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Reshma Minj
Indian Institute of Food Processing Technology
Thanjavur, Tamil Nadu, India

Irengbam Barun Mangang
Indian Institute of Food Processing Technology
Thanjavur, Tamil Nadu, India

Jaganmohan Rangarajan
Indian Institute of Food Processing Technology
Thanjavur, Tamil Nadu, India

Loganathan Manickam
Indian Institute of Food Processing Technology
Thanjavur, Tamil Nadu, India

Corresponding Author:
Reshma Minj
Indian Institute of Food Processing Technology
Thanjavur, Tamil Nadu, India

Effect of microwave heating based disinfestation of cigarette beetle (*Lasioderma serricorne*) in turmeric powder

Reshma Minj, Irengbam Barun Mangang, Jaganmohan Rangarajan and Loganathan Manickam

Abstract
Turmeric (*Curcuma longa*) is one of the important spices in India. Turmeric have a yellow pigment. Curcumin has several therapeutic effects including antiviral, antinociceptive and anti-inflammatory used for treating a wide variety of diseases. Due to the antiviral property of turmeric, it could be a new treatment option being practiced to fight against the COVID-19. Insect infestation leads to quality deterioration and contamination with turmeric powder during processing, storage and marketing. Cigarette beetle, *Lasioderma serricorne* is an important insect damaging turmeric and turmeric powder. Insect not only feed on the stored products, but they also contaminate the product through excretion, exuvae and the fragments of the dead insects, which are all undesirable at the commercial level. In addition to the damage caused by insects, infestations encourage the spread of fungal and bacterial diseases. A number of modern nonchemical methods have been found to be effective against insect pests. Microwave heating is a novel dielectric heating technique which can be adopted in postharvest disinfestation treatments for a wide range of agronomic products, and it is a feasible alternate to chemical disinfestation methods. Thus the objective of this study was to protect turmeric powder against egg stage of *L. serricorne* by using microwave treatments. This study found that microwave could be possible for achieving maximum mortality of egg with color retention of turmeric powder at different microwave power levels (350, 450, 550, and 650 W) with different intervals of time (2, 4, 6, 8, and 10 minutes). The maximum mortality of the egg was observed at 550 for 10 mins. and 650W for 8 and 10 mins.

Keywords: Microwave heating, disinfestation, turmeric powder, Lasioderma serricorne, mortality

1. Introduction

Turmeric, *Curcuma longa* L. (Zingiberaceae) is a popular spice in Asian cuisine. Turmeric contains phenolic compounds in the rhizomes, is a hydrophobic polyphenol (Akbar *et al.*, 2018) [1]. The most active constituent of turmeric is curcumin (yellow pigment) and they are used as seasoning in foods and also in the cosmetic and pharmaceutical industries (Hosseini and Hosseinzadeh, 2018) [7]. Curcumin was found to be effective against few viruses like influenza A virus, HIV, enterovirus 71, herpes simplex virus and hepatitis C virus with several mechanisms that made it valuable for antiviral therapies (Qin *et al.*, 2014; Zorofchian Moghadamtousi *et al.*, 2014; Praditya *et al.*, 2019) [12, 22, 11]. Curcumin possess various therapeutic effects in which antiviral properties is a promising option to combat the COVID-19 pandemic (Babaei *et al.*, 2020) [3]. Turmeric contains great amount of total phenolic content (TPC) and curcuminoids that help to prevent some human diseases such as cancer and coronary heart disease (Wilken *et al.*, 2011) [19].

Turmeric is cultivated in the tropical and subtropical regions of the world which covers India, Bengal, China, Taiwan, Sri Lanka, Jeva, Peru, Australia, and Thailand (Suresh *et al.*, 2009). Indian turmeric has a large share in the world market and is known for its elevated curcumin quality (Velayudhan *et al.*, 2012) [15]. The main issues during production, storage, and marketing of turmeric are the damage and losses due to infestation by storage insects. The cigarette beetle, *Lasioderma serricorne* (Coleoptera) is a serious storage insect (internal feeder) that infests dried turmeric during storage, processing and retail (Arbogast *et al.*, 2003) [2]. Insect infestation may lead to enhanced growth of mold, contamination with uric acid, exuvea and degradation of products. The phosphine fumigation has become the most commonly used treatment for control of cigarette beetle because of its efficiency and relatively low cost. The agro industries currently relies heavily on phosphine fumigation for management of stored product insects (Carpenter *et al.*, 2000) [4]. The under dosed chemical fumigation will result in inability to kill the egg stage of insects which may remain alive and re-infest the product after 3 to 7 weeks (Mohapatra *et al.*, 2015) [10].

However, environmental and public health concerns about the hazards of chemical fumigation have increased the demand for non-chemical insect control methods for food products. Interest in developing and implementing non-chemical methods for disinfesting insects may help to increased food and environmental protection standards. There are different non-chemical methods like physical, mechanical and bio-control measures which are not much explored in large scale (Figure.1). Among the different techniques, thermal treatment using microwave is a promising non-chemical alternative to control insects in postharvest agricultural products.

Wang and Tang (2001) [17] reported that microwave irradiation is found to be a feasible alternative to chemical methods of disinfestation which have drawbacks *viz.*, undesirable residues in treated matrices, long treatment periods, and noncompliance with the Montreal Protocol's international rules for preserving the earth's atmosphere. Microwave heating is a dielectric heating technique in which energy is delivered directly to materials through molecular interactions with an electromagnetic field and the conversion of electrical field energy to thermal energy. When a mixture of dried samples and insects are treated in a microwave, the insects are warmed up to the lethal temperature more rapidly due to their higher water content. Microwave thus leave the dry matrices unaffected or mildly warm during the process (Wang *et al.*, 2003; Zhao *et al.*, 2007) [18, 21].

Microwave heating process is currently applied in minerals treatments, environmental remediation processes, food industry and also in pharmaceutical industries (Chandrasekaran *et al.*, 2012; Marra, 2012; Lyng *et al.*, 2014) [5, 9, 8]. Microwave heating has found success in postharvest disinfestation treatments of many agricultural products, including rice and beans (Yadav *et al.*, 2014) [20]. Based on the review on the microwave heating, the effect of microwave on the mortality of *L. serricorne* eggs in turmeric powder was studied. Further, the effect on the color of turmeric powder was also studied.

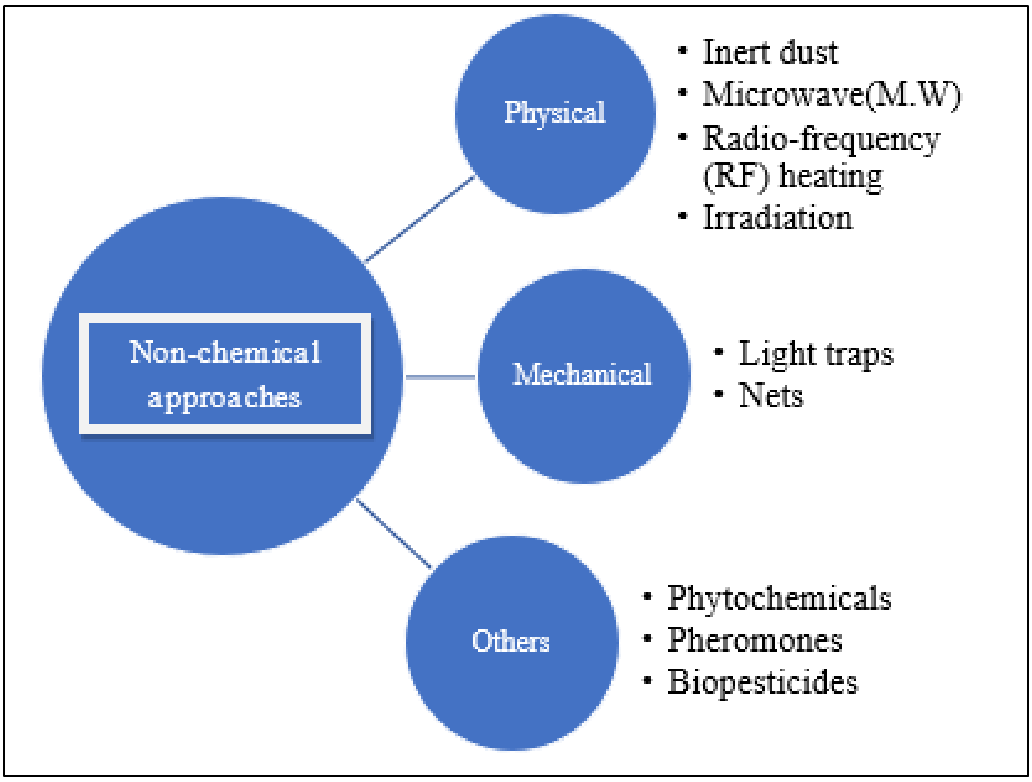


Fig 1: Non-chemical approaches for management of *L. serricorne*

2. Materials and Methods

2.1 Raw materials

The freshly processed and dried turmeric rhizomes were procured from local market of Thanjavur, Tamil Nadu. These rhizomes were powdered and sieved to have uniform particle size and to remove foreign materials. The turmeric powder was stored in an airtight container for further conducting experiments.

2.2 Culturing of insects

The parental culture of *L. serricorne* available in the laboratory was used for culturing and to get uniform aged egg of insect for microwave treatments. The freshly emerged adults (20 pairs) were released in the petri plate containing two gram of fresh turmeric powder and allowed for egg laying. The adults were removed after 24 hrs of egg laying and the uniform aged eggs were subjected to various microwave treatments to study effect of microwave on mortality of insect eggs.

2.3 Microwave (MW) treatment of infested turmeric powder

Microwave dryer (Make: Enerzi microwave system; Model: PTF 2515) was used for treating eggs of *L. serricorne* in turmeric powder. The equipment consists of a double magnetron assembly and a suitable conveyer belt for making the sample move continuously. A dedicated PLC control panel is provided to control and monitor the equipment effectively. The equipment has the minimum and maximum power level of microwave, ranging from 300W to 2900W. The disinfestation of *L. serricorne* process was modulated by changing different power levels and time combinations.

Microwave heating converts electromagnetic energy into thermal energy using a magnetron. When the samples (including insects) were subjected for treatment, the water molecule present in the sample reorients 2450 million times per second leading to volumetric heating of the sample (Tiwari *et al.*, 2021) [14]. Hurlock *et al.* (1979) reported that the main reason for effective microwave disinfestation is the more moisture content of insects when compared to dry food material, so they are more likely to heat up quickly with microwaves than the dried sample.

2.4 Effect of Microwave (MW) treatment on the eggs of *L. serricorne* in turmeric powder

The microwave dryer had a facility to adjust both exposure time and microwave power level. Based on the results of the preliminary trials, the range of process parameters was fixed. The microwave power level of 350, 450, 550, 650 W and the exposure time of 2, 4, 6, 8, 10 mins. were chosen for disinfesting turmeric powder. About 20 g of turmeric powder with 20 number of uniform aged eggs of *L. serricorne* were taken in the plastic petri dish (50×15mm) and spread in a thin layer (15mm). The petri-dishes were exposed to different combinations of power levels (350, 450, 550 and 650W) for exposure time (2, 4, 6, 8, and 10 minutes). The experiment was conducted along with an untreated control in triplicate. The petri dishes along with microwave exposed turmeric powder and eggs were kept in an ambient condition after the treatment. The mortality of eggs was observed after 10 days by observing the emergence of larvae using a stereomicroscope (Leica S8 APO; Make: Leica microsystems, Wetzlar, Germany).

2.5 Estimation of color

The MW treatment may have effect on the color changes apart from destroying the eggs of *L. serricorne*. Hence, the CIE color values (*L*, *a**, *b**) of treated and untreated turmeric powder were analyzed to study the effect of microwave disinfestation on the color using Hunter lab colorimeter with D_{25} optical sensor (Hunter Associates Laboratory, Reston, VA). The change in color was estimated using the equation (AOAC, 2000):

$$\textit{Change in colour value}, \Delta = \sqrt{(L-\mathrm{l})^2 + (A-\mathrm{a})^2 + (B-\mathrm{b})^2}$$

where, *L* = level of lightness, ranging from 0 (black) to +100 (white);

a = -100 (greenness) to +100 (redness) and

b = -100 (blueness) to +100 (yellowness)

Note: All the capital letters (L, A, B) and small letters (l, a, b) used in the equation stands for initial and final values, respectively

2.6 Statistical analysis

The time-mortality data on the survival / mortality of eggs were subjected to probit analysis (Finney, 1971) to estimate the time required to kill 50 or 90% of the insects using Polo plus 2.0 software (LeOra software, Petaluma, CA, USA). Student-Newman–Keuls test was performed using Statistical Package for the Social Sciences software (SPSS ver. 26; IBM Corp) for color. The ANOVA test was executed to assess significance of treatments on the color of turmeric powder using a 95% confidence level (Esmaeili *et al.*, 2018) [7].

3. Results and discussion

L. serricorne deteriorates the quality of turmeric powder and cause loss to the extent of 39.78 per cent in processed turmeric (Vijayalakshmi *et al.*, 1990) [16] and hence the *L. serricorne* has to be controlled at the egg stage itself in the turmeric powder. The MW disinfestation at various power levels attempted to exterminate the egg stage of *L. serricorne* without affecting the turmeric powder.

3.1 Effect of microwave on mortality of eggs of *L. serricorne*

The effect of microwave disinfestation of *L. serricorne* eggs in turmeric powder on the mortality were analyzed. Earlier, Yadav *et al.* (2014) [20] reported that microwave was shown to be effective in disinfestation of external feeders and even adults of internal feeders, but treatment must be conducted in shallow layers due to its limited penetration depth. Hence, the thickness of the turmeric powder was maintained at 15mm. Among the power levels (350, 450, 550 and 650W), 550W for 10 mins. and 650W with exposure time (8 and 10 mins.) were proved to be significantly superior to other power levels, where maximum per cent of egg mortality was observed (100%). This may be because of changes in cellular and surface of turmeric in exposed insect pests due to microwave heating. Insects are cold blooded, and their metabolism and activity are very greatly influenced by the temperature of their body (Mellan by 1939). The death of the insect is completely dependent on the mode of heat transfer, its rate and the maximum temperature the insect can sustain. The high-frequency oscillation of polar groups in insect bodies, such as water, generates heat through molecular friction, disrupts cell division, and changes the permeability of cell membranes (Fig. 2).

The lethal time for eggs of *L. serricorne* was investigated at various temperatures. The LT_{50} values were 5.84, 5.24, 4.07 and 3.24mins. at the MW power levels of 350, 450, 550 and 650W (Table 1). The LT_{99} values were 14.12, 12.73, 10.42 and 8.31mins. at the MW power levels of 350, 450, 550 and 650W. The results showed that the increase in power levels of MW, decreased the time required to kill the egg stage of *L. serricorne* (Fig. 3). So the exposure time has to be fixed based on the microwave power level, food material and thickness of material.

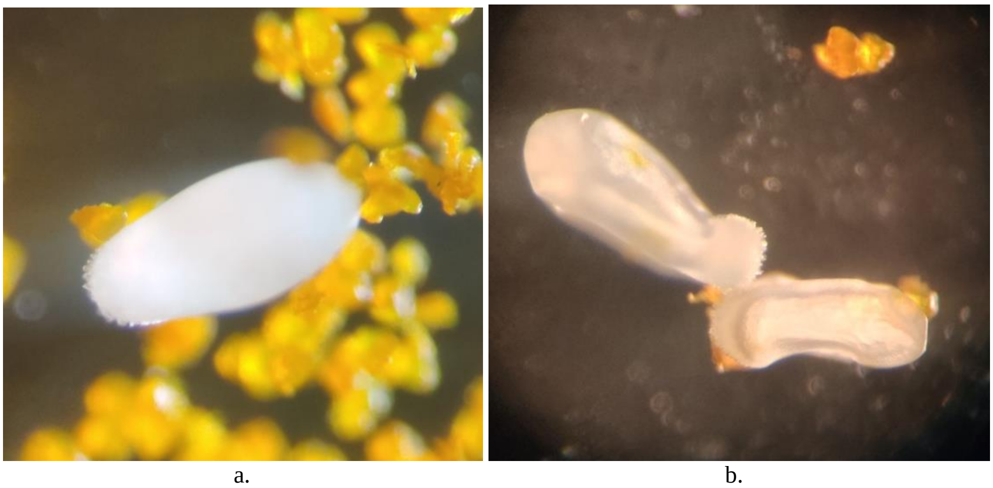
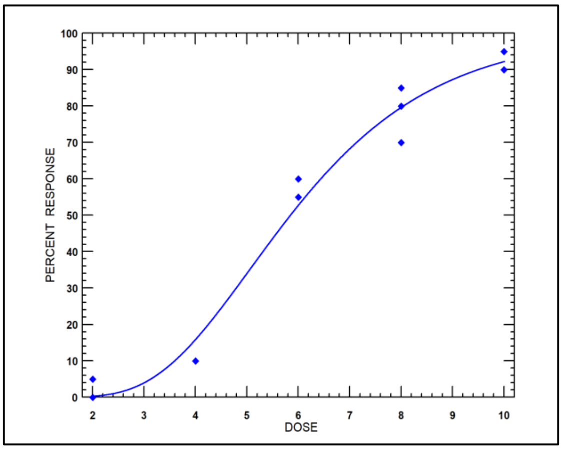


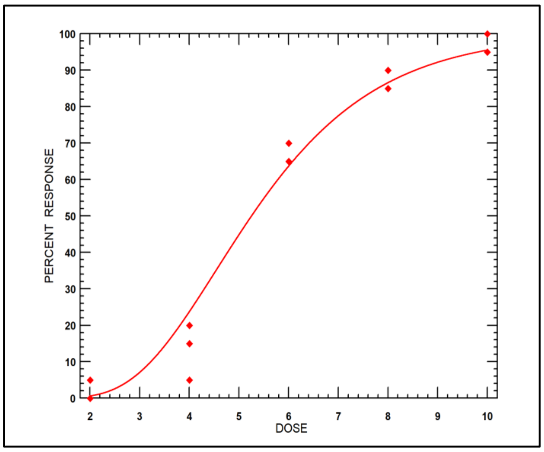
Fig 2: Stereomicroscopic image of structural changes on *L. Serricorne* egg before and after microwave treatment. (a) before MW exposure (b) after MW exposure

Table 1: Lethal time (h) to kill 50 or 95% of the eggs of *L. serricorne* exposed to MW power levels

Power level (W)	LT_{50}(95% CL) (min)	LT_{99} (95% CL) (min)	Slope ± SE	x^2 (df)
350	5.84 (5.18 - 6.48)	14.12 (11.46 - 20.41)	6.06+-0.62	23.38(13)
450	5.24 (4.66 - 5.80)	12.73 (10.53 - 17.38)	6.03+-0.59	20.71(13)
550	4.07 (3.71 - 4.42)	10.42 (9 - 12.79)	5.70+-0.54	11.48(13)
650	3.24 (2.92 - 3.54)	8.31 (7.14 - 10.29)	5.68+-0.56	10.39(13)



A.



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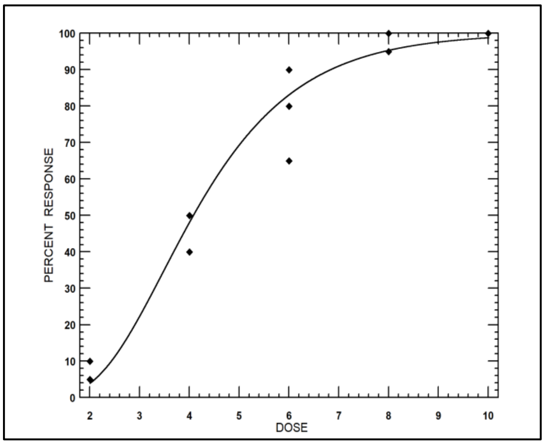

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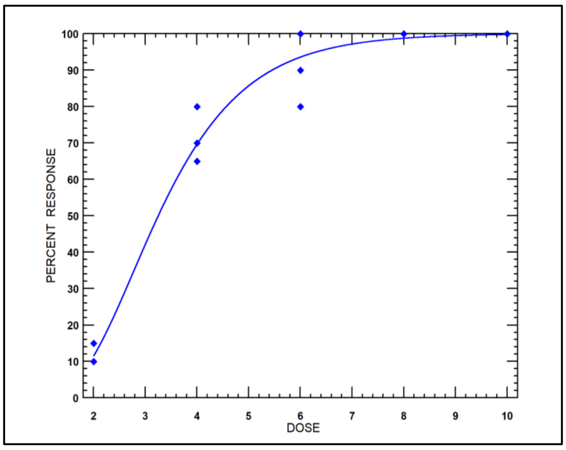

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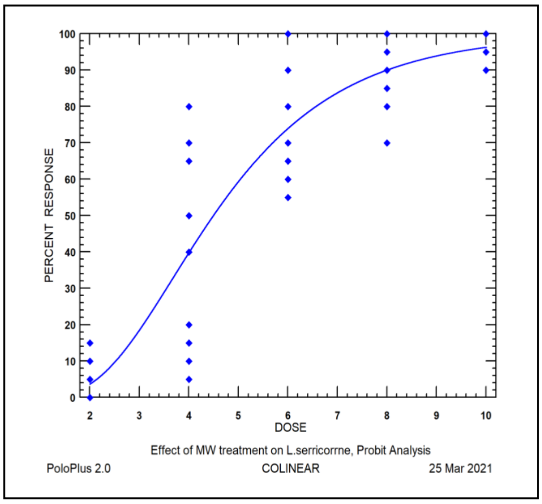

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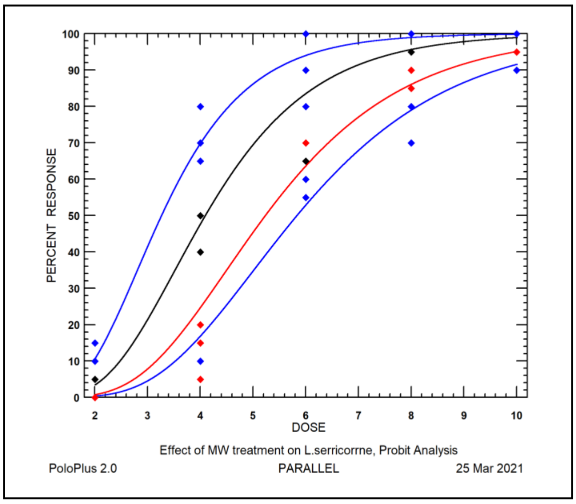

F.

(Dose: Time (mins); Response: *Mortality of L.* serricorne eggs)

Fig 3: Dose-response curves for microwave disinfested turmeric powder (a). Effect of microwave (350W) disinfestation on eggs of *L. serricorne* (b). Effect of microwave (450W) disinfestation on eggs of *L. serricorne,* (c) Effect of microwave (550W) disinfestation on eggs of *L. serricorne* (d). Effect of microwave (650W) disinfestation on eggs of *L. serricorne*

3.2 Effect of microwave on color of turmeric

The effect of different microwave power levels with different exposure time on the color of turmeric were observed (Table. 2). The most valued constituent of turmeric is yellow pigment i.e., curcumin. The maximum mortality of *L. serricorne* egg was observed at 550W for 10 mins., 650W for 8 and 10 mins. (Yadav *et al.*, 2014) [20] reported that the food commodity may be affected by the rapid rise in product temperature. Therefore, minimal change in L, a, b and ΔE values were compared at 550W for 10 mins., 650W for 8 and 10 mins. The effect of microwave power level and exposure time on the yellowness (b*) was found as61.99 ± 0.12at 550W for 10 mins. and 62.54 ± 0.14 and 63.39 ± 0.15 at 650W for 8 and 10 mins. respectively. However, Total color change (ΔE) was 2.16 at 550 W/ 10 mins. and 2.16, at 650W for 10 mins. as compared to control. The results indicated that the exposure of turmeric powder to MW at 650W for 10 mins. for disinfestation did not affect much on the colour of the turmeric powder. The present study supported to use microwave disinfestation as an alternative effective method which will also maintain the colour of turmeric powder.

Table 2: Effect of MW disinfestation on color of turmeric powder

Power level (W)	Time (min)	L*	a*	b*	ΔE
	Control	54.96 ± 0.00	28.27±0.01	63.51±0.05	-
550	10	53.59 ± 0.00	27.73 ± 0.01	61.99 ± 0.12	2.16
650	8	54.29 ± 0.00	28.42 ± 0.00	62.54 ± 0.14	1.28
	10	54.22 ± 0.028	28.14 ± 0.04	63.39 ± 0.15	1.28

4. Conclusion

Turmeric / turmeric powder is valued for its content of curcumin which imparts the typical yellow color. The insect infestation has to be controlled to avoid the quantity and quality loss. The MW disinfestation is one of the alternative technique to manage the insect infestation. The results of the present study showed the microwave power levels at 550W with exposure time of 10 mins. and at 650W with exposure time of 8 and 10 mins. gave cent per cent of *L serricorne* egg mortality. It was also observed that microwave disinfestation changed *L. serricorne* egg structure and cells were disordered. The results indicated that the exposure of turmeric powder to MW at 650W for 10 mins for disinfestation did not affect much on the color of the turmeric powder. So, it can be concluded that microwave disinfestation is an effective alternative for safe storage of turmeric powder. Future work could also be the explored for the disinfestation of *L. serricorne* larvae, pupae and adult present in turmeric powder using microwave heating.

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