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Dielectric properties characterization of the rice and rice weevil for microwave heating treatment

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ABSTRACT

This paper presents the dielectric properties characterization of the rice and rice weevil for microwave heating disinfestation treatment application. Infestations of insects in stored grain have become a major threat to food supply globally. It contributes to damage to the stored grain and had caused economic losses. The current method to control the infestation which is by using chemical fumigation could give harm to human health and cause environmental pollution. The ability of microwave energy to kill the insects using dielectric heating technique has a high potential as an alternative method to control the infestation of the insect. Knowledge of dielectric properties of the insects is important to understand the interactions of the insect with electromagnetic fields. Hence, this paper presents the evaluation of the dielectric constant, and dielectric loss factor, of the insects and grain using open- ended coaxial probe method. The dielectric properties of the rice weevil, S. Oryzae and rice are measured using an open-ended dielectric probe. Found that the dielectric constant, loss factor and loss tangent for both samples are inversely proportional to the frequency. Knowledge of the moisture content and temperature of the insects and rice is very important to characterize the dielectric properties for future development of microwave heating disinfestation treatment effectively.

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1. INTRODUCTION

The security of food security is one of the main agenda of every government around the world. Food and Agriculture Organization (FAO) defined the term "food security" refers to "a situation involving all levels, which always obtain sufficient food supply, safe and nutritious food to meet the needs and requirements of an active and healthy lifestyle"[1]. The main issue of food security globally as well as at national level is the losses during post harvesting stage. The dependence on the rice production in the country is not enough, thus the rice also imports from the neighbouring country too. To avoid a shortage of supply, usually, rice will be stored in large quantities for a certain period before they can be marketed. Although rice is a long-lasting commodity, it still can be damaged due to various factors. Thus, an efficient rice storage system is necessary to ensure the quality of stored rice is always good. One of the factors that can damage the stored rice is the infestation of insects.

Infestation of the insect of stored rice has caused a variety of damage and economic losses to the stored rice or food supplies. When the insects consumed the rice, the quantity and quality of the rice is reduced. Among the stored-product insects, rice weevil, Sitophilus Oryzae is one of the primary pests of stored rice, particularly rice (Oryza Sativa L.). Sign of infestation in the stored rice is increased in moisture levels and heating on the surface. The feeding activity of S. Oryzae contributes to heating and infested rice became damp due to moisture added by the insect‘s respirations. This may encourage the growth of the population of other insect species. Therefore, control of stored rice insects is very crucial and is one of the major task in order to prevent more economic losses because the damage imposes to rice is irreversible and if the quality of rice is to be maintained.

1.1. Disinfestation Methods

Postharvest control of insects in rice is essential to sustain the quality of stored rice and inhibit economic loss caused by the insects. The aim of the control measure is to provide the habitat unacceptable for the development and generation of stored-product insects [2]. There are different techniques that are utilized to control the bugs which can be assembled as a physical, organic, and substance strategy.

1.1.1 Physical Method

Physical methods can control the insect on stored rice by modifying the environment or by applying physical treatments to the insects and rice. It incorporates a diverse set of trap (probe traps and pheromone traps), modifying of the environment [3], mechanical impact, physical expulsion, abrasive and inert dust. The physical factors such as increasing and decreasing of temperature, relative humidity and the composition of atmospheric gasses are normally controlled. The limitations of the physical method such as it only can be used where the infestation rate is low as it has a tendency to be lethargic and may not give a lot of mortality despite when well-managed.

1.1.2 Biological Method

Biological methods involve the use of other organism to control the insect. The organism which acts as the natural enemies can be released in one area and they will search and attack the insects in the stored-product. It does not give any hazard to the environment or to the consumers because no chemical is involved [4]. Since most stored-product insects are from numerous species, thus several different species of biological enemies are required. Unfortunately, biological control techniques act very slow, hence much loss may happen before the control is viable. This method is not suitable for massive infestations [5].

1.1.3 Chemical Method

Chemical control method is the most commonly used to avoid the rice from insects due to its low cost, quick handling, and very simple technique. Chemical insecticide is used to kill the insects in stored rice. There are two classes of chemicals used which a contact insecticide and fumigants. Malathion, pirimiphos-methyl, and chlorpyrifos-methyl are contact insecticides [3] that can kill the insect pests when they contact the treated surfaces. Fumigation is a process of killing the insects that are inaccessible by the contact insecticides type by exposing them to toxic gas. The most fumigants used are phosphine and methyl bromide.

The major disadvantage of the chemical method for using insecticides is that insects have developed their own natural defence to insecticides. Despite the fact that insecticides and fumigants are handled with caution and restricted amount, there is a probability of the chemicals remaining in the stored rice and having a detrimental effect on the human being. Pesticide exposure may cause harm to human health from acute problem, for example, skin rashes and asthma attacks, to a chronic problems such as emphysema and cancer. Chemicals also hazardously affect the environment. Phosphine is used to replace methyl bromide, which caused the depletion of the ozone layer, but the drawback is resistance build-up to this compound getting faster [4].

A combination of heat and controlled atmosphere treatments was proposed in [6] as an alternative to chemical fumigants. It was used to rapidly assess tolerances of adult weevil.

The lifespan of an adult rice weevils is up to six or seven months. During that period, the female rice weevil capable of producing 300 to 400 eggs. The way these eggs are deviating for hatching is quite unique and very safe. The female rice weevil uses her strong mandibles to drill a hole in the rice kernel. Then she puts a single egg and seals the hole with a gelatinous fluid which they provide by their saliva. In the hot climax like in Malaysia, the development period for the egg to hatch is normally in twenty five days. This period is longer for cold climax. This unique hatching method of the weevil larvae causes its breeding cannot be stopped even though the disinfestation treatment process has been performed. This is a major disadvantage of the conventional treatment methods. Based on that statement, now it is answered on how the rice weevil occurs in our rice storage even though there is no weevil seen during the rice purchasing. But after a few days or a week, a lot of weevil appears in the rice storage.

Dielectric heating covers both radio frequency (RF) and microwave (MW), which are involved high-frequency electromagnetic waves. Most agricultural products, can spare electric energy and transform it into heat [7]. A heat treatment technique involving microwave radiation looks to have a great perspective as a substitute technique of killing insects. This technique appears to have a few favourable circumstances, for example, the control of every single formative phase of insects, no synthetic buildups, having an insignificant effect on the environment and giving rapid heating [7]. Insects are unable to develop their own natural defence to this treatment [8]. This electromagnetic energy associates directly with the product's internal to rapidly raise the midpoint temperature. Microwave energy may not just kill insects, but also affect the generation of survivors of the dielectric heat initiated inside them [9]. In article [10], they review the concept of radio frequency and microwave heating treatment to disinfest of kutu beras in rice. The [11] reviews the application of microwave pyrolysis of biomass materials.

The most important variables in MW heating that express the relationship of the material with electromagnetic microwave field and the heating feasibility is the dielectric properties of materials. Thus, it is very important to study and analyse the dielectric properties of materials accurately in order to implement the microwave heating efficiently. In [12], the relevance of dielectric properties in microwave assisted processes was presented.

There are few researches were presented in studying the factors that influencing the dielectric properties of agricultural and food products [13], dried fruit [14], cereal-based product [15] and insect [16,17].

This paper presented the dielectric properties characterization of the rice and rice weevil. These properties are very important in microwave heating disinfestation treatment study. The detail methodology of dielectric properties characterization will be presented in the following section.

2. RESEARCH METHODOLOGY

The permittivity of the dielectric properties of the materials is the function of the frequency and moisture content. Thus the dielectric properties, the behaviour of the rice and rice weevil at microwave frequency is the most crucial factor for the effectiveness of the using microwave energy for disinfestation.

2.1. Material Preparation

The basic materials that are used in the dielectric properties measurement are listed as below:

a. Agilent E8362B P-Series Network Analyzer and probe as shown in Figure 1(a).
b. The dielectric probe kit as shown in Figure 1(b).
c. The sample of smashed rice as shown in Figure 2(a).
d. The sample of rice weevil as shown in Figure 2(b).

(a)

(b)

Figure 1. Measuring devices. (a) The Agilent E8362B P-Series Network Analyser, (b) Dielectric probe kit

(a)

(b)

Figure 2. The Sample a) Smashed Rice b) Rice Weevil

2.2. Open-ended Coaxial Probe Measurement Technique

The dielectric properties or permittivity of the material can be resolved using a dielectric probe. The dielectric properties measurement is based on the coaxial probe method which includes the use of network analyzer, open-ended probe and coaxial probe. The reaction of material to RF or MW energy is measured using a network analyzer. In this project, the high temperature probe is used. The network analyzer is connected via coaxial cable to the open-ended probe.

The measurement is performed by touching the probe against the material under test (MUT) sample. This probe is resistant to corrosive chemicals and can withstand between -40 to +200 degree Celsius. The large flanges make it easier to do the measurement of solid materials. The generated microwave signal by the network analyzer is absorbed by the MUT and then reflected back to the network analyzer. It is important to ensure that the sample is in close contact with the probe to avoid air gaps. The reflected coefficient measured by the network analyzer.

2.3. Measurement Setup

The dielectric properties of the insect and rice are measured using a dielectric probe which is connected with an Agilent E8362B P-Series Network Analyser (PNA). Calibration of the dielectric probe with the Agilent Technologies 85070E software must be conducted before the measurement in order to prevent any systematic errors. There are three standard calibration tests that are conducted, i.e., water, short (metal) and air (open). After the probe calibration is performed, the actual measurement of the material under test (MUT) can be performed by touching the probe against the flat surface (or powder) of the MUT. Before the measurement is preformed the MUT which is rice and rice weevil must be made in powder form. The measured permittivity and the reflection coefficient displayed on the monitor. The measurement setup is shown in Figure 3. Figure 4 shows how the dielectric properties of rice are measured.

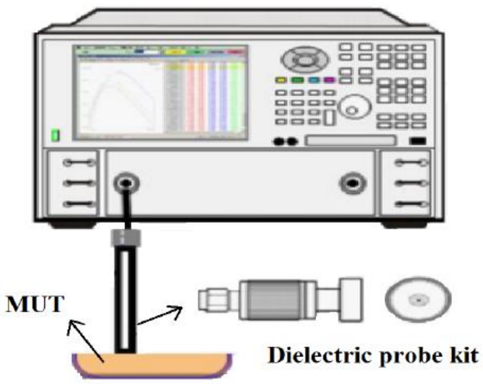

Figure 3. The Dielectric Properties Measurement Setup

Figure 4. The dielectric measurement of rice

3. RESULTS AND DISCUSSION

The dielectric properties of materials can be affected by several factors such as temperature, frequency and moisture content. This section will discuss the analysis of the data obtained from the experiment i.e. The dielectric constant (Ɛ') and dielectric loss factor (Ɛ") of the rice and rice weevil. The data have been measured repeatedly to get the average loss tangent of the rice and rice weevil.

3.1. Dielectric Constant of the Rice

Figure 5 shows the variation of the measured dielectric constant (ε‘) of the rice with the frequency range of 2-3GHz. Based on the graph, it is observed that the dielectric constant of the rice decreases as the frequency increases. The decrease of dielectric constant shows that the ability of the rice to absorb the electromagnetic energy is inversely proportional with the applied frequency.

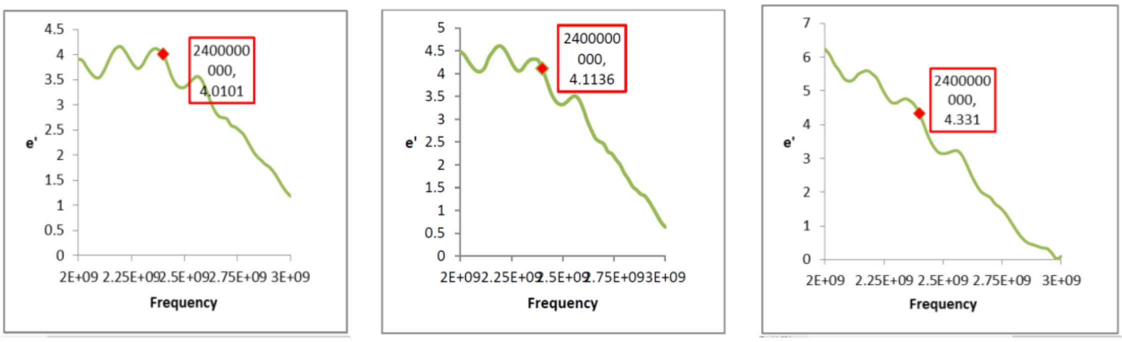

Figure 5. The measured dielectric constant of rice

3.2. Dielectric Loss Factor of the Rice

Figure 6 shows the variation of dielectric loss factor (ε") of the rice in the frequency trange of 2-3GHz. From the graph, it shown that the dielectric loss factor of the rice is decreasing as the frequency increase. It can be seen that the pattern of the graph shows that the dielectric loss factor of the rice decrease as the frequency decrease. However, the dielectric loss factor may either increase or decrease with moisture content or frequency depends on certain range of moisture content or frequency thus it is less predictable compared to the dielectric constants.

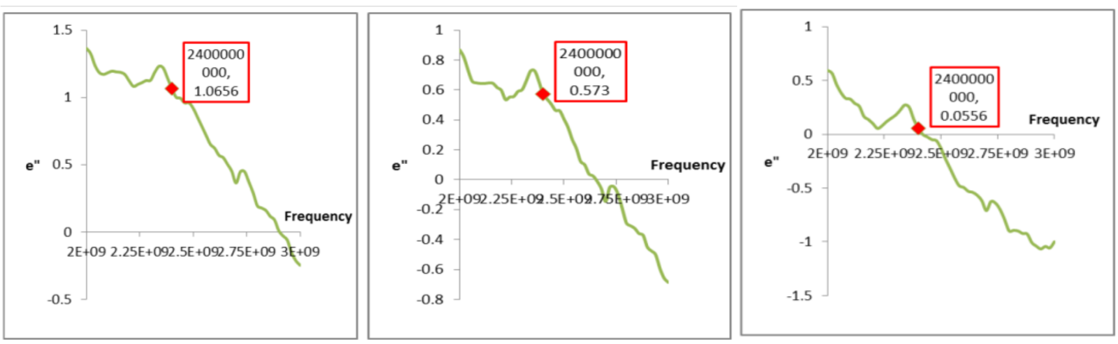

Figure 6. The measured loss factor of rice

3.3. Dielectric Constant of the Rice Weevil

Figure 7 show the variation of measured dielectric constant (ε') of the rice weevil with the rang of frequency 2-3GHz. Based on the graph, it can be observed that the dielectric constant of the rice weevil decreases as frequency increases. The decrease of dielectric constant shows that the ability of the insects to absorb electromagnetic energy is reducing when the higher frequency is applied.

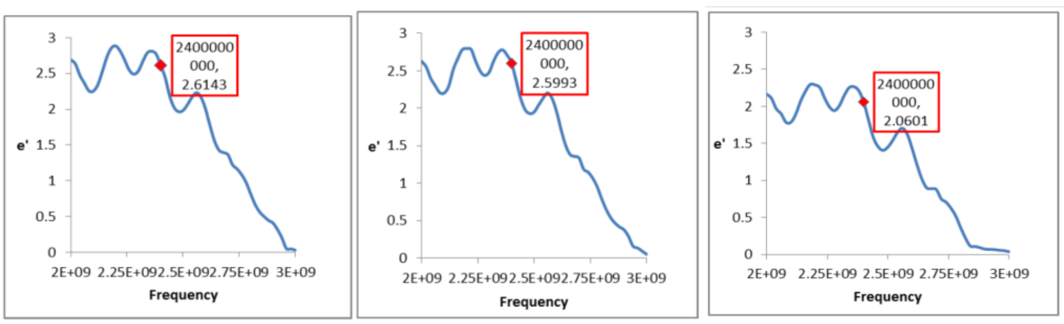

Figure 7. The measured dielectric constant of rice

3.4. Dielectric Loss Factor of the Rice Weevil

Figure 8 shows variation of the measured dielectric loss factor (ε") of the rice weevil for the frequency range of 2-3GHz. The graph show that the dielectric loss factor decrease as the frequency increase. It can be conclude that the ability of the rice weevil to disperse electrical energy into heat is inversely proportional to the frequency. The ability of the rice weevil to absorb the electromagnetic energy at higher frequency is lower.

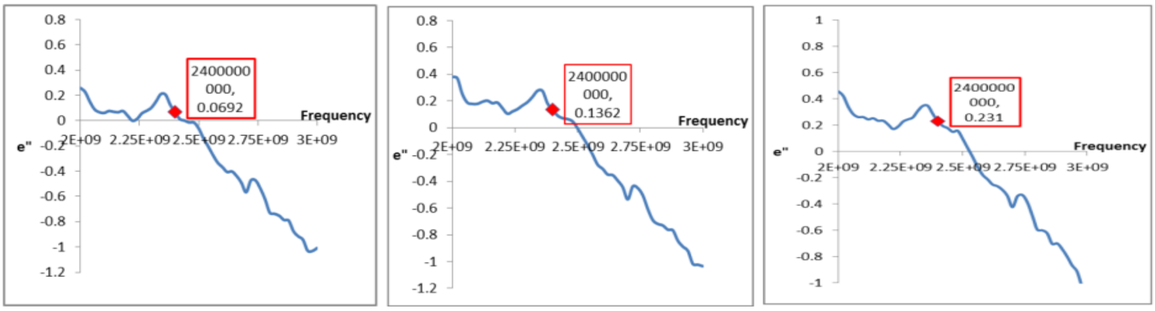

Figure 8. The measured loss factor of rice weevil

3.5. Loss Tangent

The loss tangent or dissipation factors represent the ability of the material to convert electromagnetic energy into heat at the specific frequency. The table 1 shows the loss tangent of the rice and rice weevil at frequency 2.4GHz. From the table, it shown that the calculated loss tangent of the rice is 0.136 while the loss tangent of rice weevil is 0.136. The data shown that the loss tangent of rice is higher compared to the rice weevils. It can conclude that at 2.4GHz frequency, the ability of the rice weevil to convert electromagnetic energy into heat is lower compared to rice.

Table 1. Loss Tangent of the Rice and Rice Weevil

	Material	
Average	Rice	Rice Weevil
\ε'	12.4547	7.2737
ε"	1.6942	0.4364
$tan\delta = \frac{\varepsilon''}{\varepsilon'}$	0.1360	0.0599

4. CONCLUSION

The dielectric properties behavior of the rice and rice weevil is very important to define the interaction of them with electromagnetic fields. The fundamental understanding of the properties is essential for designing industrial microwave heating application for effective controlling of the rice and rice weevil as well for other food security. The purposed of this paper to characterized the dielectric constant and dielectric loss factor of the rice and rice weevil is achieved.

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