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Moisture Dependent Electrical Parameter as an Indicator of Germination of Seed: A Case Study of Poppy Seed

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Abstract: The moisture dependent electrical properties of medicinally and nutritionally important Poppy seed have been reported in the present paper. The dielectric constant, dielectric loss and conductivity have been measured for Indian poppy seed over the temperature range 15-45°C at varying frequency i.e., from 5 KHz to 10 MHZ. The measurements have been carried out using electrical impedance spectroscopy. The electrical properties were found to increase with increases in moisture content. The electrical properties for non-viable seed (Dead seed) have also been measured and compared with the properties of viable seeds for different moisture levels. This comparison suggests that dialectic constant could be taken as an indicator of viability of seeds.

Key words: Dielectric constant, dielectric loss, moisture content, germination

Introduction

The dielectric properties of grains and seeds and their dependence on moisture content of the seeds have been of great importance because of their application in the measurement of moisture content (Nelson, 1977).The moisture content measurement of the seeds is important from the point of view of preservation of stored seeds and their protection from insects. This preservation and protection can be achieved by dielectric heating (Nelson *et al*., 1972). Therefore a lot of study have been done on cereals grains and many factors that affect, the electrical parameters i.e., dialectic constant, dielectric loss and conductivity have been evaluated from application point of view. Knowledge of these data are also important in the applications like improvement of germination of seed (Nelson *et al*., 1970), dielectric cleaning and separation of seeds by seed separator (Kazimirchuk *et al*., 1995) and improvement of nutritional qualities (Norris *et al*., 1952).

The dielectric properties of seeds are also helpful in studying the viable test (Wendell, 2000), metabolic mechanism of seed (Hunt *et al*., 1952), hydration mechanism in seed (Knosta *et at*., 1996) as well as in the designing of equipments for sensing and monitoring of moisture using electrical methods.

The electrical parameters for many agricultural materials are influenced by ionic conductivity (Gerhard, 1978) and water retention of cell (Bennet-Clark, 1959) but with the development of practical application of microwave energy, need of data on dielectric properties of seeds have gained much importance.

Poppy seeds are the main source of edible oil (68%) and its digestibility coefficient is 81% (Pushpanngadan *et al*., 2000). They are medicinally important and specially used for extracting the *Opiu*m, which provides the basic compound of the different medicines. Drying of poppy seed to an optimum moisture level is a pre-requisite for their safe quality storage before germination.

Therefore present study have been undertaken as a comparative study of electrical properties of Poppy seeds at different moisture level i.e., the dielectric constant (ε'), dielectric loss (ε''

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and a.c. conductivity ($\sigma = \omega\times\varepsilon_0\times\varepsilon''$, where ε_0 permittivity of free space and w is angular frequency has been measured to identify the viable and non-viable seeds and to analyze their dependence on moisture level for Indian poppy seeds. The measurements have been done in temperature range of 15 to 45°C and with the varying frequency from 5 KHz to 10 MHz.

Materials and Methods

Materials

The poppy seeds have been obtained from certified seed research institute (National Botanical Research Institute Lucknow, India). The nutritive value of poppy seed is reported by (Pushpanngadan *et al*., 2000) as given below.

Moisture 4.3-5.2%, Protein 22.3-24.4%, Crude fibre 4.8-5.8%, Calcium 1.03-1.45%, Phosphorus 0.79-0.89%, Iron 8.9-11.1mg/100 g, Iodine 6 µg kg^{-1}, Arginine 10.41%, Histidine 2.9%, Lysine 1.5%, Methionine 2.3%, Theonine 4.2%, Valine 7.1%.

The chemical composition of seed oil is also given a Palmitic acid (16:0): 8.90-21.48%, Stearic acid (18:0): 1.40-10.80%, Oleic acid (18:1): 13.22-36.79%, Linolenic acid (18:2): 41.00-60.00%, Linol enic acid (18:3):0. 00-9.40%, Manganese (29 mg kg^{-1}), Copper (22.9 mg kg^{-1}), Magnesium (15.6 g kg^{-1}), Zinc (130.0 mg kg^{-1}).

Methods

The capacitances (C_p) and dissipation factor (D_p) measurements have been done with the help of computer controlled Impedance Gain Phase Analyzer (Model No.-HP-4194 A) in the frequency range of 5 KHz to 10 MHz, using a specially designed open ended coaxial probe for permittivity measurement of agricultural product (Sheen *et al*., 1999). The sample holder has been gold plated to reduce dissipation losses. It is calibrated for error removal in measurements using standard liquid C_6H_6 and CCl_4 and the error was found to be less than 1%. The dielectric parameters and conductivity have been calculated with the help of following formula-

$$\varepsilon' = \frac{(C_P - C_0)}{C_g} + 1 \quad (1)$$

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} \quad (2)$$

$$\varepsilon'' = \frac{C_P \times D_P - C_0 \times D_0}{C_P - C_0} \quad (3)$$

And

$$\sigma = \omega\times\varepsilon_0\times\varepsilon'' \quad (4)$$

Where C_p is the capacitance of the sample holder with sample, C_0 is the capacitance of empty sample holder, C_g is the geometrical capacitance of sample holder

$$(C_g = \frac{q}{v} = 2\times\pi\times\varepsilon_0\times\frac{h}{\log_e\left(\frac{b}{a}\right)} = 1.463\ \mu f$$

where h is height of the sample holder, a and b are the internal and external radii respectively, ε_0 is the permittivity of free space, D_p is the dissipation factor for sample holder with sample and D_0 is the dissipation factor for empty sample holder, while w represents the angular frequency. Temperature of poppy seed have been varied by placing the sample holder in a specially designed double walled glass jacket through which heated oil has been circulated using a refrigerated circulator of Julabo (F-25 model, Germany). The accuracy of the temperature measurement is ±0.01°C. The experiments have been performed at our laboratory in Physics Department, Lucknow University, Lucknow, India, during September to November 2005.

Moisture Content

The most important part of the experiment was to prepare the samples at different moisture levels. The initial percentage of moisture content in 20 g of sample were determined using a standard oven-drying method in which the moisture contents were determined gravimetrically after drying at 130°C for 1 hour (ISTA, 1996). Then by adding distilled water to samples and by frequent agitation to aid uniform distribution of moisture sample was prepared at certain moisture level and sealed with Para film and with a plastic cap in the jar which was stored at 4°C for 72 h (Nelson *et al*., 1976) to allow complete water uptake and seed moisture equilibration. For moisture level lower than initial level, the sample were dried in open air for several hours to reach the lower desired moisture content. The sample is kept in this condition for about 48 h before the measurements were made. The moisture contents of the sample have been determined by approved oven method (USDA, 1971) and we have prepared sample in two parts one of them for measurement of dielectric properties and other is for germination of seed.

Germination of Seed

We have taken the 10 g of prepared sample having moisture content 5, 10, 20, 30% of dead seeds and normal seeds and kept in the 5 labeled disks and placed it into the seed germinator at 25°C temperatures for approximate 30 days.

Results

The experimentally determined values of dielectric constant (ε'), dielectric loss (ε'') and electrical conductivity (σ) of poppy seed, over the frequency range of 5 KHz to 10 MHz at different discrete frequencies of 5, 10, 50, 100, 500 KHz, 1, 5 and 10 Mhz and for moisture levels 5 to 30% between the temperature range 15 to 45°C has been analysed in the present study. The mean temperature coefficient per unit moisture content for dielectric parameter is calculated as per definitions given below:

Mean temperature coefficient per unit moisture content at given frequency
= [(Value of parameter at T_2 - value of parameter at T_1)/(T_2-T_1)]f/$(M_2\text{-}M_1)_f$

Where, f is a selective frequency and T, M are the temperature and moisture content, respectively.

Behaviour of Dielectric Constant and Dielectric Loss Factor

Frequency Dependence

From the Fig. 1 we have been observed that both the dielectric constant and dielectric loss of the complex permittivity decreases with increases in the frequencies. This exhibits dielectric dispersion in the material at different frequencies. The high values of dielectric constant at lower frequencies (5, 10, 50 and 100 KHz) and high moisture content could be attributed to high mobility of dipole for free water state and electrode polarization. The high values of the dielectric loss can be attributed to high mobility of water dipole, electrode polarization and increase in ionic and surface conductivity. The relation between dielectric loss and ionic conductivity is given by (Magario *et al*., 1988)

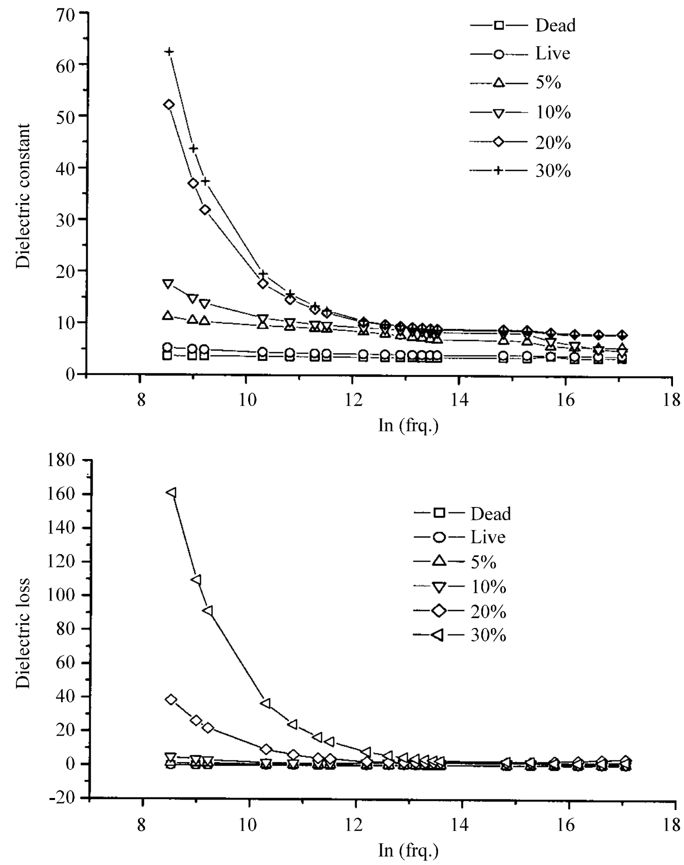

Fig. 1: Frequency dependence of dielectric properties of poppy at indicated moisture content and 25°C

$$\varepsilon'' = \varepsilon''_d + \frac{\sigma_i}{\omega \times \varepsilon_0} = \varepsilon''_d + \frac{\sigma}{2 \times \pi \times f \times \varepsilon_0}$$

As we go towards the lower frequency side the ionic loss ($\sigma_i/2\times\pi\times f\times\varepsilon_0$) is inversely proportional to frequency and it becomes almost absent at higher frequencies due to the dipolar energy dissipation, which is the predominant loss and ionic loss become almost absent. The dielectric properties of the seeds and other food materials can be represented as combination of ionic and dipolar polarization losses.

The change in dielectric constant and corresponding variation in dielectric loss at indicated frequencies showed that the changes in loss factor are less regular than the change in dielectric constant. The similar behaviours in Corn for the moisture range 5 to 10% and frequency range 1 to 11 GHz have been reported by Nelson (1979b). In other studies (Jones *et al*., 1978) on wheat, Corn and Soybean over the frequency range 1 to 200 MHz range similar types of behaviour has also been reported. The complex dielectric relaxation and dispersion phenomena may be one of the causes in the irregularity in loss factor.

From the Fig. 1 it can be observed that the curves divers and the separations increase between the curves for different moisture levels as we move to the lower end of the frequency range but no change in the curve have been observed for the dead seed and it shows nearly a straight line.

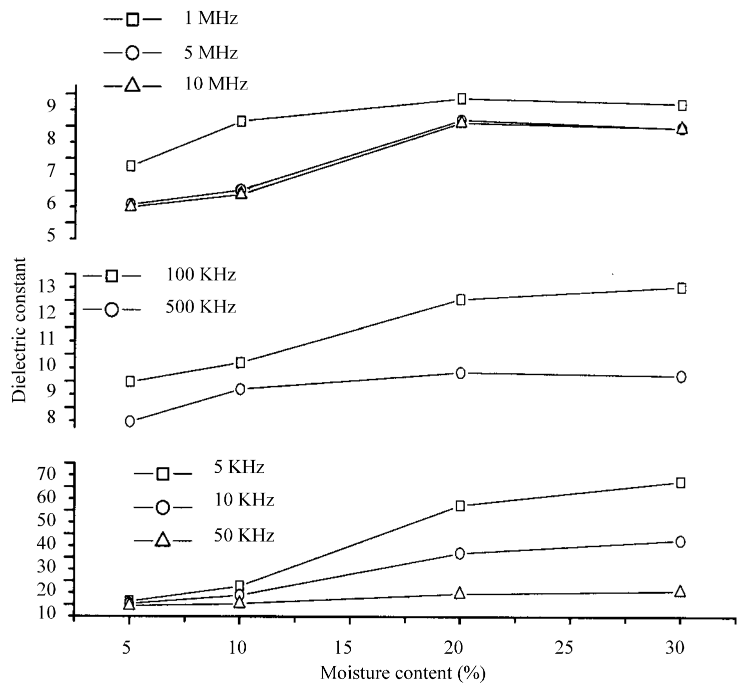

Fig. 2: Moisture dependence of dielectric constant of poppy seed at indicated frequencies and 25°C temperature

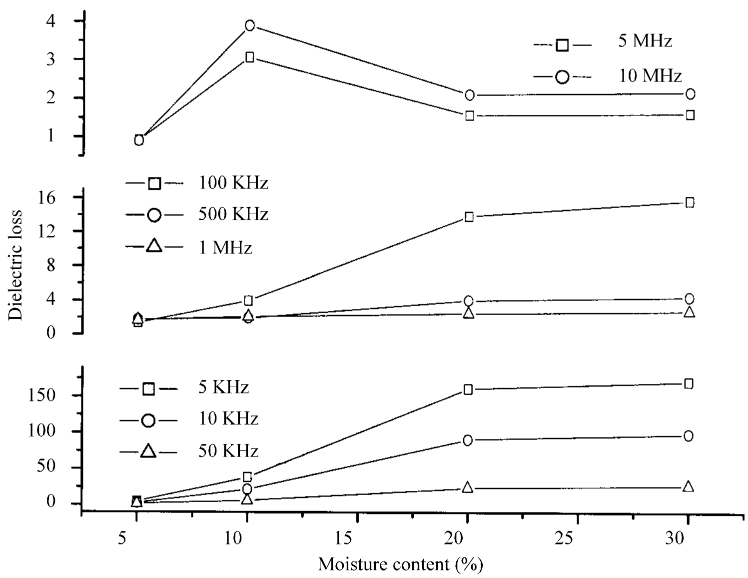

Fig. 3: Moisture dependence of dielectric loss of poppy seed at indicated frequencies content and 25°C temperature

Moisture Dependence

It is clear from Fig. 2 and 3 that the complex dielectric permittivity increases with increase in the moisture content at a given frequency and temperature. It can be observed that the rate of increase in

ε' and ε'' is high at 5 KHz and 10 KHz. The reason is water dipoles easily follow the applied field variations, at high moisture level and more water dipoles contribute to the polarization, due to high water mobility. At low moisture content, particularly below 5% both ε' and ε'' of the complex permittivity are small because the distance between the water molecule and cell wall is very small and force of attraction is very large in the case of strong bound water state (monolayer). Therefore, the dielectric constant and dielectric loss both are small.

When the moisture content increases beyond the 8%, bound water changes state from first (monolayer) to second (multilayer) type and add to the complex permittivity, which shows a sharp increase in ε' and ε'' for the moisture content over 10% for all the frequencies. At high moisture content, particularly 30% and frequency below 10 KHz, only live seeds gives high values of ε' and ε''. This behaviour could be attributed to transition of bound water state second (multilayer) to third state due to osmotic tension (Bennet-Clark, 1959) or free state of water at high moisture level. At low frequency the ionic conductivity is high therefore for such moisture level and low frequencies, the dielectric losses are considerably high.

Temperature Dependence

The Fig. 4 and 5 shows temperature dependence of ε' and ε" in the temperature range of 15-45°C. A different frequencies and moisture levels dielectric constant and dielectric loss increase with increase in the temperature at all moisture levels and frequencies with a slight non-linearity at high moisture content and low frequency, particularly at 10 KHz. The nature of the slope of the linear curve decreases with the increasing frequency and is becoming insignificant as we go to the higher end of the frequency range. The similar variations are also seen in a recent study on temperature dependence of dielectric properties of pecan (Lawrence *et al*., 1992) and fruits (Sipahioglu *et al*., 2003) in the range of 0-40°C.

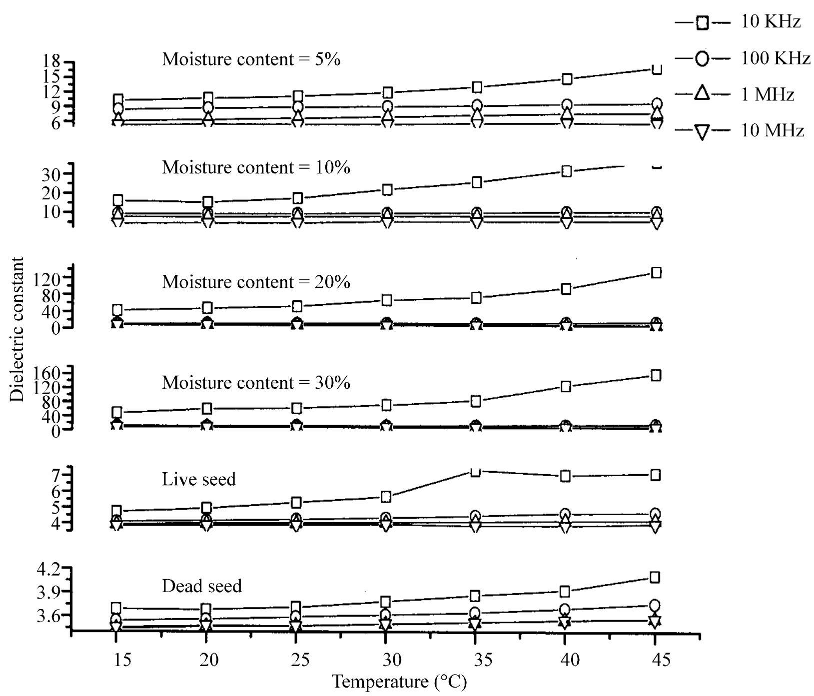

Fig. 4: Temperature dependence of dielectric constant of poppy seed at indicated frequencies and moisture content

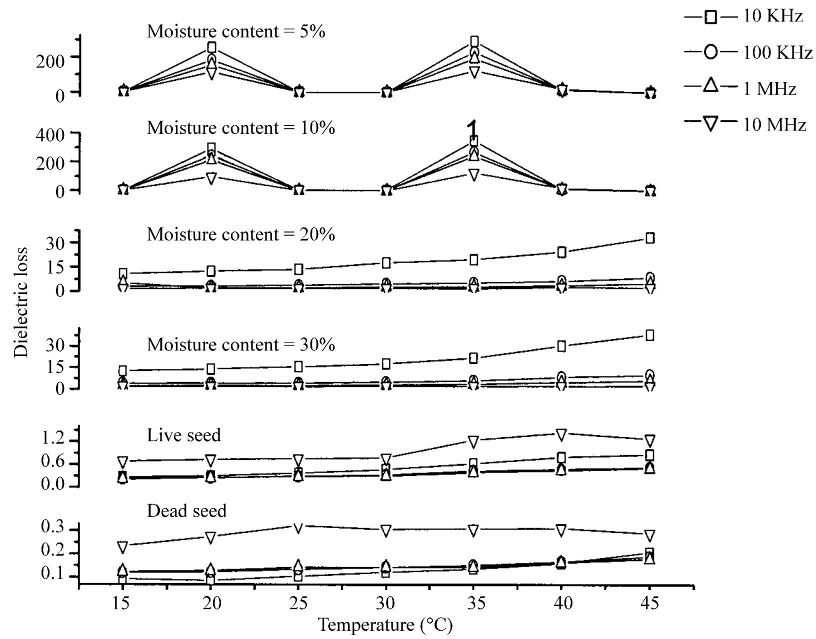

Fig. 5: Temperature dependence of dielectric loss poppy seed at indicated frequencies and moisture content

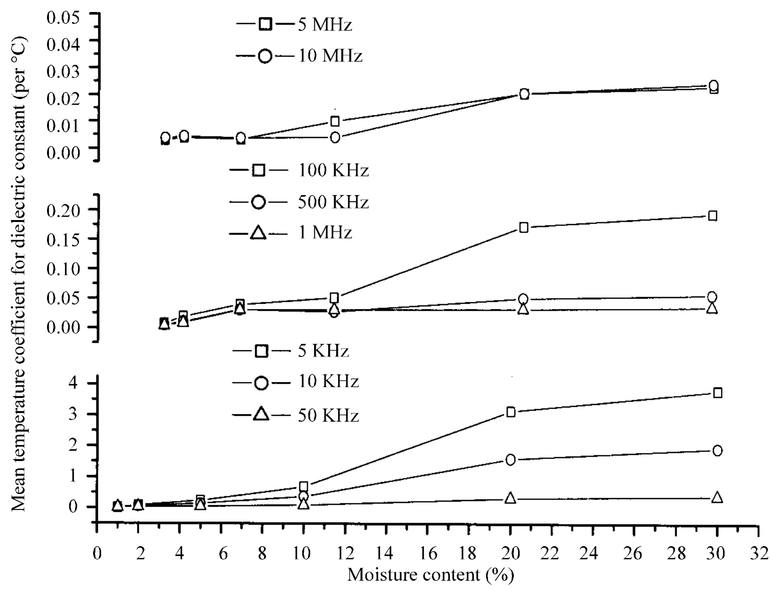

Fig. 6: Moisture dependence of mean temperature coefficient for dielectric constant of poppy seed at indicated frequencies

The energetic status of the molecules and their aptitude to rotate with electric field (Bennet-Clark, 1959) changes to the permittivity due to the increase in the temperature and hence change in effectivecomplex permittivity results in increase or the decrease of the water molecules contribution to the polarization of the medium.

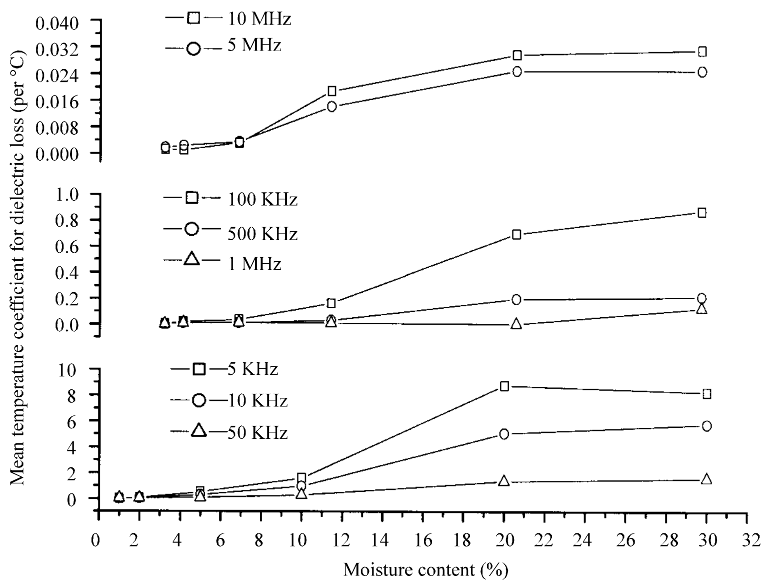

Fig. 7: Moisture dependence of mean temperature coefficient of dielectric loss for poppy seed at indicated frequencies

As the temperature increases the molecular mobility increases and relaxation frequency, which is strongly related to the molecular mobility, increases (Barrow, 1988). Therefore, the peaks of both, the dielectric constant (ε') and dielectric loss (ε'') shifts to higher frequency. Increase in temperature also increases to the ionic conduction, leading to increase in dielectric loss. Thus, as temperature increases both dielectric constant ε' and ε'' increases. The increase in dielectric parameters with temperature at lower frequency and higher moisture content indicate the predominant effect of ionic conduction as well as molecular mobility. Therefore, under these conditions rate of increase of ε' and ε" with temperature are high and might be non-linear. The dielectric constant is less affected by the temperature than that of the dielectric loss because of increase in ionic conduction gives additional effect on dielectric loss factor, whereas dielectric constant is less or not at all affected by the ionic conduction.

Figure 6 and 7 shows mean temperature coefficients for both ε' and ε'' increases with increasing moisture content at a given frequency and decreases with increase in frequency. The magnitude of mean temperature coefficient is comparatively high at higher moisture content. This indicates that moisture has an appreciable influence on the mean temperature coefficient. In general it can be assumed that the mean temperature coefficients of dielectric constants are positive at all moisture level and frequencies. These results are in agreement with the finding of (Nelson, 1979b), they reported positive temperature coefficients at radio frequencies for wheat, Corn and Soyabean over temperature range of 2-40°C.

The natures of these curves are linear increasing after 5% moisture level having a large variation at 20% moisture level. This could be due to the varying molecular mobility at different moisture content and dispersion mechanism.

Behaviour of Electrical Conductivity

Figure 8 shows that the electrical conductivity for all the poppy seeds increases with increase in frequency and the moisture content at 25°C temperature. Figure 9 and 10 shows the electrical conductivity behaviour for poppy seed at different moisture content and temperature. The higher

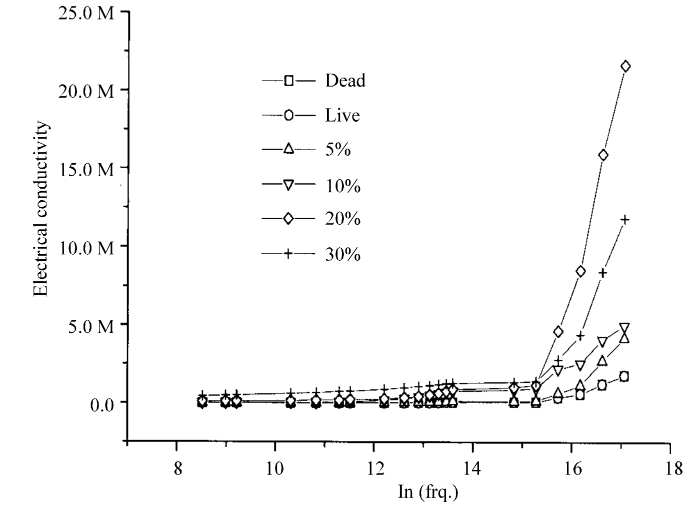

Fig. 8: Frequency dependence of electrical conductivity of poppy seed at indicated moisture content and 25°C

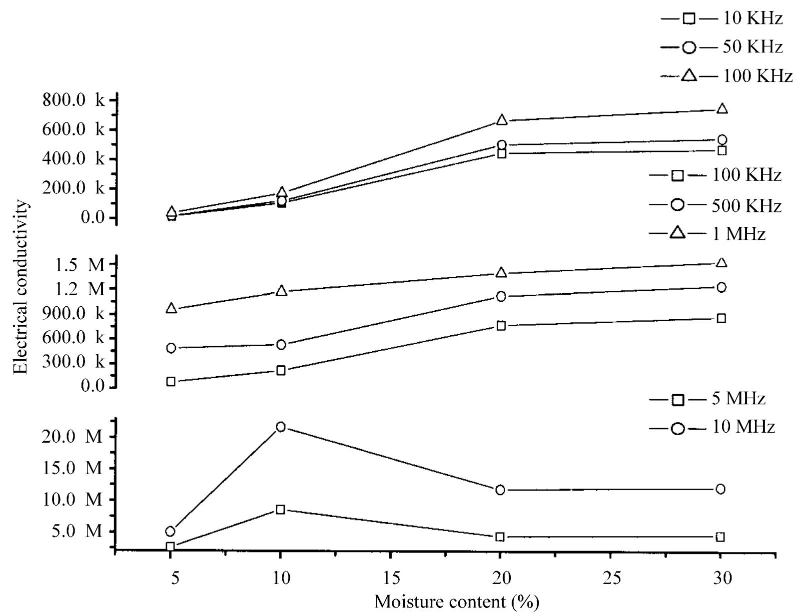

Fig. 9: Moisture dependence of electrical conductivity of poppy seed at indicated frequencies content and 25°C temperature

conductivity values in the given frequency and moisture range are observed for the normal poppy seed in comparison to dead seed.

Variation of the electrical conductivity with the temperature of poppy seed at a given moisture content and frequency is shown in the Fig. 10. From figure 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.

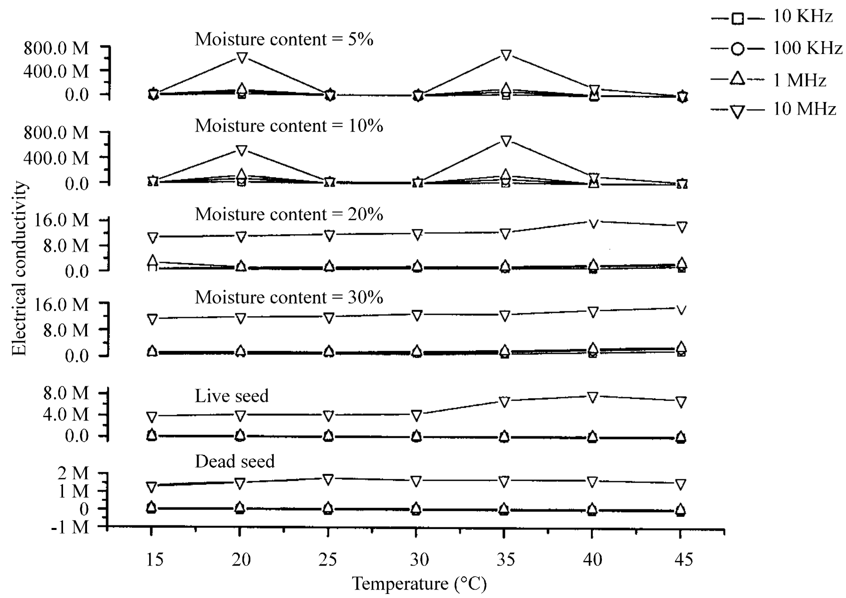

Fig. 10: Temperature dependence of electrical conductivity of poppy seed at indicated frequencies and moisture content

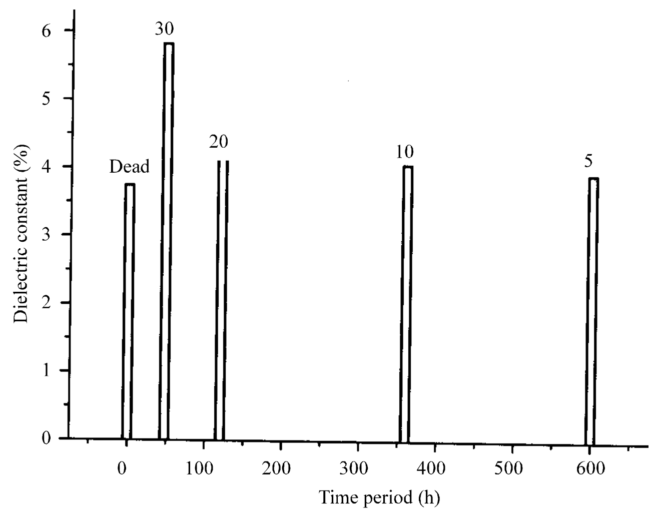

Fig. 11: Dielectric constant verses time period of germination of poppy seed at 25°C temperature

Germination Period Dependence on Electrical Parameter

Figure 11 shows a bar diagram of germination period verses dielectric constant for viable and non viable seeds (dead seed). The observed fact is that for non viable seed the dielectric constant is least in comparison to dielectric constant of viable seed at different moisture content. The germination period is maximum for 5% moisture level and minimum for the 30% moisture level whereas the dielectric constant is extreme for 30% and minimum for 5%.Thus we can conclude that the electrical parameters are definitely an indicator of germination period as well as viability of seeds (Repo *et al.*, 2002) in the case of poppy. A general theory can be derived by studying a number of seeds.

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 and germination period.

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