International Journal of Scientific Research in Science and Technology
Available online at : www.ijsrst.com
Print ISSN: 2395-6011 | Online ISSN: 2395-602X
doi : https://doi.org/10.32628/IJSRST52411118

Dielectric Spectroscopy Measurements of Foxtail Millet

Dr. Govind A. Karhale

Head and Associate Professor, M. P. ACS College, Palam Dist. Parbhani, Maharashtra, India

ARTICLEINFO

Article History:

Accepted: 05 Jan 2024
Published: 17 Jan 2024

Publication Issue :
Volume 11, Issue 1
January-February-2024
Page Number :
150-157

ABSTRACT

Dielectric spectroscopy data measured for Foxtail Millet in powder form with temperature variations are presented. The dielectric behavior is discussed with respect to important variables. A brief review of measurements on these materials and description of the methods are included. Single frequency range for the data at 9. 8 5 GHz using X-band Microwave bench used. Values of the dielectric constant and loss factor with frequency and temperature are shown graphically, and the influences of dipolar relaxation, conductivity, dielectric loss factor, dielectric constant are discussed. The Experimental values and Calculated values from LLB formulae are verified and there is good agreement found.

Keywords : Dielectric constant, Dielectric loss, Loss Tangent, Dielectric spectroscopy, Foxtail Millet. Packing fractions.

I. INTRODUCTION

Foxtail millets, magical millets or miracle grains are natively known as Kangni, Kang and kakum. These are tiny seeds covered in a thin, crispy hull and are available in a light yellow-brownish colour. Foxtail millet Setaria italica (L.) is a member of the subfamily Panicoideae and the tribe Paniceae. It is an important ancient crop of dry land agriculture. Setaria viridis is a species of grass known by many common names, including green foxtail, green bristlegrass, and wild foxtail millet.

Spectroscopy is the analytical study of electromagnetic spectra, including the visible spectrum, ultra- violet and infrared radiation, and all other portions of the electromagnetic spectrum as well. Dielectric properties of materials are important in determining how electromagnetic energy in the micro- wave range interacts with materials, and study of their dependence on wavelength or frequency is termed dielectric spectroscopy.

In this article, the term “permittivity” implies the relative complex permittivity, i.e., the permittivity of a material relative to free space, often called the complex dielectric constant, which is expressed as ε = ε - j ε. where ε' - is the dielectric constant and ε" - is the dielectric loss factor. The dielectric constant is associated with the capability for energy storage in the electric field in the material, and the loss factor is associated with energy dissipation in the material or the conversion from electric energy to heat energy1,2. Here, all loss mechanisms, both those due to dipole relaxation and ionic conduction, are included in the dielectric loss factor ε" . Measurements obtained in a study to explore the frequency and temperature dependence of the dielectric properties of the sample were reported for a temperature range from 25°C to 50°C.

The purpose of this article is to present some typical data obtained by dielectric spectroscopy measurements on Foxtail Millet in powder form with a discussion of the dependence of the dielectric properties on important variables.

DIELECTRIC SPECTROSCOPY MEASUREMENTS:

Figure 1 : Microwave Measurement X - Band setup.

The electrical measurements necessary for permittivity determination were obtained with X - band microwave bench single frequency 9.8 GHz range. A temperature controlled stainless steel sample holder cup and water jacket assembly, designed and built in Microwave research Laboratory, Science College, Nanded[9] were used to provide temperature control for the samples. Permittivities (dielectric constants and loss factors) were calculated with forward and reverse current measurement. This provides permittivity values from the reflection coefficient of the material[4,5,6].

Dielectric measurements ($\in'$) and ($\in''$) on these Foxtail Millet powder sample for different packing fractions were carried out at 9.85 GHz microwave frequency and at temperatures (20˚C, 35˚C and 50˚C). The dielectric parameters were measured by employing reflection coefficient from air dielectric boundary of the powder sample. This technique permits us to rapid measurement of VSWR. In this technique heart of the measurement centers around the dual three arm directional couplers which are placed back to back. We can measure the ratio of the magnitudes of reflected and incident power, which gives reflection co-efficient. After assembling the microwave components as shown in figure[7,8]. The microwave source is switched on. The output power noted down. This gives forward power (P_f) which is maintained throughout the experiment. Again, the shorting plunger which is initially at the bottom of the empty dielectric cell, carefully moved up in steps. The reflected output power is measured from the detector of reverse directional coupler. The position (x) of the plunger and corresponding reflected output power is measured. Form data obtained for empty cell, the guide wavelength (λ_g) is obtained. Now, a very small quantity of powder sample is introduced in the dielectric cell by lifting plunger up and then plunger is brought over the powder column. A constant pressure is applied on the sample with the help of rack and pinion arrangement[10,12]. It is worth to point out here that while powder is being introduced in the cell, we need not go to remove plunger outside the cell. We have designed and developed the dielectric cell such that one can introduce sample in the cell conveniently without taking plunger out off the cell. This process is repeated at every time of addition of powder in the cell. Thus, the position x of the plunger and the corresponding output power is measured.

If P_f and P_r – are respectively the forward and reverse powers measured by directional couplers then the power reflection coefficient is given by[13]

$$\Gamma_P = \frac{P_r}{P_f}$$

Since, voltage reflection co-efficient is square root of power reflection coefficient.

We write,

$$\Gamma_V = \sqrt{\Gamma_P} = \sqrt{\frac{P_r}{P_f}}$$

Therefore,

$$\mathrm{VSWR(S)} = \frac{1+\Gamma_V}{1-\Gamma_V} = \frac{1+\sqrt{\Gamma_P}}{1-\sqrt{\Gamma_P}}$$

Or, $$(S) = \frac{1+\sqrt{\frac{\Pr}{Pf}}}{1-\sqrt{\frac{\Pr}{Pf}}}$$

$$(S) = \frac{Pf + \Pr + 2\sqrt{\Pr * Pf}}{Pf - \Pr}$$

The above equation forms the basis for measuring VSWR using directional couplers. Using above equations one can compute the reflection co-efficient and VSWR of the load under test using directional couplers.

Thus, having determined free space wavelength $\lambda_0 = \left(\frac{c}{f}\right)$,

Cutoff wavelength λ_o = (2a), Guide wavelength (λ_g), Dielectric wavelength (λ_d), and Attenuation per wavelength ($\alpha_d \lambda_d$).

The values of dielectric constant (∈ '), dielectric loss (∈ "), loss tangent (tanδ), relaxation time ($_p$), and conductivity (σ_p), can be calculated.

Dielectric parameters: When the dielectric cell is filled with a dielectric material of complex permittivity ($\in'_p$) and excited in TE_{mm} or TM_{mm} mode the propagation constant γ_d can be written as [13-14].

$$\gamma_d = \frac{j2\pi}{\lambda c}\sqrt{\left[\in_P^* - \left(\frac{\lambda_0}{\lambda c}\right)^2\right]} \quad \ldots\ldots(1)$$

On submitting, $\in^* = \in'_P - j\in''_P$ and separating real and imaginary parts, values of ($\in'_P$) and ($\in''_p$) will be given by,

$$\in' = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_0}{\lambda_d}\right)^2\left[1-\left(\frac{\alpha_d}{\beta_d}\right)^2\right] \quad \ldots..(2)$$

$$\in'' = 2\left(\frac{\lambda_0}{\lambda_d}\right)^2 \cdot \left(\frac{\alpha_d}{\beta_d}\right)^2 \quad \ldots(3)$$

For low loss material $\left(\frac{\alpha_d}{\beta_d}\right)^2 << 1$, Hence

$$\in'_P = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_0}{\lambda_d}\right)^2 \quad \ldots(4)$$

$$\in'' = \frac{1}{\pi}\left(\frac{\lambda_0}{\lambda_c}\right)^2(\alpha_d \lambda_d) \quad \ldots(5)$$

Where,

λ_o = is the free space wavelength.

λ_d = is the wavelength in dielectric.

λ_c = is the cutoff wavelength of the waveguide.

α_d = is the attenuation introduced per unit length of dielectric material.

β_d = is the phase shift produced per unit length of dielectric material.

$\alpha_d \lambda_d$ = is the attenuation per wavelength.

For low loss materials, dielectric constant ($\in'$) and loss factor ($\in''$) for bulk materials can be correlated with their powder form by the relations derived independently by Landau-Lifshitz and Looyenga,

$$\in'_S = \frac{\left[\left(3\delta + 2\in'_p - 2\right)\in'_p\right]}{\left(3\delta - 1\right)\in'_p + 1} \quad \ldots(6)$$

$$\in''_S = \left(\frac{\in''_P}{\delta_r}\right)\left(\frac{\in'_S}{\in'_P}\right)^{2/3} \quad for \frac{\in''}{\in'} << 1 \ldots(7)$$

Where,

$\in'_s$ – is the dielectric constant for the material in bulk,

$\in'_p$ – is the dielectric constant of powder sample at relative packing fraction (δ_r).

$\in''_s$ and $\in''_p$ – are the dielectric losses for solid and powder respectively.

These experiment results have been verified with values obtained from Bottcher's equation.

$$\in'_S = \frac{\left(2\in'_P + 3\delta - 2\right)\left\{\left(3\delta - 1\right)\left(\in'^2_P + \in''^2_P\right) + \in'_P - 2\in''^2_P\right\}}{\left(3\delta - 1\right)^2\left(\in'^2_P + \in''^2_P\right) + 2\in'_P\left(3\delta - 1\right) + 1} \quad \ldots(8)$$

$$\in''_S = \frac{2\left(3\delta - 1\right)\left(\in''^3_P + \in'^2_P \in''_P\right) + \in''_P\left(3\delta - 2\right) + 4\in'_P \in''_P}{\left(3\delta - 1\right)^2\left(\in'^2_P + \in''^2_P\right) + 2\in'_P\left(3\delta - 1\right) + 1} \quad \ldots(9)$$

The values of conductivity (σ_p), loss tangent ($\tan\delta$) and relaxation time ($_p$) are obtained by employing the following relations.

$$\sigma_p = \omega \in_o \in'' \quad \ldots(10)$$

$$\tan\delta = \frac{\in''}{\in'} \quad \ldots(11)$$

And

$$\tau p = \frac{\tan\delta}{\omega} \qquad \ldots(12)$$

Graphical representation:

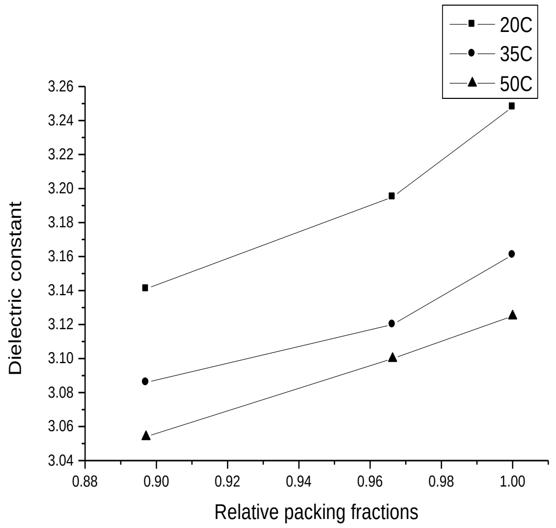

Fig.1: Packing fraction Vs Dielectric constant

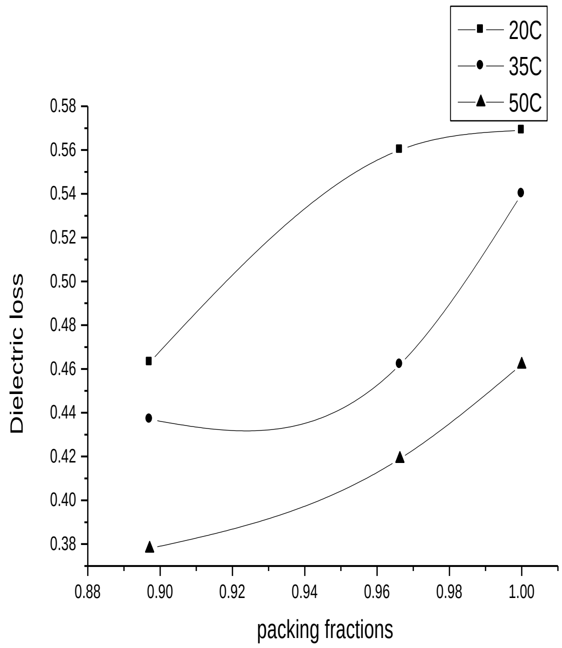

Fig. 2 : Packing fractions Vs Dielectric loss

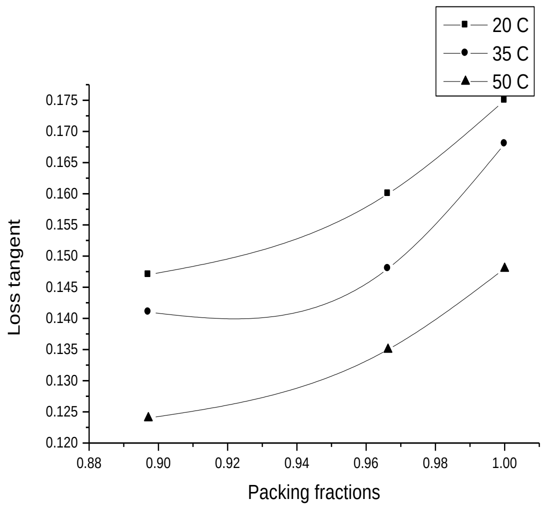

Fig.3: Packing fraction Vs Loss tangent

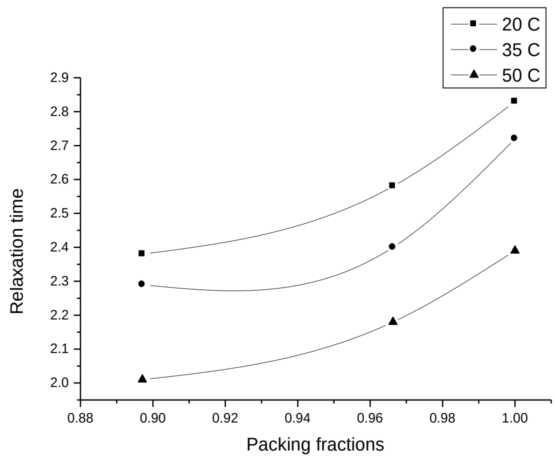

Fig .4: Packing fraction Vs Relaxation time

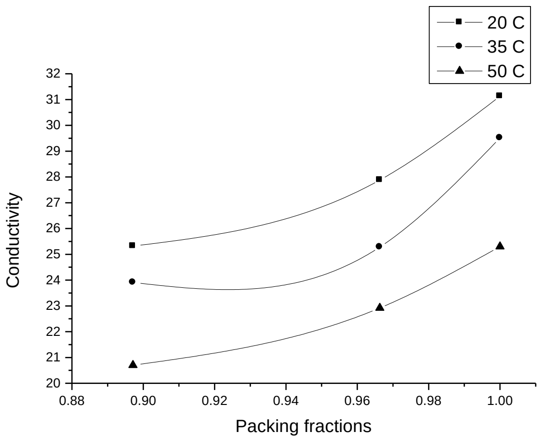

Fig.5: Packing fraction Vs Conductivity

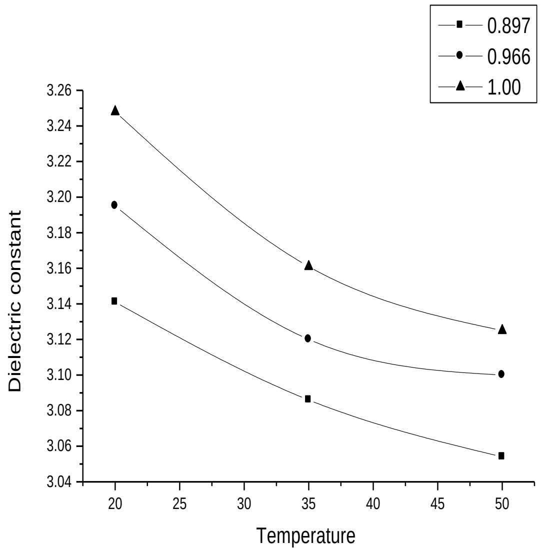

Fig.6: Temperature Vs Dielectric constant

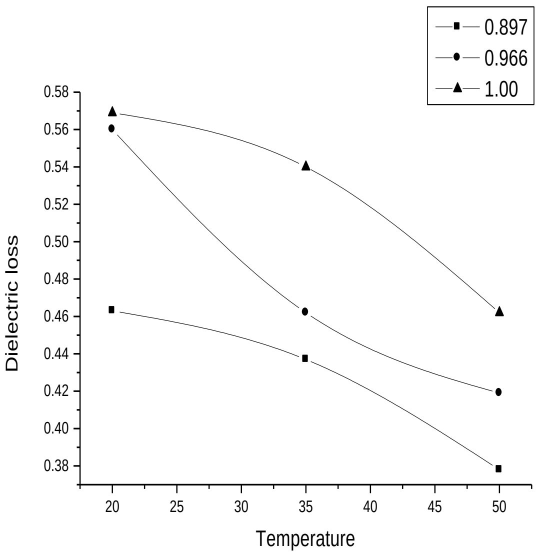

Fig.7: Temperature Vs Dielectric loss

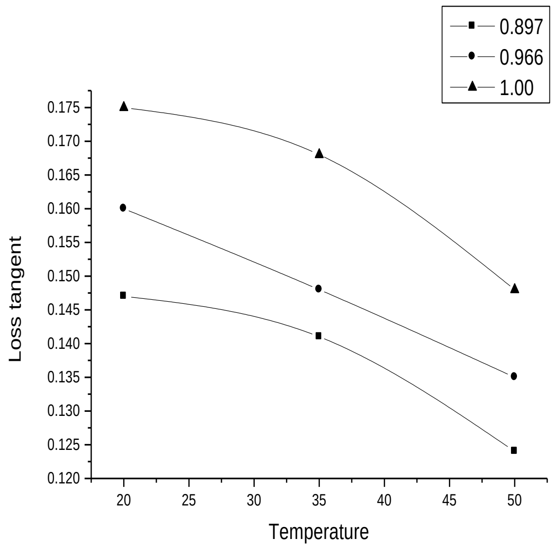

Fig.8: Temperature Vs Loss tangent.

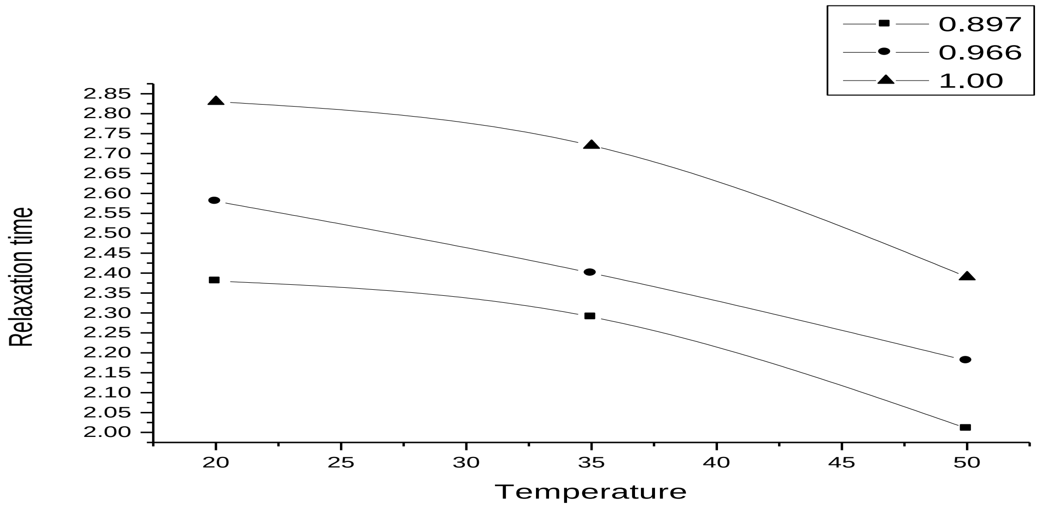

Fig.9 : Temperature Vs Relaxation time

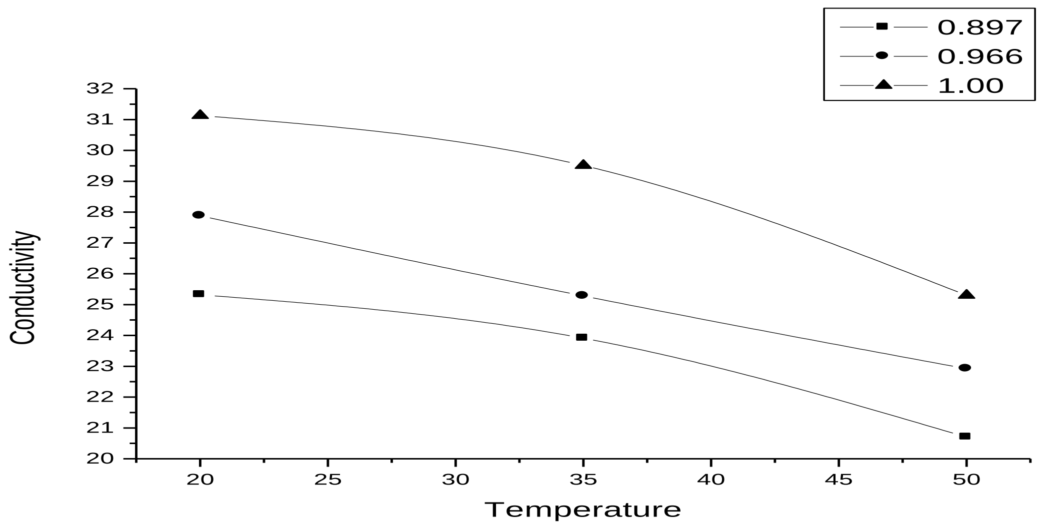

Fig.10 : Temperature Vs Conductivity

II. RESULTS AND DISCUSSION

Form above study it shows the following results, Higher values of dielectric properties can be expected with materials of higher moisture content, Both the dielectric constant and loss factor decrease monotonically with increasing temperature. The values of dielectric constant and loss systematically increases with increasing values of packing fractions. This is expected because with higher values of packing fractions, the interparticle hindrance offered to compact medium will be much higher than for material consisting less bounded particles. Relaxation time systematically increases with increasing packing fractions. According to Debye theory when polar molecules are very large, then under influence of high frequency field, the rotatory motion of molecules of system is not sufficiently rapid to attain equilibrium with field, and due to increasing hindrance to the process of polarization. Conductivity systematically increases with increasing packing fractions. It suggest that at higher compactness no microcraks developed in the sample due to high mechanical pressure.

III. REFERENCES

[1]. Bansal, A. K., Singh P. J. and Sharma, K. S. 2001. Microwave dielectric measurements in different varieties of rape seed- mustard seeds in powder form. Indian Journal of Pure and Applied Physics. 39: 799-803.

[2]. Kraszewski, A. and Nelson, S.O. 1993. Microwave permittivity of pecan nuts. Journal of Microwave Power of Electromagnetic Energy. 28(3): 165-173.

[3]. Kraszewski, A. and Nelson, S. O. 1994. Determination of moisture content and bulk density of shelled corn by measurement of microwave parameters. Journal of Agricultural Engineering Research.58: 37-46.

[4]. Nelson, S. O. 1992. Measurement and applications of dielectric properties of agricultural products. IEEE Transaction on Instrumentation and Measurement.41 (1): 116-122.

[5]. Nelson, S.O. 1993. Insect control studies with microwaves and other radio frequency. Bulletin of Entomological Society of America. 19(3): 157-163.

[6]. Panday, B.P. 2009. Economic Botany. S. Chand Publication

[7]. Peter, H. 1997. Dielectric Spectroscopy of Polymers. Adam Hilger Ltd, Bristol.

[8]. Sisodia, M. L. and Raghuvanshi, G. S. 1990. Basic microwave techniques and Laboratory Manual, Willey Eastern Ltd.

[9]. Kalamse, V. G. and Kalamse, G. M. 2007. Microwave dielectric cell for measurement of dielectric parameters of pulverized materials. Lab Experiments.7:30:38.

[10]. Bhatnagar, D., Gandhi, J. M. and Yadav,J. S 1996. Estimation of dielectric behavior of bulk material using its powder. Indian Journal of Physics. 70A(4): 539-542.

[11]. Jangid, R.A., Neeru, Bhatnagar, D. and Gandhi, J. M. 1996. Microwave probing to study particulate behavior of basic powdered materials. Indian Journal of pure and Applied Physics. 34: 316-318.

[12]. Yadav, J. S. and Gandhi, J.M. 1992. Simple microwave technique for measuring the dielectric parameters of solids and their powders. Indian Journal of Pure and Applied Physics. 30: 427.

[13]. Bottcher, C J F 1952. The Theory of dielectric polarization. Elsevier, Amsterdam. pp- 415.

[14]. Landau, L. D. and Lifshitz, E. M. 1960. Electrodynamics of continuous media. Pergamon press, London. pp-46.

Cite this article as :

Dr. Govind A. Karhale, "Dielectric Spectroscopy Measurements of Foxtail Millet ", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 11 Issue 1, pp. 150-157, January-February 2024. Available at doi : https://doi.org/10.32628/IJSRST52411118

Journal URL : https://ijsrst.com/IJSRST52411118