Control of maize weevil (*Sitophilus zeamais* Motschulsky) and lesser grain borer (*Rhyzopertha dominica* (F.)) by radio frequency

Uraichuen, J.*#[1], Pedchote, A.[1], Radchabut, S.[2], Vearasilp, S.[3]
[1]Postharvestand Processing Research and Development Office, Department of Agriculture, Bangkok, Thailand 10900
[2]Agricultural Products Quality Analysis System Development Group, Plant Standard and Certification Office, Department of Agriculture, Bangkok, Thailand 10900
[3]Department of Plant Science and Natural Resources, Faculty of Agriculture, Chiang Mai University, Chiang Mai, Thailand

*Corresponding author, Email: j_uraichuen@hotmail.com
#Presenting author, Email: j_uraichuen@hotmail.com

DOI: 10.14455/DOA.res.2014.145

Abstract

Maize samples which were separately infested by *Sitophilus zeamais* and *Rhyzopertha dominica* were treated with a radio frequency (RF) heat treatment application unit, which has been developed at Chiang Mai University. The unit has a variable power supply and operates at 27.12 MHz. The input powers were 20% (540 watts) and 25% (670 watts) at a target temperature of 50°C for 30, 60 and 90 seconds, as treatments. Evaluation of the efficacy of RF heat treatment was estimated by counting the number of surviving adults and calculating a control efficiency percentage. All developmental stage of *S. zeamais* could be controlled by both power levels. The adult seemed more tolerant to RF than the other stages. The most effective treatment for controlling *R. dominica*) was the 25% power level for 90 seconds. The control efficiency percentages of eggs, larvae, pupae and adults were 99.39, 94.59, 98.56 and 99.87%, respectively. *Rhyzopertha dominica* was more tolerant than *S. zeamais*. After all treatments, moisture content of maize was slightly reduced by both power levels. Crude protein was not changed, crude fat was increased, ash and carbohydrate were slightly different from controls, and crude fiber was decreased. However, the energy from maize was significantly increased.

Keywords: radio frequency, insect control, stored product insects

1. Introduction

Insect pests are one of the major factors affecting seed quality. Maize weevil (*Sitophilus zeamais* Motschulsky), rice weevil (*Sitophilus oryzae*) and lesser grain borer (*Rhyzopertha dominica* (F.) infest the seed damage to the endosperm and embryo. Other pests, for example red flour beetle (*Tribolium castaneum* (Herbst)), flat grain beetle (*Cryptolestes ferrugineus* (Stephens)) and saw-toothed grain beetle (*Oryzaephilus surinamensis* (L.) infest primarily the broken seed. To eliminate all the developmental stages these insects, both chemical and non-chemical treatments have been used. However, chemical treatments i.e. fumigation is now restricted in some countries, therefore non-chemical treatments such as radio frequency (RF) is an alternative disinfestation treatment for controlling insect pest in seeds. RF treatment has been successfully used for seed fruits and vegetables (Nelson, 1973). Previous research showed that a range of 10–100 MHz affected insect development (Marra et al., 2009). Nelson and Walker (1961) reported that using RF can control insect pests without affecting seed quality. In addition, *R. dominica* could be controlled after exposure to RF at 27.12 MHz at 70,

75, 80 and 85°C for 3 minutes in infested rice, however va viability of rice seed was reduced with an increase of temperature (Janhang et al., 2005). Wang et al. (2002) eradicated of navel orange worm in citrus and almond and pistachio using RF at 27.12 MHz at 55°C for 5 minutes. To determine if RF can control insect pests, an understanding of utilization (i.e. dose, temperature and time) should be determined. The objectives of this research was to evaluate the efficiency of RF to eliminate infestations of *S. zeamais* and *R. dominica* without loss of maize quality.

2. Materials and Methods

Maize was stored at -20 ± 2°C for 1 week prior the experiment at a moisture content of 12 – 13%. A 450 g of maize was placed in a closed container (Fig. 1) with each developmental stage of *S. zeamais* or *R. dominica*. Then the container was treated with RF (Fig. 2) at 27.12 MHz with the input power of 20% (540 watt) or 25% (670 watt) at 50°C for 30, 60 and 90 seconds. The treated samples were transferred glass jars and stored at room temperature. The insect mortality was assessed when insects in untreated controls reached the adult stage. The control efficiency percentage was calculated by using equation 1 (Püntener, 1981). The seed moisture content, crude protein, crude oil, crude fiber, ash, carbohydrate and energy were determined in treated and untreated maize.

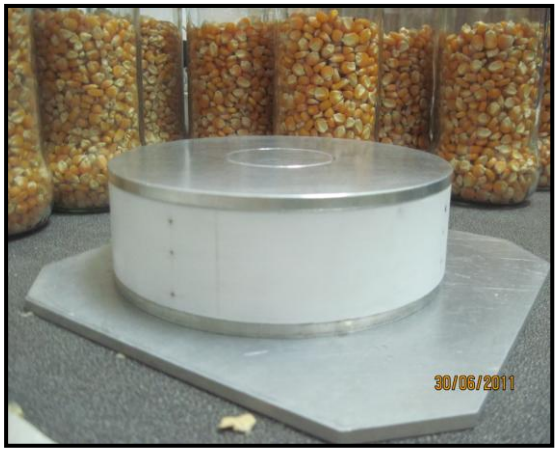

Figure 1 Maize containing pan.

Figure 2 Radio frequency application machine.

$$\text{Control efficiency percentage (\%)} = \left\lfloor 1 - \left(\frac{T_a}{C_a} \times \frac{C_b}{T_b}\right)\right\rfloor 100 \quad \ldots\ldots\ldots\ldots \quad \text{Equation 1}$$

T_b = number of insect in sample before treatment
T_a = number of insect in sample after treatment
C_b = number of insect in control sample before treatment
C_a = number of insect in control sample after treatment

All data were analyzed by using ANOVA using SPSS. Comparison of means was performed by using Duncan Multiple Range Test (DMRT) to evaluate the significant differences at P = 0.05.

3. Results and Discussion

The control efficiency percentage of *S. zeamais* or *R. dominica* was determined in radio frequency treated maize. Overall, the radio frequency treatment showed significant control (P<0.05) of *S. zeamais*. The control efficiency percentage was 99-100% for eggs and pupae

while 97.37 and 96.50% reduction was achieved of larval and adult stages at 20% power level for 30 seconds (Table 1). Previous research showed larvae were more susceptible than adults when treated with RF at 11 MHz (Webber, 1946), however Nelson (1996) found that adults stage of *S. oryzae*, *S. granarius*, and *R. dominica* were more susceptible than larvae protected by the seed.

Table 1 Control efficiency percentage of *Sitophilus zeamais* at different developmental stage after treatment by radio frequency[1/].

Power level	Time (min)	Egg	Larva	Pupa	Adult
20% (540 watts)	30	99.17a[2/]	97.37b	99.57a	96.50b
	60	100.00a	100.00a	99.72a	99.61a
	90	100.00a	100.00a	100.00a	99.74a
25% (670 watts)	30	100.00a	99.87a	99.86a	99.35a
	60	100.00a	100.00a	100.00a	99.87a
	90	100.00a	100.00a	100.00a	99.87a
Untreated		0b	0c	0b	0c
CV. (%)		7.86	7.86	7.86	7.86

[1/]Means averaged from 4 replications.
[2/]Means followed by same letters in columns are not significantly different by DMRT ($P<0.05$)

The control efficiency percentage of *R. dominica* was lower than for *S. zeamais*. The most effective treatment to control egg and larva stages of *R. dominica* was 25% power level for 90 seconds. Control efficacy was 99.39 and 94.59% for eggs and larvae respectively while pupal and adult efficacy was 98.00–99.87% efficacy at 20% power level for 90 seconds or 25% of power level for 60 and 90 seconds (Table 2).

RF reduced moisture content in maize, however there was no significant difference in crude protein. There were slightly changes in crude fat, ash crude fiber and carbohydrate in RF treated and untreated maize. Interestingly, the energy obtained from maize significantly increased after RF treatment.

4. Conclusions

RF controlled both insect species. To increase an efficiency of radio frequency unit, a continuous power supply is recommended for a large sample to reduce treatment time. In addition, a combination of radio frequency and other treatments such as controlled atmosphere should be investigated in further studies.

Table 2 Control efficiency percentage of *Rhyzopertha dominica* at different developmental stage after treatment by radio frequency[1/].

Power level	Time (min)	Egg	Larva	Pupa	Adult
20% (540 watts)	30	77.68b[2/]	81.01bc	85.09b	88.67c
	60	90.91a	83.47abc	91.65ab	96.27ab
	90	88.69ab	91.91ab	98.33a	99.47a
25% (670 watts)	30	67.07c	75.81c	85.95b	95.07b
	60	89.80ab	89.73ab	98.16a	98.00ab
	90	99.39a	94.59a	98.56a	99.87a
Untreated		0d	0d	0c	0d
CV. (%)		8.46	8.20	8.03	7.91

[1/]Means averaged from 4 replications.
[2/]Means followed by same letters in columns are not significantly different by DMRT (P<0.05)

References

Janhang, P., Krittigamas, N., Wolfgang, L., Vearasilp, S., 2005. Using radio frequency heat treatment to control the insect *Rhyzopertha dominica* (F.) during storage in rice seed (*Oryza sativa* L.) Conference on International Agriculture Research for Development, Tropentag 2005, Stuttgart-Hohenheim, October 11-13, 2005,

Marra, F., Zhang L., Lyng, J.G., 2009. Radio frequency treatment of foods: Review of recent advances. Journal of Food Engineering 91, 497–508.

Nelson, S.O., 1973. Potential insect control applications for microwaves. *In* Proceedings of the 3rd European Microwave Conference. Vol. 2 (Oct. 1973), pp. 1-4

Nelson, S.O., 1996. Review and assessment of radio-frequency and microwave energy for stored-grain insect control. Transactions of the ASAE 39, 1475-1484.

Nelson, S.O., Walker, E.R., 1961. Effects of radio-frequency electrical seed treatment. *Agricultural Engineering* 42, 688-691.

Püntener, W., 1981. Evaluation of trail-calculation of efficacy. Manual for Field trails in Plant Protection. Agricultural Division, Ciba-Geigy Limited, Switzerland.

Wang, S., Tang, J., Johnson, J. A., Mitcham, E., Hansen, J.D., Cavalieri, R.P., Bower, J., Biasi, B., 2002. Process protocols based on radio frequency energy to control field and storage pests in in-shell walnuts. Postharvest Biology and Technology 26, 265–273.

Webber, H.H., Wagner, R.P., Pearson. A.G., 1946. High-frequency electric fields as lethal agents for insects. Journal Economic of Entomology 39, 487-498.