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The Effect of Electric Field Distributions on Grains and Insect for Dielectric Heating Applications

S. Santalunai, T. Thosdeekoraphat, C. Thongsopa

***Abstract*—**This paper presents the effect of electric field distribution which is an electric field intensity analysis. Consideration of the dielectric heating of grains and insects, the rice and rice weevils are utilized for dielectric heating analysis. Furthermore, this analysis compares the effect of electric field distribution in rice and rice weevil. In this simulation, two copper plates are used to generate the electric field for dielectric heating system and put the rice materials between the copper plates. The simulation is classified in two cases, which are case I one rice weevil is placed in the rice and case II two rice weevils are placed at different position in the rice. Moreover, the probes are located in various different positions on plate. The power feeding on this plate is optimized by using CST EM studio program of 1000 watt electrical power at 39 MHz resonance frequency. The results of two cases are indicated that the most electric field distribution and intensity are occurred on the rice and rice weevils at the near point of the probes. Moreover, the heat is directed to the rice weevils more than the rice. When the temperature of rice and rice weevils are calculated and compared, the rice weevils has the temperature more than rice is about 41.62 Celsius degrees. These results can be applied for the dielectric heating applications to eliminate insect.

***Keywords*—**Copper plates, Electric field distribution, Dielectric heating.

I. Introduction

NOWADAYS, the heating technology by using electromagnetic field technology is important in engineering and sciences research. The development of heating technology is classified in various types as induction heating and dielectric heating. The induction heating is induced by using the inductive coil which is generated the magnetic field [1]-[3]. Moreover, when the magnetic field is induced, the electric current flows though the load model. So, the generally of the currents are flowed through in skin depth of the load model and the currents generated the heat at the surface of the load model. The heat is dependent on amount of induction current and the equivalent impedance, which is flow through the current path. Furthermore, the heat is transferred to the other regions of the load model by the heat conduction and the heat convection.

In the same way, the dielectric heating technology is extremely interested in the heating technology because a form of thermal energy is directed into the dielectric material with appropriate frequency range. Consequently, this technique has no effect on another material such as the rice. The dielectric heating structure uses the frequency spectrum principle, which is applied in the form of an electric field to transfer power into the dielectric material with polar molecule. The resonance of the molecules is quickly and evenly occurred in the dielectric material and dielectric heating. The dielectric heating is currently being applied in many applications [4]-[6], which are dehydration industry, fruit pre-serration industry. In addition, the dielectric heating can be used for the organism or pests in the agricultural sector. Because of the structure of an organism is a liquid or a polar molecule, it can induce the radio wave to heat [7], [8]. The organisms are embedded in the products that are rice weevil, insect, pests, and worms, which have an effect on the export or the imported product. The plate heating technique uses a plate to generate the electromagnetic wave to the medium. As a result, the dielectric is heated up by using the nature of the electric field that is distributed between the plates.

G. Jeffrey presented a form of the heating plate, which has the physical description of circular plate and square plate [9]. Because of the characteristic of the plate model and the distribution of electromagnetic wave that have the symmetrically and evenly distribution, so the plate is fed with only one point. However, the seeds are flowed through the finite structure which are circularly and square plate. They are unsuitable structures for the moveable materials. Specially, the rectangular plate is suitable used for elimination of insects that are mingled in the seeds. The heating space can be increased by using the rectangular plate, which is suitable for agricultural industry.

In agriculture, after the product is harvested, it has been stored before export. For a long time that the products are stored, so the pest which is the rice weevils devours and destroys the products. Hence, the dielectric heating is an important technique to control insects in the grain after harvesting. The advantage of the radio frequency (RF) is unadulterated toxin. Consideration to an effect of the dielectric heating, electric field distribution and intensity analysis are occurred at the dielectric load. When the materials for heat are grains and insects, this research studies and analyses the dielectric heating by using the electric field intensity that is occurred with the grains and insects. The rice and the rice weevils are used for dielectric materials in this analysis. In addition, the effects in each material are compared and to control overheat of the grains. The heat is occurred by using rectangular plates to generate the electric field. The plates are made from a copper material with size of 5 x 20 cm, thickness of 0.5 mm. An analysis is classified into two cases as case I uses the rice weevil placed1 set and various positions on plate

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and case II placed the rice weevil 2 set and two different positions on the plates. The feed points of rectangular plate are optimized by using CST EM studio program with 1000 watt electrical power at 39 MHz resonance frequency, which is a responsible frequency of rice weevil [10], [11]. The most electric field intensity is occurred when the location of materials are located near the feed point. At the same position, the rice weevils have effect of electric field intensity more than rice because the frequency respond is appropriated to the rice weevils. It can be applied for the dielectric heating applications to eliminate insects.

II. The Concept and Construction

For the most effective results in the dielectric heating applications, the properly structure and pattern are important. In Fig. 1 shows the structure of dielectric heating to eliminate the insect applications, consisted of the circuit of the power and signal frequency resonance at 39 MHz. The copper plates are used for the radiation of an electric field to transfer power to dielectric load. The upper electrode and lower electrode are copper plates. The dielectric load is group of insects and grains. In this paper, rice and rice weevils are used for the materials and the parameters of the materials are shown in Table I. The dielectric loss factor and permeability of rice are 0.4 and 3.4, respectively. Moreover, the dielectric loss factor and permeability of rice weevil are 2.4 and 7.2, respectively. The electric field distribution and intensity in the materials are compared in this paper that are discovered the appropriate heating methods. Beside this, these methods have not affected to the grain. The parameters are displayed in the model, the rectangular plate are made from a copper material with size, thickness, and the distance between the plates of 50x 200 mm, 0.5 mm, and 10 mm, respectively, as shown in Fig. 2. The compared simulation results of the distribution and intensity of electric field from input port power of one and four port, which one port at position (X = 0,Y = 0). In four ports case, the position of port 1, 2, 3 and 4 are (X = -75, Y = 0); (X = -25, Y = 0); (X = 25, Y = 0); (X = 75, Y = 0), respectively. The dielectric materials in the plates have the property, which is similar to the rice and the rice weevil. The quantity of rice is set to equal the size of the gap between the plates, as shown in Fig. 3. The material properties of rice weevil have the width, length, and height of 5 mm, 10 mm and 2 mm, respectively, is inserted in materials as rice. In this simulation model is divided into two cases, case 1 use the rice weevil placed1 set and various positions on plate and case 2 placed the rice weevil 2 set with two different positions on the plates, which each cases use the same model for all four positions in an analysis. The positions of cases analysis is concluded in Tables II and III, respectively.

TABLE I
Properties of Materials at 39 MHz

Materials	Dielectric loss factor	Permeability
Rice	0.4	3.4
Rice weevil	2.4	7.2

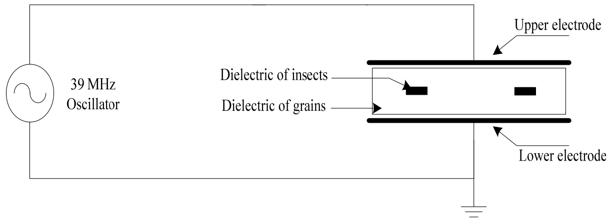


Fig. 1 Schematic of dielectric heating applications

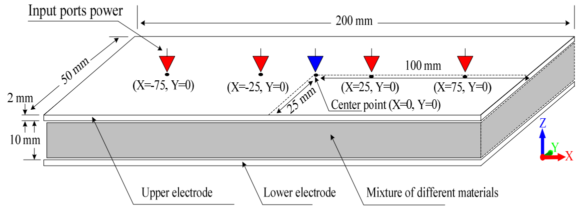


Fig. 2 The structure of input ports power on copper plates for electric field analysis

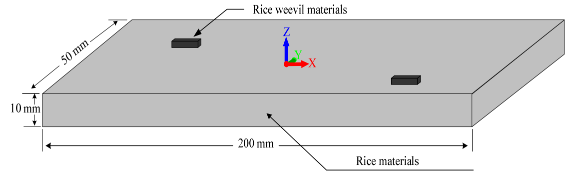


Fig. 3 The characteristics of dielectric materials placed between the rice and the rice weevils

TABLE II
Positions of Rice Weevil Simulation Tests

Code	Position (X,Y,Z) mm.
A1	0,-12.5,5
A2	0,12.5,5
A3	-75,-12.5,5
A4	75,12.5,5
A5	-85,0,5
A6	0,0,5

TABLE III
Positions of Rice Weevil Simulation Tests

Code	Position (X,Y,Z) mm.	
	P1	P2
B1	0,12.5,5	0,-12.5,5
B2	75,12.5,5	75,-12.5,5
B3	-75,12.5,5	-75,-12.5,5
B4	-15,0,5	15,0,5
B5	-75,-12.5,5	75,12.5,5
B6	-75,12.5,5	75,-12.5,5

III. Dielectric Heating

The rice and rice weevil is the loss factor feature, which are the dielectric materials that apply the electric field to the heat. The higher loss factor is the easier dielectric material that can be affected by dielectric heating. Consideration of the dielectric materials, the loss factor is greater than 0.02 [12]. Sometimes when the temperature is varied, the loss factor of some products can be increased. The permittivity is denoted by the symbol of ε, which is the ability of a dielectric material to be polarized. Dividing the permittivity by the permittivity of free space $\varepsilon_0 = 8.85\times10^{-12} F/m$ resulted in the relative permittivity (dielectric constant) ε'.

$$\varepsilon' = \frac{\varepsilon}{\varepsilon_0} \quad (1)$$

The permittivity of a material can be expressed as a complex quantity, the real part is associated with the capability of the material for storing energy, and the imaginary part is associated with the dissipation of electric energy in the material by conversion of electric energy to heat. The complex permittivity is shown here, where *j* represents the complex operator $\sqrt{-1}$

$$\varepsilon^* = \varepsilon' - j\varepsilon'' \quad (2)$$

In polarized materials, the friction between molecules is generated in reaction to the electric field applied and yields an increase in temperature of the material. However, the delay between the penetration of the electric field and the production of heat is called the loss angle δ. The ac electrical conductivity associated with the dielectric loss in the material $\sigma = \omega\varepsilon_0\varepsilon''$ (S/m) is where ω is the angular frequency, $2\pi f$. The loss angle can be expressed as a component of the loss factor as (3)

$$\tan\delta = \varepsilon'' / \varepsilon' \quad (3)$$

Both the loss tangent and the dielectric constant are varied with the frequency, applied and the temperature of the material. The power is absorbed by the material, which the value of heat generated through the material and is represented as (4)

$$P = E^2\sigma = 2\pi f E^2 \varepsilon_0 \varepsilon'' \quad (4)$$

where, *P* is power loss density (W/m^3), *E* is rms electric field strength in the material (V/m), σ is conductivity (1 Ωm), *f* is applied frequency (Hz), ε_0 is permittivity of free space (F/m), and ε'' is loss factor. The rate of temperature is increased (C/s) in the material that is given by (5). Where c is specified the heat of the material (kJ/kg^{0}C) and ρ is density of the material (kg/m^3)

$$\frac{\Delta T}{\Delta t} = \frac{P}{\rho c} \quad (5)$$

The penetration depth is defined as the depth which the power is decayed to 0.368 (l/e) of its maximum value [13]. It is varied depending on the loss factor and the resonant frequency. Usually, the higher loss factor is, the lower the penetration depth will be. When the wavelength is increased, the penetration depth is increased as well. The relationship between wavelength and penetration depth is expressed as (6) where d_p is penetration depth (cm) and *c* is speed of light (3x10^8)

$$d_p = \frac{c}{2\pi f\sqrt{2\varepsilon'\left[\sqrt{1+(\varepsilon''/\varepsilon')^2}-1\right]}} \quad (6)$$

IV. Simulation Result

These results are simulated by using CST MW studio for the analysis effect of power loss density and intensity electric field on the dielectric load in the capacitor copper plates. By each case, the electrical power and resonant frequency are 1000 W and 39 MHz, respectively. The parameter of the simulation can be used according topic to the concept and construction. The simulation results show the distribution and intensity electric field on the dielectric load in the capacitor copper plates of the section wrapping in Z-axis at 5 mm for comparisons in each case. In Fig.4 shows the electric field distribution results of input port power for one port is the cross section in Z-axis at 5 mm. We found that the electric field distribution is propagated on the plate witch symmetrical level and the maximum level of electric field distribution is occurred at the center of plate as 1120 V/m. At the same time, the level of electric field is very low at the edge and corner. Nevertheless, it cannot propagate all of the full area. Apart from this, four feeders are optimal for coverage the more area thorn only one feeder. Fig. 5 shows the electric field distribution simulation results of input port power for four ports are the cross section in Z-axis at 5 mm as well. The maximum level of electric field distribution is occurred at the center of input port power as 324 V/m. At the same time, the level of electric field is very low at the corner Therefore, it is appropriate for analysis in this case.

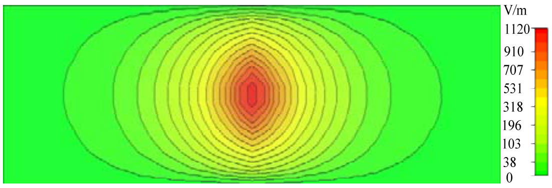


Fig. 4 Electric field distribution simulation results of input port power for one port the cross section in Z-axis at 5 mm

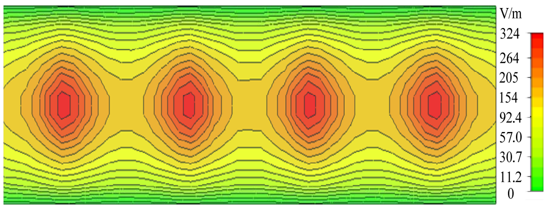


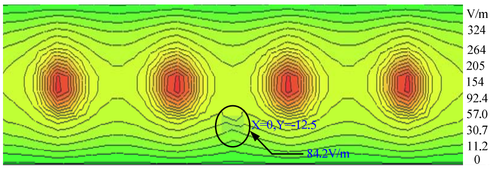
Fig. 5 Electric field distribution simulation results of input port power for four ports the cross section in Z-axis at 5 mm

A. Analysis of Electric Field on 1 Set of Rice Weevil

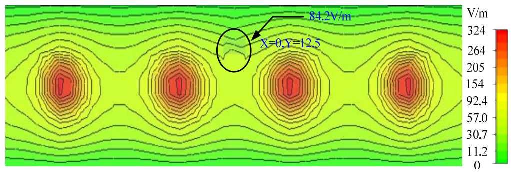
In this case, the simulation results by using rice material full area on capacitor copper plate and rice weevils are placed between copper plates which rice weevils parameter setup. It has the width, length, and height of 5mm, 10mm, and 2mm, respectively. It is placed for 1set. In addition, the rice weevils are placed in various positions for analysis electric flux density, power density and temperature of rice and rice weevil. The results in Table IV are expressed in terms of the electric flux density. However, replacing the electric flux density mentioned above into (4), the heating of power density in W/m^3 will be obtained and replacing the power density mentioned above into the last term of (5) the heating temperature in Celsius degrees unit per time will be obtained. For example, the cold of A1 shown in the Fig. 6 (a) at the position of rice weevil is (X=0,Y=-12.5) mm. the maximum value of electric flux density from rice is 75.5 V/m and rice weevil is 84.2 V/m to the form of power density will be equal to 4.64 W/m^3 and 34.45 W/m^3,respectively, and to the temperature from rice will be equal to 24.57 Celsius degrees and rice weevil is 28.22 Celsius degrees. Figs. 6 (a) and (b) are described the investigated heating of orientation.

TABLE IV
EVALUATING THE ELECTRIC FLUX DENSITY FROM DIELECTRIC HEATING

Code	Electric flux density (V/m)		Power density (W/m^3)		Temperature (°C)	
	Rice	Rice weevil	Rice	Rice weevil	Rice	Rice weevil
A1	73.50	84.20	4.69	34.45	24.57	28.22
A2	73.50	84.20	4.69	34.45	24.57	28.22
A3	100.1	114.7	8.70	63.94	25.07	31.84
A4	100.1	114.7	8.70	101.7	25.07	36.47
A5	239.8	274.7	49.90	366.7	30.12	68.94
A6	91.13	104.4	7.21	52.97	24.88	30.49



(a)



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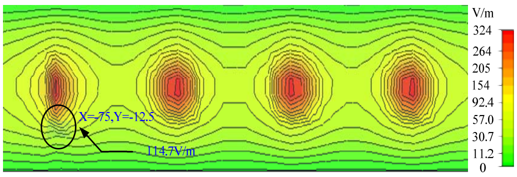
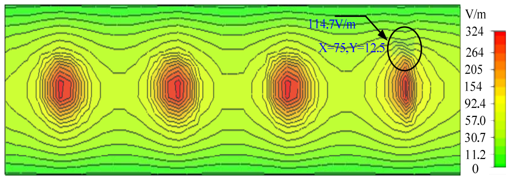
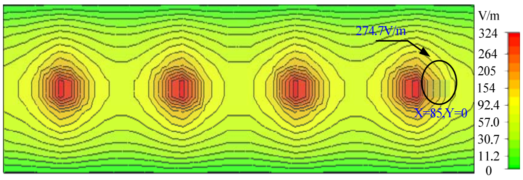


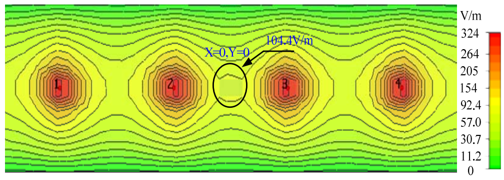
(c)



(d)



(e)



(f)

Fig. 6 Electric flux density of the heating model for rice weevil place 1 set various positions (a) A1 (0,-12.5,5), (b) A2 (0,12.5,5), (c) A3 (-75,-12.5,5), (d) A4 (75,12.5,5), (e) A5 (-85,0,5), (f) A6 (0,0,5) the cross section in Z-axis at 5 mm

The maximum level of electric field distribution is occurred at the center of input port power as 324 V/m. Moreover, the rice weevil is placed at the position that is concluded in Table II (code A1 and A2). The electric field distribution is directed to the rice weevil more than the rice. The rice weevil has the electric field intensity equal to 84.2 V/m and rice is equal to 73.5 V/m. In addition, the rice weevil is placed at the position that is concluded in Table II (code A3 and A4). In Figs. 6 (c) and (d), the electric field distribution of code A3 and A4 is satisfied because it has position as near the input port power. Rice weevil has the electric field intensity equal to 114.7 V/m and rice is equal to 100.1 V/m. In Fig. 6(e), when the rice weevil is placed at the position that is concluded in Table II (code A5). The most of electric field distribution can be obtained.

TABLE V
EVALUATING THE ELECTRIC FLUX DENSITY FROM DIELECTRIC HEATING

Code	Electric flux density (V/m)				Electric loss density (W/m^3)				Temperature ©			
	Rice		Rice weevil		Rice		Rice weevil		Rice		Rice weevil	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
B1	66.69	66.69	76.4	76.4	3.86	3.86	28.37	28.37	24.47	24.47	27.48	27.48
B2	84.84	84.84	97.2	97.2	6.25	6.25	45.91	45.91	24.77	24.77	29.63	29.63
B3	84.84	84.84	97.2	97.2	6.25	6.25	45.91	45.91	24.77	24.77	29.63	29.63
B4	248.2	248.2	284.4	284.4	53.46	53.46	393.08	393.08	30.55	30.55	72.17	72.17
B5	100.1	100.1	114.7	114.7	8.70	8.70	63.94	63.94	25.07	25.07	31.84	31.84
B6	100.1	100.1	114.7	114.7	8.70	8.70	63.94	63.94	25.07	25.07	31.84	31.84

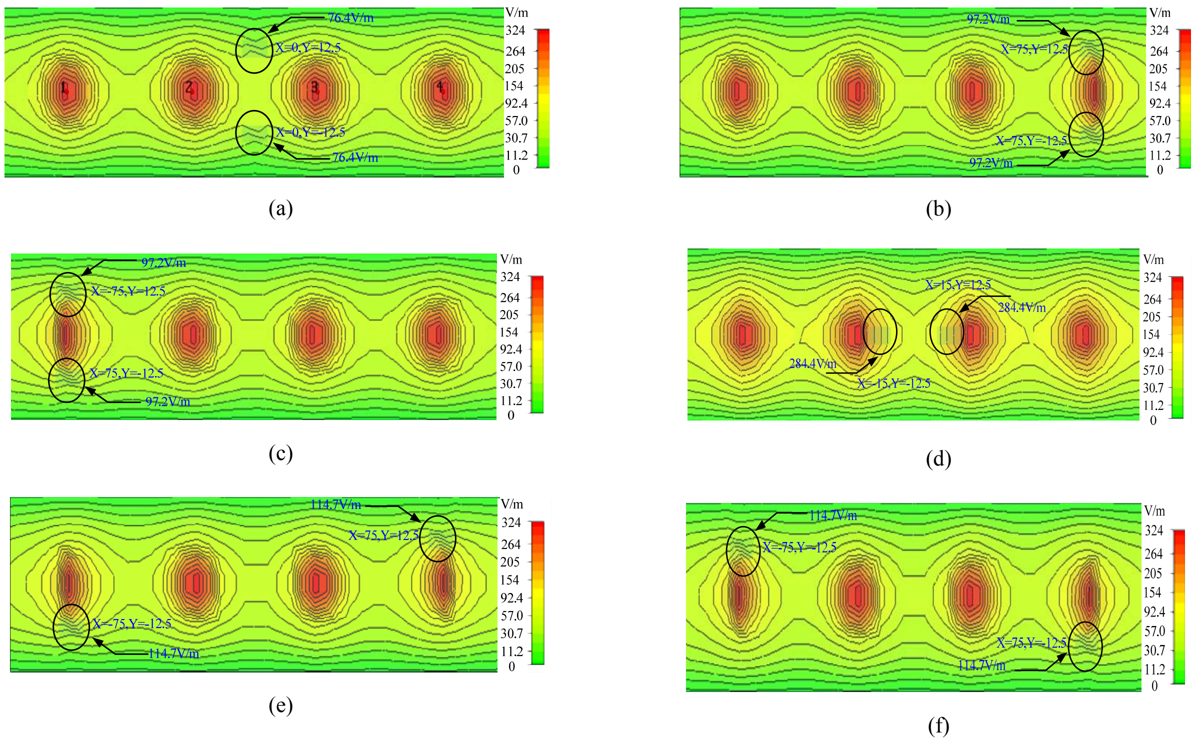


Fig.7 Electric flux density of the heating model for rice weevil place 2 set various positions (a) A1 (0,12.5,5) and (0,-12.5,5), (b) A2 (75,12.5,5) and (75,-12.5,5), (c) A3 (-75,12.5,5) and (-75,-12.5,5), (d) A4 (-15,0,5) and (15,0,5), (e) A5 (-75,-12.5,5) and (75,12.5,5), (f) A6 (-75,12.5,5) and (75,-12.5,5),the cross section in Z-axis at 5 mm

The rice weevil has the electric field intensity equal to 274.7 V/m and rice is equal to 239.8 V/m. In Fig. 6 (f), we place a sample of rice weevil at the position of Table II (code A6). The electric field distribution is directed to the rice weevil more than the rice. The rice weevil has the electric field intensity equal to 104.4 V/m and rice is equal to 91.13 V/m. Furthermore, the electric field at all the simulation into calculation of the temperature is occurred. The results in Table II, code A5 is shown that the difference temperature of the thermal of rice weevils and rice are relatively high, it has 68.94 Celsius degrees and 30.12, respectively. For the considering of two sets, the rice weevil is analyzed in the next section.

B. Analysis of Electric Field on 2 set of the Rice Weevil

In the simulation, 2 set of the rice weevils are placed to investigate the electric flux intensity, power density and temperature of rice and rice weevil. The parameter positions of rice weevils are shown in Table III and the results in Table V are expressed in terms of the electric flux intensity. However, replacing the electric flux intensity mentioned above into (4), the heating of power density in W/m^3 will be obtained and replaced the power density mentioned above into the last term of (5). The heating temperature in Celsius degrees unit per time will be obtained. Fig. 7 (a) is described the investigated heating of orientation. The maximum level of electric field distribution is occurred at the center of input port power as 324 V/m. But noted when placing a sample of rice weevil in positions of Table III is code B1, the characteristics of electric field distribution into direction approach the rice weevils both sets and it has the electric flux intensity more than the rice, compared to the same position. The rice weevil has the electric field intensity equal to 76.4 V/m and the rice is equal to 66.69 V/m. When rice weevil is placed in position that is conclude in Table III (code B2 and B3), as shown in Figs. 7 (b) and (c). The characteristics of electric field distribution into the rice weevil, it have direction approach the rice weevils both sets, because the positions as near the input port power. The rice weevil has the electric field intensity equal to 97.2 V/m and the rice is equal to 84.84 V/m. In Fig. 7 (d) when rice weevil is placed in position of Table III (code B4), the characteristic of electric field distribution is into the rice weevils same. The rice weevil has the electric field intensity equal to 284.4 V/m and the rice is equal to 248.2 V/m. In Figs. 7 (e) and (f), when placed a sample of rice weevil in position of Table III as code B5 and B6 The characteristic of electric field distribution is into the rice weevils and it has the electric field intensity equal to 114.7 V/m and the rice is equal to 100.1 V/m. Furthermore, the results in Table III (code B4) indicated that the difference temperature between the thermal of rice weevils and the rice are about 41.62 Celsius degrees. The rice weevil has an effected to the electric field over rice. Therefore, the technique to increase the input power ports is appropriate for dielectric heating system. This method can be developed to control the temperature and it has not effected to the agricultural product.

V. CONCLUSION

This paper presents the electric field distribution and intensity of grains and insects for dielectric heating applications. It is considering of the dielectric heating of rice and rice weevils, which the properties of rice and rice weevils are used to dielectric materials for analysis and compare heated of each materials. The analyzing simulation by using CST EM studio program at 1000 watt electrical power, with 39 MHz resonance frequency. The results shown that the electric field distribution and intensity on the rice and rice weevils, which the characteristics of distribution into direction approach the rice weevils more than the rice. Furthermore, the electric field of simulation into calculation of the temperature of rice weevils and rice it have difference temperature are about 41.62 Celsius degrees. Show that the rice weevil affects the electric field over rice. Thus, the technique to increasing the input power ports for dielectric heating to appropriate. It is the method that can help to control the temperature, not to affect the agricultural produce. It is can be applied for the dielectric heating applications to eliminate insect.

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