food and air). Application of both air evacuation, and food deprivation, significantly, increased the percentage of daily mortality when compared to control. Percentage accumulative mortality displayed very strong positive correlation with the time course in both cases of air-deprived and food-deprived groups. On the basis of lethal time values, the air evacuation method resulted in a comparable effect of food deprivation. Conclusively, the air-evacuation of the package is a very effective Eco-friendly and safe control method against *O. surinamensis*.

Keywords: Air-evacuation, dates, eco-friendly control, food-deprivation, *Oryzaephilus surinamensis*, sawtoothed grain beetle.

Introduction

It was reported that cereals were considered the major source of animal food. However, ≈25- 50% of the total harvested cereals were lost during storage processes[1-3]. Stored-product pests were considered the biggest challenge worldwide. The global economic losses resulting from non-standard storage conditions were estimated at thousands of millions of Euros a year[4]. An overview of the present and past pest-associated risks of stored products was published. The authors concluded that the stored product research did not attract merit funding support. This leads to the absence of both programmed systematic surveillance, and risk assessment studies of storage pests from the agendas of many countries worldwide[5].

Stored-product insects were regarded as the main cause of quantity and quality loss in stored grains[4-7, 8-11]. Especially coleopterans including the saw-toothed grain beetle, *O. surinamensis*, were regarded as the most serious primary pests of stored products worldwide[12-14]. Additionally, *O. surinamensis* was recorded as the most abundant and destructive species among stored-product coleopterans. *O. surinamensis* causes both direct injury by strong chewing mouth parts, and indirect

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injury through contamination and secondary microbial infections[15-18, 19-22]. *O. surinamensis* was reared on a variety of food materials including rice, sesame, grains, seeds, oilseeds, legume seeds, dried fruit, date palms, nuts, and cereals. *O. surinamensis* was reported to reduce both the quality and quantity of dry and semi-dry stored date fruits[23-27, 28-29]. Such damages depend on the population growth and density of the species in relation to food quality and availability[25,28].

Therefore, the present study aims to investigate the effect of air evacuation on the mortality of adult *O. surinamensis* and use it as an eco-friendly control method in comparison to food deprivation.

Materials and Methods

Sample collection and insect identification

Adults of the saw-toothed grain beetle, *O. surinamensis* were collected from infested date fruits purchased from a private store in Sakaka, Aljouf, Saudi Arabia. Insects were maintained at temperatures 25± 2 °C and 70± 5% RH inside plastic jars (10 cm height x 5 cm diameter). Each jar was supplied with sterile wheat flour as food, and covered with gauze fixed with a rubber band. Insects were identified according to the available keys for the identification of stored products beetles[30].

Effect of air deprivation and food deprivation on mortality of adult *O. surinamensis*

Five replicates of three groups of adult insects (10 newly emerged *O. surinamensis* adults per each replicate) were put in plastic sacks (19 cm height x 5 cm diameter). The first group (Control) was supplied with date fruits as food. Sacks of this group were sealed off, and punctured with a sterile needle for ventilation (air-supply). The second group (Air-dep) was supplied with date fruits as food, and deprived of air. Air was evacuated from the sacks using a vacuum pump. The third group (Food-dep) was supplied with air as previously described, and deprived of date fruits (food). Mortality was observed daily for each replicate of the three groups, and average percentage mortality was calculated. The insect was considered dead if they don't move when shaking or stimulated with a brush. The experiment was repeated three times.

Determination of LT_{50} of air-deprived and food-deprived adult *O. surinamensis*

As the control mortality was less than 5%, no corrections were done to the final mortality of the treated groups. Consequently, experimental data were subjected to probit analysis[31]. LT_{20}, LT_{50} and LT_{95} were determined for both Air-dep and Food-dep groups. The significance level of mortality differences was determined by comparing the 95% confidence limits of both groups at LT_{20}, LT_{50} and LT_{95}. Interfering 95% limits were considered insignificant.

Statistical analyses and calculations

One-way analysis of variance (ANOVA) and post-hoc tests for daily mortality data were performed. The significance level was calculated at $P< 0.05$. Additionally, Pearson's and Spearman's correlation coefficients (r) were calculated at a significance level of $P < 0.01$. All statistical analyses were done by using SPSS ver. 27.0.1.0 software.

Results and Discussion

The effect of air deprivation and food deprivation on daily mortality of adult *O. surinamensis* were compared. One-way analysis of variance (ANOVA) revealed that the overall differences in daily mortalities of *O. surinamensis* were significant (Table 1).

Table 1. ANOVA analysis of the daily mortality of control, air-deprived and food-deprived *O. surinamensis* adults.

Day	*df*	*F*	*P*
1	2	4.160	0.042
2	2	16.769	0.00
3	2	16.125	0.00
4	2	5.853	0.017
5	2	12.235	0.001

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Post-hoc tests revealed that the difference in daily mortality between air-deprived and control groups was insignificant (P> 0.05) at the 1st day from the start of application (Fig. 1). Meanwhile, the difference in daily mortality between food-deprived and control groups was insignificant (P> 0.05) at the 4th and 5th days from the start of application (Fig. 1). However, the differences with control group were significant (P< 0.05) at the 2nd, 3rd, 4th, and 5th days from the start of application for air-deprived group (Fig. 1). In parallel, the differences with control group were significant (P< 0.05) at the 1st, 2nd, and 3rd days from the start of application for food-deprived group (Fig. 1). Additionally, the differences in daily mortality between air-deprived and food-deprived groups were insignificant (P> 0.05) at the 1st, 3rd, and 4th days from the start of application (Fig. 1). However, the differences in daily mortality between air-deprived and food-deprived groups were significant (P< 0.05) at the 2nd and 5th days from the start of application (Fig. 1).

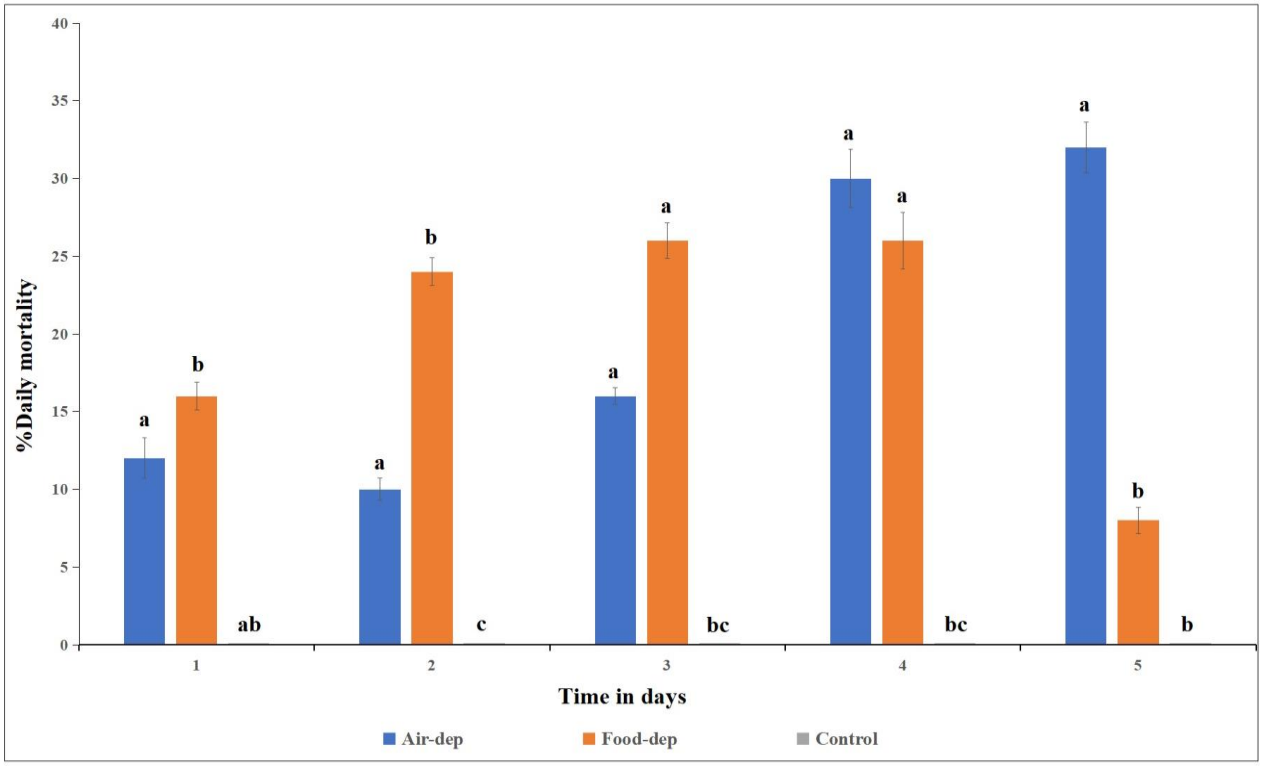

Figure 1. Daily mortality of control, air-deprived and food-deprived *O. surinamensis* adults. The lowercase letters on the columns refer to the significance level. Different letters refer to significant differences and the same letters refer to insignificant differences at P < 0.05 using LSD post hoc tests.

Time-mortality correlation of air-deprived and food-deprived adult *O. surinamensis*

The correlation of accumulative daily mortality and time course of air-deprived and food-deprived adult *O. surinamensis* were investigated (Figs. 2A and 2B). Accumulative daily mortalities of both air-deprived and food-deprived adult *O. surinamensis* were increased by increasing the time course of the experiment. The percentage mortality displayed a very strong positive correlation with the time in both cases of air-deprived (R^2 = 0.952) and food-deprived (R^2 = 0.976), as shown in Figs. 2A and 2B.

Both Pearson's and Spearman's correlation analyses regarding mortality time, air deprivation, and food deprivation are summarized in Table 2. Generally, all pairs exhibited significant positive strong (r > 0.941- 0.973 for Pearson's and r > 0.985- 1.000 for Spearman's coefficients) correlations. Time-air-deprivation, Time-food-deprivation, and air-deprivation-food-deprivation pairs exhibited positive significant strong correlations for both correlation coefficients (Table 2).

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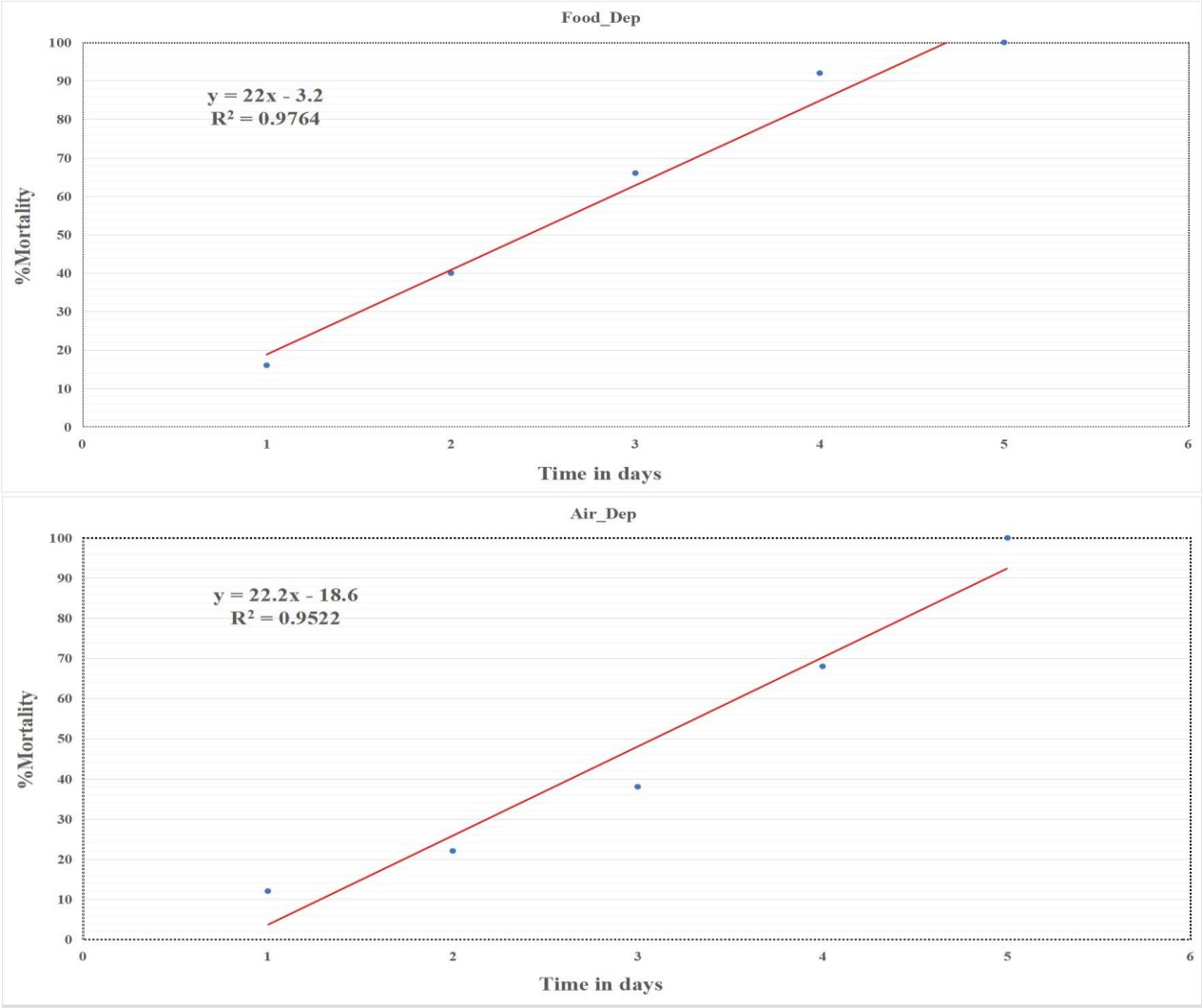

Figure 2. Correlation between (A): time and % mortality due to food-deprived, (B): time and % mortality due to air-deprivation of *O. surinamensis* adults.

Table 2. Summarized Pearson's and Spearman's correlation analyses to show the significant correlations among mortalities regarding time, air-deprivation and food-deprivation.

Pearson's correlation		***R***	**Significance**
Time course	Air-deprived	0.961**	0.00
	Food-deprived	0.973**	0.00
Air-deprived	Food-deprived	0.941**	0.00
Spearman's correlation		*R*	Significance
Time course	Air-deprived	0.985**	0.00
	Food-deprived	0.985**	0.00
Air-deprived	Food-deprived	1.000**	0.00

**: Correlation is significant at the 0.01 level (2-tailed).

Determination of LT_{50} of air-deprived and food-deprived adult *O. surinamensis*

Using probit analysis, LT_{20}, LT_{50} and LT_{95} were determined for both air-deprived and food-deprived adult *O. surinamensis* (Table 3). The estimated values of LT_{20}, LT_{50} and LT_{95} were found different between air-deprived and food-deprived groups. Statistical analysis revealed that these differences in LT values were insignificant in all estimated LT

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values. Significance was determined based on 95% confidence limits (Table 3).

Table 3. Probit analysis of lethal time (LT) mortalities in air-deprivation and food-deprivation treatments of adult *O. surinamensis*.

Treatment	LT_{20} (95% C.l)*	LT_{50} (95% C.l)*	LT_{95} (95% C.l)*
Air-deprivation	1.904 (1.037- 2.455)	3.061 (2.346- 3.974)	7.736 (5.368- 21.937)
Food-deprivation	1.483 (1.024- 1.825)	2.298 (1.879- 2.693)	5.409 (4.304- 8.247)

*95% C.l: 95% confidence limits.

O surinamensis is a well-known serious pest of stored products including cereals and related amylaceous products. Due to its higher mobility, *O. surinamensis* is also capable of infesting a wide variety of crops[21,32-34]. The present work tested the efficacy of air deprivation as a safer control method for adult *O. surinamensis* in comparison to food deprivation effect.

Our results revealed significantly increased daily mortalities of air-deprived and food-deprived adult *O. surinamensis* when compared to the control group. Accumulative daily mortalities of both air-deprived and food-deprived adult *O. surinamensis* displayed a very strong positive correlation with the time. The differences in estimated LT_{20}, LT_{50} and LT_{95} of air-deprived and food deprived groups were statistically insignificant. These results clarified that the air-deprivation method was as efficient as food deprivation in controlling adult *O. surinamensis*. It is concluded that as the majority of insects, the rate and efficiency of respiration of *O. surinamensis* are affected by changes in the concentrations of the O2: CO2 ratio[35]. These results could be interpreted by the CO2-avoidance behavior. It was previously suggested as an anti-stress mechanism in D. melanogaster adults subjected to elevated CO2 levels[36]. In consistence, egg laying, embryonic development, hatching and post-embryonic development of D. melanogaster, declined when CO2 concentration rises[36]. In addition, the chemo-sensation and response to cellular oxidation, nitrosation and acidosis caused by the hypercapnia lead to insect mortality[36].

Conclusion

This study presented that air-deprivation significantly increased the 2nd, 3rd, 4th, and 5th daily mortality when compared with control. Meanwhile, food-deprivation significantly increased the 1st, 2nd, and 3rd daily mortality when compared with control. Additionally, differences in daily mortality between air-deprived and food-deprived groups were significant at the 2nd and 5th days. However, differences were insignificant at the 1st, 3rd, and 4th days. Time-air-deprivation, Time-food-deprivation, and air-deprivation-food-deprivation mortality pairs exhibited positive significant strong correlations for both Pearson's and Spearman's correlation coefficients. Furthermore, probit analysis revealed that the differences in LT_{20}, LT_{50} and LT_{95} values between air-deprived and food-deprived groups were insignificant. Conclusively, air-evacuation of the package was as effective, safer and eco-friendly method as food-deprivation for protecting stored products against the saw-toothed grain beetle, *O. surinamensis.*

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Authors' Declaration

- Conflicts of Interest: None.
- I hereby confirm that all the Figures and Tables in the manuscript are mine. Furthermore, any Figures and images, that are not mine, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in University of Cairo.

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[2]قسم علم الحشرات، الكلية العلوم، جامعة القاهرة، الجيزة، مصر.

الخلاصة

تُعد التمور من بين الأطعمة الأكثر أهمية في الدول العربية. وعادةً ما تتعرض التمور للإصابة بخنفساء الحبوب المنشارية *Oryzaephilus surinamensis*. مما يؤثر بشكل سلبي علي إنتاج التمور من حيث كميتها وجودتها (القيمة الاقتصادية وقابلية البذور للنمو). وقد صممت هذه الدراسة للتحقق من فعالية إزالة الهواء كطريقة صديقة للبيئة وآمنة للسيطرة على بالغ حشرة *O. surinamensis*. حيث تم الحصول على الحشرات من التمور المصابة من متجر خاص في مدينة سكاكا بمنطقة الجوف في المملكة العربية السعودية. حيث تمت دراسة تأثير الحرمان من الهواء (باستخدام مضخة فراغ) ومقارنته مع تأثير الحرمان الحشرات من الغذاء على *O. surinamensis*، وتم ملاحظة وفيات الحشرات يوميًا بالمقارنة مع مجموعة الضابطة (التي تم إدارة الطعام والهواء). وقد خلصت النتائج الي ان الحرمان من الهواء او الغذاء يتسبب في زيادة كبيرة في نسبة الوفيات اليومية بالمقارنة مع المجموعة الضابطة. وقد أظهرت نسبة الوفيات التراكمية ارتباطًا إيجابيًا قويًا جدًا مع مدى الزمن في حالتي حرمان الهواء وحرمان الغذاء. استنادًا إلى قيم الزمن القاتل، مما يؤكدان الحرمان من الهواء يعد طريقة فعالة للغاية وصديقة للبيئة وآمنة للسيطرة على *O. surinamensis*.

الكلمات المفتاحية: إزالة الهواء، التمر، مقاومة صديقة للبيئة، الحرمان من الغذاء، حشرة خنفساء، الحبوب المنشارية.