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Study of Conductivity and Penetration Depth in Argemone Seeds at Different Concentrations of Moisture

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ABSTRACT

The conductivity (σ) and penetration depth (dp) of argemone seeds have been measured over the range of temperature 30-45ºC with varying frequency from 5 kHz to 10MHz. The effects of change in moisture level on conductivity and penetration depth has also been studied. The conductivity was found to increase with increase in moisture level and frequency while penetration depth decreases with increases in moisture level and frequency.

Key words: moisture content, conductivity, penetration depth, argemone.

INTRODUCTION

The Electrical properties of agricultural materials have been of interest for many years. The use of dielectric properties of agricultural products for sensing moisture in grain and seed and their application in radio-frequency and microwave dielectric heating is discussed[1]. The dielectric properties of grains and seeds are important for many applications such as, moisture content determination by electrical means[2] and control of stored grains from insects through radio frequency (RF), dielectric heating[3]. Dielectric properties of oil seeds are also important from point of view of the viable test[4]. Dielectric parameters of grains and seeds have also been utilized in improving germination[5] in nondestructive testing fruit seed's internal quality[6] dielectric separation of seeds (separator). Some researchers have also utilized dielectric data for measuring the oil content in Soya bean and Sunflower[7] study of metabolic mechanism[8] and dielectric and conductivity studies of the hydration mechanism of seeds[9]. The dielectric properties which are useful in such practical applications are, the dielectric constant (ε'), dielectric loss (ε'') and a.c. conductivity $\sigma = \omega\varepsilon_0\varepsilon''$, where ε_0 is the permittivity of free space and ω is angular frequency. The dielectric properties of fruits and vegetable are also dependent upon the temperature, and moisture content[10] frequency of the applied field. The electrical properties of many agricultural materials are influenced by ionic conductivity, water relaxation effects and presence of micro-fertilizers[4]. Different kind of studies related with seeds or their properties have been reported by many groups, viz. glass transition in soybean seed[11], effect of temperature treatment on seed water content and viability of green pea and soybean seeds[12], G. M. S. El-Bahy reported FTIR and RAMAN spectroscopy of fenugreek seeds[13], dielectric and conductive studies on variety of seeds[14-24], have been reported by many researchers.

In view of above mentioned applications, study of argemone seeds have become important. As very few information is available on dielectric properties of seeds cultivated in India, therefore, it was considered interesting to study electrical properties of oil seeds cultivated in India. The present paper reports conductive properties of argemone seeds in the temperature range of 30-45ºC in the varying frequency range of 5 kHz to 10 MHz. In order to investigate the effect of moisture content on the conductive properties of argemone seeds the measurements have been taken at five different moisture levels.

MATERIALS AND METHODS

The word argemone is derived from the Greek argema meaning cataract in the eye, as the juice of the plant was used as remedy in diseases of the eye. In India the plant has numerous vernacular names of which Satyanashi meaning devastating seems most appropriate. Seeds namely argemone have been obtained from fields near district Basti, U.P. India.

Experimental Methods

The capacitances (C_M) and dissipation factor (D_M) measurements have been made with the help of impedance/gain phase analyzer (Model No. HP-4194A) frequency range (100Hz to 40 MHz) using a coaxial cylindrical capacitor. The sample holder has been gold plated to reduce dissipation losses. It is calibrated by using standard liquids (Benzene and Methanol) and error in measurement for (ε') was found to be less than 1% and for (ε'') was 1.5%. The dielectric parameters and conductivity have been calculated with the help of the following relations:-

$$\varepsilon' = \frac{C_M - C_0}{C_G} + 1 \quad (1)$$

$$\varepsilon'' = \frac{D_M - D_0}{2\pi f C_G} \quad (2)$$

$$\sigma = \omega \varepsilon_0 \varepsilon'' \quad (3)$$

$$dp = \frac{\lambda_0 \sqrt{\varepsilon'}}{2\pi\varepsilon''} \quad (4)$$

Where C_M is the capacitance of sample holder with sample, C_O is the capacitance of empty sample holder, C_G is the geometrical capacitance $\left[C_G = q/v = 2\pi\varepsilon_0 h/\log_e(b/a)\right] = 1.46$ where a and b are the internal and external radii, respectively, ε_0 is the permittivity of free space, while ω represents angular frequency. Temperature of oil seeds have been varied by placing sample holder in a specially designed glass jacket through which heated oil was circulated using refrigerated circulator of Julabo (model number F-25, Germany). The accuracy of temperature measurement was up to $\pm 0.01^0$C .The experiments have been performed at our laboratory in physics Departments, Lucknow University, Lucknow, India, during May to July 2010.

MOISTURE CONTENT

Moisture contents in argemone seeds were determined on a wet basis. The moisture contents were adjusted by adding distilled water and conditioning of the sample at 20ºC. The samples were subjected to frequent agitation to aid uniform distribution of moisture. These were stored in sealed jars at 20ºC and permitted to reach room temperature (30ºC) in sealed jars before opening for measurements. The samples were kept in this condition for about 26 h before the measurements were made. The moisture contents of the samples have been determined by approved oven method[25] and we have prepared samples for the measurement of dielectric properties.

RESULT AND DISCUSSION

Dielectric data was used to calculate conductivity of argemone seeds and dielectric data alongwith conductivity and penetration depth was calculated using equations 1-4, over the frequency range of 5 kHz to 10 MHz and for moisture levels 0 to 10% between the temperature range 30 to 45ºC.

Behavior of Electrical Conductivity

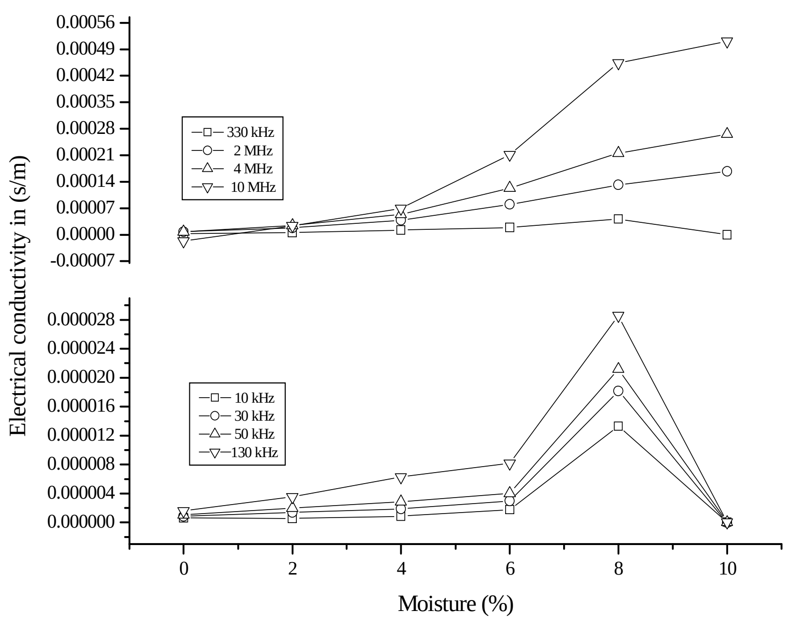

Fig-1: Variation of electrical conductivity of argemone seeds with moisture at 30^{0}C

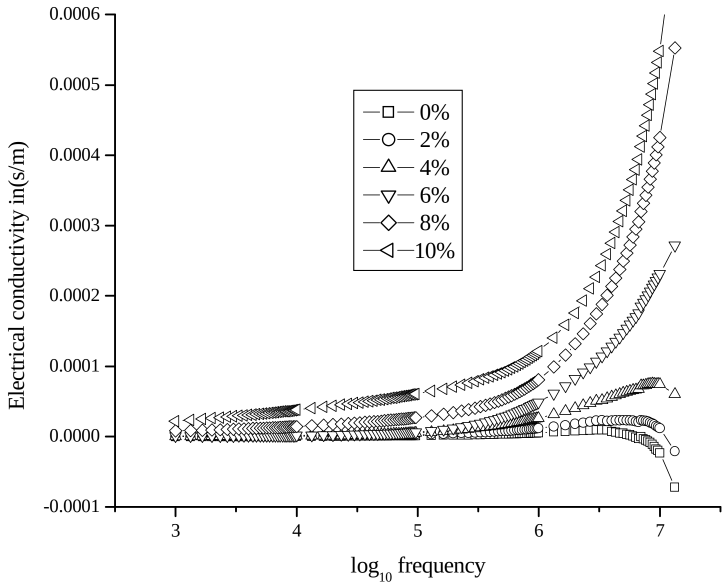

Fig-2: Variation of electrical conductivity of argemone seeds with $\log_{10}$ frequency 35^0C

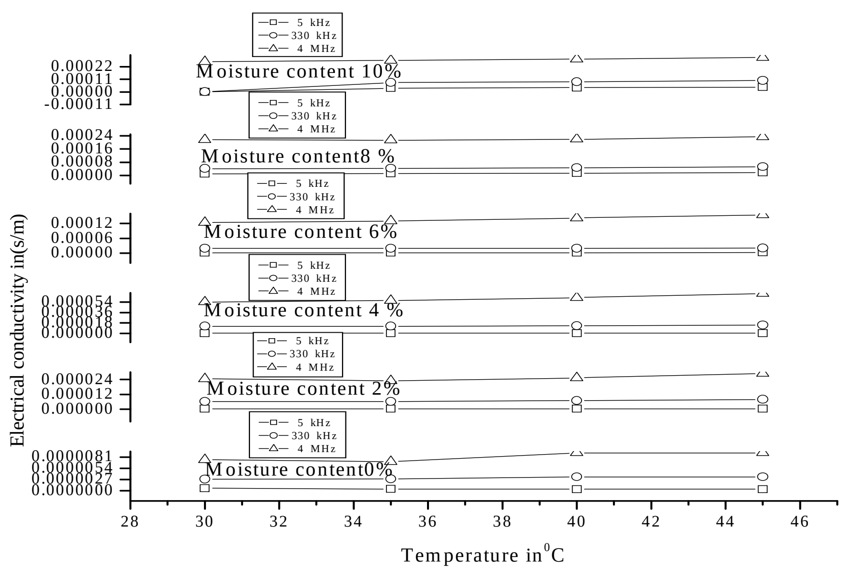

Fig-3: Variation of electrical conductivity of argemone seeds with temperature

Fig-1 and Fig-2 show that the electrical conductivity for argemone seeds increases with increase in frequency and for all the moisture content at 30ºC temperature. Fig- 1 shows the electrical conductivity of argemone seeds at different moisture contents and temperature. The higher conductivity values are observed for higher values of frequency and moisture range[9, 15, 16, 19,20,23,24].

Variation of the electrical conductivity with the temperature of argemone seed at a given moisture content and frequency is shown in the fig- 3. From fig-3 it is observed that the variations with temperature are almost linear in general for all moisture levels at higher frequencies, however non-linearity is present at lower frequencies.

The regression of moisture content M on conductivity yielded the following polynomial equations at 35^0C:

$$\sigma_{10kHz} = \sigma_{10kHz} = -10^{-08}M^5 + 3x10^{-07}M^4 - 2x10^{-06}M^3 + 7x10^{-06}M^2 - 7x10^{-06}M + 6x10^{-07}$$

$$\sigma_{50kHz} = -2x10^{-08}M^5 + 5x10^{-07}M^4 - 4\,x10^{-06}M^3 + 1\,x10^{-05}M\;M^2 - 1\,x10^{-05}M + 1x10^{-06}$$

$$\sigma_{2\,MHz} = -2\,x10^{-07}M^3 + 4\,x10^{-06}M^2 - 5\,x10^{-06}M + 9\,x10^{-06}$$

$$\sigma_{10\,MHz} = -5\,x10^{-07}M^4 + 9\,x10^{-06}M^3 - 4\,x10^{-05}M^2 + 7\,x10^{-05}M - 2\,x10^{-05}$$

with coefficients of determination R^2 of 1, 1, 0.997 and 0.999, respectively and all very close to unity or unity.

Behavior of Penetration Depth

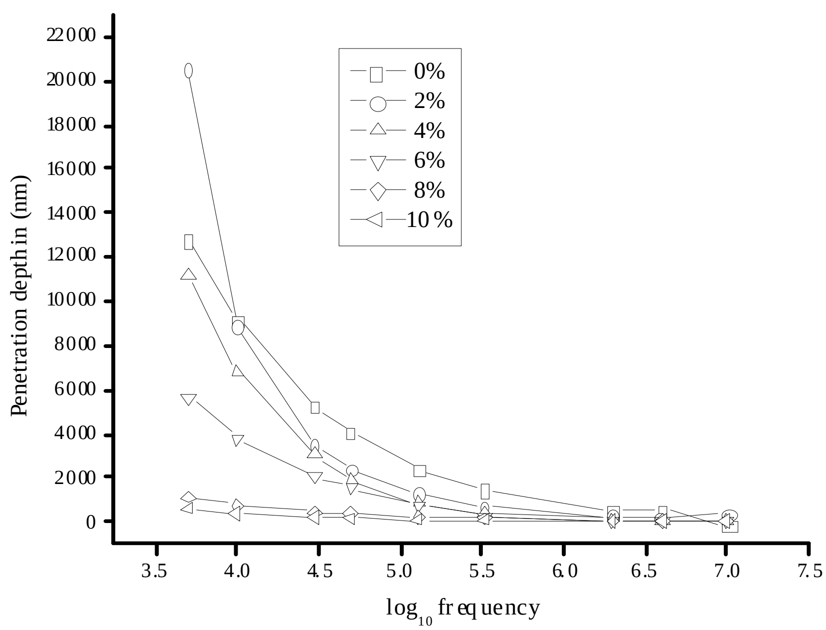

Fig-4: Variation of penetration depth of argemone seeds with $\log_{10}$ frequency at 35^0C

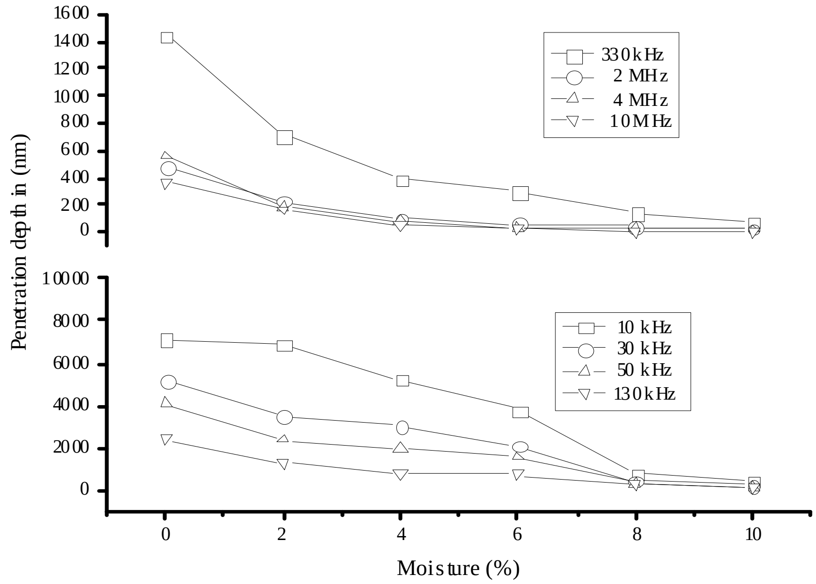

Fig-5: Variation of penetration depth of argemone seeds with moisture content at 35^{0}C

Materials which do not contain magnetic components, respond only to the electric field. The penetration depth, dp is usually defined as the depth into a sample where the electromagnetic power has dropped to 1/e or 36.8% of its transmitted value. Sometimes, dp is defined as the distance at which the microwave power has been attenuated to 50% of transmitted power (P_{max}). The penetration depth is a function of ε' and ε''.

The most common food products have ε''<25, which implies a dp of 6-10 mm. Although dielectric properties of some foods can be found in the literature, data are mostly limited to pure foods and food components. The dielectric properties of materials dictate, to a large extent, the behavior of the materials when subjected to radio-frequency (RF) or microwave fields for purposes of heating or drying[26].

The regression of moisture content M on penetration depth yielded the following polynomial equations at 35^{0}C

$$dp_{\,10kHz} = 3.527M^4 - 53.51M^3 + 151.3M^2 - 374.8M + 7211$$

$$dp_{\,50kHz} = 3.903M^4 - 82.38M^3 + 565.1M^2 - 1710.M + 4087$$

$$dp_{\,2\,MHz} = 0.000M^5 + 0.056M^4 - 2.048M^3 + 27.63M^2 - 175.0M + 484.7$$

$$dp_{\,10\,MHz} = -0.038M^5 + 1.214M^4 - 15.05M^3 + 95.06M^2 - 327.2M + 556.8$$

with coefficients of determination R^2 of 0.991,0.998, 1 and 1, respectively and all very close to unity or unity.

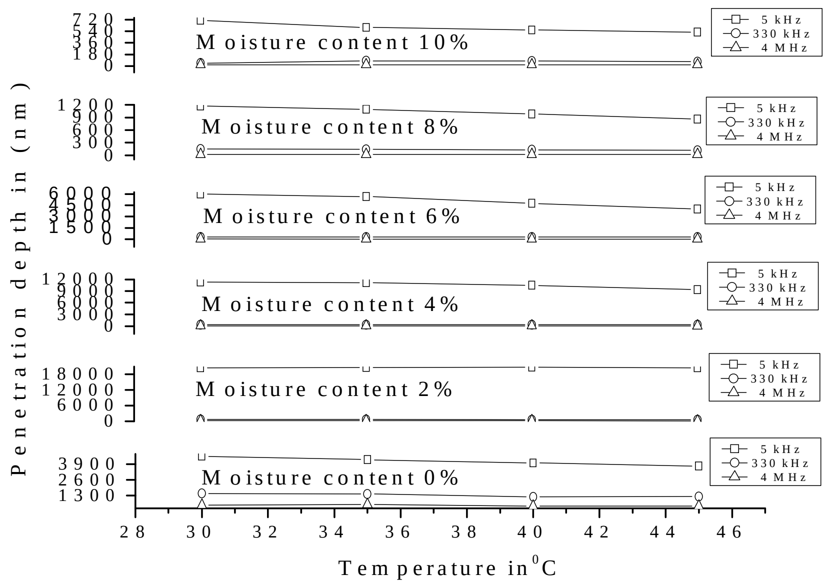

Fig-6: Variation of Penetration depth of argemone seeds with temperature

From fig-4 it is observed that the penetration depth decreases with increase in frequency and increases with increasing moisture content and from fig-5 it is clear that the penetration depth decreases with increases in moisture content. Variation of the penetration depth with the temperature of argemone seed at a given moisture content and frequency is shown in the fig-5 and fig-6. From fig- 5 and 6 it is observed that the variations with temperature are almost linear in general for all moisture levels at higher frequencies, however non-linearity is present at lower frequencies. This type of variation has been shown for many materials.[27-28]

CONCLUSIONS

It can be concluded that moisture level affects the electrical properties of seeds up to a large extent. The electrical properties can be used to measure moisture level, which is directly related with germination of seeds and their viability. Hence we can say that dielectric properties can be used to determine the seed quality. It can be concluded that the electrical conductivity increases with increase in moisture content and frequency for the sample.

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