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DIELECTRIC PROPERTIES OF DRIED TURMERIC RHIZOMES AND RELATED STORAGE INSECTS

Aswathy T[1*], S Parveen[1], M Balakrishnan[1], M Anand[1] and T Srinivasan[2]

[1]Department of Food Process Engineering, Agricultural Engineering College and Research Institute
[2]Department of Agricultural Entomology, Agricultural College and Research Institute,
Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India
*Email: aswathyt729@gmail.com (corresponding author): ORCID ID 0009-0006-3238-0820

ABSTRACT

The dielectric properties of dried turmeric finger rhizomes and the related storage insects namely *Stegobium paniceum* L. (drugstore beetle) and *Lasioderma serricorne* F. (cigarette beetle), were studied using an impedance analyzer. The measurements were conducted with the frequency range of 25 to 32 MHz and at temperatures ranging from 60 to 80°C. The dielectric constant and loss factor decreased with increasing frequency from 25 to 32 MHz at all temperatures whereas, the dielectric constant and loss factor increases with increasing temperatures at constant frequency for all samples were studied. The sample with maximum moisture content revealed maximum dielectric property. New equations were formulated through regression analysis to explore how the dielectric properties are influenced by changes in temperature and frequency.

Key words: *Lasioderma serricorne*, *Stegobium paniceum*, dried turmeric finger rhizomes, dielectric constant, dielectric loss factor, frequency, heat treatment, impedance analyzer, temperature, moisture content, storage

Turmeric, also known as curcuma longa, is a perennial herb that belongs to the Zingiberaceae (ginger) family and is largely farmed in Asia, most notably in India and China. A lot of consumers use turmeric as a spice, food preservative, colouring agent and medicine. Roughly 1.1 mt of turmeric are produced annually on a global scale, and India is accounting for 80% (Source: www.agriwatch.com), with a production of 1.33 mt in 2002 (Source: www.statista.com).There is a potential risk of turmeric infestation during storage and processing. *Lasioderma serricorne* F. and *Stegobium paniceum* (L.) pose a notable threat to the storage of stored turmeric and turmeric powder, as they target and damage turmeric rhizomes. Due to their internal feeding habits, the larvae of these pests consume dry turmeric rhizomes extensively, leading to their development inside the rhizomes. This process results in the deterioration of rhizome quality and a reduction in the nutritional and therapeutic value of turmeric (Tripathi, 2018). Many researchers have studied various properties of turmeric; PP (Thul et al., 2022) studied engineering properties of fresh turmeric rhizomes; (De Ramos et al., 2021) investigated physical and medicinal properties, while (Rajkumar et al., 2021) compared the engineering properties of selected turmeric varieties; phytochemical and pharmacological properties were analyzed by (Umar et al., 2020); Mechanical strength properties were studied by (OBASA et al., 2020). The dielectric properties of agricultural and biological materials can be influenced by various factors, including moisture content, temperature, frequency, composition, structure, and density. The dielectric loss factor (ε'') is a reflection of a material's capacity to transform electromagnetic energy into thermal energy, whereas the dielectric constant(έ) is connected to a material's capacity to store electrical energy in the presence of an external electric field (Nelson, 1973). The dielectric properties can define how the materials react in applied electromagnetic field. Dielectric properties have been among the topics of numerous researches for various temperature ranges, frequency ranges, and moisture content levels. The main purpose of this research was to examine the dielectric properties of dried turmeric finger rhizomes and the accompanying storage insects, namely the *S. paniceum* and *L. serricorne.* The study aimed to explore their potential applications in industrial heating and other relevant fields within a frequency range of 25–32 MHz and temperature range of 60-80ºC.

MATERIALS AND METHODS

Fresh dried turmeric samples were collected from Sri Venkateswara Agro Foods, Erode. The moisture content of the dried turmeric finger rhizomes were found to be 8.75± 0.25 % (w.b). The adult *L.*

serricorne and *S. paniceum* were initially collected from the Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore (11°00'49.6"N, 76° 56'01.5"E). A plastic jar, housing approximately 200 insects, was provided with around 2 Kg of rearing material (wheat powder). To ensure proper ventilation, the jar was covered with muslin cloth and it was then kept in a growth chamber, which was carefully maintained at a temperature of 30°C and a relative humidity of 70%. These insect cultures were subsequently used to establish new cultures after an approximate period of 35 days, and this process continued accordingly. For moisture content determination of insects, two aluminium moisture dishes were heated for 1 hr at 105ºC in a common hot-air oven and then cooled in a desiccator. Each dish had 1 g of insects, which were heated for 16 hr at 105ºC, and 3 replicates were done. Before reweighing, the heated dishes were allowed to cool in the desiccators. All weighing was done on a weighing balance with 0.0001 g precision (Nelson et al., 1998).

The dielectric properties of samples were evaluated using an impedance analyzer (Model SI1260 Impedance/Gain-Phase Analyzer, Solartron a division of Solartron Group Ltd., Victoria Road, Farnborough, Hampshire GU14 7PW, UK) across a frequency range of 25 to 32 MHz at temperatures of 60, 70, and 80ºC. These temperature settings are pertinent to thermal treatments aimed at insect control in agricultural commodities. For measuring the dielectric properties of dried turmeric finger rhizomes, it powdered and made into pellet by giving a 5 ton of pressure. During measurement it kept in between the sample holder. For insect samples, about 2 to 3 g of the insect sample was put in a stainless steel test cell (coin cell cap) with an inner diameter of 20 mm and a height of 3.2 mm and it is placed in between the sample holder. During measurement AC amplitude of 10 mV was applied. Data were obtained in the Smart software. The values of dielectric constant and loss factor were calculated by using the equation (1) and (2) respectively:

$$\acute{\varepsilon} = \frac{sin\theta}{z(2\pi f)D} \quad ...1$$

$$\ddot{\varepsilon} = \frac{cos\theta}{z(2\pi f)D} \quad ...2$$

where D is the electrode gap (mm), f is the frequency (Hz), z is the impedance magnitude (Ω) and Θ is the Impedance Phase Degrees. Simple linear regression was chosen to develop the regression equations at 60, 70, and 80 ℃ and at frequencies from 25 to 32 MHz. The response variables (έ and ε̈) were fitted using linear regression analysis in R software version 4.2.2. The equation's goodness of fit was evaluated based on the coefficient of determination (R^2) of the model.

RESULTS AND DISCUSSION

Moisture content of the dried turmeric finger rhizomes, *S.paniceum* and *L. serricorne* are found as 8.75± 0.25, 70.3± 0.15, and 71.25± 0.05% respectively on wet basis. The dielectric constants and loss factors of dried finger rhizomes, *S. paniceum* and *L. serricorne* at different frequencies and temperatures are depicted in Fig. 1. Tested samples showed a similar pattern in their dielectric properties, which dropped with increasing

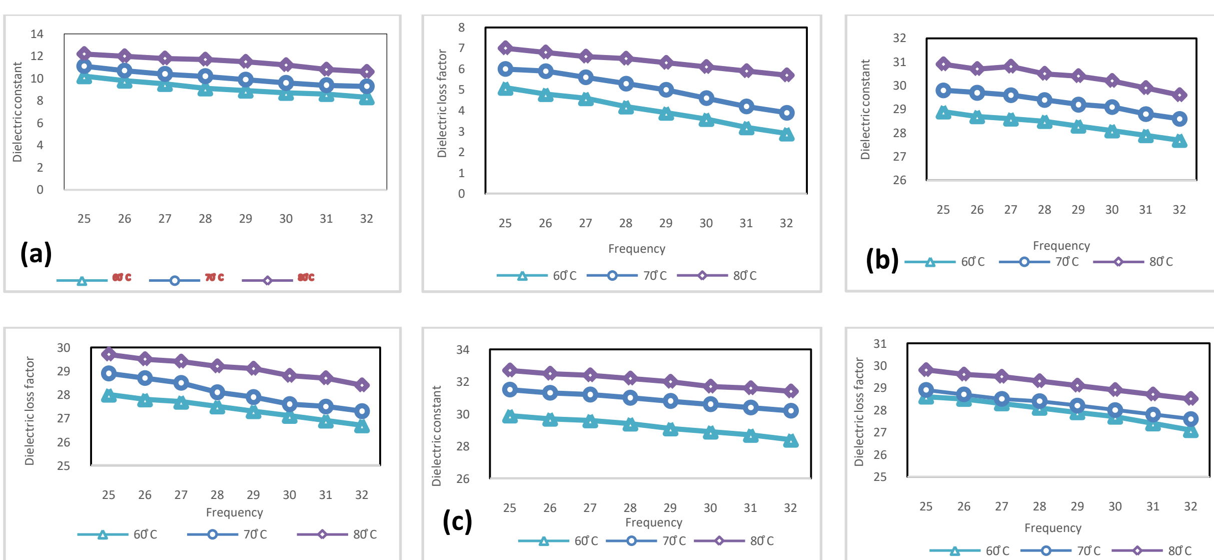

Fig. 1. Frequency-dependent dielectric constant (ε′) and loss factor (ε″) of turmeric (a), *S. paniceum* (b), and *L. serricorne* (c) at three temperatures

frequency. All studied samples are having highest dielectric properties at 25 MHz and lowest at 32 MHz. At 80°C and a frequency of 25 MHz, the *L. serricorne* exhibited maximum dielectric constant, measuring 32.7, along with the higher loss factor of 30.4. This may be because of *L. serricorne* had the highest moisture content of 71.25± 0.05%. *S.paniceum* is having a dielectric constant of 30.9 at 25 MHz and a loss factor of 29.7 at 25 MHz at 80 ˚C. Throughout all temperatures, the loss factor showed a linear decrease with increasing frequency (Fig. 1). This trend is believed to be primarily influenced by ionic conduction, as suggested earlier (Liu et al., 2009); (Gao et al., 2012). Such behaviour is commonly observed in materials with high moisture content, as had been reported (Sosa-Morales et al., 2009; Zhu et al., 2012). The dielectric constant exhibited a continuous decrease with rising frequency at a constant temperature. (Kagdi et al., 2020) also found a decrease in dielectric constant with frequency in samples prepared with ginger root extract and the same results were obtained by (Aziz et al., 2017) for four types of rhizomes from Zingiberaceace families, namely java turmeric ,mango turmeric, black turmeric and tumeric. This decline can be attributed to the decreasing ionic polarization of the viscous components present in the insect bodies as the frequency increases (Shrestha and Baik, 2013). Dried turmeric finger rhizomes are having lowest dielectric properties as compared with the insects studied.

Figure 2 show the temperature-dependent dielectric properties of dried turmeric rhizomes, *S. paniceum* and *L. serricorne*; from 60 to 80°C, these exhibited an increase at each studied frequency, and in dried turmeric rhizomes it varied from 8.3 to 10.6, and loss factors of 2.9 and 5.7 at 32 MHz. Similar trend was found in insect samples also. The dielectric constant showed a linear increase with temperature while maintaining a constant frequency. These observations are in line with those reported by Bijay Shrestha and Oon-Doo Baik (2012) for the rusty grain beetle at 25 MHz. Insects showed significantly higher dielectric properties than dried turmeric rhizomes (Fig. 3). When the frequency increased from 25 to 32 MHz at 80°C, *S. paniceum* and *L. serricorne* showed dielectric constants ranging from 30.9 to 30.6 and 32.7 to 31.4, respectively; however, with dried finger rhizomes, it varied from 12.2 to 10.6, which was 2.5 to 3x lower than that of the insects. The same trend was observed for the dielectric loss factor and the increase in loss factor will lead to the generation of thermal energy at particular frequencies (Fig. 4). Therefore, for frequencies in the studied range, *S. paniceum* and *L. serricorne* are likely to absorb more energy than rhizomes.

Regression equations demonstrate that both temperature and frequency exerted a substantial influence on the dielectric properties of the samples. Every equation proves that an increase in temperature leads to an increase in the dielectric properties and an increase in frequency leads to a decrease in the dielectric property. In every sample M3 (9.16 + 0.17 T-0.25 F,

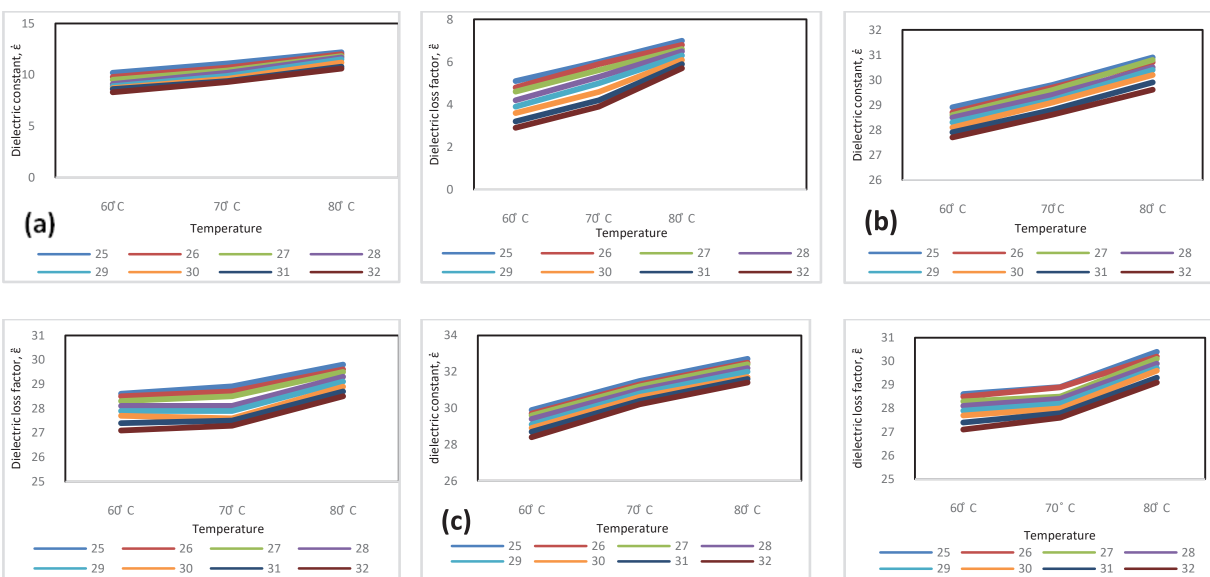

Fig. 2. Temperature-dependent dielectric constant (ε′) and loss factor (ε̈) of turmeric (a), *S. paniceum* (b), and *L. serricorne* (c) for comparison at eight frequencies

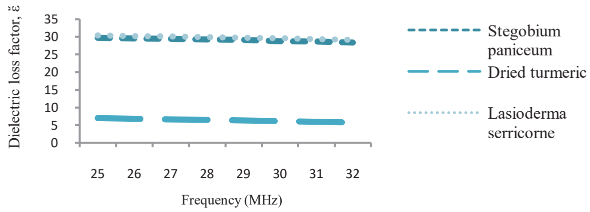

Fig. 3. Dielectric loss factor of turmeric, as compared to the data of *S. paniceum* and *L. serricorne*, as a function of frequency at 80 °C

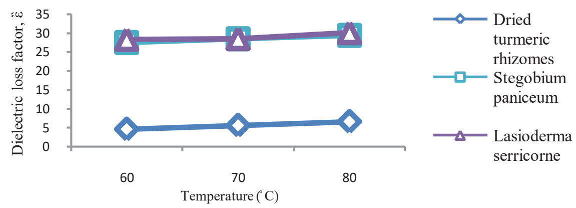

Fig. 4. Dielectric loss factor of turmeric as compared to the data of *S. paniceum* and *L. serricorne*, as a function of temperature at 27 MHz

27.14 + 0.1 T – 0.17 F, and 26.32 + 0.14 T – 0.19 F for dielectric constant and 4.76 + 0.12 T – 0.27 F, 27.87 + 0.08 T – 0.2 F, and 27.85 + 0.09 T – 0.19 F for dielectric loss factor of dried turmeric rhizomes *S. paniceum*, and *L. serricorne,* respectively) is having highest R^2 and F-statistic value, and which can be considered as the best model. The lesser p value for the model suggested that it is statistically significant. The dielectric properties of insects play a crucial role in understanding their response to electromagnetic fields. The studied properties showed that, since the dielectric constant and loss factor of the studied dried turmeric rhizomes are lower than for common insect, heat treatments for the control of postharvest insect pests is practicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION STATEMENT

AT and SP conceived and designed the research and wrote the manuscript. AT conducted experiments. MB, MA and TS supported the research. All authors read and approved the manuscript.

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