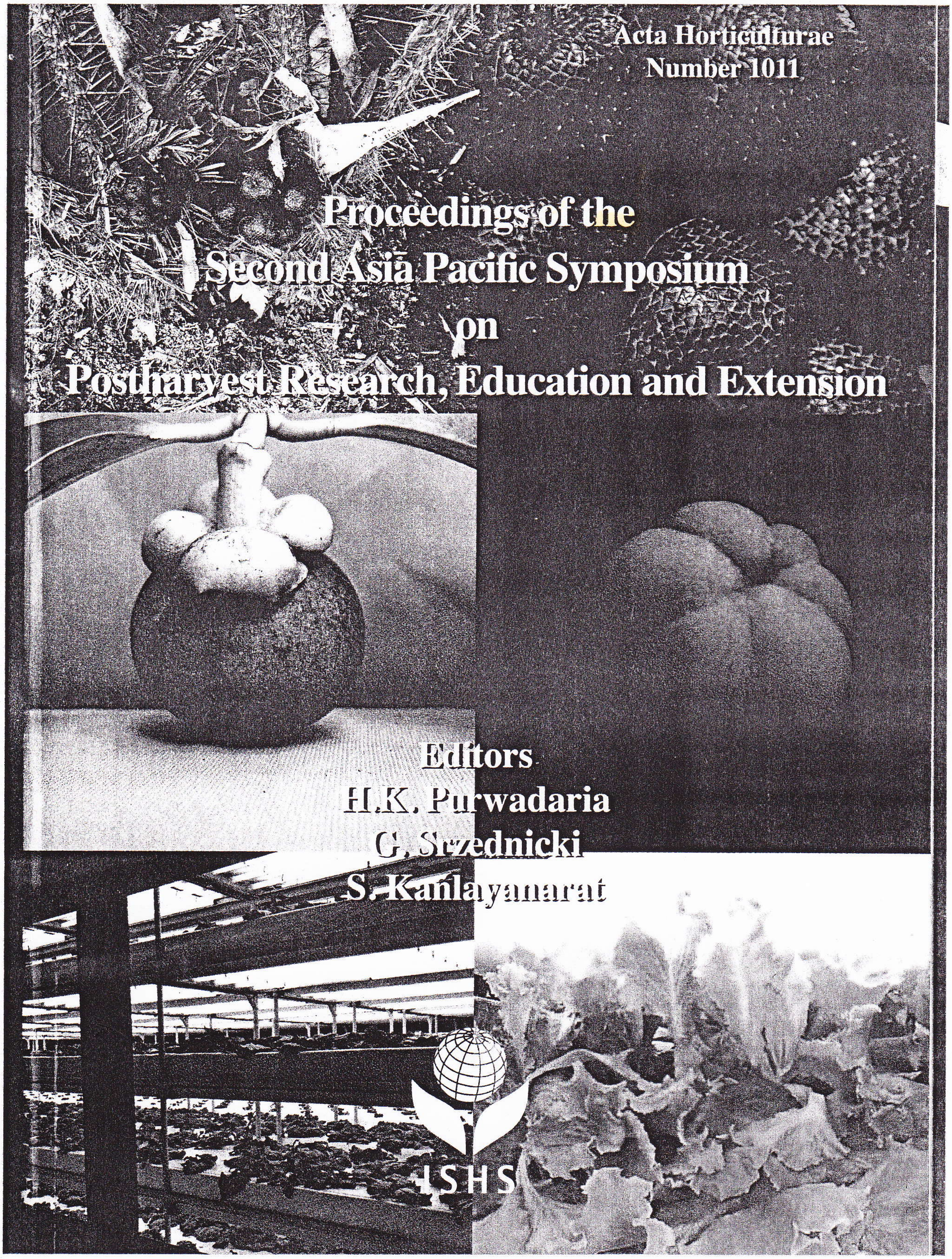

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1. Salak Pondoh plants and fruits (by courtesy of G. Szrednicki).
2. Salak Pondoh fruits (by courtesy of W. Maneerat).
3. Mangosteen maturity index 3 for export (by courtesy of H.K. Purwadaria).
4. Ready to eat mangosteen (by courtesy of H.K. Purwadaria).
5. Demonstration facility for multipurpose plant factory, Osaka Prefecture University, Japan (by courtesy of H. Murase).
6. Demonstration facility for high efficiency energy conservation plant factory, Osaka Prefecture University, Japan (by courtesy of H. Murase).

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Microwave Treatment for Killing the Silo Insect Pest *Sitophilus zeamais* Motsch in Maize

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Keywords: maize, microwave treatment, *Sitophilus zeamais* Motsch

Abstract

Maize represents an important source of feed as well as raw material for food. One of the problems normally faced in tropical countries is pest infestation by the insect *Sitophilus zeamais* Motsch during the storage of maize in silo. This research aimed to study the influence of microwave treatment to the mortality of insect pest *Sitophilus zeamais* Motsch and to the content of starch and protein of treated maize. The research was conducted in the Laboratory of Agicultural Energy and Laboratory of Food Chemistry, Bogor Agicultural University. The sample of 200 g of dry maize was invested by 50 insects and heated in a microwave exposed at 240, 480 and 720 W, respectively, for 60, 90 and 120 s. The results showed that 100% mortality could be achieved using microwave treatment with 720 W in 60 s which generated temperature of 74°C. The treatment used a very short time (60 s) compared to the use of hot air oven which needed 22 min exposure for a similar temperature. The short time heating by microwave had an advantage to maintain 68.5% starch content, and 9.4% protein while killing the insect pest totally.

INTRODUCTION

Maize is considered to be an important source of carbohydrate food and feedstuffs, as well as industrial raw materials. According to FAO statistics (2011) Indonesia produced 17,629,000 MT of maize. Increased maize demand in recent years is not in line with the rate of increase in production in the country, resulting that the importation of maize is still necessary. Intensive measures to increase production have been done, but increased production of maize should be followed up by proper postharvest handling to reduce losses. In tropical regions, insect is commonly the cause of shrinkage and damage during storage. Adams (1976) reported that *Sitophilus zeamais* Motsch insect pests are the main warehouse and most destructive of maize gain during storage. Maize weevil (*Sitophilus zeamais*) can penetrate the gains and multiply quickly when moisture content in the gain is quite high. The most destructive stadia of the insect are larvae and imago which perforated maize gains and left the rest of the host in powder form (Kalshoven, 1981). The use of insecticides, although effective, had an impact on the environment and could create resistance in a long time. Physical control, i.e., by using a "sack of Yusup" designed airtight had also weakness that the new insect gowth stunted after 10-12 days (Ekoputro, 1990).

Weevil insect would expand rapidly if the stored maize gains or kernels had a moisture content over than 15% (Kalshoven, 1981). Drying would deactivate enzymes, microorganisms, fungi and insects damaging agicultural materials (Henderson and Perry, 1976). Improper drying allowed the outer stalks to dry while parts of it were not dry or had not reached the desired moisture content. This made it possible that the insect eggs or larvae in the gains (the endosperm) did not die yet. The heating using microwave was an alternative to stop the growth of pests quickly and efficiently (Hartulistiyoso, 1999).

Microwave is a form of electromagnetic waves in the frequency spectrum between 300 MHz and 300 GHz or between radio waves and infrared (Datta and Anatheswaran, 2001). Microwaves cannot be absorbed by the metallic materials but can only be absorbed by materials containing water. The microwave equivalent of air moving at the speed of light (c=2.9979 × 108 m/s) and can penetrate materials such as air, porcelain and plastic. The heating in microwave is a result of the interaction of electromagnetic waves with foodstuffs (Decareau, 1985). An electrical generator which produces 2.45 GHz frequency electric field will cause the movement of the wave field as much as 2.45 billion times per second. Therefore, microwave heating is principally dielectric heating systems that use electromagnetic waves directly to the position of the water molecules in the material. Thus, applying electromagnetic waves to the infected maize will expectedly kill the insects effectively. The process will expectedly not interfere with the quality of the maize which mainly contains starch and other nutritional components needed for feeding livestock.

This study aimed to observe the effects of microwave heating on the mortality of warehouse insect pest *Sitophilus zeamais* Motsch and the maize moisture content, starch content, and protein content.

RESEARCH METHOD

The study was conducted in the Laboratory of Agricultural Energy and Electrification, and Laboratory of Food Chemistry at the Faculty of Agicultural Technology, Bogor Agicultural University. Maize used in this study was 'Arjuna', obtained from the Post Harvest Research Center, Cimanggu, Bogor. The *Sitophilus zeamais* Motsch was obtained from the laboratory of Pest and Diseases Management, SEAMEO BIOTROP, Bogor. The equipment used in this study are Microwave Oven Elektrolux 1920, EME type Hybrid recorder, digital scales type EK 1200A, capacity 1200 g - 0.1 g, oven dryer IKEDA IZUMI type SS-200 D (220 V, 8A), digital Multimeter APPA-101, and other standard apparatus for chemical analysis. The moisture content of the materials were measured with oven method. The temperature of maize was measured using CC thermocouple with hybrid recorder for data logging. Measurement of maize temperature was done on the three dots (the middle and edge of maize).

The observations of the mortality of *Sitophilus zeamais* were conducted by looking at the condition of imago directly after it was heated on the respective power levels and time. The analysis of the starch content was performed using the hydro-lysate acid method, whereas the protein content was measured using the Kjeldahl method.

For the treatment, 200 g of maize in plastic jars containing 50 tails of *Sitophilus zeamais* insects was treated in microwave oven with various setting of power levels and times. The treatment was done at microwave power input of 0 (control), 240, 480 and 720 W, with heating time of 60, 90 and 120 s. The plastic jars were used to avoid insects creeping out into the space around the oven. The jars were made of plastic material that could be used for microwave ovens. The experimental design used was the Basic Design with Factorial Experiment RAL (Complete Random Design) with three replicates.

RESULTS AND DISCUSSION

The measured surface temperature of maize infected with *Sitophilus* insect pest after microwave treatment is illustrated in Figure 1. Figure 1 and the results of statistical tests indicated that the surface temperature of the material was influenced both by power level and treatment time. ($F_{6.24}$=18.6, P<0.0001). Higher power level and longer heating time resulted in higher surface temperature. Each power level and time showed significant difference in temperatures except on heating with the power level of 240 Ws for 120 s and 480 W for 60 s. Both produced no significant temperature difference. Similarly, on heating with the power level of 480 W for 90 s and 720 Ws for 60 s also showed that the temperature did not differ significantly. In light of energy, it was found out that increasing the amount of energy applied to the treatments would increase the temperature independent of the power level. Thus, the energy applied was an important factor in the microwave treatment.

Figure 2 showed the water content (wet basis, wb) of treated maize infected artificially with *Sitophilus* insect pest after microwave treatment at various levels of power and heating time. Statistically, both time and power treatment had no effect on the actual water content after treatment ($F_{3,24}$=9.33, P=0.0001, $F_{2,24}$>=2.50, P>0.0001 and $F_{6,24}$=0.23, P>0.0001) except at heating with 720 Ws that decreased the water content about 2-3.4% wb. On the heating with 240 Ws for 60 and 90 s the water content had not experienced a downturn.

Table 1 indicated different mortality of *S. zeamais* outside and inside maize at various power levels and exposure times. The percentages of *S. zeamais* mortality outside maize were higher than the ones inside maize due to the direct microwave exposure. Inside maize, the insect pest had lower percentages of mortality since the microwave was also absorbed by the maize water content. The insect mortality of *S. zeamais* due to microwave treatment at various power levels and exposure times was illustrated in Figure 3. The result showed that both the power level and heating time were statisticaly influential against *S. zeamais* mortality ($F_{6,24}$=57.45, P>0.0001). The higher the power level and the longer the heating time, the insect mortality became greater. Interestingly, 100% mortality reached at the relatively same amount of energy, those are 16 Wh (480 W × (120/3600) h) and 15 Wh (720 W × (75/3600) h).

The mortality of *S. zeamais* in this case was influenced by the reaction of the liquid in the body of insects exposed in microwave and also affected by maize surface temperature. The liquid in the body of *S. zeamais* contained water (H_2O) which was dipolar. In the electromagnetic field, this water would experience ionic conduction due to the collision between water molecules and dipole rotation of water molecules (dipolar). This raised the body heat of *S. zeamais* and caused death. This was also evident by comparing to the test on heating *S. zeamais* in hot air oven. At the same temperature of 57.5°C, the mortality using microwave heating reached an average of 96% (240 W for 90 s), while using hot air dryer it reached an average of 4% in 9 min of treatment. To achieve 100% mortality, hot air oven needed longer time of 10 min at 74.9°C (Table 2).

Figure 4 presents the comparison of temperature, time and energy between microwave and hot air oven treatments to reach 100% mortality of *S. zeamais* inside maize. The results indicated that the microwave treatment performed shorter processing time and much lower energy use.

The microwave treatments provided no significant effect on the nutrient content of the treated maize. The results of statistical tests showed that neither the power nor the exposure time gave significant influence on the starch content changes after warming ($F_{3,4}$=4.25, P>0.0001 and $F_{2,4}$=1.83, P>0.0001). Starch which was the largest maize nutrient component (77.1%) remained as such after microwave heating with the longest exposure time at all power levels. Insignificant changes of protein content were also shown during the microwave treatments of maize. The protein content in all treatments was above the Indonesian National Standard (SNI 01-4483-19986) of 7.5%.

CONCLUSIONS AND RECOMMENDATIONS

The dielectric heating of microwave made possible to kill insect pest *Sitophilus zeamais* Motsch in maize without significant changes of nutrient content. 100% mortality of *Sitophilus* could be achieved in a short time of 60 s and low energy use of 16 Wh. This indicated a very short and low energy consumption treatment comparing with that of hot air oven which needed 22 min exposure. This short time microwave treatment had the advantage to keep 68.5% starch content and 9.4% protein content as high maize quality standard. For further study, it was recommended that the experiment would be carried out for *Sitophilus zeamais* in larvae, pupae and egg stadium.

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Tables

Table 1. Mortality percentage of *Sitophilus zeamais* during microwave treatment outside and inside maize on the various power levels and heating times.

Heating time (s)	Power (W)							
	0		240		480		720	
	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside
15	0	0	0	0	58	0	90	2
30	0	0	10	0	68	0	98	24
45	0	0	34	0	98	0	100	86
60	0	0	60	0	100	56	100	92
75	0	0	70	2	94	82	100	100
90	0	0	96	6	100	94	100	100
105	0	0	100	26	100	98	100	100
120	0	0	100	50	100	100	100	100

Table 2. Mortality percentage of *S. zeamais* during hot air oven treatment on various temperatures and exposure times.

Temperature (°C)	Time (minutes)	Mortality (%)
47.47	7	0
48.30	7	0
47.07	7	0
50.00	9	4
57.50	9	4
58.30	9	6
60.00	12	94
63.70	15	96
68.16	15	98
74.90	22	100
80.30	22	100

Table 3. Maize starch content (%) after microwave treatment at various power levels and exposure times.

Time (s)	Power (W)			
	0	240	480	720
60	64.9	58.6	66.7	68.5
90	64.9	65.4	67.8	68.4
120	64.9	67.0	70.1	71.3

Table 4. Protein content (%) after microwave treatment at various power levels and exposure times.

Time (s)	Power (W)			
	0	240	480	720
60	9.18	9.38	9.28	9.18
90	9.28	9.44	9.36	9.28
120	9.38	9.29	9.34	9.38

Figures

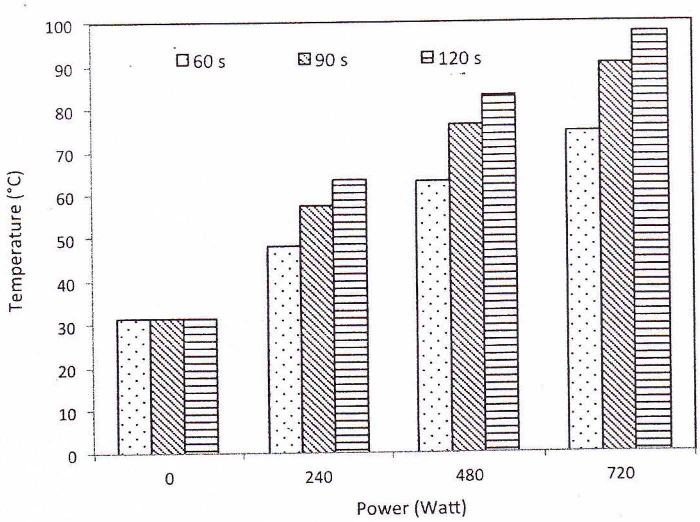

Fig. 1. Surface temperature of maize infected with *Sitophilus* insect pest after microwave treatment at various power levels and heating time.

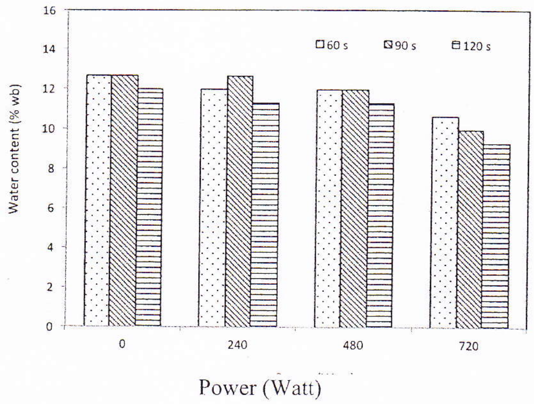

Fig. 2. Water content (wb) of treated maize infected with *Sitophilus* insect after microwave treatment at various power levels and heating time.

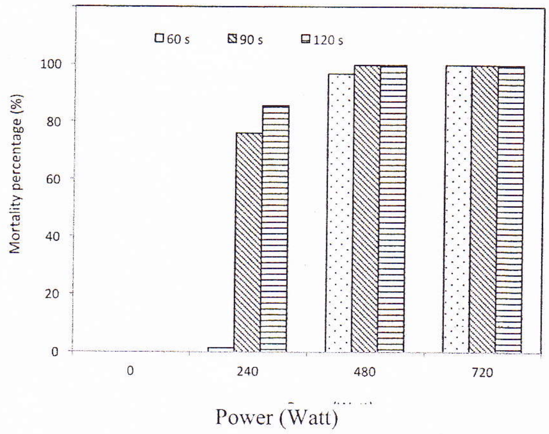

Fig. 3. Mortality percentage of *Sitophilus zeamais* pest inside maize during microwave treatment at various power levels and exposure times.

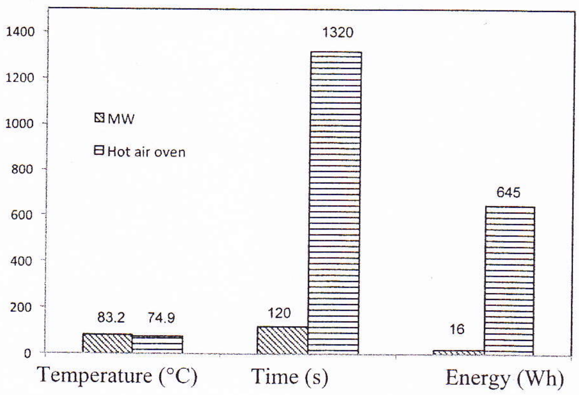

Fig. 4. Comparison of temperature, time and energy between microwave and hot air oven treatments to reach 100 % mortality of *Sitophilus zeamais* inside maize.