Eradication of the Stored-Product Mite, *Tyrophagus putrescentiae* (Shrank) in Flour and Wheat Bran Using Microwave Energy

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ABSTRACT

Mortality of adults and larvae of the stored product mite, *Tyrophagus putrescentiae* infested flour or wheat bran exposed to microwave radiation (2450 MHZ) was evaluated as a function of exposure time and power. Mortality experiments were conducted at exposure times 60-300 sec at power level of 110 W and from 10 to 90 sec at 330 and 550 W. Adult and larva mortalities were higher in flour with 12.5% moisture content (m.c.) than in wheat bran with 8.5 % m.c. The minimum average temperature (27.8 °C) was recorded in wheat bran at 330 W for 10 sec, whereas the maximum average was 60.5°C in flour at 550 W for 90 sec. Complete mortality of larvae and adults of *T. putrescentiae* was obtained at 45 and 46.6 °C, respectively. *T. putrescentiae* larvae presented a mortality rate higher than adults when exposed to the same Mw energy radiation.

Key words: Stored-product mite**,** ***T.*** *putrescentiae,* Control, Microwave energy.

INTRODUCTION

Mites are considered one of the most abundant groups of pest arthropods (Athanassiou *et al*, 2005; Stejskal and Hubert, 2008). In tropical and subtropical areas, *Tyrophagus putrescentiae* Schrank is a most common mite with high reproductive potential and short life cycle in stored products (Hughes, 1976). Great numbers of mites in stored food and its derivatives not only damage the stored product directly causing economic losses, reducing nutrient content (Boczek, 1991; Krantz, 1955) but can also cause allergic reactions in humans (Kondreddi *et al*., 2006). It can contaminate stored foods with mycotoxins of toxicogenic microorganisms, causing great harm to human health (Hubert *et al*., 2003). Controlling of storage mites includes physical and chemical methods. The major problem of chemical methods is that residues remaining the food affecting the health of consumers and the environment. Thus, modern methods of mite control without adverse effects is needed.

Microwave seems to have a great potential as an alternative method of killing pests in stored cereals and its products. Microwaves are electromagnetic waves with 300-3000MHZ (Decareau, 1985). The lethal effect could be attributed partly to the heat generated within the materials being irradiated by the microwaves energy source and partly to direct absorption of microwaves (Shayesteh and Barthakur, 1996). The amount of energy absorbed by a medium in a microwave field is a function of its physical and dielectric properties, and the power output and frequency of the MW energy source (Watters, 1975).

There has been a lot of research on microwave disinfestation of cereals and cereal products from insects (Hamid *et al*., 1968; Wilkin and Nelson, 1987; Vadivambal *et al*., 2010; El Zun *et al*., 2012; Barbosa *et al*., 2017).

However, little work has been applied to investigate the influence of MW energy against some species of mites. Therefore, the following experiments were conducted to determine the effectiveness of microwave energy in controlling the stored-product mite *T. putrescentiae*.

MATERIALS AND METHODS

Mite rearing:

A culture of *Tyrophagus putrescentiae* (Shrank) was originated from old infested wheat bran samples obtained from grain stores in Alexandria, (Egypt). The mites were mass-reared on brewer's yeast and flour (3:1) in plastic cages (9 cm diameter and 3 cm height at 25±1°C and 80±5 %R.H. in continuous darkness.

Microwave irradiance:

A 2450 MHZ microwave oven, SHARP® (R-534R (w), oven capacity 33 L and cavity dimensions (375 X 226 X 387 mm) was used. Three power levels, 10, 30 and 50% of power output (output: 1100W) were selected for this study.

Adult and larva treatments:

Samples of wheat bran or flour with moisture content 8.5 and 12.5%, respectively infested with the grain mite, *T. putrescentiae* (Schrank), were irradiated in glass microcell 1 cm diameter and 2.5 cm height. Each microcell contained 0.2 g of wheat bran or white flour (70% extraction).

Ten adults or larvae of *T. putrescentiae* were distributed throughout the wheat bran or flour sample in a glass microcell, then covered and placed on plate rotation in the oven. Irradiation times were set at 60, 120, 180, 240 and 300 sec at 110W and set at 10, 20, 40, 60 and 90 sec. at 330 and 550W.

A set of 10 mites (adults or larvae) was used as the control kept beyond the influence of microwaves at room temperature. Five replications for each developmental stage of larvae and adults were achieved.

Measurement of temperature:

For each exposure period and power setting the temperature in a vial containing wheat bran or flour was recorded immediately after exposure by inserting the bulb of a thermometer into the center of the selected stored products. That process was replicated 3 times for each exposure period and power setting. After 24h at 25±1°C and 80±5 %R.H. mortality was assessed.

Data analysis:

Mean mortalities were compared and analyzed by Duncan's multiple range test.

RESULTS AND DISCUSSION

Temperature distribution in wheat bran and flour:

The average temperature range was 27-54 °C in wheat bran and 31-60°C in flour samples (Table, 1). The average temperatures increased with increase in the power or exposure period or both. The minimum average temperature (27.8°C) was recorded in 8.5% m.c wheat bran at 330W for 10 sec., whereas the maximum average was 60.5°C in 12.5% m.c. flour at 550w for 90 sec. Flour at 12.5% m.c. attained higher temperatures in a given time than wheat bran at 8.5 % m.c. (Table 1). The dielectric properties of a material are responsible for the ability of the material to store charge (Mudgett, 1982) which related to both moisture content and the frequency of the MW energy source (Nelson, 1965). Thus, high moisture materials would be expected to absorb more electrical energy, manifested as heat, than dry materials (Watters, 1975).

Mortality in adults:

Mortality rates of *T. putrescentiae* adults treated at various power settings and exposure times in flour and in wheat bran are given in Table (2).

Mortality increased with increase of exposure time or power settings for both stored products. Generally, *T. putrescentiae* adults were more susceptible to the heating effects of microwave energy in 12.5% m.c. flour than in 8.5% m.c. wheat bran (Table 2).

The mortality of *T. putrescentiae* adults was 5.5 and 6.3% by use of microwave energy at power level of 110W and an exposure time of 60 sec in flour and wheat bran, respectively. When the exposure time increased to 300 sec, 85.6% mortality in flour and 77.6% in wheat bran were achieved. Full mortalities (100%) were obtained at 330 or 550 W with an exposure time of 60 sec or more in flour. On the other hand, in wheat bran 100% mortality was seen at 330W for 90 sec. or at 550W for 60 sec. or more (Table 2).

Table (1): Average temperature in °C (± S.E) generated by microwave in flour and wheat bran

Exposure time (sec)	Power (W)	Stored product	
		Flour	Wheat bran
60	110	31.6±0.32	30.8±0.34
120		33.6±0.34	31.6±0.17
180		35.3±0.34	32.8±0.20
240		39.3±0.34	37.8±0.79
300		45±0	40.6±0.34
10	330	32±0.14	27.8±0.43
20		36±0.28	33.1±0.16
40		41.8±0.16	37.3±0.32
60		48±0.28	39.3±0.32
90		52.3±0.17	52±0.28
10	550	42±0.28	35.5±0.28
20		42.3±0.66	36.8±0.40
40		45.5±0.28	42±0
60		51.3±0.16	46.6±0.32
90		61.5±0.28	54.3±0.16

Table (2): Mortality percentage (± S.E.) of *T. putrescentiae* adults infesting flour and wheat bran exposed to microwave irradiation at various exposure times and power levels.

Exposure time (sec)	Power (W)	% Mortality in adults	
		Flour	Wheat bran
Control		3.3±0.057[h]	0.00±0.0[f]
60	110	5.56±0.05[gh]	6.33±0.05[f]
120		8.2± 0.007[gh]	6.0±0.05[f]
180		17.2±0.02[fg]	7.75±0.002[ef]
240		53.33±0.14[e]	32.0±0.8[d]
300		85.66±0.04[b]	77.66±0.05[b]
10	330	8.2±0.007[gh]	3.33±0.06[f]
20		21.66±0.07[f]	9.66±0.04[ef]
40		66.33±0.12[d]	37.66±0.07[d]
60		100±0.0[a]	65.0±0.04[c]
90		100±0.0[a]	100±0.0[a]
10	550	70.6±0.07[cd]	17.66±0.08[e]
20		77.0±0.11[bcd]	34.0±0.1[d]
40		82.0±0.08[bc]	78.66±0.06[b]
60		100±0.0[a]	100±0.0[a]
90		100±0.0[a]	100±0.0[a]

In each column means followed by the same letter are not significantly different at P>0.05

Mortality in larvae:

Table (3) showed that, mortality percentages of *T. putrescentiae* larvae in flour with 12.5% m.c. were higher than those in wheat bran with 8.5% m.c. at each input power level and exposure time.

One hundred percent mortality was obtained after 300 sec. exposure in flour compared with 86% in wheat bran at 110W. At 330W, the highest mortality rate was recorded with 60 sec. exposure time or above in flour and wheat bran. In flour, larvae mortalities were not significantly different at various exposure times at 550W, whereas mortality increased significantly with exposure times in wheat bran, reached one hundred percent at 60 sec exposure or above at 550 W.

Table (3): Mortality percentage (± S.E.) of *T. putrescentiae* larvae infesting flour and wheat bran exposed to microwave irradiation at various exposure times and power levels.

Exposure time (sec)	Power (W)	% Mortality in Larvae	
		Flour	Wheat bran
Control		3.3±0.05[e]	3.0±0.05[ef]
60	110	5.6±0.04[e]	5.3±0.04[ef]
120		11.00±0.01[e]	9.5±0.04[ef]
180		24.0±0.05[d]	12.3±0.06[def]
240		62.6±0.14[b]	48.0±0.13[c]
300		100±0.0[a]	86.6±0.1[b]
10	330	8.3±0.005[e]	5.3±0.04[ef]
20		39.0±0.1[c]	15.0±0.04[de]
40		94.0±0.05[a]	45.6±0.04[c]
60		100±0.0[a]	94.6±0.0[4]
90		100±0.0[a]	100±0.0[a]
10	550	91.3±0.08[a]	20.0±0.0[d]
20		93.0±0.06[a]	46.33±0.04[c]
40		100±0.0[a]	91.3±0.01[ab]
60		100±0.0[a]	100±0.0[a]
90		100±0.0[a]	100±0.0[a]

In each column means followed by the same letter are not significantly different at P>0.05

T. putrescentiae adults were more tolerant of the heating effects of MW energy than larvae exposed at the same times and powers of the Mw energy radiation. Larvae of Astigmata are commonly sensitive than adults when exposed at the same dose of many control protocols (Bakr, 2010).

Thermal treatment methods including microwave radiation have been extensively investigated in much researches as an alternative way of killing insects, (Karabulut and Baykal, 2002; Vadivambal *et al*, 2010). Ernieenor and Ho (2010) indicated that direct exposure of *Dermatophagoides pteronyssinus* and *D. farinae* adults to 2450 MHZ microwave radiation at high and medium power settings for 300 seconds, resulted in nearly 100% lethality. The complete kill of *T. putrescentiae* adults and Larvae were obtained for a combination of watt and exposure time corresponding to a temperature about 45°C and more. Most infesting biological agents can't survive over a certain temperature called lethal temperature, generally between 45°C and 60°C, which can be rapidly reached by the irradiation of microwave (Fields, 1992). The lethal temperatures which kill pests were found to vary considerably with species and stage of development. The data in tables 2, 3 suggest that wheat bran infested with *T. putrescentiae* adults or larvae should be irradiated at higher temperatures than flour to obtain comparable control. Microwave heating is based on the changing of electromagnetic field energy into thermal energy by affecting polar molecules of a material such as water. The rapid movement of these molecules causes friction and results in heat in the material (Das *et al*., 2013).

Living organisms can also be affected by microwave radiation in different ways (Ondracek *et al.*, 1976). Water stress, changes in lipids and proteins, perturbation of ionic activities, and desiccation have been proposed as possible mechanisms of death for living organisms resulting from high temperatures (Fields, 1992). Because of good penetrability of microwave radiation, it can kill pests existing inside or outside grain kernels (Halverson *et al.*, 1999). Microwave radiation can control all developmental stages of storage pests and can also reduce the reproduction rates in surviving pests (Nelson, 1996).

Microwave energy has an attractive character in the pest control as the pests can be heated at a faster rate than the material infested because of high moisture content (Vadivambal *et al.*, 2006). The endues quality of grain was not affected when the temperature was held at about 60°C (Banks and Fields, 1995). No significant difference was found in the quality of grain flour protein and flour yield of samples treated with microwave energy at which 100% mortality was obtained (Das *et al.*, 2013).

Brooker *et al.*, 1974 recommended that cereal grain should not be heated above 60°C to maintain milling and baking quality. The temperature reached during microwave heating for complete kill of adults and larvae of *T. putrescentiae* was between 45-61°C, which lies within the safe ranges obtained in the literature. Hence, the microwave radiation could kill the mites without affecting the end quality characteristics of the product. Another advantage of this method is that it can even be used on packaged products.

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