Journal of
Entomology

ISSN 1812-5670

Academic
Journals Inc.

www.academicjournals.com

Journal of Entomology 11 (2): 102-108, 2014
ISSN 1812-5670 / DOI: 10.3923/je.2014.102.108

Effect of Noionizing Electromagnetic Waves on Some Stored Grain Pests

A.A.A. Abdelaal and B.M. El-Dafrawy
Deptartment of Economic Entomology and Agricultural Zoology, Facaulty of Agriculture, Menoufia University, Shebin Elkom, Egypt

Corresponding Author: A.A.A. Abdelaal, Deptartment of Economic Entomology and Agricultural Zoology, Facaulty of Agriculture, Menoufia University, Shebin Elkom, Egypt

ABSTRACT

The current search aimed to use non traditional methods to control stored products pests which attacking stored products specially grain and cause great losses without any changes on contents and quality. A microwave apparatus was tested for capability to detect hidden insects of different sizes and activity levels in stored products. In initial studies, *Bruchidius incarnates* and *Tribolium castaneum* (Herbst) were easily detected. Boxes of broad bean and flour were artificially infested with 30 insects to estimate the reliability of detection. The ratings were significantly correlated with the numbers of infesting insects. The microwave has potential applications in management rapid, nondestructive targeting of incipient insect infestations would be of benefit to the producers and consumers of packaged foods. Insect mortality studies were performed with a high-power microwave source operating at a frequency of 2.45 GHz to irradiate samples of wheat infested with red flour beetle, *Tribolium castaneum* (Herbst) and broad bean *Beetle bruchidius incarnates*. These pests are common internal and external feeders in stored products, respectively. Samples at Larvae and adult were exposed. The results support the hypothesis that the insect-to-host dissipation ratio increases at frequencies >2.45 GHz. Mean mortalities were 93 and 96% for both adults and larvae of *T. castaneum*, respectively. But for *Bruchidius incarnates*, mean mortalities were 90 and 92% for both adults and larvae, respectively.

Key words: *Bruchidius incarnates*, *Tribolium castaneum*, microwave, stored products

INTRODUCTION

The idea of using microwave energy for controlling insects was studied early by Webber *et al.* (1946) beside insect control radiofrequency and microwave energy was used in other applications such as seed treatment and grain drying (Nelson, 1987). On the other hand, continuous microwave irradiation used in treating flour and flat gain storage beetles to controlling insects (Langlinais, 1989) recently many researchers attended about generation of hot spots during industrial microwave heating (Hill and Jennings, 1993; Zhu *et al.*, 1995).

Hill (1990) reported that the annual losses of grain due to rodents and insects, about 30% in Africa. One of the most important advantages of using microwave heating is that materials absorb microwave energy directly and internally and convert it into heat and adopt the idea of killing insects by microwave on the dielectric heating effect produced in grain which is a relatively poor conductor of electricity. Since this heating depends upon the electrical properties of the material, there is a possibility of advantageous selective heating in mixtures of different substances (Mullin, 1995).

The hygiene and do not leave any residues or chemical pollutants is the most important advantages of using microwave energy (Hurlock *et al*., 1979). It is also difficult for insects to be resistant against this type of means of genocide (Watters, 1976). Microwave energy affect on insects by killing or reducing survivors (Hamid and Boulanger, 1969).

The red flour beetle, *Tribolium castaneum* (Coleoptera: Tenebrionidae), feeds on flour and stored grain. The scent glands of the adult secrete a malodorous fluid, imparting a 'mildewed's mell to infested material, there by ruining it for consumption. Phosphine fumigation is the most common control method for mass grain storage (Stephen, 2003). However, large-scale and longterm use of fumigant pesticide results in both highly resistant pests and environmental pollution. Use of high-intensity microwaves has a clear insecticidal effect but affects food quality (Frings, 1952; Headlee and Burdette, 1929; Nelson, 1996; Nelson and Payne, 1982; Wang *et al*., 2003). Wang and Tang (2001) studied the using of electromagnetic energy in laboratory research to control insects in agricultural products.

The US Federal Communications Commission (FCC) allocates five frequencies for industrial, scientific and medical applications: 13.56, 27.12 and 40.68 MHz in the Radio Frequency (RF) range and 915 and 2450 MHz in the microwave range.

Wang *et al*. (2002) found that codling moth completely killed after a full exposure to 50 and 52°C for 5 and 2 min, respectively, also fruit flies can be eliminated after similar heat treatment (Gazit *et al*., 2004). Campbell and Runnion (2003) stated that the red flour beetle, *Tribolium castaneum* (Herbst) is the major pest in flour mills and retail stores.

In this study, the mortality of beetles and develop a lethal model was investigated with a continuous industrial microwave oven for *Tribolium castaneum* (Herbst) and *Bruchidius incarnates* in industrial application storage. A major problem in the production, storage and marketing of wheat grain is infestation by these insect pests. Therefore, The objectives of this research were: (1) To determine the mortality of adult and larval stages of *Tribolium castaneum* (Herbst) and *Bruchidius incarnates* in wheat and broad bean at various power levels and exposure times. (2) To determine if there are any detrimental effects on the flour quality from wheat treated with microwave (3) To make microwave unit used in industrial wheat packages for protection against grain pests.

MATERIALS AND METHODS

These pests reduce the product quality by direct damage through feeding and indirectly by producing webbing and frass. It is estimated that annual losses of cereal grains due to insects and rodents are approximately 10% in North America and up to 50% in Africa and Asia (Hill, 1990). Post-harvest control of insects in wheat is essential under quarantine regulations in many countries. The traditional treatment is chemical fumigation due to low cost, fast speed in processing and ease of use. Insect culture and irradiation with microwaves specimens of *Tribolium castaneum* (Herbst) and *Bruchidius incarnates* for cultures were obtained from the rearing culture of Economic Entomology andAgricultural Zoology Dept. Fac. Agriculture Menoufia Univ. These insects were selected because of their economic importance as harmful and destructive pests to stored cereals and other food products worldwide. *Tribolium castaneum* beetles were cultured in 1.71 glass jars in wheat flour and brewer's yeast (19:1 = w/w) medium; while *Bruchidius incarnates* were reared on broad bean and brewer's yeast (9:2 = w/w/w). Cultures and all test insects were maintained in a growth chamber at 27±1°C temperature and 75% relative humidity. For each trial, 10 insects were placed inside a 0.251 glass jar containing 50 g of whole wheat flour for

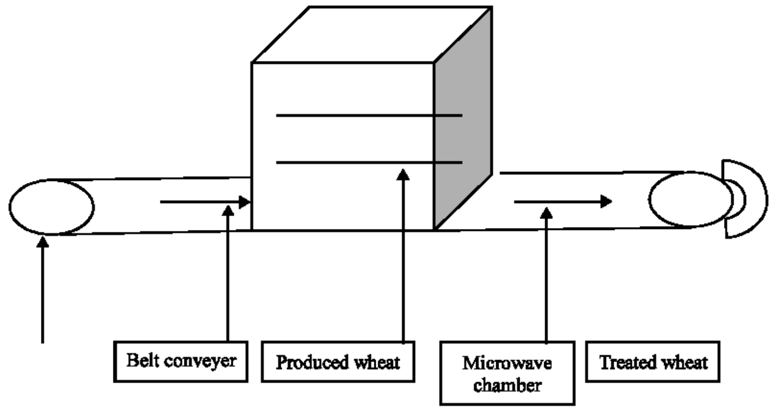

Fig. 1: New device proposed for wheat protection at grain mill with microwaved chamber

T. castaneum and 50 g of broad bean for *Bruchidius incarnates* and positioned directly under the microwave applicator. A cheese cloth was used to cover the jar tops. Irradiation times were either continuous or intermittent and were set at 10, 20, 30, 40, 50, 60, 70 and 80 sec the power was varied from 10-100% of power level. A set of 30 insects was used as the control which was kept beyond the influence of microwaves at 23°C room temperature. The experiment for each growth stage of larvae and adults was replicated four times, mature larvae and 1-3 days old adults were used in replications. An industrial microwave oven (Model Galanz, model P70B20AP-ST co Ltd., China.) with 2450 MHz frequency was used in the study. The microwave applicator was placed inside a housing (Fig. 1) constructed of a fibrous, microwave-absorbing material called Eccosorb CH 460. The distance between the applicator and the food surface was 5 cm. Any radiation that was transmitted, reflected, or missed the jars containing the insects was absorbed by the Eccosorb. The power outputs of the generator were set at 700 W.

Determination of mortality: The experiments were conducted with wheat samples at three infestation levels of 10, 20 and 30 adult insects per 50 g of sample. Fifty grams of sample were placed in the box and insects were added to the sample. The grain, along with the insects, was then placed on the conveyor belt and the sample was subjected to microwave energy. When the box came out of the conveyor it was gently lifted from the conveyor and the sample was spread on a sheet of study. The numbers of live and dead insects were considered dead if they failed to respond to gentle rubbing with a small brush. The sample was allowed to cool and the insects were checked for mortality again after 15 min. The experiment was repeated if insects went missing and the final count was not the same as the initial count. For the larval stage of *T. castaneum* and *Bruchidius incarnates* the experiments were conducted in the same way as for adult insects.

Quality analysis: Five samples of 50 g each were treated at 30, 60 sec at 20% power level, 60 sec at 40% power level and two control sample exposed and non exposed wheat were determined for various quality analyses like flour protein, flour ash, flour carbohydrate and moisture. All determined at Central Lab. At Faculty of Agriculture, Menoufia University.

Statistical analysis: All obtained data were analyzed by SPSS software computer program.

RESULTS AND DISCUSSION

Mortality of adult insects: The mortality percentages for all the insects at various power levels and exposure times are shown in Table 1. At a power level of 20% and an exposure time of 15 sec, the mortality of *T. castaneum* was 81%. As the power was increased to 40, 60, 80 and 100% the mortality also increased to 82, 82, 84 and 85%, respectively. As exposure time was increased, higher mortality was achieved. For example, at 75 sec with 80 and 100%, the mortality was 100%. When the exposure time was increased to 90 sec, 100% mortality was achieved at a power from 20-100%. LSD test shows that mortality of *T. castaneum* was significantly higher in 60,75 and 90 sec of exposed time at all power levels, whereas there was no significant difference in the mortality between 15, 30 and 45 sec at all power levels. The effect of power level and exposure time on mortality was the same for *T. castaneum*. While the mortality of *Bruchidius incarnates* was 81% with 15 sec exposure time with 20% power level. As the power was increased to 40, 60, 80 and 100% the mortality also increased from 81-84%, respectively. As exposure time was increased, mortality percentage was not achieved. The mortality was 100% when the exposure time was increased to 90 sec, with 60, 80 and 100% power levels. These results agreed with Mankin (2004), Lu *et al.* (2010), Birla *et al.* (2004), Wang *et al.* (2006), El-Naaggar and Mikhaiel (2011), Vadivambal *et al.* (2007) and Zhao *et al.* (2007).

Mortality of insect larvae: The mortality percentages for all larval stage at various power levels and exposure times are shown in Table 2. At a power level of 20% and an exposure time of 15 sec,

Table 1: Mortality percentage of *T. castaneum* larvae and adults exposed to combination of microwave heating in wheat flour

		Power level					
Insects	Time (sec)	Control	20%	40%	60%	80%	100%
Larvae	15	0.0	75	77	77	78	78
	30	0.0	79	82	85	84	86
	45	0.0	81	82	83	84	86
	60	0.0	82	85	87	88	89
	75	0.0	89	85	91	92	94
	90	0.0	91	92	94	94	96
Adults	15	0.0	81	82	82	84	85
	30	0.0	84	86	86	87	88
	45	0.0	85	85	87	89	91
	60	0.0	91	91	92	93	92
	75	0.0	93	94	95	100	100
	90	0.0	100	100	100	100	100

Table 2: Mortality percentage of *B. incarnates* larvae and adults exposed to combination of microwave heating in broad bean

		Power level					
Insects	Time (sec)	Control	20%	40%	60%	80%	100%
Adults	15	0.0	81	81	83	84	84
	30	0.0	84	84	87	85	85
	45	0.0	91	91	92	93	93
	60	0.0	92	93	94	94	95
	75	0.0	95	95	96	96	97
	90	0.0	99	99	100	100	100

Table 3: Quality aspects of wheat flour subjected to microwave irradiation

Treatment	Crude fiber	Crude protein	Total carbohydrate	Ash	Moisture
30 sec 20%	1.50	3.750	69.92	1.10	14.2
60 sec 20%	1.65	4.375	63.40	1.14	13.7
60 sec 40%	1.80	5.000	32.16	1.12	13.9
Untreated control	1.10	5.625	57.06	1.10	14.7
Treated control	1.40	6.250	42.98	1.10	14.2

the mortality of *T. castaneum* was 75%. As the power was increased to 40, 60, 80 and 100% the mortality also increased to 77, 77, 78 and 78%, respectively. As exposure time was increased, higher mortality was achieved. at 90 sec with 100 and 99%. When the exposure time was increased the mortality was achieved at a power from 20-100%. LSD test shows that mortality of *T. castaneum* was significantly higher in 75 and 90 sec of exposed time at all power levels, whereas there was no significant difference in the mortality between 15, 30, 45 and 60 sec at all power levels. The effect of power level and exposure time on mortality was the same for *T. castaneum*. These results agreed with Mankin (2004), Lu *et al*. (2010), Birla *et al*. (2004), El-Naaggar and Mikhaiel (2011) and Vadivambal *et al*. (2007).

Quality analysis: The quality characteristics of wheat, i.e., flour protein, flour ash, flour carbohydrate, crude fiber and wheat moisture are shown in Table 3. Analysis of variance was performed between the control sample and treated samples. The results showed that there were significant differences in flour protein, total and hence there was no significant difference in flour ash, moisture and crude fiber (Macarthur and D'Appolonia, 1979). Campana *et al*. (1993) studied the physical, chemical and baking properties of wheat dried with microwave energy. They found that the protein content was not changed but the functionality of gluten was altered gradually with increasing time of exposure. Walde *et al*. (2002) studied the microwave drying characteristics of wheat and reported that there was no change in the total protein content of microwave-treated wheat samples but the structural and functional characteristics of wheat protein gluten were changed. The change in the functionality of gluten was observed by the absence of elasticity and stretchability of the dough. The researchers found that the use of microwave suitable for drying wheat while it is not suitable where the final products made out of flour required soft textural characteristics. Kaasova *et al*. (2002) investigated both chemical and biochemical changes during microwave treatment of wheat and found that advance in the baking quality was found at higher energy doses and higher end temperatures.

Based on experimental results, it can be concluded that there was no significant difference in the quality of flour ash, crude fiber and moisture of the wheat subjected to microwave energy.

Data in Table 3 showed that there is no difference in all contents of treated grains compared with un treated except in total carbohydrate which increased to 96.92% while it was 42.98% in control. it may be related to changing in the sugar content. this point want further studies.

CONCLUSION

The present study showed that the mortality percentages for all insects at various power levels and exposure times was increased, mortality percentage was not achieved. The mortality was 100% when the exposure time was increased to 90 sec. The mortality percentages for all larval stage at various power levels, was significantly higher in 75 and 90 sec of exposed time at all power levels, whereas, there was no significant difference in the mortality between 15, 30, 45 and 60 sec at all power levels. The quality characteristics of wheat, i.e., flour protein, flour ash, flour carbohydrate, crude fiber and wheat moisture are studied the microwave drying characteristics of wheat and reported that there was no change in the total protein content of microwave-treated wheat samples but the structural and functional characteristics of wheat protein gluten were changed. The change in the functionality of gluten was observed by the absence of elasticity and stretchability of the dough.

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