



Assessment of short-term mortality of granary weevil, *Sitophilus granarius* (Coleoptera: Curculionidae) triggered by different microwave irradiation powers

Sándor Keszthelyi, András Nyári & Ferenc Pál-Fám

To cite this article: Sándor Keszthelyi, András Nyári & Ferenc Pál-Fám (2019): Assessment of short-term mortality of granary weevil, *Sitophilus granarius* (Coleoptera: Curculionidae) triggered by different microwave irradiation powers, International Journal of Pest Management

To link to this article: <https://doi.org/10.1080/09670874.2019.1615657>



Published online: 28 May 2019.



Submit your article to this journal [↗](#)



View Crossmark data [↗](#)



Assessment of short-term mortality of granary weevil, *Sitophilus granarius* (Coleoptera: Curculionidae) triggered by different microwave irradiation powers

Sándor Keszthelyi, András Nyári and Ferenc Pál-Fám

Department of Plant Production and Plant Protection, Faculty of Agricultural and Environmental Sciences, Kaposvár University, Kaposvár, Hungary

ABSTRACT

The insecticidal efficacy of microwave irradiation against the at 12, 24, 48 and 72 h following exposure to microwave irradiations (100, 300 W) and the progeny production was assessed 45 days later. Linearly increasing irradiation power range (100, 200 and 300 W) was set up for determining mortality tendency. An increase of insect mortality caused by higher irradiation period and times elapsed after treatment has become evident commencing from 12 h after the treatment, which has significantly decreased at later elapsed time after treatment. The irradiation periods inducing the highest mortality at the examined powers were at 10 min and at 100 W power (72 h: 64.93%) and at 4.5 min. and at 300 W power (12 h: 87.01). In addition, a complete suppression of progeny production was achieved by 4.5 min treatment at 300 W power. Lognormal-type mortality process was caused by the linearly increased irradiation range. The properly chosen microwave irradiation can be used for management of *Sitophilus granarius* larval and adult developmental stages. This treatment could provide an effective and friendly environmental treatment technique in Integrated Pest Management (IPM) program.

ARTICLE HISTORY

Received 10 October 2018
Accepted 1 May 2019

KEYWORDS

Microwave irradiation;
mortality; reproduction;
Sitophilus granarius;
stored product

Introduction

The granary weevil, *Sitophilus granarius* L. 1758 (Coleoptera: Curculionidae) is a typical cosmopolitan pest. It can cause significant damage to stored grains, and may drastically decrease yields. The females lay 125 eggs on average and the larvae eat the interior of the grain kernels (Stejskal and Kucerova 1996). Damaged grain has reduced nutritional value, low percentage germination, reduced weight and lowered market value (Longstaff 1981).

Cereal grain losses during storage can reach 50% of the total harvest in some countries, a world-wide loss equivalent to billions of Euros per year (Haff and Slaughter 2004). Residual insecticides are the most commonly used protectants in stored grain against stored-product pests in many countries of Europe. They are applied directly to the product and provide protection as long as the insecticidal effect persists. However, these pesticides have negative side-effects: they can be toxic to mammals and residues can be accumulated in the treated products. Moreover, many pest species could become resistant to the protectants (Zettler and Arthur 2000). Therefore, environmentally friendlier, economical and effective methods are required for reducing *S. granarius* damage to protect stored grains.

Microwave-treatment can be a feasible alternative solution for the eradication of stored product pests. Microwaves are a form of electromagnetic radiation with wavelengths ranging from one meter to one millimetre; with frequencies between 300 MHz and 300 GHz. Exposure to microwaves could cause physical injuries, distorted development both in eggs and larvae and reduce reproduction rates in adults (Nelson 1996). Microwave radiation with high penetration capacity can kill pests living inside or outside grain kernels (Halverson et al., 1996). Microwave irradiation to control insect infestations has been widely reported for stored grain (Nelson 1996; Zhao et al. 2007; Gasemzadeh et al. 2010). The method can be deemed to be effective in disinfection of floor gaps of warehouses, in which insects can be found as well as in inaccessible areas of an edifice such as walls, spaces between floors, or ceilings and the like which would be impossible to place in an enclosure for extermination by exposure to microwave radiation (Upadhyay and Ahmad 2011). Notwithstanding that there are some results in connection with the effects of microwave irradiation on *Sitophilus* genus (Tilton and Vardell 1982; Vadivambal et al. 2008; Gasemzadeh et al. 2010; Hassan et al. 2010). *Inter alia* complete mortality was achieved for *S.*

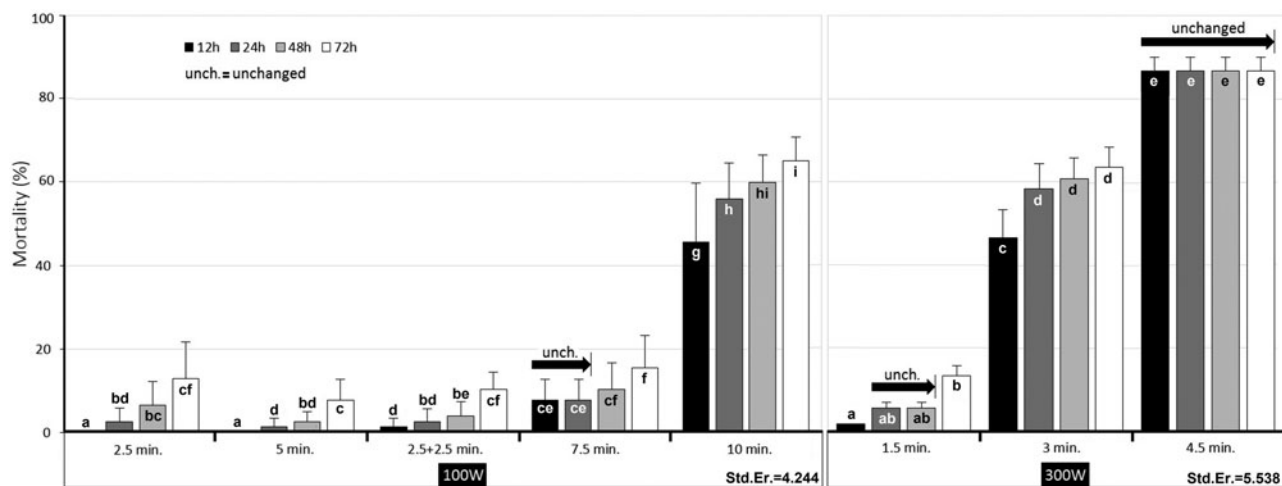


Figure 1. Abbott corrected percent mortality of *S. granarius* adults (mean \pm SE) treated with two different powers of microwave, as a function of different irradiation times. a, b, c, d, e, f, g, h, i: small letters indicate significant difference ($p \leq 0.05$) between means of different irradiation times.

granarius at 500 W for 28 s elapsed after treatment in barley and rye by Vadivambal et al. 2008. Tilton and Vardell (1982) observed that the 50 °C treatment for 3 and 5 min was sufficient to control the *S. zeamays*. According to Gasemzadeh et al. (2010), the synergistic interaction indicates that microwave radiation can be used with cold storage for management of *S. oryzae* adult developmental stage. Nevertheless, relevant information about *S. granarius* is rather scarce. Therefore, the objectives of this research were to obtain information about the efficacy of two different microwave irradiation doses against *S. granarius* on maize grain, and to evaluate the influence of the different times elapsed after treatment of applied doses on weevil mortality and progeny production.

Materials and methods

Untreated, clean and all infestation-free maize grains with 13.5% moisture content were used for the experiment. Each sample (100 g maize) was placed in a small glass jar and 20 healthy *S. granarius* adults of mixed sex and age were added. The glasses were covered with ventilated textiles and placed in a climate chamber at 26 ± 2 °C, $60 \pm 7\%$ rh and 14/8 photoperiod.

A household microwave oven (Euromarkt, M0700M17W) with 2.45 GHz frequency was used in the experiment. Its capacity range was: 100 to 700 W microwave power. The microwave oven was calibrated based on Japanese Industrial Standard prior to launching the experiment (Gallawa, 2000).

The insect mortality effects of two different microwave powers, at 100 and 300 W were analysed. Besides the untreated samples, a total of eight irradiation periods of two microwave powers were set up. The irradiation was deployed continuously for 2.5

and 5 min or intermittently (2.5 min under irradiation, 1 min pause and removal from the oven followed by irradiation for 2.5 min again), 7.5 and 10 min at 100 W power, and 1.5, 3, and 4.5 min at the 300 W power. Each treatment included 4 repetitions. Four samples per treatment were irradiated at the same time at 28 °C, $60 \pm 7\%$ rh.

Dead adults were counted and removed after four times elapsed after treatment: 12, 24, 48 and 72 h. After the 72 hours counts, from each sample, the adult insects (both dead and alive ones) were removed, after which the vials were returned to the climate chamber for an additional 45 d. following this period, the emerged *S. granarius* adults were counted, classified as dead or alive and removed from the vials. These adults were observed for survival and progeny were as indication of reproductive ability.

Additionally, the linearly increasing irradiation power range (100, 200 and 300 W) was set up with the above-mentioned similar parameters in order to determine mortality tendency. We analysed the effects of 2.5, 5, 7.5 and 10 min irradiation times of three microwave powers on *S. granarius* mortality.

Mortality counts were corrected by using Abbott's (1925) formula. The data were analysed by using one-way ANOVA of SPSS 11.5 software, with weevil mortality response as the variable and time elapsed after treatment and dose rate of microwave power as the main effects. Means were separated by using the Tukey (HSD) test, at $p \leq 0.05$.

Results

Insect mortality is shown in Figure 1 as a function of treatments. An increase of insect mortality caused by higher irradiation period and times elapsed after treatment was evident from 12 h after the treatment

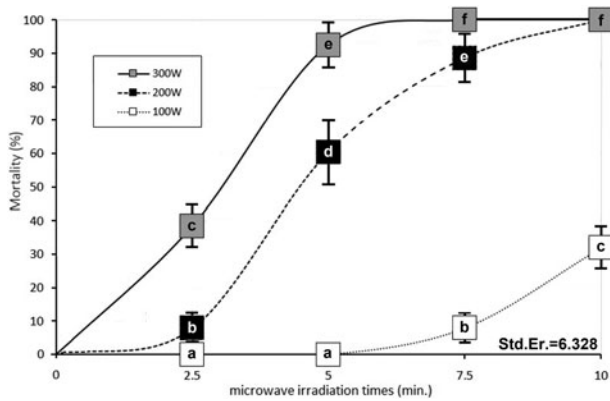


Figure 2. Abbott corrected mortality data (mean \pm SE) and estimated mortality trends of *S. granarius* of linear increased irradiation range at three chosen microwave powers. a, b, c, d, e, f: small letters indicate significant difference ($p \leq 0.05$) between means of different irradiation times.

was implemented. The highest irradiation periods induced the highest mortality in both examined powers: at 10 min and at 100 W power (72 h: 64.93%) and at 4.5 min. and at 300 W power (uniformly in each times elapsed after treatment: 87.01%). None of the shortly applied irradiation periods triggered acceptable mortality/plant protection efficacy. Remarkable perishing ratio was evinced in the first time elapsed after treatment (12 h) in the case of each treatment time, which has significantly decreased at later times elapsed after treatment. However, this moderation of efficacy cannot be statistically proven ($p \leq 0.05$). Its complete absence was observed in certain cases (12 and 24 h after 7.5 min irradiation. at 100 W; 24 and 48 h following 1.5 min. irradiation as well as from 12 to 72 h elapsed after 4.5 min. irradiation at 300 W).

There were significant differences between the mortality ratios of irradiation times. Similar relationships were seen in each time elapsed after treatment of three irradiation times at the 300 W power (uniformly: $p = 0.000$). No significant increase of insect mortality was detected between 2.5 and 7.5 min. at 100 W. Interestingly, significant mortality differences could not be accounted for by two irradiation times (un- and interrupted 5 min at 100 W power) of similar length. The significant increase of insect mortality between 7.5 and 10 min. was detected at 100 W. In contrast, the insects exposed to the longest time elapsed after treatment (72 h) have not shown a significant increase of mortality even for this long irradiation time. Total mortality of the experimental insects has not occurred in any of the applied treatments.

Lognormal-type mortality process was caused by the linearly increased irradiation levels of all three selected microwave powers (Figure 2). Mortality curves can be divided into three well-defined parts upon all three microwave powers applied. Slow

mortality increase can be observed in the first third (until irradiation time of 2.5 min at 200 and 300 W), later this tendency continues with a pronounced significantly destruction in the second third (between irradiation time of 2.5 and 5 min at 200 and 300 W, and 7.5 and 10 min at 100 W) ($p \leq 0.05$). Finally, in the last third the complete desolation of the experimental population occurred. Mortality tendency -after a slow rise- showed an exponential increase in response to different microwave powers at increasing irradiation times until the total eradication of insect population. It is confirmed by this survey that the complete eradication of the experimental insect population corresponds to higher irradiation times.

With increasing irradiation times the number of adult progeny decreases at both microwave powers (100 and 300 W) (Table 1). This observation was statistically proven at both microwave powers (uniformly: $p = 0.001$). After forty five days, the number of adult progeny of the control and that obtained at the shortest irradiation time (2.5 min at 100 W) were similar. Progeny production of sample populations dropped to 50% at irradiation times 2.5 + 2.5 and 7.5 min. of 100 W as compared to the intact weevil populations. However, adult progeny numbers gained after two irradiation times, 2.5 + 2.5 and 5 min. at 100 W power, differed, but this difference was not statistically proven ($t = 0.208$). Significant progeny decrease was triggered by longer irradiation periods (10 min at 100 W and 3 min at 300 W). In addition, a complete suppression of progeny production was observed at 4.5 min. elapsed after treatment at 300 W power. Nevertheless, in all cases, the effect of irradiation treatment on the number of dead progeny adults was not confirmed statistically.

Discussion

Adult-perishing and progeny-suppressive effects of *S. granarius* caused by microwave irradiation were confirmed by our experiment. The efficacy of microwave treatment in plant protection has been corroborated by other studies in connection with several arthropod pests including especially those in the orders Coleoptera and Lepidoptera, e.g.: *Callosobruchus maculatus* (Fabr.) (Purohit et al. 2013), *Rhynchophorus ferrugineus* (Olivier) (Massa et al. 2011), *Tribolium castaneum* (Herbst) (Gasemzadeh et al., 2010), *T. confosum* Jacquelin du Val (Watters 1976), *Rhyzopertha dominica* (Fabr.), *Corcyra cephalonica* (Stainton) (Bedi and Singh 1992), *Ephestia kuehniella* (Zeller) (Azizoglu et al. 2011). From *Sitophilus* genus, primarily the maize weevil [*Sitophilus zeamays* (Motschulsky)] and the rice weevil (*S. oryzae* L.) have been examined in

Table 1. Progeny production of *S. granarius* (mean number of adults \pm SE) and percentage (\pm SE) of dead progeny on microwave irradiated maize, 45 days after the removal of exposed *S. granarius* adults, and the statistic relationships ($p \leq 0.05$).

	No. progeny	% dead adults	No. progeny	% dead adults
control	37.75 \pm 5.517	9.51 \pm 2.63		
microwave irradiation times (min)			300 W	
1.5			9.75 \pm 1.11	8.85 \pm 6.43
2.5	36.50 \pm 16.52	0.12 \pm 0.12		
3			7.75 \pm 5.42	4.21 \pm 2.94
4.5			0 \pm 0	0 \pm 0
5	42.75 \pm 13.91	0.6 \pm 0.6		
2.5 + 2.5	19.52 \pm 2.25	0 \pm 0		
7.5	18.25 \pm 2.28	7.09 \pm 2.87		
10	7.25 \pm 2.46	38.79 \pm 29.11		
<i>p</i>	<i>0.001</i>	<i>0.152</i>	<i>0.001</i>	<i>0.254</i>

Note: Italic characters show the statistically significant correlations.

previous researches (Kirkpatrick et al. 1972; Halverson et al. 1996)

According to our results, higher *S. granarius* mortality rates were reached by applying higher powers and longer treatment times of microwave irradiations. Vadivambal (2009) observed that mortality of *S. granarius* significantly varies with moisture content, time elapsed after treatment and power and reported higher mortality in wheat for longer time elapsed after treatment.

Significant decrease of *S. granarius* mortality can be observed in the progression of post-treatment period, which highlights the acute insect-perishing effect of the presented method. The initially moderated increase of mortality was followed by its rapid rise as a result of the linear increase of the irradiation time, which abruptly brought about a complete destruction of the experimental insect population. Therefore, shorter, but more powerful microwave irradiations should be applied as these treatments could provide an acceptable efficiency within a short time

Our results showed the use of interrupted power to be more effective (although it was not statistically proven) in killing insects as compared to continuous irradiation. From this point of view our results partly bolstered the findings of Shayesteh and Barthakur (1996).

Suppressive consequences of the treatment on the progeny have been confirmed by our experimental observation, which can be explained by sterility in the treated adults (Vadivambal et al. 2010). It is known that microwave irradiation has deleterious effects on insects such as reduction of reproductive rate, losing body weight and malformation as well (Nelson 1996; Azizoglu et al. 2011).

Previous results pointed out (Aladjadjian 2010; Purohit et al. 2013), that although eradication of the stored product pests could increase with the total microwave energy applied, seed embryo viability and seedling vigour decreased, accordingly. Therefore, careful selection of irradiation dose and

time should be realised in the case of treatment of seed items (Bhaskara Reddy et al. 1998)

It can be ascertained that a control agent must kill the target insect with an acceptable level of the agent in a short period of time. Our study showed that microwave radiations have insecticidal activity on *S. granarius* adults and suppressive effect on its progeny. So, microwave radiation may be promising in control strategies as an alternative (less hazardous) means superseding chemical control in certain situations. Our results may also contribute to developing a more reliable and feasible method for controlling stored product pests.

Summarizing, the properly chosen microwave irradiation can be used for management of *S. granarius* larval and adult developmental stages. This treatment alone and combined with other solutions (e.g. plant oils: Obeng-Ofori and Reichmuth 1999; entomopathogenic fungi: Batta and Kavallieratos 2018) could provide an effective and friendly environmental treatment technique in Integrated Pest Management (IPM) program.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the EFOP-3.6.3-VEKOP-16-2017-00008 project. The project is co-financed by the European Union and the European Social Fund.

References

- Abbott WS. 1925. A method of computing the effectiveness of an insecticide. *J Econ Entomol.* 8:265–267.
- Aladjadjian A. 2010. Effect of microwave irradiation on seeds of lentils (*Lens culinaris*). *Rom J Biophys.* 20: 213–221.
- Azizoglu U, Yilmaz S, Karaborklu S, Ayvaz A. 2011. Ovicidal activity of microwave and UV radiations on Mediterranean flour moth *Ephestia kuehniella* Zeller,

- 1879 (Lepidoptera: Pyralidae). Turk J Entomol. 35: 437–446.
- Batta YA, Kavallieratos NG. 2018. The use of entomopathogenic fungi for the control of stored-grain insects. Int J Pest Manag. 64(1):77–87.
- Bedi SS, Singh M. 1992. Microwaves for control of stored grain insects. Nat Acad Sci Lett. 15:195–197.
- Gallawa JC. 2000. The complete microwave oven handbook: operation, maintenance, troubleshooting and repair. London (UK): Pearson College Division Publisher.
- Gasemzadeh S, Deji OF, Jayas DS, White NDG. 2010. Effect of microwave radiation and cold storage on *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae) and *Sitophilus oryzae* L. (Coleoptera: Curculionidae). J Stored Prod Res. 50:140–145.
- Haff RP, Slaughter DC. 2004. Real-time X-ray inspection of wheat for infestation by the granary weevil, *Sitophilus granarius* (L). Trans ASAE. 47:531–537.
- Halverson SL, Burkholder WE, Bigelow TS, Nordheim EV, Misenheimer ME. 1996. High-power microwave radiation as an alternative insect control method for stored products. J Econ Entomol. 89(6):1638–1648.
- Hassan A, Horsten DV, Lucke W. 2010. Application of microwave energy to control maize weevil (*Sitophilus zeamais*) in maize grains (*Zea mays*). In: Tielkes E, editor. World food system – a contribution from Europe. Proceedings of Tropentag; Zurich Switzerland, Sept 14–16. p. 374.
- Kirkpatrick RL, Brower JH, Tilton EW. 1972. A comparison of microwave and infrared radiation to control rice weevils (Coleoptera: Curculionidae) in wheat. J Kansas Entomol Soc. 45:434–438.
- Longstaff BC. 1981. Biology of the grain pest species of the genus *Sitophilus* (Coleoptera: Curculionidae: a critical review. Prot Ecol. 3:83–130.
- Massa R, Caprio E, De Santis M, Griffio R, Migliore MD, Panariello G, Pinchera D, Spigno P. 2011. Microwave treatment for pest control: the case of *Rhynchophorus ferrugineus* in *Phoenix canariensis*. EPPO Bull. 41(2): 128–135.
- Nelson SO. 1996. A review and assessment of radio-frequency and microwave energy for stored-grain insect control. Trans ASABE. 39:281–289.
- Obeng-Ofori D, Reichmuth C. 1999. Plant oils as potentiation agents of monoterpenes for protection of stored grains against damage by stored product beetle pests. Int J Pest Manag. 45(2):155–159.
- Purohit P, Jayas DS, Yadav BK, Chelladurai V, Fields PG, White NDG. 2013. Microwaves to control *Callosobruchus maculatus* in stored mung bean (*Vigna radiata*). J Stored Prod Res. 53:19–22.
- Reddy MVB, Raghavan GSV, Kushalappa AC, Paulitz TC. 1998. Effect of microwave treatment on quality of wheat seeds infected with *Fusarium graminearum*. J Agric Eng Res. 71(2):113–117.
- Shayesteh N, Barthakur NN. 1996. Mortality and behaviour of two stored-product insect species during microwave irradiation. J Stored Prod Res. 32(3):239–246.
- Stejskal V, Kucerova Z. 1996. The effect of grain size on the biology of *Sitophilus granarius* L (Col, Curculionidae). 1. Oviposition, distribution of eggs and adult emergence. J Appl Entomol. 120(1-5):143–146.
- Tilton EW, Vardell HH. 1982. An evaluation of a pilot-plant microwave vacuum drying unit for stored-product insect control (*Rhyzopertha dominica*, *Sitophilus oryzae*). J Georgia Entomol Soc. 17:133–138.
- Upadhyay RK, Ahmad S. 2011. Management strategies for control of stored grain insect pests in farmer stores and public ware houses. World J Agric Sci. 7:527–549.
- Vadivambal R. 2009. Disinfestation of stored grain insects using microwave energy. [accessed 2018 August 28]. <https://mspace.lib.umanitoba.ca/handle/1993/3152>.
- Vadivambal R, Deji OF, Jayas DS, White NDG. 2010. Disinfestation of stored corn using microwave energy. Agric Biol J North Am. 1:18–26.
- Vadivambal R, Jayas DS, White NDG. 2008. Mortality of stored-grain insects exposed to microwave energy. Trans ASABE. 51:641–647.
- Watters FL. 1976. Microwave radiation for control of *Tribolium confusum* in wheat and flour. J Stored Prod Res. 12(1):19–25.
- Zettler JL, Arthur FH. 2000. Chemical control of stored product insects with fumigants and residual treatments. Crop Prot. 19(8–10):577–582.
- Zhao S, Qiu C, Xiong S, Cheng X. 2007. A thermal lethal mode of rice weevils subjected to microwave irradiation. J Stored Prod Res. 43(4):430–434.