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Radiofrequency Assisted Disinfestation of *Caryedon serratus* in Peanuts

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ABSTRACT: Peanut is an important oilseed and rich source of nutrients. The peanuts seed are stored as pods and seeds for further processing to extract oil or for edible purposes. One of the major concerns of the peanut industry is the contamination of peanuts with insects and microorganisms. Hence, post-harvest management is of major importance for maintaining the quality of the products from the peanut. The chemical fumigants have raised toxicity issues in grains. It is evident that the safety of food materials depends on the creation and application of novel disinfestation techniques. In this study, pest management in peanuts using Radio frequency (RF) technology is being investigated. The infested peanuts were exposed to RF to the selected electrode heights of 230 and 250 mm with conveyor speeds of 2.5, 5, 7.5, 10, and 12.5 m/h for each electrode height. The lethal time for 50 (LT_{50}) and 99 percent (LT_{99}) mortality was determined for the egg and adult stages of *Caryedon serratus.* The electrode height of 230 mm showed the least LT_{50} and LT_{99} of 5.51 and 14.22 minutes respectively egg stage. Similarly, the least LT_{50} and LT_{99} of 3.01 and 11.60 minutes respectively for the adult stage was observed. Researchers are tackling challenging issues linked to preventing dielectric breakdown and thermal runaway heating from hot spots. Therefore, to prevent breakdown, the electrode gaps, the material of the sample holder, and all the specifications like voltage and ampere were selected wisely. Hence, RF technology can be considered as one of the managements of peanut insects.

Keywords: Peanut, Radiofrequency, Mortality, *Caryedon serratus*, Disinfestation.

INTRODUCTION

Peanut (*Arachis hypogaea* L.) is a cheap, nutrient-dense, and frequently grown crop that produces one of the most significant edible oils in the world. As a significant source of edible oil, peanuts or groundnuts are revered in India as the "King of Oil Seeds" (Kanabur, 2019). Mixed glycerides make up groundnut oil, which has a high content of unsaturated fatty acids including oleic (50–65%) and linoleic acid (18 to 30 percent) (Dudekula *et al.*, 2021). Peanuts are eaten in raw and processed forms, as well as peanut butter, confectionery, and peanut oil. Indian cuisine showcase an inclusive spectrum of culinary variety arising from India's pluralism (Dhanshetty *et al.,* 2021). Peanuts have received a lot of attention as a functional food (Francisco & Resurreccion 2008).

One of the major concerns of the peanut industry is the contamination of peanuts with insects, insect fragments (Torres *et al*., 2014), fungi, and mycotoxin (Fu *et al.,* 2018). Groundnut postharvest losses due to insects, mould, and rodents range from 10 to 25 percent. Tamarind/groundnut bruchid, *Caryedon serratus* (Olivier) is the main pest of peanuts found in storage godowns. Many additional minor pests like *Tribolium castaneum,* and *Coecyra cephalonica* also attack peanuts, making them unfit for consumption (Nataraja *et al.,* 2014). Pesticides were traditionally used to control stored product pests. However, as insects develop resistance and possibility of residues in product, consumers are concerned about pesticide toxicity (Ahmed *et al.*, 2021). Hence, non-chemical methods need to be developed for managing the insects in storage and to avoid residues in food products. The application of Radio Frequency (RF) at an optimum condition is an alternative for the management of insects in food products.

In recent years, RF is gaining a lot of importance for applications such as drying, baking, and disinfestation. The molecules inside a product positioned in an RF environment continuously reorient themselves (27 M times/s at 27 MHz) in reaction to the applied field. This is how radio frequency heating works. Because of the frictional interaction amongst the molecules, the

reaction starts volumetric heating inside the entire product, which selectively heats only the product and not the air or surrounding equipment (Mahendran & Jojo 2013). RF is used to control stored-product insects through direct treatment of the food materials, resulting in a residue-free procedure of pest control through complete insect mortality. The disinfestation with RF technology is based on a lethal time of 100 percent mortality, allowing the population of insects invading stored commodities to be controlled. The RF disinfestation process involves exposing the product and the insect to alternating currents, which causes the insects to die.

It is critical to experiment with the insect's mortality when considering RF's potential use in the food processing line. Hence, the investigation was planned to study the effect of RF treatment on the life stage of *C. serratus (*eggs and adults).

MATERIALS AND METHODS

A. Procurement of peanuts

The dried peanut samples with an initial moisture percent of 7.5 were obtained from the local market of Pudukkottai, Tamil Nadu. All the dirt and unwanted materials were removed. The malformed, contaminated peanuts were screened off and a collection of uniform-shaped peanuts was done. The sorted peanuts were stored in airtight containers for further analysis.

B. Insect culturing

The parent adults of *C. Serratus* were obtained from the NIFTEM Thanjavur Storage Entomology department. About 50unsexed adults were introduced to each 500 ml glass jar containing about 100 g of susceptible peanut seeds. The containers were covered with muslin cloth to avoid suffocation and passage of insects. It was observed for 28 ± 3 days at a temperature of 28 ± 0.5 °C for the arrival of new adults. The insects used in the study were of the same age (Sewsaran *et al.*, 2019).

Fig. 1. Culturing of *C. Serratus.*

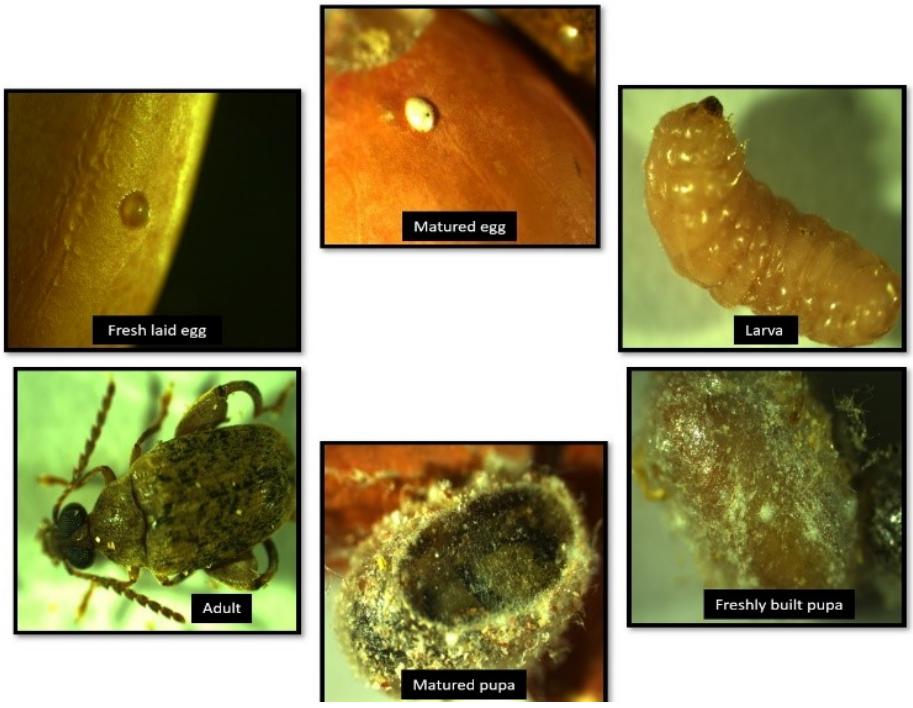


Fig. 2. Life cycle of *C. serratus* observed under stereomicroscope.

C. RF sterilizer

The infested peanuts were disinfested with a 10 kW RF sterilizer (40.68 MHz; Make: Lakshmi Insta 10/4) was utilized. The system consists of an applicator linked with a generator and two parallel flat plate rectangular electrodes (Fig. 3). A high voltage (5kV) alternating electric field was applied to the sample placed between the electrodes. A current of 0.5 A was required for the disinfestation.

Fig. 3. RF sterilizer.

D. RF treatment for mortality assessment

Peanut samples (250 g) were placed in Petri plates (200X30 mm), and eggs (20 in no's) and adults (10 in n's) were introduced into the Petri plate. These were then subjected to RF treatment with various combinations of electrode height and conveyor speed. The selected electrode heights were 230, and 250 mm with conveyor speeds of 2.5, 5, 7.5, 10, and 12.5 m/h for each electrode height. The time required for exposure was noted for each conveyor speed. Then the samples were cooled and stored (eggs) in plastic containers covered with muslin cloth for 60 days to investigate any emergence of adults. And to check the mortality of adults after treatment, it was kept for 24 hours for observation.

E. Imaging of insect morphology before and after RF treatment

The life stages of insects were imaged using a stereomicroscope (Leica S8 APO; Make: Leica microsystems from Wetzlar, Germany) that was linked with a computing system (Fig. 4) in order to determine the changes in insect eggs and adults. The object was then observed on the computer screen by changing the focus and zoom to make it clear for observation. Later, then images were captured and saved using the software, Leica Application Suite 2.0.

F. Statistical analysis

The experiential response was analysed using the Poloplus 2.0 software (LeOra Software, Petaluma, CA, USA) to calculate the Lethal Time for 50 and 99.99 percent of mortality due to dielectric treatments for both life stages. The results were interpreted by comparing the time required for mortality (Loganathan *et al.*, 2011) of the egg and adult stages of the insect.

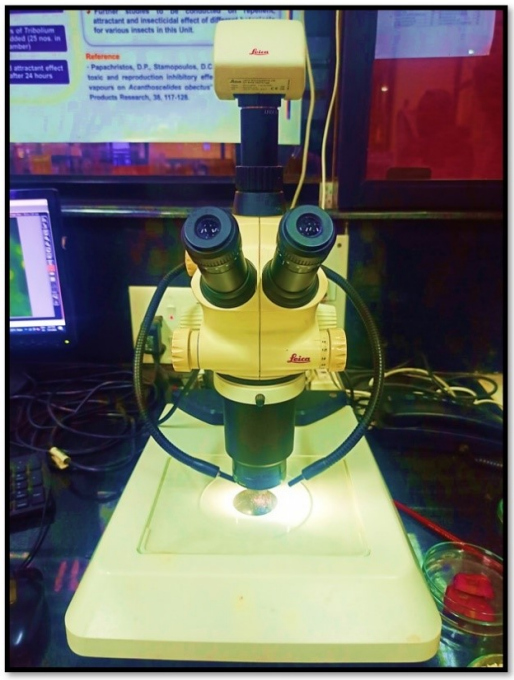


Fig. 4. Stereomicroscope (Leica S8 APO; Make: Leica microsystems, Wetzlar, Germany).

RESULTS AND DISCUSSION

A. Radiofrequency-assisted disinfestations of eggs

The infestation of *C. serratus* must be controlled from the egg stage itself because it reduces the quality of peanuts and results in losses of up to 73 percent (Nataraja *et al.,* 2014). The egg stage of *C. serratus* was attempted to be eradicated by the RF disinfestation at various electrode heights and conveyor speed combinations with an aim to minimize the loss. The results of disinfestations of egg stage showed that eggs subjected at 230mm electrode height took minimum time to kill, with LT_{50} and LT_{99} of 5.51 and 14.22 minutes, respectively. The electrode height of 250 mm required more time with 8.40 and 49.05 minutes for the LT_{50} and LT_{99} respectively to control the insect. The temperature was recorded as 70 ± 2 ºC, fluctuating with treatment time. The electric field intensity increases as the electrode gap/ height are lowered (Jiao *et al.,* 2014; Li *et al.,* 2017).

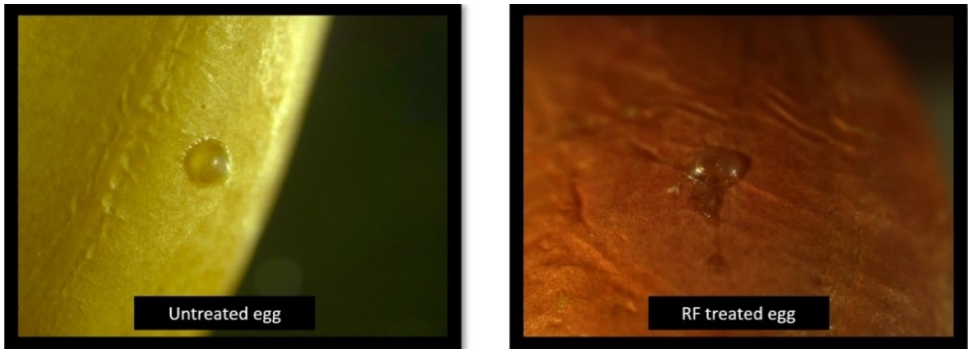
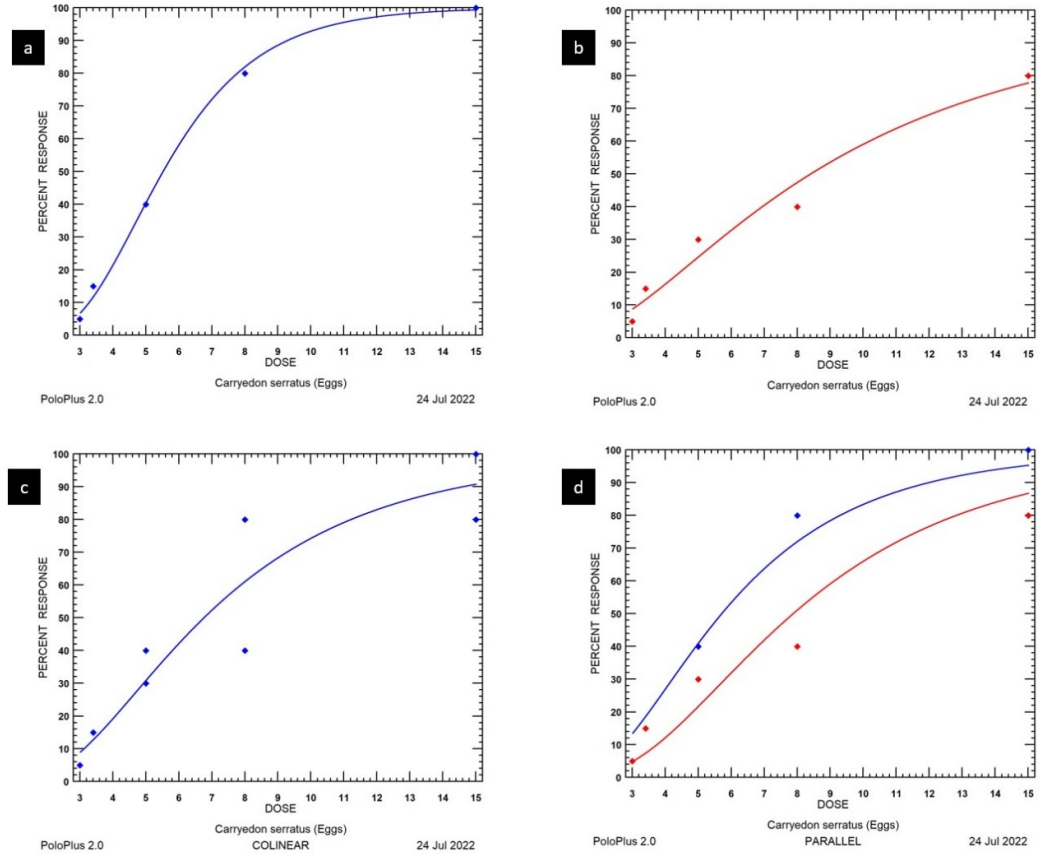


Fig. 5. Eggs before RF treatment (left) and after RF treatment showing disruption (right).



(a) mortality percent response of eggs at 230mm electrode height; (b) mortality percent response of eggs at 250mm electrode height; (c) colinear mortality response of eggs; (d) parallel comparison of mortality percent response of eggs at both electrode height.

Fig. 6. Dose-response curve for egg.

B. Radiofrequency-assisted disinfestations of adults

The results of disinfestations peanut with adult bruchid showed that insects subjected at 230mm electrode height took minimum time to kill, with LT_{50} and LT_{99} of 3.01 and 11.60 minutes respectively. The electrode height of 250mm required more time, taking 5.69 and 35.72 minutes for the LT_{50} and LT_{99} respectively. The temperature was recorded as 70 ± 2 ºC, fluctuating with treatment time. Because RF waves penetrate deeper than microwaves, they can heat low moisture goods more quickly (Boreddy *et al.,* 2014; Chen *et al.,* 2019). A similar study was performed by Tiwari *et al*., (2021) using various electrode height and conveyor speed combinations to investigate the mortality of *Callosobruchus maculatus* in blackgram (*Vigna mungo*) where it was reported that LT for 99.99 percent mortality ($LT_{99.99}$) was ranged from 3.62 to 8.23 for the egg stage,4.70 to 7.27 min. for larvae 7.10 to 8.96 min. for pupae, and 5.40 to 7.73 min. for the adults.

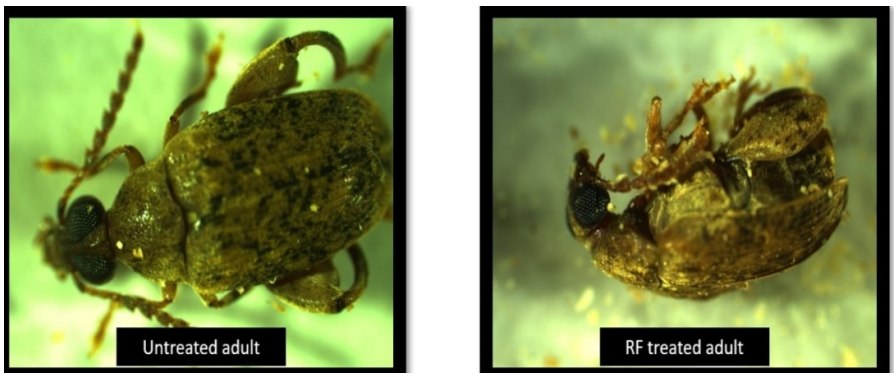
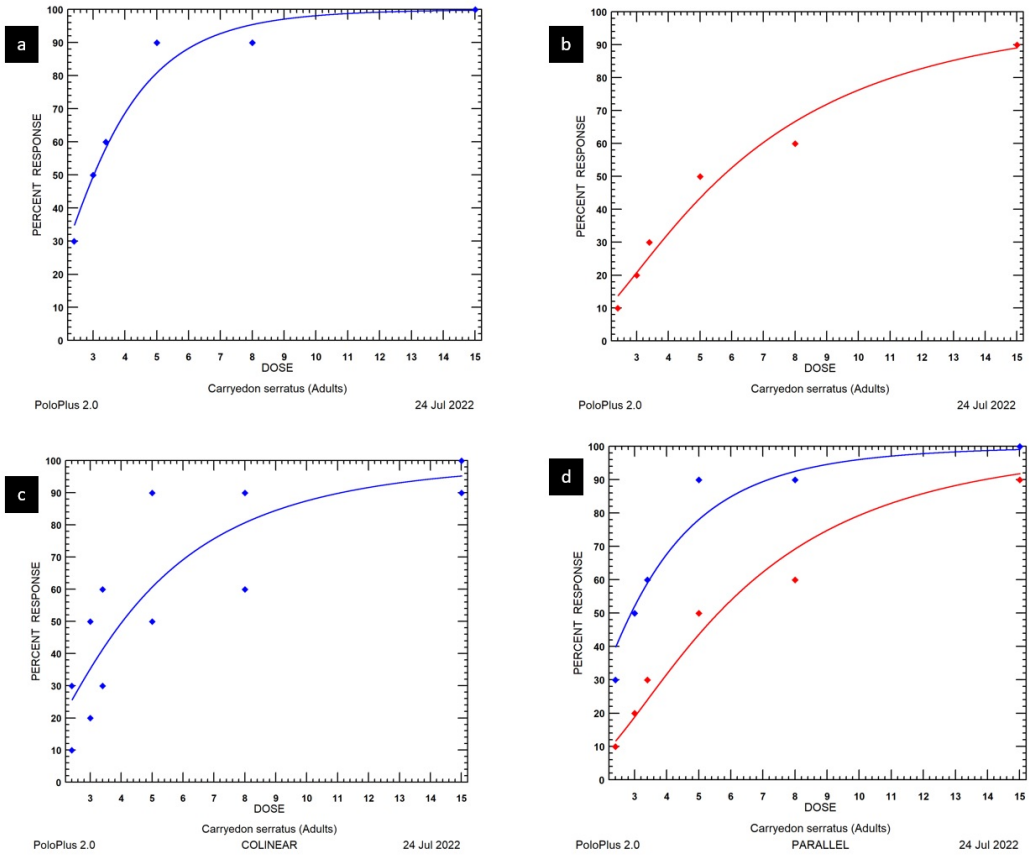


Fig. 7. Adults before RF treatment (left) and after RF treatment showing shrinkage (right).



(a) mortality percent response of adults at 230mm electrode height; (b) mortality percent response of adults at 250mm electrode height; (c) colinear mortality response of adults; (d) parallel comparison of mortality percent response of adults at both electrode height.

Fig. 8. Dose-response curve for adult.

Table 1: Lethal time for 50 (LT_{50}) and 99.99 percent ($LT_{99.99}$) mortality of the eggs of *C. serratus* during RF disinfestations.

Treatment (Electrode Height in mm)	LT_{50} (min.)	LT_{99} (min.)	Slope ± SE	χ^2 (df)
230	5.51 (4.61 - 6.91)	14.22 (10.05 - 33.04)	5.65 ± 0.96	0.495 (3)
250	8.40 (6.32 - 13.53)	49.05 (23.78 - 403.29)	3.03 ± 0.592	1.371 (3)

Values are at 95% level of confidence

Table 2: Lethal time for 50 (LT_{50}) and 99.99 percent ($LT_{99.99}$) mortality of the adults of C. *Serratus* during RF disinfestations.

Treatment (Electrode Height inmm)	LT_{50} (min.)	LT_{99} (min.)	Slope ± SE	χ^2 (df)
230	3.01 (1.11 - 3.77)	11.60 (7.25- 63.60)	3.97 ± 1.19	1.34 (4)
250	5.69 (4.26 - 8.38)	35.72 (17.78- 258.91)	2.92 ± 0.73	0.60 (4)

Values are at 95% level of confidence

Earlier, Indumathi *et al.*, (2021) reported that there was 100 percent mortality at each stage of *T. castaneum* lifecycle at 0.9 A of radiofrequency current and 0.5 kV for 15 minutes. *T. castaneum* was susceptible to RF heating in the following order: adults<larvae<pupae<eggs. Another study by Zhou & Wang (2016) showed that 100 percent mortality of *S. oryzae* adults was observed in different kinds of rice when treated at 50ºC for 5 minutes through 27.12 MHz with, a 6 kW RF sterilizer with 11cm electrode height. Similarly, 100 percent mortality of Mixed-age immature *S. oryzae* in rough brown and milled rice was observed when treated at 50ºC for 5 min with 27.12 MHz, 6 kW RF sterilizer with a 9.5cm electrode gap (Jiao *et al.,* 2017).

CONCLUSION

Peanuts are economically and culturally important throughout the world because they are the primary raw material for peanut oil and ethnic foods such as peanut chikki, masala peanut, and roasted salted peanuts in India. Therefore, post-harvest pest management is of utmost importance. RF technology is an alternative technology to chemical fumigation to reduce the toxic chemicals entering the food. The current investigation proves that RF is a novel thermal technology that provides a promising alternative for the disinfestation of many food commodities.

FUTURE SCOPE

The scope of the present study is that radiofrequency disinfestation can be potentially used in storage godowns and can be included in integrated pest management of granaries.

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Conflict of Interest. The authors have no conflict of interest.

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