Vol. 159,
2022

IOBC-WPRS

# Working Group „Integrated Protection of Stored Products“

Preceedings of the 13th Meeting
at Barcelona (Spain)

03-06 October, 2022

Edited by:

Nuria Agustí, Cristina Castañé, and
Jordi Riudavets

IOBC-WPRS

The content of the contributions is in the responsibility of the authors.

The IOBC-WPRS Bulletin is published by the International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palearctic Regional Section (IOBC-WPRS).

Le Bulletin OILB-SROP est publié par l'Organisation Internationale de Lutte Biologique et Intégrée contre les Animaux et les Plantes Nuisibles, section Regionale Ouest Paléarctique (OILB-SROP).



The Publication Commission of the IOBC-WPRS:

Dr. Ute Koch
Schillerstrasse 13
69509 Moerlenbach, Germany
Tel +49-6209-1079
e-mail: u.koch_moerlenbach@t-online.de

Dr. Annette Herz
Julius Kühn-Institute (JKI)
Federal Research Center for Cultivated Plants Plant Protection in Fruit Crops and Viticulture
Schwabenheimer Str. 101
69221 Dossenheim, Germany
Tel +49 3946 474965
e-mail: Annette.Herz@julius-kuehn.de

Address General Secretariat:

Paula Baptista
Polytechnic Institute of Bragança
School of Agriculture
Campus de Santa Apolónia
5300-253 Bragança, Portugal
Phone: +351 273 303 332
e-mail: pbaptista@ipb.pt

ISBN 978-92-9067-345-3

Web: http://www.iobc-wprs.org

Darmstadt, 2022

# Committees

## Local organizers

Nuria Agustí, Cristina Castañé, Jordi Riudavets (IRTA), Spain
Montse Martí [Institució Catalana d'Estudis Agraris (ICEA)], Spain

## Scientific Committee

Cornel Adler, Julius Kühn- Institut, Berlin, Germany
Nuria Agustí, IRTA, Cabrils (Barcelona), Spain
Christos Athanassiou, University of Thessaly, Greece
Maria Otilia Carvalho, Universidade de Lisboa, Portugal
Cristina Castañé, IRTA, Cabrils (Barcelona), Spain
Mevlüt Emekci, Ankara University, Turkey
Benjamin Fürstenau, Julius Kühn- Institut, Berlin, Germany
Sonja Gvozdenac, Institute of Field and Vegetable Crops Novi Sad, Serbia
Rey Iturralde-García, Universidad de Hermosillo, México
Nickolas Kavallieratos, Agricultural University of Athens, Greece
Hagit Navarro, Green Storage Ltd., Rishon LeZion, Israel
Jordi Riudavets, IRTA, Cabrils (Barcelona), Spain
Vaclav Stejskal, Crop Research Institute, Prague, Czech Republic
Stanislav Trdan, University of Ljubljana, Slovenia
Pasquale Trematerra, University of Molise, Italy

## Liaison Officer

Marc Bardin, INRAE-PACA, Montfavet, France

# Table of contents

## Session 1. Pest prevention during storage and transportation

## Session 2. Biology of stored product pests and diseases, insects as food

## Session 3. Biological control, mating disruption and natural products

## Session 4. Chemical pest control

## Session 5. Physical control, modified atmospheres

*Integrated Protection of Stored Products*
*IOBC-WPRS Bulletin Vol. 159, 2022*
*pp. 116-120*

# Susceptibility of different dried fruits to infestation by *Plodia interpunctella* (Lepidoptera: Pyralidae) in laboratory conditions

**Filip Vukajlović[1], Dragana Predojević[1], Sonja Gvozdenac[2], Snežana Tanasković[3], Vesna Perišić[4], Ana Mitrovski Bogdanović[1], Snežana Pešić[1]**
*[1]University of Kragujevac, Faculty of Science, Department of Biology and Ecology, Radoja Domanovića 12, 34000 Kragujevac, Serbia; [2]Institute of Field and Vegetable Crops, National Institute of the Republic of Serbia, Maksima Gorkog 30, 21101 Novi Sad, Serbia; [3]University of Kragujevac, Faculty of Agronomy, Cara Dušana 34, 32000 Čačak, Serbia; [4]University of Niš, Faculty of Agriculture, Kosančićeva 4, 37000 Kruševac, Serbia*
*E-mail: filip.vukajlovic@pmf.kg.ac.rs*

**Abstract:** The aim of this study was to assess the susceptibility of nine dried fruit species (apple chips, prunes, sour cherries, raspberries, blackberries, strawberries, chokeberries, goji berries and figs) to be infested by *Plodia interpunctella* in laboratory conditions. Six dried fruit species (prune, sour cherry, raspberry, blackberry, strawberry, and chokeberry) were resistant, while dried goji and figs were moderately susceptible. Higher susceptibility was associated with higher content of protein and fat in tested dried fruits, but also with lower content of total and reducing sugars, as well as secondary metabolites, which indicates that these groups of macronutrients potentially enhance its susceptibility.

**Key words:** Indian meal moth, dried fruits, index of susceptibility, susceptibility rating

## Introduction

Indian meal moth, *Plodia interpunctella* (Lepidoptera: Pyralidae) is one of the most important pest of dried fruits (Johnson et al., 2009), being a moth of a great importance for dried fruits processors (Burks and Johnson, 2012). Its larvae feed on the fruit itself and cover it with excrements and silk, making it unusable for human diet (Burks and Johnson, 2012).

Dried fruits have their own, natural susceptibility to infestation by different pests and it depends on different factors, mainly on its nutritional quality and level of moisture. In general, dried fruits contain a lot of sugars, commonly more than 30 % (Vukajlović et al., 2019). Also, moisture level is usually high, more than 10 %. This makes dried fruits very appropriate for the development of pests, especially *P. interpunctella*. On the other hand, proteins and fats are found in very small amount in dried fruits, being these two macronutrients very important for insect development. Therefore, we hypothesize that the amount and ratio of nutrients could be an important factor that influences the susceptibility of dried fruits to the development of *P. interpunctella*. Based on this hypothesis, the aim of this study was to assess the susceptibility of the most commonly used dried fruits to be infested by *P. interpunctella* in correlation with the content of macronutrients and the secondary metabolites in tested dried fruits.

## Materials and methods

***Insect rearing***

*Plodia interpunctella* was reared in a climate chamber at 28 ± 1 °C, 60 ± 10 % R. H., and 14:10 (L:D) photoperiod, in transparent plastic containers (1.2 l in volume) on a standard laboratory diet (Silhacek and Miller, 1972) for ~50 generations at the Faculty of Science of the University of Kragujevac, Serbia. One-day-old moths *in copuli* were aspirated from the rearing containers to oviposition jars and one-day-old eggs were used in assays.

***Experimental design***

Susceptibility of nine dried fruits to *P. interpunctella* infestation were tested: apple chips, prunes, sour cherries, raspberries, blackberries, strawberries, chokeberries, goji berries and figs. Data of nutritive constituents of tested dried fruits (moisture, the content of total ash, proteins, fats, carbohydrates, sugars, reducing sugars, total phenolics, flavonoids, and tannins) was obtained from Vukajlović et al. (2019).

Assays were conducted in 12 replicates for each tested dried fruit type, with a total of 108 assays. Each assay contained 100 ml of different dried fruits placed into 250 ml glass jar with 50 one-day-old *P. interpunctella* eggs. The mass of the diet in each assay was also measured. The experiment was carried out in the same conditions as for growing the parental insect population.

***Experimental procedure***

The experimental procedure on life history traits of *P. interpunctella* immature stages were described in Vukajlović et al. (2019). Shortly, after the emergence of *P. interpunctella* adults from each assay, their number was counted and the mean developmental duration (MDD) for each adult was recorded. The mean developmental duration was calculated as the average time (in days) from the start of the experiment to the emergence of each adult. The susceptibility of 16 dried fruit species to the infestation of *P. interpunctella* was calculated based on the Index of susceptibility (IS) for insect development (Dobie, 1974):

$$IS = \frac{\ln F1}{MDD} \times 100$$

where F1 represents the mean number of *P. interpunctella* adults that emerged in twelve replications during the experimental period, while MDD represents the mean developmental duration in twelve replications. Susceptibility rating (SR) was based on the calculated Indexes of susceptibility, as suggested by Mensah (1986).

***Statistical analysis***

Data were statistically analysed using the IBM SPSS Statistics 21 software package. A one-way ANOVA and post hoc Bonferroni test ($P < 0.05$) were carried out to test the differences among mean IS values in tested dried fruits. Pearson's coefficient was used to test the correlations between IS values and nutritive constituents' contents in tested dried fruits.

## Results and discussion

Results of susceptibility of nine dried fruit species to infestation of *P. interpunctella*, based on the obtained ISs and susceptibility ratings are presented in Table 1. Mean values of IS

(F = 42.78; p < 0.001) were siginificantly different among tested dried fruit species. Six dried fruit species (prune, sour cherry, raspberry, blackberry, strawberry and chokeberry) were resistant to infestation by *P. interpunctella*, with IS values ranging from 0.84 to 2.41. Higher IS were observed for dried goji and figs (5.16 and 7.14, respectively) and these dried fruit species were rated as moderately susceptible to infestation by *P. interpunctella*.

Table 1. Mean values of the Index of Susceptibility (± SE) and Susceptibility Rating of the tested dried fruit species to the infestation by *Plodia interpunctella*.

| **Dried fruits** | **Index of susceptibility (IS)** | **Susceptibility rating (SR)** |
|---|---|---|
| Apple chips | 2.84 ± 0.10 $^{c}$ | Moderately resistant |
| Prune | 0.84 ± 0.19 $^{a}$ | Resistant |
| Sour cherry | 1.14 ± 0.29 $^{ab}$ | Resistant |
| Raspberry | 2.40 ± 0.42 $^{bc}$ | Resistant |
| Blackberry | 2.41 ± 0.36 $^{bc}$ | Resistant |
| Strawberry | 2.26 ± 0.22 $^{abc}$ | Resistant |
| Chokeberry | 2.02 ± 0.18 $^{abc}$ | Resistant |
| Goji | 5.16 ± 0.27 $^{d}$ | Moderately susceptible |
| Fig | 7.14 ± 0.50 $^{e}$ | Moderately susceptible |
| F value | 42.78*** | - |

Values with different letters in superscript are statistically different by one-way ANOVA test and Bonferroni test at p < 0.05; *** - p < 0.001.

Even if *Plodia interpunctella* is one of the most serious pest of dried fruits (Hagstrum and Subramanyam, 2009; Burks and Johnson, 2012; Sarwar, 2015), based on numerous laboratory research, dried fruits are a much less suitable diet for the development of *P. interpunctella* than other diet types, such as nuts. For example, prunes and apricots are an unsuitable food for *P. interpunctella*, because a small number of adults emerge from them, and the development lasts very long (Johnson et al., 1995; Johnson, 2004; Sambaraju and Phillips, 2008; Almaši and Poslončec, 2010; Vukajlović et al., 2017). Numerous research results showed that the nutritional content of the diet is of high importance for the survival and development of *P. interpunctella*, while other diet constituents, such as moisture and other chemicals are less important (LeCato, 1976; Sambaraju and Phillips, 2008; Burks and Johnson, 2012; Predojević et al., 2017; Gvozdenac et al., 2018; Vukajlović et al., 2019).

In this research, susceptibility of tested dried fruit species to the infestation by *P. interpunctella* was higher in those species that contained more proteins (r = 0.47; p < 0.001) and fats (r = 0.25; p < 0.05), and less total sugars (r = -0.24; p < 0.05) and reducing sugars (r = -0.29; p < 0.01), while differences in total carbohydrates, moisture and ash content did not affect the susceptibility of the tested dried fruits (Table 2). It was also found that higher contents of total phenolics (r = -0.59; p < 0.001), flavonoids (r = -0.31; p < 0.01) and tannins (r = -0.26; p < 0.01) negatively correlates with the susceptibility of dried fruit to *P. interpunctella* infestations.

Table 2. Correlation between the Index of Susceptibility of the tested dried fruits to the infestation of *Plodia interpunctella* and the nutrient content of the tested dried fruits.

| Nutrient content | Index of Susceptibility (IS) |
|---|---|
| Moisture | -0,02 ns |
| Total ash | -0,01 ns |
| Crude proteins | 0,47 *** |
| Crude fats | 0,25 * |
| Total carbohydrates | -0,16 ns |
| Total sugars | -0,24 * |
| Reducing sugars | -0,29 ** |
| Total phenolics | -0,59 *** |
| Total flavonoids | -0,31 ** |
| Condensed tannins | -0,26 ** |

r values; *** - $p < 0,001$; ** - $p < 0,001$; * - $p < 0,05$; нз - $p > 0,05$.

Our results show that the higher susceptibility of dried fruits, especially of dried figs and goji berries, to *P. interpunctella* is associated with higher protein and fat content in dried fruits, but also to the lower contents of total and reducing sugars, as well as to the secondary metabolites, which indicates that these groups of macronutrients potentially enhance its resistance.

By assessing the susceptibility of different diet types to the infestation by *P. interpunctella* and correlating it with its nutritional characteristics, we could better understand this pest feeding preferences, its biology, ecology, and potential pest management strategies.

## Acknowledgements

This study is part of the PhD Thesis of Filip N. Vukajlović. This work was financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia under the Agreement on the Implementation and Financing of Research of the Faculty of Science, University of Kragujevac (No. 451-03-68/2022-14/200122). The authors thank Vesna Matović from the Institute of Public Health, Kragujevac, Serbia, who helped with the analyses of macronutrient content in dried fruits.

## References

Almaši, R. and Poslončec, D. 2010. Survival, reproduction, and development of Indian meal moth (*Plodia interpunctella* Hbn.) on dried fruits. Contemp. Agr. 59(1-2): 72-80.

Burks, C. S. and Johnson, J. A. 2012. Biology, Behavior and Ecology of Stored Fruit and Nut Insects. In: Hagstrum, D. W., Phillips, T. W., and Cuperus, G. (eds.): Stored Product Protection, pp. 21-32. Kansas State University.

Dobie, P. 1974. The laboratory assessment of the inherent susceptibility of maize varieties to post-harvest infestation by *Sitophilus zeamais*. J. Stored Prod. Res. 10: 183-197.

Gvozdenac, S. M., Prvulović, D. M., Radovanović, D. M., Ovuka, J. S., Miklič, V. J., Ačanski, J. M., Tanasković, S. T. and Vukajlović, F. N. 2018. Life history of *Plodia interpunctella* Hübner on sunflower seeds: Effects of seed qualitative traits and the initial seed damage. J. Stored Prod. Res. 79: 89-97.

Hagstrum, D. W. and Subramanyam, B. 2009. Stored-product insect resource. AACC International, Inc., St. Paul, Minnesota, USA.

Johnson, J. A. 2004. Dried fruit and nuts: United States of America. In: Hodges, R., and Farrell, G. (eds.): Crop post-harvest: Science and technology, Volume 2: Durables, pp. 226-234. Wiley-Blackwell.

Johnson, J. A., Wofford, P. L. and Gill, R. F. 1995. Development thresholds and degree-day accumulations of Indian meal moth (Lepidoptera: Pyralidae) on dried fruits and nuts. J. Econ. Entomol. 88: 734-741.

Johnson, J. A., Yahia, E. M. and Brandl, D. G. 2009. Dried fruits and tree nuts. In: Yahia, E. M. (ed.): Modified and controlled atmospheres for storage, transportation, and packaging of horticultural commodities, pp. 507-526. CRC Press, Boca Raton.

LeCato, G. L. 1976. Yield, development, and weight of *Cadra cautella* (Walker) and *Plodia interpunctella* (Hübner) on twenty-one diets derived from natural products. J. Stored Prod. Res. 12: 43-47.

Mensah, G. W. K. 1986. Infestation potential of *Callosobruchus maculatus* (F) (Coleoptera: Bruchidae) on cowpea stored under subtropical conditions. Int. J. Trop. Insect Sci. 7(6): 718-784.

Predojević, D. Z., Vukajlović, F. N., Tanasković, S. T., Gvozdenac, S. M. and Pešić, S. B. 2017. Influence of maize kernel state and type on life history of *Plodia interpunctella* (Lepidoptera: Pyralidae). J. Stored Prod. Res. 72: 121-127.

Sambaraju, K. R. and Phillips, T. W. 2008. Ovipositional preferences and larval performances of two populations of Indian meal moth, *Plodia interpunctella*. Entomol. Exp. Appl. 128: 283-293.

Sarwar, M. 2015. Protecting dried fruits and vegetables against insect pest invasions during drying and storage. Am. J. Mark. Res. 1(3): 142-149.

Silhacek, D. L. and Miller, G. L. 1972. Growth and development of the Indian meal moth, *Plodia interpunctella* (Lepidoptera: Phycitidae), under laboratory mass-rearing conditions. Ann. Entomol. Soc. Am. 65(5): 1084-1087.

Vukajlović, F., Predojević, D., Perišić, V., Gvozdenac, S., Tanasković, S. and Pešić, S. 2017. Otpornost sušenih plodova šljive, kajsije i višnje na infestaciju *Plodia interpunctella* (Lepidoptera: Pyralidae). XXII Savetovanje o biotehnologiji sa međunarodnim učešćem, Vol. 22(1): 345-352.

Vukajlović, F. N., Predojević, D. Z., Miljković, K. O., Tanasković, S. T., Gvozdenac, S. M., Perišić, V. M., Grbović, F. J. and Pešić, S. B. 2019. Life history of *Plodia interpunctella* (Lepidoptera: Pyralidae) on dried fruits and nuts: Effects of macronutrients and secondary metabolites on immature stages. J. Stored Prod. Res. 83: 243-253.