Article

Dielectric Properties of Fresh Vegetables and Jamun

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Abstract

The Present work is concerned with the measurement of the complex dielectric permittivity, conductivity, and loss tangent and penetration depth of some vegetables. The measurement makes use of the "Von-Hipple method" for bulk sample. If the sample is not available with the dimension of the wave guide then reflectrometry technique is used for the pulverized (Powder) form of the sample and computed all the above parameters and relaxation time for the sample Jamun Seed (Scientific Name of Jamun is Syzygium cumini Lin). The measurement were performed for different packing densities at 9.85 GHz. at different temperature (20°c, 35°c and 50°c).The result was correlated with Landau- Lifshitz-Looyenga and Bottcher.

There is fair agreement between the calculated values of dielectric parameters and the values obtained experimentally for solid bulk and pulverized one.

Introduction

Biological effects of microwave radiation have been focus of various research efforts in the last decade. Key to this is the determination of complex permittivity (ε' and ε") of biological samples Dielectric properties of materials are important in determining how electromagnetic energy in the radio-frequency and microwave range interacts with materials [1-2]. There are many ways in which dielectric measurements may be made [3]. In this paper the short circuited waveguide method is used originally reported by Roberts and von-Hippel when the sample is in bulk form [4].and Reflectrometry Technique when sample is in Pulverized form.

The evergreen Syzygium Cumini plant is originally from Indonesia and India; The juicy fruit-pulp contains resin, gallic acid and tannin; it tastes usually from acid to fairly sweet. The somewhat astringent, Syzygium Cumini fruit can be utilized for juice.

In India the seed and bark is used for diabetes which reduces the blood sugar level quickly, the fruit for dysentery, blood pressure.

In the present paper, dielectric properties of Syzygium Cumini were determined at various packing fractions and temperatures. The effects of temperature and density on the dielectric parameter were reported. We correlated dielectric parameter of powder with solid bulk. This type of correlation is useful because it makes possible to correlate without the necessity of making big enough samples of the bulk materials for the dielectric measurement. We compared measured values with the values obtained from the correlation formulae between powder and bulk derived independently by Landau-Lifshitz-Looyenga and Bottcher [5-6].

Theoretical Background

Von-Hipple or short-circuited line method for determining the complex dielectric permittivity, the sample of unknown permittivity is placed against a short-circuited termination at the end of waveguide where electromagnetic standing waves with fixed wavelength λ are established. Position of the minima (nodes) is measured in both cases (i.e. without sample (air) and with dielectric sample), the shift in the minima (nodes) was observed. The shift of the minima (nodes) position is due to the presence of the sample depends mainly upon the relative dielectric constant (ε_r') and the change in the standing wave ratio (VSWR) depends mainly upon the relative dielectric loss factor (ε_r'')[7].

Relating the sample impedance as calculated from its intrinsic parameters to that calculated from the characteristics of the standing wave, which can be measured, yields the transcendental equation on the complex plane [8]:

$$\frac{-j\lambda_g}{2\Pi d}\;\frac{1-jS\tan\left(\frac{2\Pi D_m}{\lambda_g}\right)}{S-j\tan\left(\frac{2\Pi D_m}{\lambda_g}\right)} = \frac{\tanh(\gamma d)}{\gamma d} \quad (1)$$

The left-hand side of this equation is known from experiment; where D_m is the distance between the surface of the dielectric and the first minimum of the standing wave pattern; $S = E_{max} / E_{min}$ is the voltage standing wave ratio (VSWR), of the standing wave pattern; d is the sample thickness.

The complex propagation coefficient for electromagnetic waves inside a nonmagnetic sample can be written as $\gamma = \alpha + j\beta$ where α is attenuation constant and β is phase constant. Complex propagation coefficient γ, is a function of the complex relative permittivity $\varepsilon^* = \varepsilon' - j\varepsilon''$, where ε' is the dielectric constant is associated with the capacity for energy storage in the electric field in the material and ε'' is the dielectric loss factor is associated with energy dissipation in the material or the conversion from electric energy to heat energy.

Electric conduction and various polarization mechanisms , including dipole, electronic, atomic and Maxwell-Wagner all contribute to the dielectric loss factor [9-10].The loss factor of a material possessing ionic solution can be expressed as: $\varepsilon'' = \varepsilon_d'' - \varepsilon_\sigma''$ where ε_d'' is relative dipole loss, and ε_σ'' is relative ionic loss.

Propagation coefficient is expressed as

$$\gamma = j2\Pi\sqrt{\varepsilon^*} / \lambda_0 \quad (2)$$

where λ_0 is the wavelength in vacuum.

Writing T / τ for the polar form of γd, (1) becomes

$$c\angle -\xi = \frac{\tanh(T/\tau)}{T/\tau} \quad (3)$$

Knowing C and ξ , values of T and τ are seen from the standard Von Hipple charts .The admittance is expressed as

$$Y_\varepsilon = \left(\frac{T}{\beta l\varepsilon}\right)^2 \llcorner\, 2(\tau - 90^0) = G_\varepsilon + jS_\varepsilon \text{ (say)}$$

$G\varepsilon$ and S_ε are related to ε' and ε'' or

$$\varepsilon' = \frac{G_\varepsilon + (\lambda_g/2a)^2}{1+(\lambda_g/2a)^2} \quad (4)$$

$$\varepsilon'' = \frac{-S_\varepsilon}{1+(\lambda_g/2a)^2} \quad (5)$$

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} = \frac{\sigma}{\omega\varepsilon} \quad (6)$$

where $\varepsilon' = \frac{\varepsilon}{\varepsilon_0}$ and $\varepsilon'' = \frac{\sigma}{\omega\varepsilon_0}$

ac conductivity is expressed as

$$\sigma = \omega\, \varepsilon_o\, \varepsilon'' = 2\Pi f\, \varepsilon_o\, \varepsilon'' \quad (7)$$

where $\varepsilon_o = 8.854 \times 10^{-12}$ F/m is the absolute permittivity.

Penetration depth , d_p is the depth into a sample where the microwave power has dropped to (1/e or 36.8%) of its transmitted value. Penetration depth is a function of ε' and ε''. It is expressed as

$$d_p = (\lambda_0\sqrt{\varepsilon'}) / 2\Pi\, \varepsilon'' \quad (8)$$

and hence propagation constant ($\gamma = \alpha + j\beta$) is determined.

The relation used in to calculate dielectric parameter in Reflectrometry method are

$$\varepsilon' = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_0}{\lambda_d}\right)^2 \qquad (9)$$

$$\varepsilon'' = \left(\frac{1}{\pi}\right)\left(\frac{\lambda_0}{\lambda_d}\right)^2 \alpha_d \lambda_d \qquad (10)$$

$$\sigma_p = \omega \varepsilon_o \varepsilon'' \qquad (11)$$

$$\tau_p = \frac{\varepsilon''}{\omega \varepsilon'} \qquad (12)$$

Where λ_o is the wavelength of the free space

λ_c = 2a is the cut off wavelength of the waveguide.

a- is the broader side dimension of the rectangular waveguide

α_d. Is the attenuation /unit length of the material

$\beta_d = 2\pi/\lambda_d$ is the phase shift introduced by the unit length of the dielectric material

λ_d is the wave length in dielectric powdered material

ω is angular frequency (9.85 G.Hz.)

ε_o is permittivity of vaccum

Methods and Materials

Sample Preparation

Tuber vegetables such as [(Potato, Solanum tuberosum); (Yam, Dioscorea spp.); and sweet potato; culkesia] and root vegetables such as [(Carrot, Daucus carota); (Radish, Raphanus sativus L.); and Beetroot] were obtained at local grocery stores for the measurements of permittivity at a frequency of 9.9 GHz.

A metallic die is designed and fabricated by the author for the sample preparation. The dimension of metallic die is same as the dimension of X band waveguide.

The prepared sample and metallic die is as shown in Figure 1&2 and Jamun fruit , Seed powder and Powder in pellet form is as shown in Figure 3.

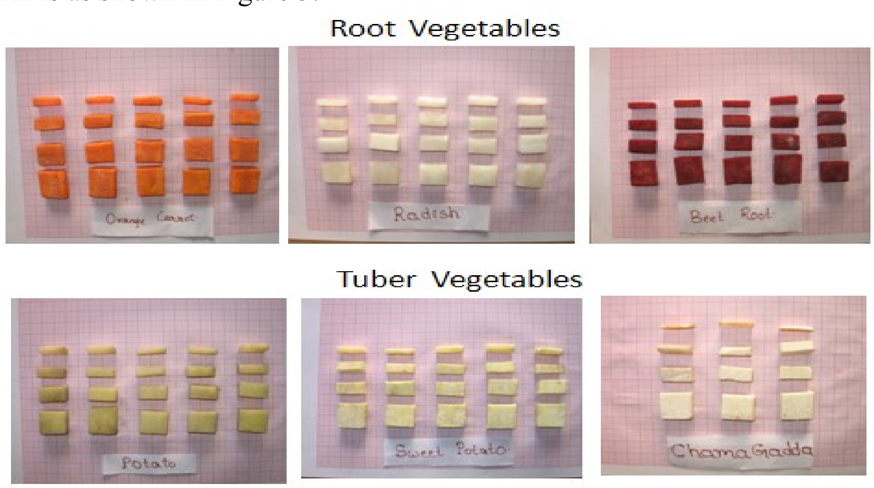
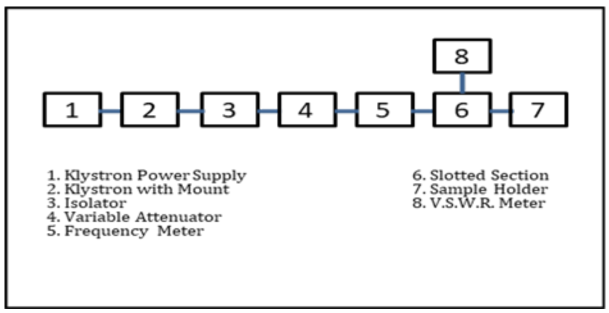


Figure 1. Vegetables sample prepared

Figure 2. X band dimension Metallic Die is prepared

Measurement of Dielectric parameters

The method involves mounting of the sample in a rectangular waveguide excited in the TE_{10} mode. The basic equipment for this measurement is shown in Figure. 4.



1. Figure. 4. Schematic diagram of setup for Short circuited or Von Hipple method

Results and Discussion

The computed dielectric parameters are tabulated by von- Hipple and reflectrometery method in table 1,2&3.

Table 1. shows the values for permittivity, conductivity, penetration depth for the different vegetable tissues.

Vegetables	*Dielectric constant ε′*	*Dielectric loss ε″*	*Loss tangent tanδ*	*Conductivity σ (S/cm)*	*Penetration depth d_p (cm)*
Carrot	*10.12*	*2.16*	*0.21*	*1.19*	*0.89*
Radish	*7.35*	*1.64*	*0.22*	*0.90*	*1.008*
Beetroot	*2.81*	*0.29*	*0.1*	*0.16*	*3.5*
Potato	*31.89*	*8.31*	*0.26*	*4.57*	*0.41*
Sweet potato	*12.27*	*1.20*	*0.098*	*0.66*	*1.77*
Culkesia	*9.82*	*2.15*	*0.21*	*1.18*	*0.88*

Table 2. Dielectric constant (ε') dielectric loss (Є″), relaxation time (τp), conductivity (σp) and moisture percentage of Jamun powder at different temperature and packing fraction (δr) [11-12]

Temp ºC	Packing Fraction (δr)	Є′	Є″	tanδ	tp (p.s.)	Σp (10^{-2})	Moisture (%)
20	0.8601 0.9536 1	2.329 2.353 2.107	0.195 1.204 0.235	0.084 0.086 0.097	1.35 1.4 1.58	10.66 11.14 12.85	0.768 0.715 0.508
35	0.8601 0.9536 1	2.285 2.331 2.382	0.156 0.175 0.225	0.068 0.075 0.094	1.1 1.2 1.52	8.52 9.57 12.33	1.193 1.06 0.792
50	0.8601 0.9536 1	2.231 2.323 2.352	0.108 0.138 0.217	0.048 0.059 0.082	0.77 0.96 1.3	5.91 7.55 10	0.761 0.69 0.495

Table 3. Measured and calculated values of dielectric constant (Є′), and dielectric loss (Є″) for bulk from powder of Syzygium Cumini at different temperatures and packing fraction. (δr) [11-12]

Temp ºC	Relative Packing Fraction (δr)	Measured	Є′ For solid bulk		Meas-ured	Є″For solid bulk	
			Calculated From Bottcher's Formula	Calculated From Landu, et al formula		Calculated From Bottcher's formula	Calculated From Lan-du, et al formula
20	0.8601 0.9536 1	---- ---- 2.407	2.608 2.435 2.407	2.593 2.422 2.398	---- ----- 0.235	0.244 0.218 0.235	0.24 0.217 0.235
35	0.8601 0.9536 1	---- ---- 2.382	2.552 2.433 2.383	2.543 2.423 2.381	----- ---- 0.225	0.195 0.188 0.225	0.192 0.187 0.225
50	0.8601 0.9536 1	---- ----- 2.352	2.529 2.404 2.325	2.52 2.398 2.351	---- ---- 0.217	0.135 0.148 0.218	0.133 0.147 0.218

Conclusions

The results obtained shows that a simple experimental setup i.e. The Von Hipple method can be very use full for measuring the complex dielectric permittivity of biological samples. The Program is developed to evaluate the above parameter is relatively exact method for the determination of dielectric parameters this makes simpler in calculation instead using von Hipple charts.

There is fair agreement between the values obtained experimentally and calculated theoretically by using Bottchers formulae. The correlation formulae of Landau-Lifshitz and Bottcher can be used to provide accurate estimates of (ε'p) and (ε”p) of powdered material at known bulk densities.

Appendices

Appendix 1 Von Hipple Graphs
Appendix 2. Mat lab Programs For mathematical computations.

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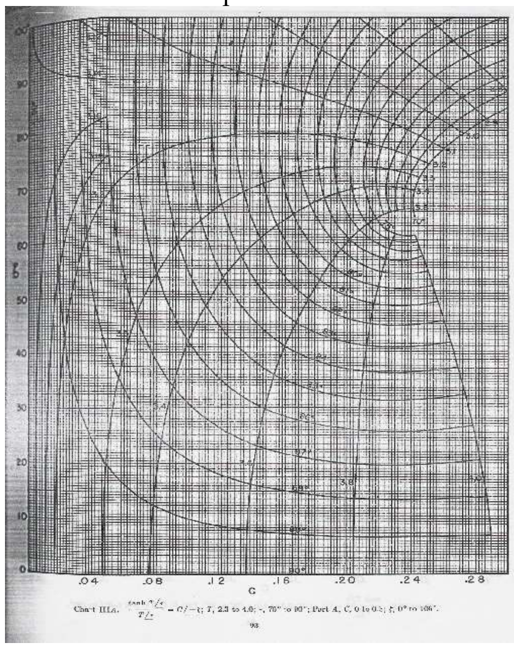
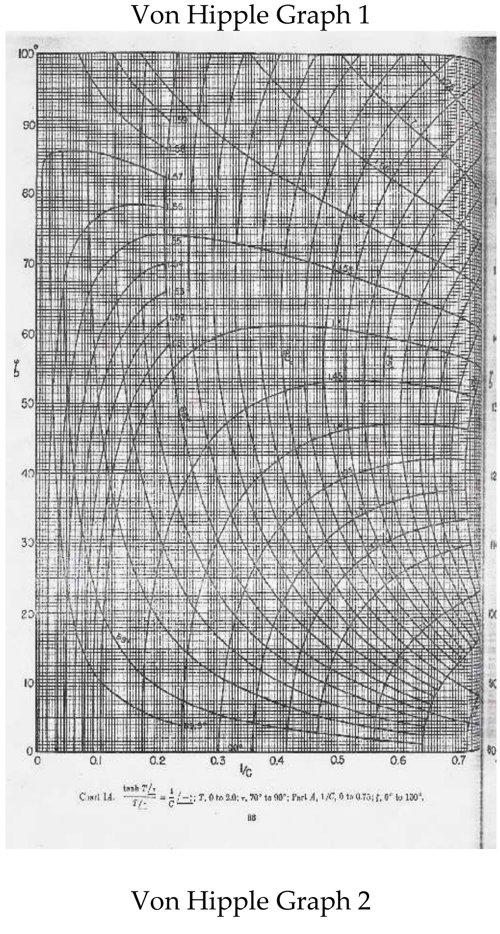
Apendix 1



Von Hipple Graph 1



Von Hipple Graph 2

Appendix 2.

Matlab Programs For mathematical computations.

To evaluate the above parameters the following is programs are developed using mat lab software.

Program –I , example

```
% von Hipple method
lamg = 4.11;
lamc = 2*2.286;
Dr   = 0.23;
l    = 0.523;
D    = 0.78;
S    = 6.9;
beta = (2*pi)/lamg;
phi  = 2*beta*(D-Dr-l);
Gama = (S-1)/(S+1);
c = Gama * exp(i*phi);
c1 = (1-c)/((1+c));
c2 = complex (0,(-1/(beta*l)));
c3 = (c2*c1);
r = abs(c3);
a = (angle(c3))*180/pi;
x1 = r*exp(i*a*pi/180)
% Calculation E' and E"
T = 2.8906;
tau =80.11;
c1 = T*exp(i*tau*pi/180);
cr =(tanh(c1))/c1
X= T;
zee= tau;
Y = (X/(beta*l))^2;
a=2*(zee-90);
x=Y*exp(i*a*pi/180);
Gepselon = real(x);
Sepselon = imag(x);
eprime1= (Gepselon+(lamg/lamc)^2)/(1+(lamg/lamc)^2)
eprime2= -Sepselon/(1+(lamg/lamc)^2)
```

Programe – II

```
a = 2.286;
lamc = 2 * a ;
lamg = 4.1;
f = 9.9*10^9;
c = 3.8*10^10;
lam0 = c/f;
eo = 8.854*10^-12;
eprime1 = 2.8112 ;
eprime2 = 0.2913 ;
```

```
% dp- penetration depth in cms.It is a function of eprime1 and eprime2
dp=(lam0*(eprime1)^0.5)/(2*pi*eprime2)
% conductivity ...... semens/cm
sigma = 2*3.14*f*eo*eprime2
% loss tangent
Losstangent  = eprime2 / eprime1
```