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The Impact of Microwave Irradiation and Cold Storage on *Lasioderma serricorne* (F.) (Col. Anobiidae)

Orouj Valizadegan, Ali Asghr Pourmirza and Mohammad Hassan Safaralizadeh
Department of Entomology, Faculty of Agriculture, Urmia University,
P.O. Box 57135-165, Urmia, Iran

Abstract: The impact of microwave irradiation and cold storage against adults of cigarette beetle, *Lasioderma serricorne* (F.), over various exposure times and cold storage periods was evaluated. The insects were exposed to 2450 MHz at 5 different power levels of 0, 100, 200, 300 and 400 W for 5 exposure times of 0, 3, 6, 9 and 12 min. A complete mortality was achieved for tested insect at 400 W power levels for exposure time of 12 min and 72 h cold storage period. In all experiments, a direct positive relationship between mortality rates and microwaves irradiation power level was obtained. For instance at 100, 200, 300 and 400 W power levels and 24 h cold storage for 3 min exposure period, the mortality rates were 40, 50, 55 and 72%, respectively. Similar trend was obtained for LT_{50} values. Considerable variation in the susceptibility of tested insect to microwaves power levels and cold storage periods was apparent in the fiducial limits of the LD_{50} values. In the Analysis of Variance (ANOVA), the R^2 value revealed that 90.8% of variability in the susceptibility of *L. serricorne* could be explained by the microwaves power, cold storage period and exposure duration. Combinations of microwaves irradiation and cold storage were found highly compatible and synergistic. This was more significant for the insects, which were exposed to the highest level of microwaves irradiation and cold storage period. Synergistic interaction indicates that microwaves irradiation can be used with cold storage for management of *L. serricorne* populations. This treatment could provide an effective and friendly environmental treatment technique in IPM program.

Key words: Temperature manipulation, cigarette beetle, bioassay, synergism, exposure period, cold storage

INTRODUCTION

Control of stored products pests has been one of the major tasks for conservators because the damage inflicted to foodstuff is irreversible. A number of insect species pose a potential threat to a variety of stored-products. *L. serricorn*e has a widespread distribution worldwide. This species is recognized as a cosmopolitan pest attacking stored-products and cause serious losses both in quantity through feeding damage and quality by contaminating the product with cast skin and frass (Papadopoulou and Buchelos, 2002).

Fumigants are commonly applied for control of stored-products pests. Two of the commonly used fumigants are methyl bromide and phosphine. Methyl bromide is now under threat of withdrawal because it apparently depletes the Earth's ozone layer (Leesch *et al*., 2000). Phosphine has been used in a variety of habitats for a long time (Rajendran and Muralidharan, 2001). Conventional use of phosphine has been frequent failure to control insects and certain insects have developed resistance to phosphine (Bell and Wilson, 1995). Moreover, concerns about the further development of resistance to phosphine have made the search for new alternatives imperative.

Any compound that can reduce the insecticide load in a particular storehouse with adequate effectiveness to control insects may be of outmost importance in stored-product insect control programs. The main challenge is now for alternative substances and methods, which are inexpensive, convenient to use and without substantial disruption of the environment. According to these criteria, physical control methods could be of paramount importance. Some physical control methods such as microwaves energy and temperature manipulation have been used for treatment alone earlier (Johnson *et al*., 2003; Wang *et al*., 2003).

Microwaves energy is no persistent in the environment and does not hazardous impacts or damage to foodstuff (Vadivambal *et al*., 2007; Warchalewski *et al*., 2000; Halverson *et al*., 1996). Exposure to microwaves energy could cause physical injuries and reduced reproduction rates in surviving insects. For instance treated larvae may develop into adults with deformed or

Corresponding Author: Orouj Valizadegan, Department of Entomology, Faculty of Agriculture, Urmia University, Urmia, Iran

missing legs and although, surviving insects were capable of reproduction, however, the reproduction rate decreased considerably (Nelson, 1996). Microwaves utilize very high frequencies; this enables rapid heating to be achieved with much lower field intensities (Halverson *et al*., 1996). The penetration depth is an important factor, as the microwaves intensity diminishes with increased penetration. With retrospect, due to limited penetration of microwaves energy into foodstuff mass, it seems likely that employment of microwaves radiation alone could be considered as a promising insect control measure under field conditions.

Insects under microwaves irradiation are prone to some types of stress such as controlled atmosphere and cold ambient (Wang and Tang, 2001). The warehouse environment is usually one that is enclosed, allowing for the manipulation of temperature. Thus, the use of temperature to restrict insect population is an excellent tool for the stored-product industry. Exposure to temperatures only 5°C above the optimum are capable of slowing or stopping insect activity and development and depending on the species are capable of causing death. Exposures to temperatures between 42-50°C for short periods of time have produced over 90% mortality (Field, 1992).

The review of the literature revealed the scarcity of information concern over optimal power levels of microwaves radiation combined with cold storage period in insect killing programs. To clarify the combined impact of these insect control measures the present investigation was undertaken.

MATERIALS AND METHODS

Test insect: *L. serricorne* samples were collected from tobacco stores, in Urmia (37.39°N, 45.4°E), a town in West Azarbijian province (Iran) in 2008. This insect was selected due to its economic and hygiene importance throughout the world including Iran. Stock cultures were established and maintained on wheat flour at 27±2°C, 65±5% Relative Humidity (RH) and 14 h photoperiod in wide-mounted glass jars covered with pieces of muslin cloth fixed by rubber bands. All insects were cultured under moderately crowded conditions to ensure proper development of the resultant insects. Insects were reared for two generations before initiation of experiments.

Preparation of insects for experiments: Before each treatment run, using a fine sable brush mixed sex of 7 days old adult insects was counted out in batches of 60 on to Petri-dishes containing 20 g of rearing medium.

Bioassays: The bioassay experiments using microwaves power and cold storage duration (alone and in combination) were conducted. The experiment units and bioassay procedures were identical in all trials. Preliminary power level tests were carried out prior to each experiment to determine a range of power that would produce ≈25-75% mortality at the lowest and the highest levels, respectively (Robertson *et al*., 2007). In each experiment, after termination of cold storage duration insects were allowed to recover on their usual media under rearing conditions. In each bioassay, mortality was recorded after exposure to cold storage and recovery period. Those insects that did not move when lightly probed or shaken in the light and mild heat were considered dead.

To commence microwaves irradiation each Petri-dish containing 60 insects and 20 g of rearing medium was placed in an appropriate adjustable kitchen type, microwaves oven with capability of producing 100 through 1000 W microwaves power. For microwaves radiation 5 power outputs of generator was set at 0, 100, 200, 300 and 400 W. The exposure times were 0, 3, 6, 9 and 12 min. The LD_{50} values were estimated at different post treatment times. Then in identical trials at the termination of treatment, the samples along with their respective control group were maintained under cold storage conditions (4±1°C) for 0, 24, 48 and 72 h. In each trial, the control Petri-dish was treated identically except that no microwaves radiation and cold storage treatment was employed. At the termination of cold storage period, insects were transferred to clean jars containing rearing medium and maintained under rearing conditions. After 24 h of incubation, the data were recorded in term of the number of live and dead adults. Each test was replicated 3 times. Mortality data from the replicates were pooled and mortality response was determined. In order to evaluate, the combinations effect of the microwaves power and cold storage, the estimated LD's of either agent were separately combined and employed in trials. The bioassays were conducted at 25±2°C, Relative Humidity (RH) 65±5% and 14 h photoperiod.

Data analysis: The median Lethal Dosage (LD_{50}) and LD_{95} of microwaves radiation and LT_{50} values was estimated by subjecting mortality data to the maximum likelihood program of probit analysis (Robertson *et al*., 2007) using SPSS software. This program has a provision for control mortality. Two insects group were considered significantly different in their susceptibility to microwaves radiation and cold storage if fiducial limits (95%) of LD_{50} of either treatment did not overlap. The Synergistic Ratio (SR) of each combination was calculated by the following equation:

$$\text{Synergistic ratio} = \frac{\text{LD's of the microwaves radiation}}{\text{LD's of the mixture(microwaves radiation + cold storage duration)}}$$

The synergistic, antagonistic and additive effect was calculated according to this equation. The value of joint action ratio >1.05 will indicate synergism and between 0 and 0.95, the antagonistic action and those between 0.95 and 1.05 will indicate additive effect. Mortality data were normalized by an arc-square-root transformation, analyzed by a one-way ANOVA through factorial trial and followed by Tukey's test to compare differences among the various treatments at the $\alpha = 0.05$ level.

RESULTS

Lethality of microwave energy, cold storage and exposure period: Dosage-mortality values estimated from the probit analyses of different insect groups are given in Table 1 through 5. Table 1-5 show that in all experiments microwaves power showed lethal effects to the tested insects. In some cases, considerable overlap in 95% fiducial limits of regression lines was obtained (Table 1-5). Therefore, no statistically significant difference between the estimated LD_{50} values was secured. Treatment of cold storage alone on average caused negligible mortality (3.2%) only 1% more than control group. The lethality of microwaves radiation enhanced greatly at higher power level and an inverse relationship between microwaves power level and estimated LT_{50} values in a given cold storage period was obtained (Table 6). This effect was more striking at the highest level of either treatment. Almost always the combined effect of microwaves radiation and cold storage period was synergistic. This effect was more pronounced at the highest period of cold storage (Table 2-5). Analysis of variance revealed that the main effect of microwaves radiation level, exposure time and cold storage period was highly significant (Table 7). Therefore, there was a significant difference between evels of these treatments. For instance mortalities at 100 and 400 W power levels for *L. serricorne* at a given cold storage period and exposure time were significantly different. Similar conclusions from separation of means were secured in the case of cold storage and exposure period. All interactions among microwaves radiation level, exposure period and cold storage duration was highly significant (Table 7). Table 7 display that interactions involving 2 factors, for example power level with cold storage period and interaction 3 factors (power level×cold storage period×exposure time) are highly significant. The significant interaction indicates that the factors are not independent; the difference between simple effects of microwaves power level for different levels of cold storage is significant, conversely, the difference in simple effects of cold storage at the different levels of microwave power is significant. Thus, any simple effect is dependent upon the level of the other factor in the experiment.

Table 1: LD_{50} and LD_{95} values of microwaves power (W) at different irradiation periods and post treatment times on *Lasioderma serricorne* adults

Min.	h	LD_{50}	LD_{95}
	24	452.2 (334-928)	10171 (2896-382263)
3	48	391.7 (269-1414)	1337 (2542-38030)
	72	235.2 (137-836)	7776 (1430-355100)
Mean	-	360	-
	24	182.6 (151-213)	1300 (843-2855)
6	48	128.6 (76-168)	1260 (606-13634)
	72	123.5 (31-192)	960 (386-644100)
Mean	-	145	-
	24	139.9 (114-161)	682 (522-1051)
9	48	117.6 (81-147)	555 (338-2374)
	72	92.6 (1-133)	441 (220-45467)
Mean	-	116.7	-
	24	104.9 (75-128)	678 (495-1183)
12	48	113.8 (55-146)	795 (435-8110)
	72	81.8•	870•
Mean	-	100.1	-

•The fiducial limits could not be calculated with reasonable accuracy

Table 2: Summery of regression of probit analysis of *Lasioderma serricorne* exposed to microwaves radiation for 3 min

Treatments	LD_{50}	LD_{95}	Slope	SR[a]	Type of action
Cold storage[b]					
Power	360	-	-	-	-
Power + 24 h cold storage	305.8 (220.4-629.2)	4851 (1418-202357)	1.73	1.17	Synergism
Power + 48 h cold storage	245.9 (182.2-298.9)	3646•	1.41	1.46	Synergism
Power + 72 h cold storage	170.2•	22510•	0.78	2.11	Synergism

[a]SR = Synergistic Ratio; [b]Treatment of cold storage alone caused 1% more mortality compared to control group after 72 h; •The fiducial limits could not be calculated with reasonable accuracy

Table 3: Summery of regression of probit analysis of *Lasioderma serricorne* exposed to microwaves radiation for 6 min

Treatments	LD_{50}	LD_{95}	Slope	SR[a]	Type of action
Cold storage[b]					
Power	145	-	-	-	-
Power + 24 h cold storage	149 (129.2-184.5)	475 (381.9-690.2)	3.46	0.97	Additive
Power + 48 h cold storage	127.7 (101.8-149.2)	356.2 (294.2-484.8)	3.69	1.13	Synergism
Power + 72 h cold storage	118.3 (0.31-185.0)	309.4 (195.9-1697506)	3.94	1.22	Synergism

[a]SR = Synergistic Ratio; [b]Treatment of cold storage alone caused 1% more mortality compared to control group after 72 h

Table 4: Summery of regression of probit analysis of *Lasioderma serricorne* exposed to microwaves radiation for 9 min

Treatments	LD_{50}	LD_{95}	Slope	SR[a]	Type of action
Cold storage[b]					
Power	117	-	-	-	-
Power + 24 h cold storage	112.1 (90.8-129.7)	263.6 (223-342.7)	4.43	1.04	Additive
Power + 48 h cold storage	102.1 (78.31-120.9)	265.0 (221.2-355.9)	3.97	1.14	Synergism
Power + 72 h cold storage	80.9 (51.5-102.8)	257.2 (209.0-370.4)	3.28	1.44	Synergism

[a]SR = Synergistic Ratio; [b]Treatment of cold storage alone caused 1% more mortality compared to control group after 72 h

Table 5: Summery of regression of probit analysis of *Lasioderma serricorne* exposed to microwaves radiation for 12 min

Treatments	LD_{50}	LD_{95}	Slope	SR[a]	Type of action
Cold storage[b]					
Power	100	-	-	-	-
Power + 24 h cold storage	92.8 (57.9-101.9)	142.9 (120.9-655.9)	6.8	1.07	Synergism
Power + 48 h cold storage	76.0 (48.1-93.3)	176.5 (147.2-254.9)	4.5	1.31	Synergism
Power + 72 h cold storage	79.1 (43.35-93.07)	147.7 (124.7-281.1)	6.1	1.26	Synergism

[a]SR = Synergistic Ratio; [b]Treatment of cold storage alone caused 1% more mortality compared to control group after 72 h

Table 6: LT_{50} values (min) for *Lasioderma serricorne* exposed to microwaves radiation and cold storage

	Power (W)			
Cold storage (h)	100	200	300	400
24	8.07 (5.74-13.81)	4.23 (0.14-6.63)	4.01(0.44-6.16)	3.56 (291-376)
48	5.46 (3.28-7.33)	3.85 (2.84-4.65)	3.09 (2.58-3.50)	3.05 (261-4.36)
72	4.37 (2.02-5.98)	2.94 (1.93-3.72)	2.86 (2.23-3.35)	•

•The LT_{50} value could not be calculated with reasonable accuracy

Table 7: Significance levels for ANOVA on mortality of *Lasioderma serricorne* exposed to microwaves radiation, cold storage at different exposure periods

Source	df	F	Sig.
Corrected model[a]	63	22.5	0.00
Intercept	1	15892	0.00
Microwave power level	3	178.5	0.00
Cold storage period	3	152.2	0.00
Exposure time	3	13.7	0.00
Microwave power level x cold storage	9	8.2	0.00
Microwaves power x exposure time	9	5.5	0.00
Cold storage period x exposure time	9	4.9	0.00
Microwave power x cold storage x exposure time	27	5.2	0.00
Error	128	-	-
Total	192	-	-
Corrected total	191	-	-

[a]R^2 = 88% (adjusted R^2 = 83%)

The significant interaction of 3 factors implies that the power level with cold storage period interaction differs with the level of exposure period. The adjusted R^2-value revealed that 84% of variability in the susceptibility of *L. serricorne* could be explained by the microwaves power, cold storage duration and exposure period. Moreover, R^2-value revealed that the analysis of variance as a statistical model does fit the data well.

Synergistic effect between microwaves energy, cold storage and exposure period: At the 12 min exposure period, microwaves energy in combination with cold storage produced the highest synergistic effect (Table 4). However, at the 3 min exposure time with combined effect of microwaves power at 24 h cold storage period, only an additive type of action was secured (Table 1). Therefore, to obtain the best synergistic effect prolongation of cold storage period is imperative. From Table 1 through 4, it could be concluded that a direct relationship between exposure period and synergistic effect do exist. The synergistic ratio at 3, 6, 9 and 12 min exposure time combined with 72 h cold storage period was 1.90, 2.28, 2.68 and 2.83, respectively (Table 1-4).

DISCUSSION

Stored products insects cause numerous quality and health issues. Because of this, international organizations such as FDA (1997) and FGIS (1999) set tolerances and grade standards regulating the number of insects and insect fragments above specified tolerances make the product illegal for human consumption. The cigarette beetle (*L. serricorne*) is a cosmopolitan and destructive invader of foodstuff. Control of stored-products pest insects is essential wherever, foodstuffs quality is to be maintained.

One of the most successful methods of rapidly controlling insect's, infesting stored-products is fumigation. A good fumigant should have some characteristics consistent with the fumigation protocol, which ensures an appropriate level of insect control and produces the minimum of hazardous side effects. Unfortunately, the two available fumigants, methyl bromide and phosphine, fall short of this ideal (Collins *et al*., 2002).

A new approach in insect control research could be the use of less hazardous substances or control methods, which are more compatible with environment. Method for the control strategies that are environmentally sustainable and avoid the use of conventional pesticide is of paramount important. Disinfestations of stored-products with physical control methods such as using microwaves

energy coupled with cold storage treatment can be an alternative measure to pesticides in killing insects, but little attention has been paid to this theme earlier.

In the current study, microwaves radiation was lethal to test insect. The mechanisms involved in the lethal action of microwaves radiation are previously understood. The hazardous impacts could be due to the high frequency oscillation of the water molecules in the body of the insects. Microwave radiation has deleterious effects on insects such as reduction of reproductive rate, losing body weight and malformation as well (Nelson, 1996). However, application of microwaves radiation in insect killing programs could be limited due to insufficient penetration depth. Zhu *et al.* (1995) reported that microwaves attenuate exponentially in penetration to foodstuffs.

Cold storage can affect the insects in various ways. Ayvaz and Karabörklü (2008) reported that reproductive ability and number of living adults of *Ephestia kuehniella* decreased depending on the length of the cold storage period. Similar results have been reported for the other insects (Johnson *et al*., 1997; Özder, 2004; Larentzaki *et al*., 2007).

The major advantage of cold storage is that it can easily be coupled with other method of pest control measures, such as microwaves radiation. In general, the reduction of temperature in the environment stresses the insect (Ikediala *et al*., 1999), thereby making it more susceptible to other control measures (Wang and Tang, 2001). Almost in all trials there was sufficient indication that longer microwaves energy exposure and cold storage duration could achieve better kill than shorter ones of similar power level. From this point of view, results were in agreement with the findings of Neven (1994), who studied the combined effects of heat treatment and cold storage on mortality of fifth-instar codling moth.

A number of scholars argue that a good control agent must kill the target insect with acceptable level of the agent in a short period of time. Since, microwaves power combined with cold storage is lethal to the stored-products insects and because methyl bromide may not be available for use as a fumigant in immediate future, combined application of microwaves power with cold storage treatment could be considered as a potential measure, which helps to reduce stored-products insect's populations in IPM programs.

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REFERENCES

Ayvaz, A. and S. Karabörklü, 2008. Effect of cold storage and different diets on *Ephestia kuehniella* Zeller (Lep.: Pyralidae). J. Pest Sci., 81: 57-62. http://www.springerlink.com/content/w55846441563602j.

Bell, C.H. and S.M. Wilson, 1995. Phosphine tolerance and resistance in *Trogoderma granarium* Everts (Coleoptera: Dermestidae). J. Stored Prod. Res., 31: 199-205. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T8Y-3YMFW44-J&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=20f57c64a6b3808348a09bd4afcdb50b.

Collins, P.J., G.J. Daglish, M. Bengston, T.M. Lambkin and H. Pavic, 2002. Genetics of resistance to phosphine in *Rhyzopertha dominica*. J. Econ. Entomol., 95: 862-869. http://www.bioone.org/perlserv/?request=get-abstract&doi=10.1603%2F00220493(2002)095% 5B0862%3AGORTPI%5D2.0.CO%3B2&ct=1.

FDA (Food and Drug Administration), 1997. Wheat flour-adulteration with insect fragments and rodent hairs (CPG 7104.06). Compliance policy guides manual, chapter 5, Foods, Color and Cosmetics, Sub Chapter 578-processed Grain. http://www.fda.gov/ora/compliance_ref/cpg/cpgfod/cpg578-450.htm.

FGIS (Federal Grain Inspection Service), 1999. Official United States standards for grain subpart M: United States Standards for Wheat. www.usda.gov/gipsa/reference-library/standards/810101.pdf.

Field, P.G., 1992. The control of stored-product insects and mites with extreme temperatures. J. Stored Prod. Res., 28: 89-118. http://home.cc.umanitoba.ca/~fieldspg/fields/cold-rev.pdf.

Halverson, S.L., W.E. Burkholder, T.S. Bigelow, E.V. Nordheim and M.E. Misenheimer, 1996. High power microwaves radiation as an alternative insect control method for stored products. J. Econ. Entomol., 89: 1638-1648. http://cat.inist.fr/?aModele=ffficheN&cpsidt=2529366.

Ikediala, J.N., J. Tang, L.G. Neven and S.R. Drake, 1999. Quarantine treatment of cherries using 915 MHz microwaves: Temperature mapping, codling moth mortality and fruit quality. Postharvest Biol. Technol., 16: 127-137. http://www.ingentaconnect.com/content/els/09255214/1999/00000016/00000002/art00018;jsessionid=329vsiwbaige3.alice?format=print.

Johnson, J.A., S. Wang and J. Tang, 2003. Thermal death kinetics of fifth-instar *Plodia interpunctella* (Lepidoptera: Pyralidae). J. Econ. Entomol., 96: 519-524. http://www.bioone.org/perlserv/?request=get-abstract&doi=10.1603%2F0 022-0493(2003)096%5B0519%3ATDKOFP%5D2.0.CO%3B2.

Johnson, J.A., K.A. Valero and M.M. Hannel, 1997. Effect of low temperature storage on survival and reproduction of Indian meal moth (Lepidoptera: Pyralidae). Crop Prot., 16: 519-523. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T5T-3RJR1D04&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=c0749ee423e0e00e21bfcdcf2bc59a98.

Larentzaki, E., G. Powell and M.J.W. Copland, 2007. Effects of cold storage on survival, reproduction and development of adults and eggs of *Franklinothrips vespiformis* (Crawford). Biological. Control, 43: 265-270. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6WBP-4PMJK1G-4&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=280eeb3a6aab246405db682cade90f2b.

Leesch, J.G., G.F. Knapp and B.E. Mackey, 2000. Methyl bromide adsorption on activated carbon to control emissions from commodity fumigations. J. Stored Prod. Res., 36: 65-74. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T8Y-3XV298G7&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=fe15ab97940d4d02e55820761c9f4c67.

Nelson, S.O., 1996. Review and assessment of radio-frequency and microwaves energy for stored-grain insect control. Trans. ASAE, 39: 1475-1484. http://cat.inist.fr/?aModele=afficheN&cpsidt=3200466.

Neven, L.G., 1994. Combined heat treatments and cold storage effects on mortality of fifth-instar codling moth (Lep.: Tortricidae). J. Econ. Entomol., 87: 1262-1265. http://www.fao.org/agris/search/display.do?f=./1995/v2125/US9534007.xml;US9534007.

Özder, N., 2004. Effect of different cold storage periods on parasitization performance of *Trichogramma cacoeciae* (Hymenoptera: Trichogrammatidae) on eggs of *Ephestia kuehniella* (Lepidoptera: Pyralidae). Biocontrol Sci. Technol., 14: 441-447. http://www.ingentaconnect.com/content/tandf/cbst/2004/00000014/00000005/art00002.

Papadopoulou, S.C. and C.T. Buchelos, 2002. Comparison of trapping efficacy for *Lasiderma serricorne* (F.) adults with electric, pheromone, food attractant and control-adhesive traps. J. Stored Prod. Res., 38: 375-383. http://cat.inist.fr/?aModele=afficheN&cpsidt=13703882.

Rajendran, S. and N. Muralidharan, 2001. Performance of phosphine in fumigation of bagged paddy rice in indoor and outdoor stores. J. Stored Prod. Res., 37: 351-358. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T8Y-43GPT1T-5&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=ba0f7454983fd78b2b7e5bb1763e8c5a.

Robertson, J.L., R.M. Russell, H.K. Preisler and E. Savin, 2007. Bioassays with arthropods. CRC Press, Boca Ratone, FL. ISBN: 0849323312, 9780849323317.

Vadivambal, R., D.S. Jayas and N.D.G. White, 2007. Wheat disinfestations using microwave energy. J. Stored Prod. Res., 43: 508-514. http://cat.inist.fr/?aModele=afficheN&cpsidt=19037094.

Wang, S. and J. Tang, 2001. Radio frequency and microwaves alternative treatments for insect control in nuts. J. Agric. Eng., 10 (3): 105-120. http://www.wsu.edu/~sjwang/review-rf-insect.pdf.

Wang, S., J. Tang, J.A. Johnson, E. Hassan, G. Hallman, S.R. Drake and Y. Wang, 2003. Dielectric properties of fruits and insect pests as related to radio frequency and microwave treatments. Biosys. Eng., 85: 201-212. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6WXV-48GDXFD-1&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=08f62d43f83e4d62fa706e69e95263f5.

Warchalewski, J.R., A. Pradzynska, J. Gralik and J. Nawrot, 2000. The effect of gamma and microwave irradiation of wheat grain on development parameters of some stored grain pests. Nahrung, 44: 411-414. http://www.ncbi.nlm.nih.gov/pubmed/11190835.

Zhu, S., Y. Zhang and T.R. Marchant, 1995. A DRBEM model for microwave heating problems. Applied Mathematical. Model., 19: 287-304. http://cat.inist.fr/?aModele=afficheN&cpsidt=3524035.