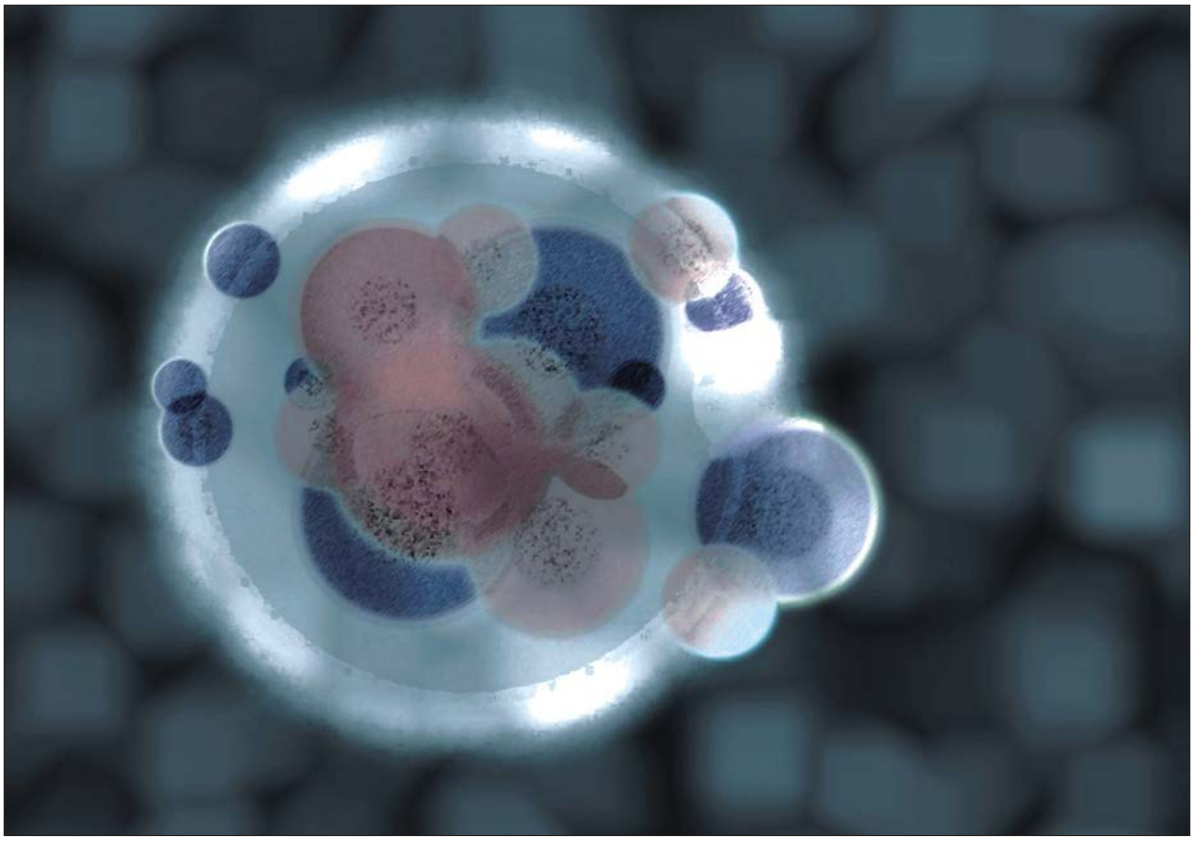

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Investigation on the Possibility of Foodstuff Pest Control Using Radiofrequency Based on Dielectric Heating (Case Study: Rice and Wheat Flour Pests)

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Abstract: In order to test the effect of radio frequencies in rice and wheat flour pest control, the samples were dirtied by *Tribolium confusum* flour pest and *Sitophilus oryzae* rice pest. The wheat flour pests were radiated at 13.56 MHz in 10, 20, 30, 40, 45 and 60 sec, at 27.12 MHz in 5, 10, 20, 25, 30, 35 and 60 sec and at 40.68 MHz in 5, 10, 20, 12, 15 and 60 sec. The rice samples were heated at 13.56 and 27.12 MHz in 60, 75, 85, 95 and 105 sec. After above mentioned times, the number of died insects were counted. Quality test of treated flour and rice samples were done after treatments. Based on the results, the mortality of wheat flour pests after 45 sec at 13.56 MHz reaching 45°C, after 35 sec at 27.12 MHz reaching 46°C and after 15 sec at 40.68 MHz reaching 47°C was 100%. Temperature sensitivity of *Tribolium confusum* at 13.56, 27.12 and 40.68 MHz frequencies were 40, 38 and 43°C, consequently. Also, the results demonstrated that the mortality of rice pests after 105 sec at 13.56 MHz, reaching 57°C and after 95 seconds at 27.12 MHz, reaching 58°C was 100%. Temperature sensitivity of *Sitophilus oryzae* at 13.56 and 27.12 MHz frequencies were 48 and 50°C, in order. The combination of the results showed that pest control potency and intensity increases as frequency rises.

Key words: Radiofrequency, dielectric heating, pest control, quality test

INTRODUCTION

Radio frequency has applied from many years ago in different aspects of human life, and today has a very important role in several industrial applications. Their usages are seen in medical, Industry and science (ISM). Radio Frequencies (RF) can cover 1-300 MHz frequency band in industry. They are absorbed by different materials and are converted to heat. Today, this function which is named Radio frequency Heating is a kind of technology which is done by dielectric and induction heating (Wang *et al*., 2002a, b, 2005).

Dielectric heating is used to heat non-metallic material which is done by putting dielectric material under a high frequency and voltage electric field. However, induction heating is used to heat metal. In dielectric heating, energy is transferred directly from electromagnetic field to the object. This method is used widely in weaving, food, wood industries, etc. The frequency band is from 10 to 30000 MHz, which contains the boundary between audio and infra red frequencies. In radio frequency, energy is directly carried into materials, which causes to decrease the heating time and to improve in product quality (Ikediala *et al*., 2002).

The methods of food conserving by heating processes has started since 1800. Pasteurization and sterilization are kinds of heating process which are used to increase food shelf life. Heating which is used to inactivate enzyme, damages vegetative cells and micro organisms is named pasteurization. Sterilization is usually used to preserve food for longer periods. The needed temperature for this method is between 60 to 80°C from some seconds to some hours. Ordinary sterilization temperatures are 100°C for food with high acid and 121°C for food with low acid. Although sterilized food contains seeds of temperature resistant bacterium, but they are stored at temperature which this bacteria will be inactivated. Marra *et al*. (2009) stated canning method was used by Appert (a French confectioner) previously. In new canning industries, the necessary heat is supported by vapor. Conductivity and syndrome causes heat transfer to products in the vessel. In solids, heating process is done by conductivity and at lower speed (Monzon *et al*., 2006). To date many researches are conducted for investigation on radio frequency treatment of foods, pathogens and pests such as Al-Holy *et al*. (2005), Ahmed *et al*. (2007), Birla *et al*. (2008), Farag *et al*. (2008) and Geveke and Brunkhorst (2008) etc.

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Regarding to the effects of radio frequency on dielectric materials and distinctive heating, their uses are recently considered by researchers for pest control. The goal of this experiment was to investigation on the possibility of foodstuff pest control using radio frequency based on dielectric heating using *Tribolium confusum* and *Sitophilus oryza*e, from two important agriculture products; wheat flour and rice as case study.

MATERIALS AND METHODS

This study was conducted in Iran University of Science and Technology during February 2008 until January 2009. In this research, by radio frequency heater which was made by authors (Mirhosseini, 2009), the efficiency of these frequencies were tested on some agricultural products. To do so, wheat flour pest, *Tribolium confusum* and rice pest, *Sitophilus oryzae* were used. The experiment was done on two strategic products, wheat flour and rice at 13.56, 27.12 and 40.68 MHz frequencies, and also the rate of temperature sensitivity of pests was measured. Experiment was conducted based on methods and analytical techniques of Zhong *et al*. (2004).

The required samples of *Tribolium confusum* and *Sitophilus oryzae* pests in fifth in-star age were provided from Pest Control Institute of Iran and Institute of Seed and Plant Breeding of Agricultural Ministry of Iran. These pests were kept in netted cans until testing.

Tests were done at equal voltages (2600 Volts) and electrical powers (800 W) in 3 frequencies for *Tribolium* and 2 frequencies for *Sitophilus* in order to make equal the conditions. So, variable parameters were frequency and time. To do a better test, each treatment was considered 3 repetitions. The final conclusion was stated according to the average of those 3 testes. In each treatment 25 insects were used. After each test, the dead insects were counted and alive ones were transferred into a separate vessel for accuracy in subsequent tests. Wheat flour samples were also transferred to the laboratory in order for quality test after treatment. These samples were packed according to the radio frequency heating time.

Wheat flour radio frequency were done at 13.56 MHz for 10, 20, 30, 40, 45 and 60 sec, at 27.12 MHz for 5, 10, 20, 25, 30, 35 and 60 sec and finally at 40.68 MHz for 5, 10, 12, 15 and 60 sec. Rice flour radio frequency heating was done at 13.56 and 27.12 MHz for 60, 75, 85, 95 and 105 sec. The temperatures of flour and rice seeds were measured and recorded by an alcohol thermometer immediately, after each treatment. The treated wheat flour was tested by Zeleny test. For this goal, wheat flour samples were transmitted to Seed Research Centre of Commercial Ministry of Iran. In Zeleny test which shows the changes in foodstuff proteins, samples are suspended test by means of SPSS statistical Package version 11.0 for in an intermediate solution and then the volume of suspended material is recorded as the output.

The experiment was set in a Completely Randomized Design (CRD) with three replications. For the statistical analysis, the data analyzed using one-way ANOVA and the means were grouped using Duncan's multiple range windows using the GLM procedure. Results are expressed as Means±SE (Standard Error).

RESULTS

Inactivation of wheat flour pest

Pest control at 13.56 MHz frequency: It can be seen that all of the pests were died at the fifth treatment in 45 sec and 45°C. Although the temperature reaches to 58°C after 60 sec, but according the results of mortality, there is no reason to increase the time after 45 sec. Temperature and mortality percentage versus time are shown in Table 1 which shows the temperature sensitivity of wheat flour pest at 13.56 MHz frequency which is shows that this parameter for *Tribolium* is almost 40°C.

Pest control at 27.12 MHz frequency: The results of pest control at 27.12 MHz, 2600 V are shown in Table 1. It can be seen that all the pests were died at the sixth treatment in 35 sec and 46°C. Although the temperature reaches to 60°C after 60 sec, but according the results of mortality, there is no reason to increase the time after 35 sec (Table 1). Temperature and mortality percentage versus time are shown in Table 1 shows the temperature sensitivity of wheat flour pest at 27.12 MHz frequency which is shows that this parameter for *Tribolium* is almost 38°C.

Table 1: Wheat flour pest control from Tribolium at 13.56, 27.12 and 40.68 MHz, 2600 V

Frequency (MHz)	Time (sec)	Flour's temp. (°C) (Mean±SE)	Mortality percentage (Mean±SE)
13.56	10	31.0±0.000^{f}	9.33±0.013^{f}
	20	35.0±0.333^{e}	29.33±0.013^{e}
	30	39.0±0.333^{d}	66.67±0.035^{d}
	40	42.0±0.333^{c}	94.67±0.013b^{c}
	45	45.0±0.333^{b}	100.00±0.013^{a}
27.12	5	29.0±0.333^{g}	2.67±0.013^{g}
	10	30.0±0.333^{f}	9.33±0.013^{f}
	20	39.0±0.167^{d}	58.67±0.013^{d}
	25	42.0±0.167^{c}	90.67±0.013^{c}
	30	43.0±0.333^{c}	92.00±0.00^{bc}
40.68	35	46.0±0.333^{b}	100.00±0.00^{a}
	5	39.0±0.333^{d}	14.67±0.026^{ef}
	10	43.0±0.333^{c}	68.00±0.061^{d}
	12	44.5±0.167^{b}	97.33±0.026^{ab}
	15	46.0±0.333^{a}	100.00±0.00^{a}

Mortality percentages and Flour's temperatures with same letter(s)in column are not significantly different at p>0.05

Table 2: Rice flour pest control from Sitophilus at 13.56 and 27.12 MHz, 2600 V

Frequency (MHz)	Time (sec)	Flour's temp. (°C) (Mean±SE)	Mortality percentage (Mean±SE)
13.56	60	40.5±0.333^{g}	3.33±0.033^{e}
	75	43.5±0.287^{f}	13.33±0.033^{de}
	85	47.5±0.333^{e}	46.67±0.033^{c}
	95	50.5±0.333^{d}	76.67±0.033^{b}
	105	56.5±0.333^{b}	100.00±0.00^{a}
27.12	60	47.0±0.167^{d}	23.33±0.033^{cd}
	75	50.5±0.333^{e}	76.67±0.033^{b}
	85	54.0±0.000^{c}	93.33±0.033^{a}
	95	58.0±0.441^{ba}	100.00±0.00^{a}
	105	58.5±0.333^{a}	100.00±0.00^{a}

Mortality percentages and Flour's temperatures with same letter(s) in column are not significantly different at p>0.05

Pest control at 40.68 MHz frequency: It can be seen that all the pests were died at the fourth treatment in 15 sec and 47°C (Table 1). Although the temperature reaches to 76°C after 60 sec, but according the results of mortality, there is no reason to increase the time after 35 sec. Temperature and mortality percentage versus time are shown in Table 1 shows the temperature sensitivity of wheat flour pest at 40.68 MHz frequency which is shows that this parameter for *Tribolium* is almost 43°C.

Inactivation of rice pest

Pest control at 13.56 MHz frequency: It can be seen that all the pests were died at the fifth treatment in 105 sec and 57°C. Temperature and mortality percentage versus time are shown in Table 2 shows the temperature sensitivity of rice pest at 13.56 MHz frequency which shows that this parameter for *Sitophilus* is almost 48°C (Table 2).

Pest control at 27.12 MHz frequency: The results of pest control at 27.12 MHz, 2600 V are presented in Table 2. It can be seen that all the pests were died at the fourth treatment in 95 sec and 58°C. Temperature and mortality percentage versus time are shown in Table 2 shows the temperature sensitivity of rice pest at 27.12 MHz frequency which shows that this parameter for *Sitophilus* is almost 50°C.

The results of quality test for treated samples at RF: Since human health and the food have a compacted, bilateral relation, quality control of foodstuff has very important role in industry. In order to examine the quality of the treated food in radiofrequency heating process, their qualities were tested with Zeleny method after treatments. Regarding to the results, the quality of the wheat flour for these tests in both controlled and treated samples in all the times was 18. This It is proposed to arrange some additional tests on larger demonstrates that RF heating do not have any bad effect on wheat flour and rice seeds qualitatively.

DISCUSSION

Based on our knowledge, this experiment is the first report regarding effects of radio frequency based on dielectric heating on rice and wheat flour pests. Hence, these results differ from previous studies. Also to date there is not report regarding application of radiation at 13.56, 27.12 and 40.68 MHz for rice and wheat flour pests. Regarding to the results, at 13.56 MHz after 45 sec and reaching 45°C, at 27.12 MHz after 35 sec and reaching 46°C and at 40.68 MHz after 15 sec and reaching 47°C, *Tribolium* insects were killed completely. These show that Radio frequency heating has such a high ability for pest control of wheat flour. The temperature sensitivity of *Tribolium confusum* at 13.56, 27.12 and 40.68 MHz are 40, 38 and 43°C consequently. Also for treatments on *Sitophilus* insects 43°C, at 13.56 MHz after 105 sec and reaching 57°C and at 27.12 MHz after 95 sec and reaching 58°C insects were killed completely. The results demonstrate that RF heating can kill the insects completely in rice seeds. The temperature sensitivity of *Sitophilus oryzae* at 13.56 and 27.12 MHz frequencies are 48 and 50°C consequently. The combination of the results shows that the potency and intensity of pest control increase as the frequency rises. quantity of materials to prove the pest control effect of RF heating.

Wheat flour pests are categorized into two types, *Confusum* and *Castaneum* which are very important concerning to preserve productions for storage, specially flour and bran. These pests are small red-brown beetles with 3-4 mm in length. Both groups are cosmopolite and could be found all over the world. They feed from starchy food such as flour, bran, seed, etc. (Zonuz, 1985). These pests damage products and for their fast increasing in quantity, they make the stored food polluted by their own feces and larva and decrease the products' quality dramatically. Flour pests are polyphage insects and can even eat oily seeds, peanuts, wheat, cereals, cotton seed, dried fruits, macaroni, etc. Moreover, they sometimes tend to eat meaty food. The tests have showed that a couple of male and female of these insects can generate 1 million insects within 5 months that causes flour lose its nutrition which will be forbidden to consume for human. This insect can also be alive for 40 days without eating food. Factors such as heat and coldness affect its life. If the environments temperature decreases to 7°C or increases over 50°C, it will be inactivated. This fact is the basis of the pest control (Zonuz, 1985).

Sitophilus is a brown insect which is 3-5 mm in length. This insect could be found largely in India, Australia, Mediterranean Sea coasts, Middle East and USA It attacks rice, wheat, corn, barley storages and can

eat flour and bran. In this case, its reproduction will be canceled. The rate of damages by it is severe on different cereals. In some countries, this insect damages products by 75% (Zonuz, 1985).

Regarding to the results, at 13.56 MHz after 45 sec and reaching 45°C, at 27.12 MHz after 35 sec and reaching 46°C, and at 40.68 MHz after 15 sec and reaching 47°C, *Tribolium* insects were killed completely. These show that Radio frequency heating has such a high ability for pest control of wheat flour. The temperature sensitivity of *Tribolium confusum* at 13.56, 27.12 and 40.68 MHz are 40, 38 and 43°C consequently. Also for treatments on *Sitophilus* insects, at 13.56 MHz after 105 sec and reaching 57°C and at 27.12 MHz after 95 sec and reaching 58°C, insects were killed completely. The results demonstrate that RF heating can kill the insects completely in rice seeds. The temperature sensitivity of *Sitophilus oryzae* at 13.56 and 27.12 MHz frequencies are 48 and 50°C consequently. The combination of the results shows that the potency and intensity of pest control increase as the frequency raises. It is proposed to arrange some additional tests on larger quantity of materials to prove the pest control effect of RF heating.

Before this case, the first result of pasteurization by radiofrequencies was done by Kathkart in 1947. He conducted this experiment by radiating the loaves of bred in range of 14-17 MHz, 3 kW for 47 sec reaching to 60°C. He saw no fungus or musty reproduced on the loaves of bread. Volter used 26 MHz\, 1.7 kW radio frequency generator on loaves of bread. After 14 days he saw 3 kinds of fungus on loaves of bread which were treated by dielectric heating method (Safaii, 2008).

In recent years, Wang *et al.* (2006) on in-shell walnuts, Ikediala (2002) and Monzon (2006) on cherries, Birla *et al.* (2004) on orange and apple, Tang *et al.* (2000), Awuah (2005) on milk and Guo *et al.* (2006) have had some successful experiments on inactivation pest in foodstuff. But *Tribolium* and *Sitophilus* inactivation in wheat flour and rice (Mirhosseini, 2009) has not had any similar experiment and has done for the first time. Other researchers report similar results (Wang *et al.*, 2001a, b, 2002c; Tang *et al.*, 2005; Romano and Marra, 2008). Also, recently Marra *et al.* (2009) advances in radio frequency treatment of foods.

Because of the deficiency of commercial methods, and on the other hand, hazards of chemical ways, pest control is one of the major problems for food industries. The solution method which has reached a scientific raise in recent years Is pest control of foodstuff using radio requency heating.

As conclusion, based on the results of this research, deficient commercial methods can be replaced by the industrial scale of the radio frequency generator for pest control of foodstuff. Radio frequency based on dielectric heating can use for pest control of foodstuff especially *Tribolium confusum* and *Sitophilus oryza*e. Also, it must investigate on effect of radio frequency based on dielectric heating on other important pests in future studies.

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