Chapter 2

LITERATURE REVIEW
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2.1 INTRODUCTION

This chapter reviews the work carried out by the researchers in the area of RF and MW to control the insect pests and dielectric heating after post harvesting and food processing.

The methods, implementation, and development are reviewed in this chapter. This chapter reviews the RF and MW used in agriculture applications, the dielectric measurement techniques, and dielectric properties of fruits and insects, SAR measurement, the effect of heat on tomato, the analysis parameters, and design of waveguide for microwave source in detail.

2.2 APPLICATIONS OF RF AND MW FOR DIELECTRIC HEATING

The applications of RF and MW energy in the area of food processing, stored–grain insect control, healing of plant seeds very much popular. The measurement of dielectric properties to characterize the product has been proposed. The effect of chemical pesticides on grains and need of RF and MW to overcome toxic effect has been explained. The dielectric properties of rice weevils and wheat, selective heating have reported by Stuart O. Nelson et al. [1].

Authors also provided information of RF and microwave energy to control the stored products. The dielectric properties at 37 MHz and 2450MHz have been measured and fast heating at low frequency is reported [2].

The comparison between different traditional methods of insect control and the RF and microwave energy have reported. The potential means to replace the other quarantine technique and the possibility of future industrial application of RF and MW with limitation has focused [3-4].
Hossein Ameri Mahabadi, et al. [5] have proposed the idea of electromagnetic heating and selective heating to control the insects in agriculture. Authors showed the repelling response of Sunne pest by MW radiations set up and discussed the pre-harvesting treatment on soil, anti-freezing and post-harvest treatment using ISM band.

The non-destructive way of measuring the water contents in the material using microwave meters and sensors has focused [6]. Today’s need of microwave power in the applications like food processing, communication and industrial applications etc. required the low cost and low interference device like magnetron has proposed [7].

Stuart Nelson [8] has focused on the improvement of RF and MW treatment to control the insect. The selective and differential heating effect on the insect than the host plant is possible if the more energy absorbed by insects. The influence of various physical factors like E-field intensity, heating rate, frequency and modulation are reported. The heating rate of the host at higher frequencies in the range of 2450 MHz has mentioned based on previous findings [8][10]. The granular activated carbon used for carbon in pulp process is treated by microwave heating [25].

Hamid, M. A. K, et al.[9] has experimented on wheat and insects at 2450MHz and 10 GHz. It has suggested that the illumination of wheat above the 4 inches is not suitable in bulk due to a depth of penetration reduces as frequency increases. This finding motivated during research and provided a vision for insect control at high frequency.

The electromagnetic energy used in an agricultural application like pre-harvest and anti-freezing operation have simulated in HFSS software [11]. To enhance the crop quality by implementing the microwave heating technique and its instrumentation in agriculture has proposed [12].

J.Tang, et al. [13] has proposed an RF or MW heating treatment on commodities to avoid the adverse effect of heat. During experimentation, the codling moth with in-shell walnuts have focused and the relation of duration and temperature rise has reported for high-temperature short time thermal quarantine method.

The possibility of RF and MW low power treatment to control the insect pests has proposed and verified with simulation software. The MW parallel plate applicator has designed and implemented with mathematical model [15][16].
The low power effect on the germination of seed has experimented and the growth rate of the plant has observed. The higher frequency and power density have reduced the seed germination [18]. The influence of water content at the RF and MW heating treatment reported that the loss factor increases with increasing temperature because of the ionic conduction. The free water contents influences more than the bonded water in the food during heating [20].

Microwave energy radiation used on paddy melon seed, plant and fruit during managing weeds. The lethal microwave energy reported for the melon plant is 145 J/cm² using horn antenna connected to microwave oven [21]. The dielectric properties of mango have measure and the post-harvesting treatment to control the pests at optimal ripening stage has recommended [22].

2.3 DIELECTRIC PROPERTIES OF FRUITS AND INSECTS

Nelson, S. O. [26] has proposed the RF and MW dielectric heating of fruits, grains, vegetables and seed for which the dielectric properties have measured and listed. The effect of temperature and frequencies on the dielectric properties has reported.

The moisture contents in the cereal grains have measured using RF and MW dielectric properties in correlation. The development and practical aspect of grain storage and spoilage have presented [41].

S. Wang, J. Tang et al. [27][28] have experimented on the **dried nuts and fruits at 27 MHz and 915 MHz as differential heating.** The dielectric properties were measured using an **open-ended coaxial probe** with **VNA** and the effect of temperature and frequencies on permittivity is discussed.

Based on the measurement of dielectric properties of insects and commodities with respect to temperature provides the information about the possibility of dielectric heating. On this line, the comparison of bulk insect data to insect body from the frequencies 40MHz to 20 GHz at 20⁰ to 25⁰ C have done. The method of dielectric properties with the probe calibration during measurement has focused. The penetration depth, electrical conductivity of insect and fruit at RF and MW frequencies has listed [29] [30]. The water contents of some of the insect tissue like body fats, muscular tissue, eggs and hemolymph have measured at RF and MW frequencies [31].
There are different approaches to measuring the dielectric properties of food and biological materials, the composition of water or air. The different types of losses in the heterogeneous mixture, dielectric behavior with free water, the effect of temperature with respect to frequency has considered and their relation is presented in the graphical form. The penetration depth for cooking the food material with water influence has presented [33][45][47][48].

The dielectric measurement of apple, strawberry at 2800MHz has reported with the effect of moisture content. It is reported that the relative permittivity decreases with temperature and high moisture. The characteristics of fruits like moisture tissue density and TSS have measured and reported. The comparison of controlling the codling moth on apple at 915 MHz and 2450 MHz has discussed and mentioned lower frequency is good for such applications [34]-[40].

The dielectric relaxation characteristics of fruits and vegetables have considered determining the experimental permittivity. The relaxation time decreases by increasing the temperature as well as it depends on the frequency [42][43]. The overview of dielectric measurement methods and the comparison of different dielectric properties have discussed [44].

J. Tang, et al. [46][49] providing the measurement of tomato dielectric parameters with the help of an open-ended coaxial probe method. The frequency range 300 MHz to 3 GHz has reported between the 220ºC to 120ºC. The effect of NaCl on the conductivity and permittivity has investigated and it was observed that the increase in NaCl improves the loss factor at 915 MHz as compare to 2450MHz.

Several studies have been done on the measurement of dielectric constants and loss factor and measurement techniques like cavity resonator, coaxial probe associated to the microwave and RF [50]-[60].

The specific heat of insects at different stages has provided. These parameters we have used during simulation of dielectric heating on insects with commodities [70][71].

2.4 SAR AND EM EFFECT ON BIOLOGICAL MATERIAL

The measurement of SAR using the simulation has proposed to evaluate the effect of EM wave while talking on mobile phone at 900 MHz and 1800 MHz and compared it
with ICNIPR limits [68]. The temperature rise of head tissue has validated by the infrared camera. The scattering and continuous boundary conditions were used during simulation process and bioheat equations used to verify the results [61].

The leakage of EM wave at 915 Hz and 2450 MHz and the human body has observed in relation with industrial dielectric heating in high power applications. The measured SAR was dependent on the biological material dielectric and thermal properties as well as the depth of penetration [62][63].

The use of radiofrequency (98–2450 MHz range) personal exposimeters for the compliance test has reported and the corrections like correction factor in measurement have reported [66]. The FEM based SAR evaluated for mobile phone and human head [68]. The assessment of human influence on indoor Wi-Fi application has evaluated and change in E-field strength due to absorption of the human body has reported [67].

2.5 EFFECT OF TEMPERATURE ON TOMATO AND INSECT

David J Perovic, M Johnson, B Scholz et al.[75] authors have focused on the mortality of ‘Helicoverpa armigera’ larvae in relation to drop-off and soil surface temperature have focused. The author recorded that above 40 °C larvae can get mortality if they drop on the soil.

Mukesh K. Dhillon , Hari C. Sharma [74][77][79] have experimented the different temperature in laboratories to understand the hatching of eggs. The author discussed natural environment and controlled environment in the laboratory condition for the mortality of eggs. The degree-days required to complete the life cycle have decreased at 27°C and 18°C. Different stages of ‘Helicoverpa armigera’ gas tested at different temperature and degree-day period has obtained [78].

The natural mortality of ‘Helicoverpa armigera’ has observed in different seasons and environmental condition. The average mortality of 23-24 % reported[80]. The survival rate of both sexes was reduced with increased in temperature around 40°C to 46°C. No eggs were oviposited and adult mating due to heat treatment at 46°C at the time duration of 15 min. to 90 min [81].

The nutrient analysis of vegetables and fruits are an important parameter to understand the effect of RF and MW heating [85]. The early yield observed towards
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the higher side of temperature at the cost of vegetation growth. The growth rate of fruit at a certain stage is independent of temperature. Short-term effect of temperature has not analyzed and hypothecated as it for high temperature [87]. S. R. Adams, K. E. Cockshull et al.[88] described the yield of tomato plant at a different temperature.

Thermally treated tomato is the major source of lycopene, as well as beta-carotene, are present in the fruit. They occur in tomato fruits and various tomato products in amounts of **2.62-629.00 and 0.23-2.83 mg/100 g** respectively [92]. The beta-carotene content has increased as the temperature increased [93].

The salinity levels in the nutrient solution **increased lycopene and beta-carotene to 35%**. The higher electrical conductivity increases the TSS count and test of tomato [95][96].

### 2.6 MICROWAVE GUIDE DESIGN

Roussy G, Kongmark N. [97] have shown the matching of bidirectional waveguide launcher with the magnetron. The applicator has connected in the tours structure of waveguide. Based on the back short wall calculations the impedance has calculated and optimized.

The calculation details of the **TE_{10}** mode of the rectangular waveguide, the power handling capacity calculation of a waveguide, back short plate calculations, and impedance matching have determined [100].

### 2.7 CONCLUDING REMARKS

The literature survey reveals that the pre-harvesting and post-harvested food products disinfestations did use RF and MW radiation. Many researchers have proposed that the RF and MW radiation is the new and faster insect pest control technique. The simulation of differential dielectric heating technique was projected for pistachio plant to control insect pests. The dielectric properties of many agro-products were measured and used as data-base for dielectric heating.

The influence of RF and MW radiations on the human body was simulated to decide the SAR range for general public and occupational person. The different
posture of human body models was used to measure SAR and compare the results with exposimeter system. The salinity effect may be useful in improving the conductivity and heating effect in the commodities. The harmful effect of chemical pesticides was observed and suggested to investigate different methods to control insect pests in agriculture.

In this research, we have proposed and developed the applicator at RF & MW frequencies. The dielectric heating simulation performed in COMSOL software and the magnetron launcher waveguide as MW source for the developed applicator has developed.