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RESEARCH ARTICLE

Influence of Temperature and Microwave Radiation on the Lesser Grain Borer, Rhyzopertha dominica (F.) (Coleoptera: Bostrychidae)

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Abstract: The effect of high and low temperature and microwave radiation on the adult of the lesser grain borer, Rhyzopertha dominica (F.) infested wheat seeds was studied. At high temperature (55°C), 29% of the death occurred after 30 minutes and the complete death occurred after 60 minutes. The lethal time of 50% mortality (LT50) and lethal time of 90% mortality (LT90) values were 36.96 and 63.4 minutes. Cold temperature (-7°C) caused 12% mortality after 20 minutes and complete succumb was obtained after 75 minutes. The LT50 and LT90 values were 38.6 and 71.3 minutes. Microwave at power of 2450 MHZ caused 33% mortality after 10 seconds and 100% mortality after 35 seconds. The LT50 and LT90 values on this power were 12.8 and 26.3 seconds. The mean germination rate of wheat seeds was 5% for microwave treatment (2450 MHZ, 30 seconds). However, 70% germination rate was achieved when the seeds were exposed to low temperature (-7°C, 3 months), and 77.5% when high temperature (55°C, 60 minutes) were used. In conclusion, the present study showed that, cold temperature (-7°c), high temperature (55°c), and microwave radiation had been successfully controlled R. dominica in a short period of time, however, microwave radiation had adverse effects on the germination of wheat seeds. Radiation seeds should therefore not be used in planting.

Keywords: Rhyzopertha dominica, radiation, wheat insect, control.

Introduction

Wheat is an important agricultural crop in the world, grown commercially on all continents worldwide. In 2011, wheat production amounted to about 694 million tons (Taylor and Koo, 2012). The lesser grain borer, Rhyzopertha dominica (F.) (Coleoptera: Bostrichidae) extensively attacks a wide range of stored seeds in a warm climate (Box et al., 1978). The insect destroys stored grains and cereal products.

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The adults and larvae bore into grain seeds and eat the kernel, leaving a hollow husk (Cornell and Khuri, 1987). Various methods were used to control this pest, such as chemical fumigation, and bacteria that play an important role in the control of insect pests in agricultural commodities (Neven, 1998).

Previous reports have shown that mixture of pirimiphos- methyl, permethrin and piperonyl butoxide has been used to fully prevent pest infestation throughout the grain storage period (Montgomery, 2001). To overcome the adverse effects of chemical use on human and domestic animals, there is an urgent need for non-chemical treatments to control stored grain pests. Electromagnetic heat treatment is a new thermal method for post-harvest treatment. This method leaves chemical residues, ensures acceptable quality, and causes minimal environmental impacts (Wang and Tang, 2004; Wang et al., 2002).

Physical control methods, such as low and high temperatures are gaining interest because they are compatible with organic production. Heat disinfestations of grain have been used for many years to control stored product insects (Fields, 1992; Beckett et al., 2007). The objectives of the present study are to evaluate the effect of high and low temperatures in addition to the microwave radiation against the adults of R. dominica, and their effects on germination of wheat-seeds.

Materials and Methods

1. Rearing technique of the insect

Rearing conducted in the laboratory of Plant Protection Researches Faculty of Agriculture Assiut University during September 2018. The stock population of the pest was obtained by collecting the adult individuals from the infested grain wheat. The pest eggs were collected from the stock population, the method of Elek (Elek, 1994) was followed, who used about 30g wheat grains of Seds1 variety with about 50-200 adults of R. dominica put on filter paper in Petri dish (17 cm in diameter). After 48 h, fresh wheat was added to the culture, encouraging egg laying. Then 500g of wheat grains (Seds1 variety) was put in a wide glass jar (2 Kg) covered with parafilm. Then e incubated at constant temperature (30 ± 1°C) and (65 ± 5%) R.H in order to obtain pure stock population of the pest. After 150 days' exposure period, certain experiments were started.

2. Treatment methods

20 individuals of R. dominica adults were reared in Petri dishes (7cm diameter, n=5) each dish (previously sterilized with ethanol 75%) and provided with 20g wheat grains (Seds1 variety). The insects' mortality rate was determined after one hour to ensure the complete death.

2.1. High temperature: The experiment was conducted in the Department of Food Science and Technology. Hot air oven was adjusted at (55°C). Twenty Petri dishes were put in the oven. The percentage of mortality in adult beetles was recorded after 20, 30, 40, and 60 minutes.

2.2. Low temperature: Twenty-five Petri dishes were placed in a deep freezer (-7°C). The mortality percentage was recorded after 20, 30, 40, 60, and 75 minutes of exposure.

2.3. Microwave radiation (2450 MHZ): Forty Petri-dishes (5 dishes/ time interval) were placed in a microwave adjusted at power of 700 W and 2450 MHZ. The mortality of beetle adults was estimated at 10, 12, 15, 18, 20, 25, 30, and 35 seconds following exposure.

3. Seeds germination

The percentages of germination of wheat seeds subjected to the above-mentioned three treatments (55°C/1 h, -7°C for 3 months and microwave radiation, 30 sec.) was determined after planting 8 seeds in each dish (5 replicates), sterilized with ethanol 75%, using a cotton (1cm thickness, 5cm diameter) wetted by 5mL of distilled water and placed on plastic cups with same size. The cups were covered with plastic bags, held at 30°C for 8 days. Then the percentages of wheat seeds germination were recorded in all treatments relative to the control treatment.

4. Statistical analysis:

Five replications were done for determination of mortality and germination rates relative to the control samples in all the experiments. Analysis of variance was used to check the LT50 and LT90 between the all three treatments (low temp.-7°C, high temp. 55°C and microwave radiation at power of 700W), finding the slope and the confidence limits, to determine the maximum and minimum levels, so we use the SPSS program V.20 and using probit analysis.

Results and discussion

1.Effect of high and low temperature on R. dominica adults

Results of the effect of high temperature (55°C) and low temperature (-7°C) on the adults of R. dominica are presented in (Tables 1 & 2). High temperature (55°C) caused 29% mortality in average after 30 minutes' exposure, the mortality percentage was increased as the exposure period increased, and complete kill was achieved after 60 minutes of exposure (Table 1). The LT50 and LT90 values were recorded at 36.96 and 63.4 minutes. The slope value of LTP line of high temperature was relatively high (5.65), indicating homogeneity response of the insect to the effect of high temperature (Table 4).

The effect of cold temperature (-7°C) on the beetle mortality resulted in 12% mortality after 20 minutes' exposure. The percentage of mortality increased by an increase in exposure period to attain 100% mortality after 75 minutes. The LT50 and LT90 values of cold temperature were 38.6 and 71.3 minutes, and the slope value was 4.88 indicating relatively high homogeneity response to cold temperature effect (Table 2).

Comparing the LT50 and LT90 mortality rates of both high and low temperatures for adult insects, high temperatures appear to have had a higher harmful effect than low temperatures. Cold and heat have long been used either to disinfect stored products or to protect products from insect infestation. Insects are killed at extremely high or low temperatures in stored products.

There is a wide variation between insect species in their ability to survive high temperatures. R. dominica is considered one of the most tolerant insect species., there is different tolerability between stored product pests (stages and instars) to survive high or low temperatures. The pupae were found to be the most tolerant heat stage for Lasioderma serricorne (F.) (Fields, 1992; Strang, 1992 and Alder, 2002), whereas Yu (2008) found that egg was the most resistant stage. Hou, L. et al. (2019), investigated the thermal death kinetics of R. dominica adults at temperatures of 48, 50, 52, and 54° C. The results revealed that Complete mortality of R. dominica adults was recorded at 54° C after 5 min. exposure.

The thermal tolerance of R. dominica stages was found to be affected by the grain moisture content. Beckett et al. (1998) found that the LT99.9 value of the most tolerant stage of R. dominica at 9% m.c. ranged from 78.22 min. to 2.49 h between 45 and 53°C., whereas at 12% m.c. it was 96.81 min. to

3.36 h and exposure to 14% m.c. resulted in LT99.9 equals 114 min. to 4.14 h. In general, there is a wide range in temperature tolerance between pest species, stage and instar, exposure period, and the grain moisture content.

2.Effect of microwave radiation on R. dominica adults

Data presented in Table 3 showed the mortality percentage of R. dominica adults after exposure to microwave radiation at the power of 2450 MHZ at different time intervals (10-35 sec.). The average percentage of mortality was determined to be 33% after 10 sec. which was increased gradually by an increase in exposure time to attain 100% after 35sec.The LT50 and LT90 values of microwave radiation were recorded at 12.8 and 26.3 sec. The slope value of LTP line equals 4.2 indicating the relatively high homogeneity response to microwave radiation.

Microwaves may be an alternate to chemical methods of killing grain insects as their application do not leave any undesirable residues and thus may be very effective for controlling insect pest compared to other available methods. Microwave disinfestation may provide a continuous process to enable large quantities of products to pass through a shorter period. Microwave is also considered a safe and competitive alternative to fumigation, as it circumvents environmental pollution (Yadav et al., 2014). Vadivambal et al. (2008) investigated the influence of certain microwave energy on Tribolium castaneum Herbst, Cryptolestes ferrugineus Stephen and Sitophilus granarius Linnaeus, and found that the complete kill for three species was recorded at 500W for an exposure time of 28 sec. in barley and rye. However, exposure of Ephestia kuehniella Zeller larvae to microwave radiation at power of 70W for 50 sec. resulted in a complete mortality (Pandir and Guven, 2014). Moreover, Al-Akhdar et al. (2019) recorded complete reduction in R. dominica adults after microwave exposure at medium power for 4 min.

The influence of microwave radiation on the physical, chemical, and baking characteristics of dried wheat has been previously studied by many scientists. Macarthur and d'Appolonia (1979) reported that high levels of microwave radiation on flour resulted in abnormal farino-graph curve with two peaks, while low levels produced bread with loaf volumes and over all bread characteristics equal to or better than those of the control flour. On the other hand, Campana et al. (1993) and Walde et al. (2002) stated that the protein content was not changed but that the functionality of gluten was gradually altered with an increase in exposure time. However, Kaasova et al. (2002) found an enhancement in the quality of baking at higher energy doses. On contrary to the previous findings, Vadivambal et al. (2007) concluded that there were no significant differences in either the quality of grain protein, flour protein, flour yield, flour ash, and loaf volume of the wheat subjected to microwave energy.

3. Effect of high and low temperature and microwave radiation on the germination of wheat seeds.

Data demonstrated in Table 5 show the percentage of germination of wheat seeds subjected to cold temperature (-7°C) for 3 months, high temperature (55°C) for 60 minutes, and microwave radiation at power of 2450 MHZ for 30 sec. After 8 days of planting, the average percentage of seed germination was 5%, 75% and 77.5% in microwave, cold temperature, and high temperature treatments, respectively.

However, the percentage of germination in control grain was averaged of 77.5%. It might be concluded that microwave at power of 2450 MHZ had an adverse effect on seed germination, but cold and high temperature did not affect germination. These results agree with those obtained by Vadivambal et al. (2008) who reported that the germination of barley and rye exposed to microwave energy were significantly reduced as the power level or exposure time were increased. Also, Campana et al. (1993) concluded that germination capacity was decreased by exposure to microwave energy, and this was related to the final temperature and the initial moisture content of the grain.

According to the present results, cold (-7°c), high temperature (55°c) and microwave radiation at power of 2450 MHZ successfully controlled R. dominica adults in short period, but microwave radiation expressed adverse effect on wheat seeds germination so, radiation seeds should not be used for planting.

Table (1): The effect of high temperature (55°C) on *R. dominica* adults

Exposure period per minutes	% Mortality in Replicate					Mean % ± SE
30	35	30	20	25	35	29 ± 0.03
40	55	50	40	60	50	51 ± 0.03
50	80	90	85	80	75	82 ± 0.025
60	100	100	100	100	100	100 ± 0.0
Control	0	0	0	0	0	0

Table (2): The effect of low temperature (-7°C) on *R. dominica* adults

Exposure period per minutes	% Mortality in Replicate					Mean % ± SE
20	10	5	15	15	15	12 ± 0.02
30	20	30	35	30	35	30 ± 0.03
40	50	55	50	45	50	50 ± 0.02
60	75	80	65	70	75	73 ± 0.03
75	100	100	100	100	100	100 ± 0.0
Control	0	0	0	0	0	0

Table (3): The effect of Microwave radiation at power (2450 MHZ) on *R. dominica* adults

Exposure period per sec.	% Mortality in the five replicates					Mean % ± SE
10	25	35	35	40	30	33 ± 0.025
12	50	55	45	55	50	51 ± 0.020
15	60	55	70	55	50	58 ± 0.030
18	70	65	80	70	75	72 ± 0.025
20	75	65	85	70	80	75 ± 0.035
25	90	90	95	85	85	89 ± 0.020
30	100	95	95	85	95	94 ± 0.020
35	100	100	100	100	100	100 ± 0.0
Control	0	0	0	0	0	0

Table (4): The LT_{50}, and LT_{90} and their confidence limits and slope values for high and low temperatures, and microwave tested against *R. dominica* adults.

Treatments	LT_{50}	Confidence limit		LT_{90}	Confidence limit		Slope ± SE
		Lower	Upper		Lower	Upper	
Microwave (sec.)	12.8 ± 0.3	10.7 ± 0.4	14.4 ± 0.2	26.3 ± 1.1	22.6 ± 0.7	34.3 ± 2.8	4.2 ± 0.3
Heating (55° C)	36.9 ± 0.4	34.4 ± 0.5	39.4 ± 0.5	63.4 ± 3.8	55.7 ± 2.1	81.0 ± 9.4	5.7 ± 0.5
Cooling (-7° C)	38.6 ± 0.5	27.5 ± 1.5	52.8 ± 2.8	71.3 ± 2.3	52.6 ± 0.2	268.5 ± 84.7	4.9 ± 0.3

Table (5): The effect of high and low temperatures and microwave power on the germination of wheat grains.

Treatment	Mean germination percentage ± SE							
	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8
2450 MHZ (30 sec.)	_	_	_	2.5 ± 2.2	2.5 ± 2	5 ± 2.7	5 ± 2.7	5 ± 2.7
-7°c (3 onhs)	_	5 ± 2.3	7.5 ± 2.7	27.5 ± 2.2	40 ± 2.2	52.5 ± 4.2	70 ± 4.5	75±3.5
55°c (60 in.)	7.5 ± 3.06	22.5 ± 2.5	30 ± 3.06	42.5 ± 5	52.5 ± 2.5	70 ± 6.4	77.5 ± 4.7	77.5 ± 4. 7
Control	7.5 ± 3.06	22.5 ± 2.5	32.5 ± 3.1	45 ± 3.06	52.5 ± 4.7	67.5 ± 6.4	77.5 ± 4.7	77.5 ±4 .7

References

Adler, C. (2002) 'Efficacy of high temperatures to control Lasioderma serricorne and Rhyzopertha dominica' *IOBC WPRS BULLETIN, 25 (3), pp.199 - 203.*

Al-Akhdar, H., Rasha H., Zinhoum A. and Nilly, A. Abdelfattah H., (2019) 'Microwave energy as an alternative control method for stored grain pests'. *Egyptian Journal of Plant Protection Research Institute, 2(4), 612-621.*

Beckett, S.J., Morton, R. and Darby, J.A. (1998) ‘The mortality of Rhyzopertha dominica (F.) (Coleoptera: Bostrychidae) and Sitophilus oryzae (L.) (Coleoptera: Curculionidae) at moderate temperatures’ *Journal of Stored Products Research, 34(4), 363-376.*

Beckett, S.J., Fields, P.G. and Subramanyam, B.H. (2007) ‘Disinfestation of stored products and associated structures using heat. Heat treatments for postharvest pest control: theory and practice’ *CAB International, Oxon, United Kingdom, 182-236.*

Box, G.E., Hunter, W.G. and Hunter, J.S. (1978) ‘Statistics for experimenters’ *New York: John Wiley and Sons. (Vol. 664).*

Campana, L.E., Sempe, M.E. and Filgueria, R.R. (1993) ‘Physical, chemical, and baking properties of wheat dried with microwave energy’ *Cereal Chemistry, 70(6), 760-762.*

Cornell, J.A. and Khuri, A.I. (1987) Response surfaces: designs and analyses. *Marcel Dekker, Inc.*

Elek, J.A. (1994) ‘Methods for collecting eggs and monitoring egg-hatch and immature development of Rhyzopertha dominica (F.) (Coleoptera: Bostrichidae)’ *Journal of Stored Products Research, 30(4), 261-265.*

Fields, P.G. (1992) ‘The control of stored product insects and mites with extreme temperatures’ *Journal of Stored Products Research, 28(2) 89-118*.

Hou, L., Wu, Y. and Wang, S. (2019). ‘Thermal death kinetics of Cryptolestes pusillus (Schonherr), Rhyzopertha dominica (Fabricius), and Tribolium confusum (Jacquelin du Val) using a heating block system’ *Insects, 10 (5), 119*.

Kaasova, J., Hubackova, B., Kadlec, P., Prihoda, J. and Bubnik, Z. (2002) ‘Chemical and biochemical changes during microwave treatment of wheat’ *Czech Journal of Food Science, 20(2), 74–78.*

Macarthur, L.A. and Appolonia, B.L. (1979) ‘Effects of microwave radiation and storage on hard red spring wheat flour’ *Cereal Chemistry, 58(1), 53-56.*

Montgomery, D.C. (2001) ‘Design and analysis of experiments’ *Fifth Edition. By John Wiley & Sons. Inc. All rights reserved*.

Neven, L.G. (1998) ‘Effects of heating rate on the mortality of fifth-instar codling moth (Lepidoptera: Tortricidae)’ *Journal of Economic Entomology, 91(1), 297-301.*

Pandir, D. and Guven, E. (2014) ‘Effect of microwave radiation on stored product pest Ephestia kuehniella Zeller (Lepidoptera: Pyralidae) larvae’ *Turk. Entomol. Derg. Tu, 38, 135-142.*

Strang, T.J. (1992) ‘A review of published temperatures for the control of pest insects in museums’ *Collection Forum 8(2). 41- 67.*

Taylor, R.D. and Koo, W.W. (2012) ‘Outlook of the U.S. and World Wheat Industries, 2012-2021’ *Agribusiness and Applied Economics Report No. 696.*

Vadivambal, R., Jayas, D.S. and White, N. D.G. (2007) ‘Wheat disinfestation using microwave energy’ *Journal of Stored Products Research, 43(4), 508-514.*

Vadivambal, R., Jayas, D.S. and White, N.D. (2008) ‘Mortality of stored-grain insects exposed to microwave energy’ *Transactions of the ASABE, 51(2), 641-647.*

Walde, S.G., Balaswamy, K., Velu, V. and Rao, D.G. (2002) 'Microwave drying and grinding characteristics of wheat (Triticum aestivum)' *Journal of Food Engineering 55(3), 271-276.*

Wang, S., and Tang, J. (2004) 'Radio frequency post-harvest quarantine and phytosanitary treatments to control insect pest in fruits and nuts' *In Production Practices and Quality Assessment of Food Crops (pp. 17-53). Springer, Dordrecht.*

Wang, S., Ikediala, J.N., Tang, J. and Hansen, J.D. (2002) 'Thermal death kinetics and heating rate effects for fifth instar Cydia pomonella (L.) (Lepidoptera: Tortricidae)' *Journal of Stored Products Research, 38(5), 441-453.*

Yadav, D.N., Anand, T., Sharma, M. and Gupta, R. K. (2014) 'Microwave technology for disinfestation of cereals and pulses: An overview' *Journal of Food Science and Technology, 51(12), 3568-3576.*

Yu, C. (2008) 'Susceptibility of Lasioderma serricorne (F.) life stages exposed to elevated temperatures' *M.S. Thesis, Kansas State University, Manhattan.*