International Journal of

Agricultural Research

ISSN 1816-4897

Academic Journals Inc.

www.academicjournals.com

International Journal of Agricultural Research 5 (8): 678-689, 2010
ISSN 1816-4897 / DOI: 10.3923/ijar.2006.293.304

Dielectric Properties of Some Oil Seeds at Different Concentration of Moisture Contents and Micro-fertilizer*

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Abstract: Dielectric constant (ε′), dielectric loss (ε″) and conductivity (σ) of some oil seeds (namely Brassica Compestris Yellow and Black) have been measured over the range of temperature 15- 45°C with varying frequency from 5 KHz to 10 MHz. The effect of change in the moisture content and varying concentration of micro-fertilizers on dielectric properties has been studied. Both the dielectric constant and conductivity were found to increase with increase in moisture level and also with increasing concentration of micro-fertilizer. The dielectric parameters show a decreasing trend with increase in frequency. The dielectric constant, dielectric loss and the conductivity of the dead seed has also been measured and compared for both the varieties.

Key words: Oil seeds, dielectric properties, moisture content, micro-fertilizer

Introduction

Dielectric andproperties of various agri-food and biological materials are finding increasing application (Venkatesh and Raghavan, 2005), as fast and new technology is adapted for use in their respective industries and research laboratories. The earlier concept of permittivity measurements was based on dc electrical resistance to determine grain moisture content. A non-linear increase in resistance of the grain as temperature decreased gave useful observation (Nelson, 1991).

The dielectric properties of grains and seeds are important for many applications such as, moisture content determination by electrical means (Nelson, 1977) and control of stored grains from insects through radio frequency (RF), dielectric heating (Nelson and Charity, 1972) and sorting and cleaning of seed mixtures by dielectric methods (Kazimirchuk and Kahiretidionov, 1995)and. Dielectric properties of oil seeds are also important from point of view of the viable test (Wendell, 2000). Dielectric parameters of grains and seeds have also been utilized in improving germination (Nelson *et al*., 1970) in nondestructive testing fruit seed's internal quality (Ragani and Jhang, 2001) dielectric separation of seeds (separator).

Some researchers have also utilized dielectric data for measuring the oil content in Soyabean and Sunflower (Brandenburg *et al*., 1961), study of metabolic mechanism (Hunt *et al*., 1952) and hydration mechanism (Elena *et al*., 2001) of seeds (Knosta *et al*., 1996) and (Norris and Brant, 1952) have reported designing of equipments for sensing and monitoring of moisture content using electrical methods. 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 fruits and vegetable are also dependent upon the temperature, frequency and moisture content (Funebo and Ohlsson, 1999) of the applied field. The electrical properties of many agricultural materials are influenced by ionic conductivity, water relaxation effects and presence of micro-fertilizers (Wendell, 2000).

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**Originally Published in International Journal of Agricultural Research, 2006*

In view of above mentioned applications study of dielectric properties of oil seeds have become all the more important. However very few information is available on dielectric properties of oil seeds cultivated in India. Therefore it was considered interesting to study electrical properties of oil seeds cultivated in India. The present paper reports dielectric properties of mustered seeds of two varieties namely Brassica Compestris (Yellow and Black) in the temperature range of 15-45°C in the varying frequency range of 5 KHz to 10 MHz. In order to investigate the effect of moisture content and the presence of micro fertilizer on the dielectric properties of seeds, the measurements have been taken at five different moisture levels and at different concentrations of micro fertilizer inducted in to the grain material.

Materials and Methods

Experimental Method

The capacitances (C_p) and dissipation factor (D_p) measurements have been made with the help of Impedance/Gain Phase Analyzer (Model No. -HP- 4194A, range of frequency 100 Hz to 40 MHz) using specially designed open ended coaxial probe for permittivity measurement of agricultural product (Sheen and Woodhed, 1999). 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 + 1% and for ε″ was 1.5%. The dielectric parameters and conductivity have been calculated with the help of the following relations

$$\varepsilon' = \frac{C_P - C_0}{C_G} + 1 \tag{1}$$

$$\tan\delta = \frac{C_P D_P - C_O D_O}{C_P - C_O} \tag{2}$$

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} \tag{3}$$

$$\sigma = \omega \times \varepsilon_0 \times \varepsilon'' \tag{4}$$

Where, C_p is the capacitance of sample holder with sample, C_o is the capacitance of empty sample holder, C_g is the geometrical capacitance ($C_g = q/v = 2\pi\varepsilon_0 h/\log_e(b/a) = 1.46$ where a and b are the internal and external radii, respectively), ε_o 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±0.01°C. The experiments have been performed at our laboratory in physics Department, Lucknow University, Lucknow, India, during May to July 2005.

Material

Oilseeds namely Brassica Compestris (Yellow and Black) have been obtained from certified seed bank (National Bureau of Plant Genetic resources PUSA New Delhi.) and Micro-fertilizers ($ZnSO_4$ and $MgSo_4$) have been purchased by Ranbaxy Chemicals.

The oil seeds selected for measurement differed in constituents and value of different nutrients such as moisture, protein, fat, minerals, fiber and carbo-hydrate as shown in Table 1.

Table 1. The chemical compositions of oil seeds

	g kg^{-1}					
Brassica compestris	Moisture	Protein	Fat	Mineral	Fibre	Corbohydrate
Yellow	8.5	20.0	39.7	4.2	1.8	23.8
Black	8.0	17.4	30.0	4.0	2.0	20.5

Source: C. Gopalan, B.V. Ramasastri and S.C. Balsusbramaniam, `Nutrivtive Value of Indian Foods, Pub. National Institute of Nutrition, ICMR, Hydrabad, India

Moisture Content

Moisture contents in all the oil seeds were determined on a wet basis. The moisture contents were adjusted by adding distilled water and conditioning of the sample at 15°C. The samples were subjected to frequent agitation to aid uniform distribution of moisture. These were stored in sealed jars at 15°C and permitted to reach room temperature (24°C) in sealed jars before opening for measurements. The samples were kept in this condition for about 48 h before the measurements were made. The moisture content of the samples has been (USDA, 1971) and determined by approved oven method.

Micro-fertilizers Contents

The solutions of Micro-fertilizers were made in 1.0, 0.75, 0.50 and 0.25 pm concentrations. Adding and conditioning the sample at 150°C adjusted the solutions. The samples were subjected to frequent agitation to aid uniform distribution of solution and were stored in sealed jars at 15°C. These were permitted to reach room temperature (24°C) in sealed jars before opening for measurements. The samples were kept in this condition for about 48 h before the measurements were made.

Results and Discussion

Dielectric properties of pure seeds

The present investigations have been made with the objective, how electrical properties of seeds vary with the different levels of moisture and concentration of micro fertilizers. It has also been considered important to investigate weather the dielectric properties can be used as strong indicator of percentage moisture content, which is very important for seed germinations as well as preservation. We have also tried to find a correlation in the dielectric properties of pure seed and micro fertilizers treated seeds. The dielectric properties of vegetables and fruits as a function of temperature, ash and moisture content are reported by other workers (Sipahioglu *et al*., 2003) but the effect of micro fertilizer concentration on dielectric properties have not been examined and correlated with the other properties earlier. The dependence of dielectric parameters have been examined by plotting curves between dielectric constant and dielectric loss with natural log of the frequency for different moisture levels. A representative curve at 25°C has been given in Fig. 1. From Fig. 1, it is observed that both the dielectric constant and dielectric loss decreases with increase in frequency, which exhibits the dielectric dispersion in the material. High values of dielectric constant at low frequencies (5 and 10 KHz) and high moisture content could be attributed to high mobility of dipole due to free water state and electrode polarization. The high values of the dielectric loss may be attributed to high mobility of water dipole, electrode polarization and increase in ionic and surface conductivity. Increase of dielectric loss due to increase in ionic conductivity lies in definition given by Magario and Yamaura (1988).

$$\varepsilon''=\varepsilon''_d+\sigma_i/\omega\varepsilon_0=\varepsilon''_d+\sigma_i/2\pi f\varepsilon_0 \quad (5)$$

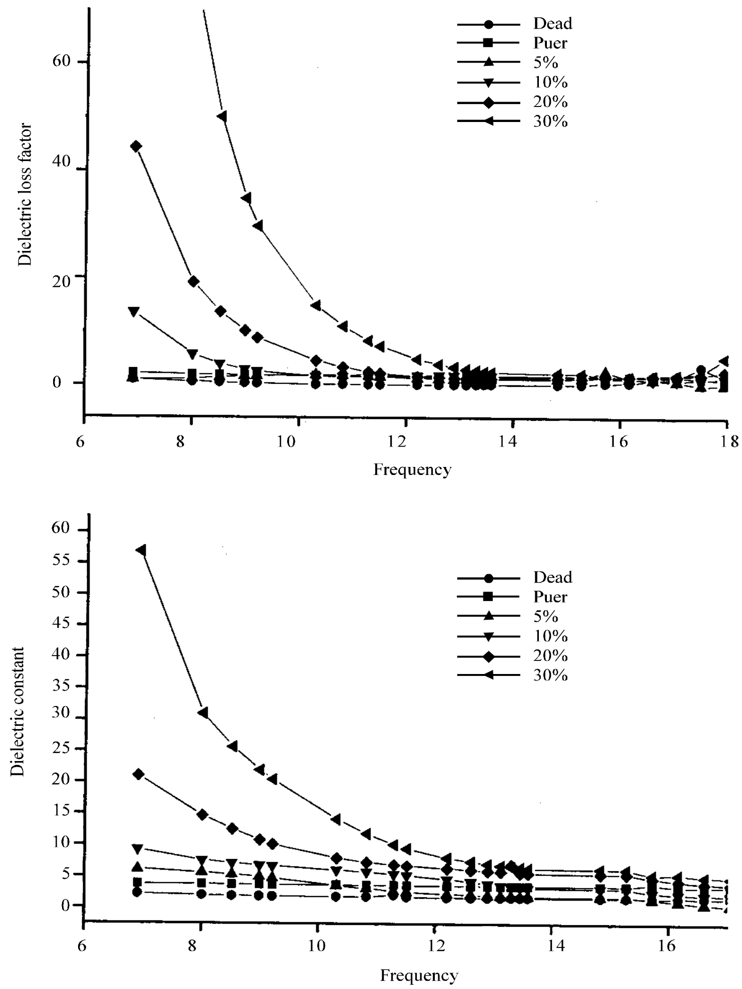

Fig. 1: Frequency dependence of dielectric properties of oil seed (Black) at indicated moisture content and 25°C

This ionic loss ($\sigma_i/2\ \pi\ f\varepsilon_0$) is inversely proportional to frequency and become critical as we go to the lower frequency. At higher frequencies dipolar energy dissipation is the predominant loss and ionic loss becomes almost absent. The combination of ionic and dipolar polarization losses make the interpretation of the dielectric properties of the seeds and other food materials complex. This combination of ionic and dipolar polarization decreases the numerical value of loss which can be observed from the figure.

Variations in dielectric constant and the corresponding variation in dielectric loss with frequency indicate that the changes in loss factor are less regular than the changes in dielectric constant, Nelson (1979b) reported similar behaviour in corn seeds between the moisture range of 10 to 50% and frequency range of 1 to 11 GHz. In other studies (Jones *et al*., 1978) on wheat corn and Soybean over the frequency range of 1 to 200 MHz range similar types of behavior have been reported. The irregular behaviour of loss may be due to the complex nature of dielectric relaxation and dispersion phenomena. The ionic component of dielectric loss increases as the concentration of dissociated ions increases (Mudgett, 1995), thus this was expected. We can say that the studies previously done by other groups on other seeds also support our findings regarding measurement of dielectric parameters in the seeds at different moisture level.

Moisture Dependence

It is clear from Fig. 2 and 3 that for a given frequency and temperature for the oil seeds, ε' and ε'' of the complex dielectric permittivity increases with increase in the moisture levels for all given temperatures and frequencies. The rate of increase of ε' and ε'' with the moisture content are high at low frequencies particularly at 5 and 10 KHz. This is obvious from the fact that at high moisture level more water dipoles contribute to the polarization, due to high water mobility, showing that the water dipoles easily follow the applied field variations. At low moisture contents, particularly below 8% both ε' and ε'' of the complex permittivity are small. This is because of strong bound water state (monolayer) where distance between the water molecule and cell wall is very small and attraction force is very large. Therefore the dielectric constant and dielectric loss both are small.

As moisture level increases beyond 8% increase in the both the, ε' and ε'' of the complex permittivity accelerates and this trend could be attributed to change of bound water state from first (monolayer) to second (multilayer) type. Sharp increase is noticed for all the frequencies for the

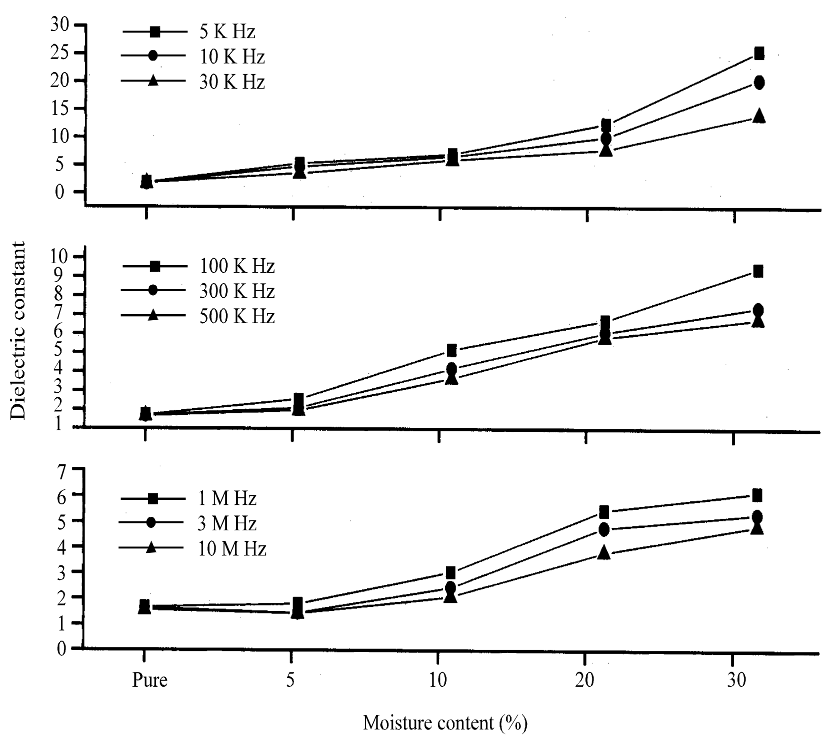

Fig. 2: Percent moisture dependence of dielectric constant of oil seed (Black) at indicated frequencies and temperature 25°C

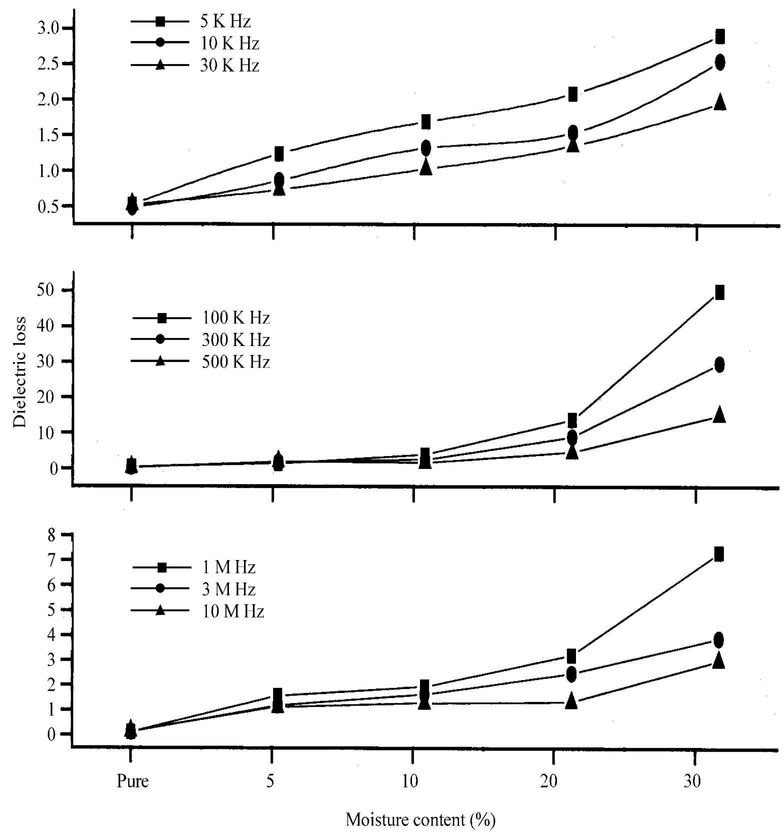

Fig. 3: Percent moisture dependence of dielectric loss of oil seed (Black) at indicated frequencies and temperature 25°C

moisture content reaching beyond 13%. At high moisture content, particularly when moisture content is 20% and frequency 10 KHz, oil seeds give very high values of ε′ and ε″. This behavior could be attributed to the transition of bound water state second (multilayer) to third (osmotic tension) type or free state water. At high moisture level and low frequency the ionic conductivity is high, therefore for such moisture level and frequencies, the dielectric losses are considerably high.

Temperature Dependence

It can be observed from Fig. 4 and 5 that both, the dielectric constant (ε′) and dielectric loss (ε″) of the effective complex permittivity of the oil seed increases with increase in temperature at all moisture levels and frequencies. At lower moisture levels, the relationship between the dielectric constant, dielectric loss and the temperature are found to be linear for all the frequencies. However a slight non-linearity is also noticed at high moisture content level and low frequencies, particularly at 5 KHz. Slopes of the linear curve decreases with the increasing frequency and is becoming insignificant as we go to the higher end of the frequency range. In a recent study on temperature dependence of dielectric properties of pecans (Lawrence *et al.*, 1992) have reported similar variations in the temperature range of 0-40°C.

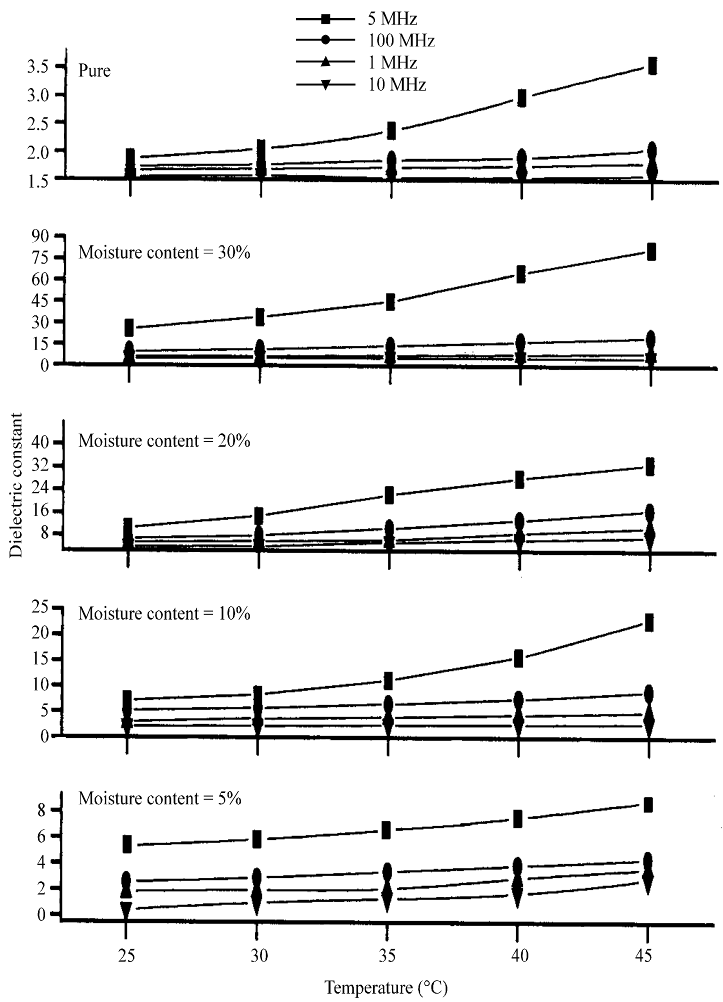

Fig. 4: Temperature dependence of dielectric constant of oil seed (Black) at different concentration of percent moisture content and indicate frequencies

The effect of temperature on the permittivity is due to the fact that temperature change modifies the activations state of the molecules and their aptitude to rotate with the electric field. As the temperature increases the molecular mobility increases and relaxation wavelength, which is strongly related to the molecular mobility decreases (Barrow, 1988). Therefore, the peaks of both, the dielectric constant (ε′) and dielectric loss (ε″) shifts to higher frequency region. Increase in temperature also increases the ionic conduction, leading to an increase in dielectric loss. Thus, both dielectric constant (ε′) and dielectric loss (ε″) increases as the temperature increases. At lower frequency and higher moisture content ionic conduction as well as molecular mobility is more prominent in affecting the dielectric parameters with increase in temperature. Therefore, under these conditions rate of increase of dielectric constant (ε′) and dielectric loss (ε″) temperature are high and might be non-linear. The dielectric constant is less affected by the temperature than the dielectric loss because an increase in

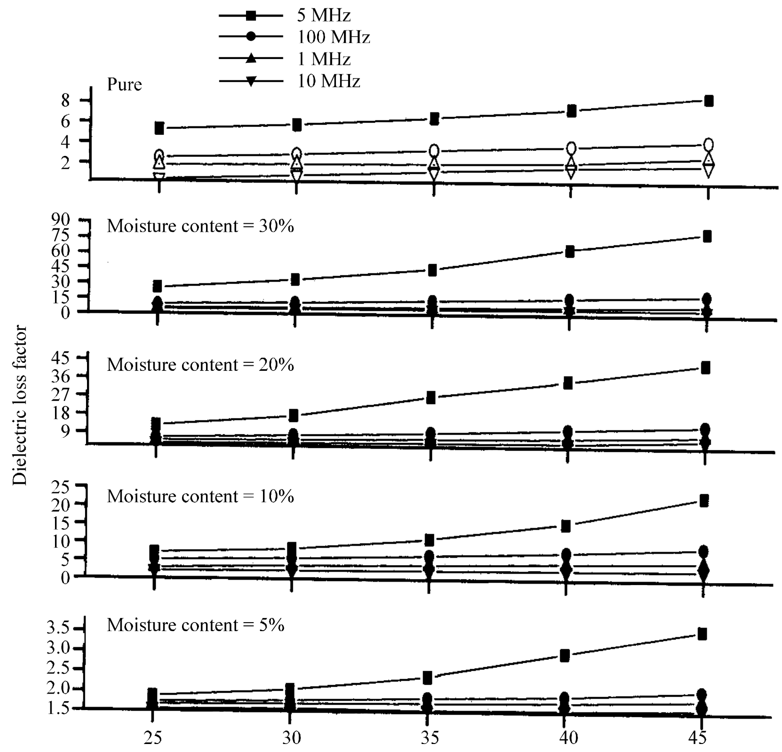

Fig. 5: Temperature dependence of dielectric loss of oil seed (Black) at different concentration of percent moisture content and indicate frequencies

ionic conduction gives additional effect on dielectric loss, whereas dielectric constant is much less affected by the ionic conduction.

Behavior of Electrical Conductivity

The experimental data for electrical conductivity over the frequency range of 5 to 10 MHz in the temperature range of 25-45°C for oil seeds have been taken. It may be seen in Fig. 6 that the electrical conductivity for all the oil seeds under investigation increases with increase in the moisture content and frequency, for the same reasons as given in the discussion of the dielectric parameters. This type of similarity is well expected as the conductivity has been evaluated using dielectric data.

Dependence on Micro Fertilizer

The experimental results for micro- fertilizers over the frequency range of 5 to 10 MHz and temperature range of 25 to 45°C for oil seeds are shown in results. The values of dielectric constant and dielectric loss at different frequencies and at increasing concentration of micro fertilizers with temperature for oil seeds are examined by plotting dielectric constant and dielectric loss with $\log_e$ of frequency at indicated micro fertilizer concentration and at temperature, 25°C in Fig. 7. It has been observed that dielectric constant and dielectric loss increases linearly with increase in frequency and

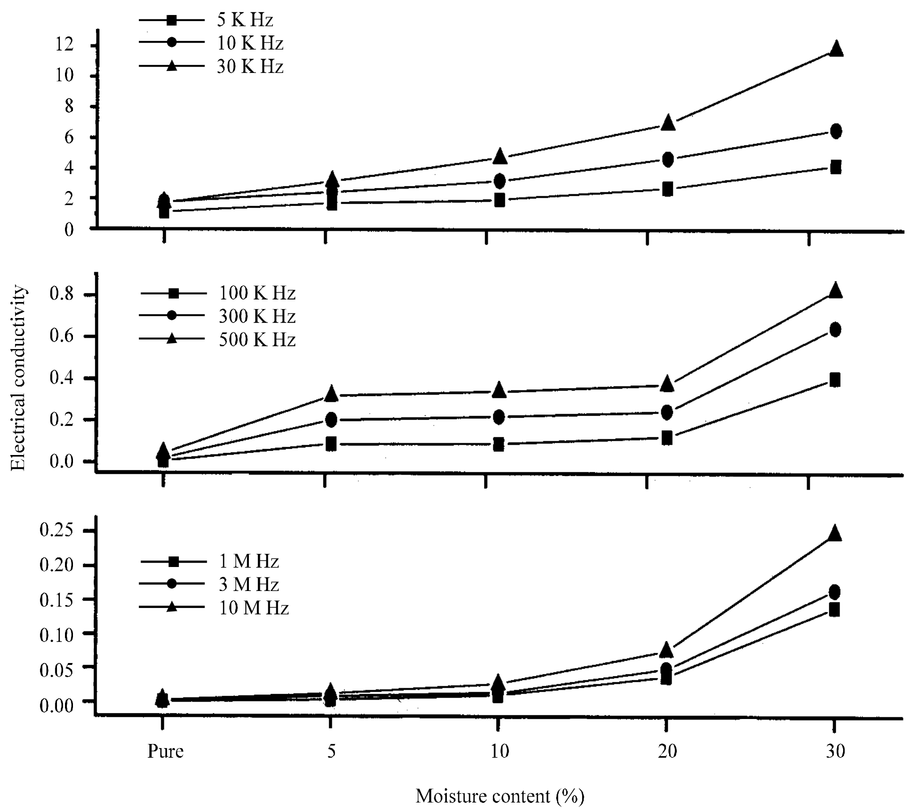

Fig. 6: Percent moisture dependence of electrical conductivity of oil seed (Black) at indicated frequencies and temperature 25°C

temperature (Sipahioglu *et al*., 2003) as expected. If we compare the dielectric constant and dielectric loss of micro fertilizer treated seeds with untreated seeds i.e. (Fig. 7 and 1), it can be observed that the nature of curve remains same but the values of dielectric constant and loss are quite higher in the case of micro fertilizer treated seeds.

The comparative value of anddielectric constant and dielectric loss are also depicted in the form of bar diagram (Fig. 8 and 9). The dielectric constant of seed increases by a large amount with the addition of micro fertilizer. For lower concentration of micro fertilizer the dielectric constant shows a gradual increase while after a certain level that is 0.75 ppm this increase in small and we can say that the saturation level is achieved.

If the concentration of micro fertilizer is further increased then the values decreases indicating deviation from linear behaviour. This is due to fact that after reaching a certain concentration the absorption of micro fertilizer into seeds saturates and the dielectric behaviour of micro fertilizer have predominant over the dielectric behaviour of seed treated with micro fertilizer. The dielectric properties of seeds treated with micro have not been studied previously. Thus any type of conclusive explanation in this regard will be premature at this stage and we are studying a number of seeds treated with micro fertilizer for developing a complete explanation and theory.

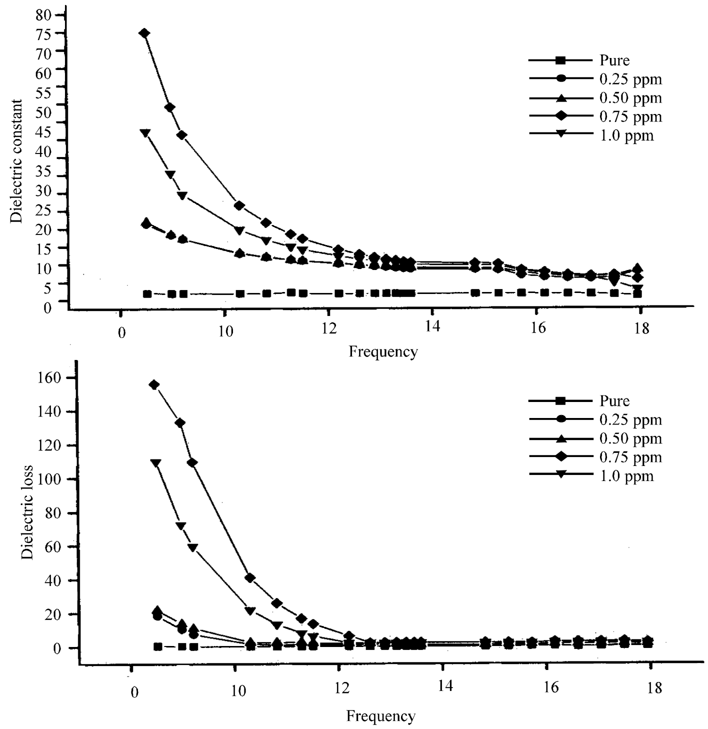

Fig. 7: Frequency dependence of dielectric properties of oil seed (Black) at indicated different concentration of micro-fertilizer and 25°C

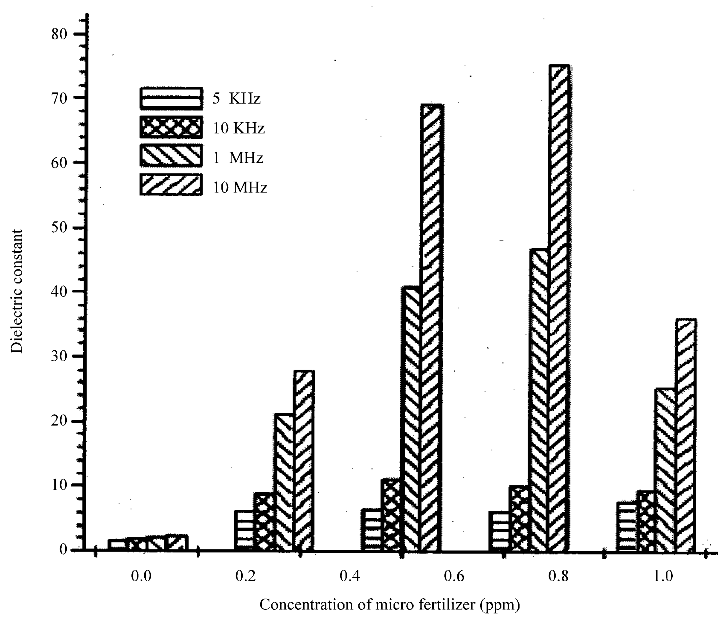

Fig. 8: Variation of dielectric constant with concentration of micro fertilizer at at indicated frequency and temperature 35°C

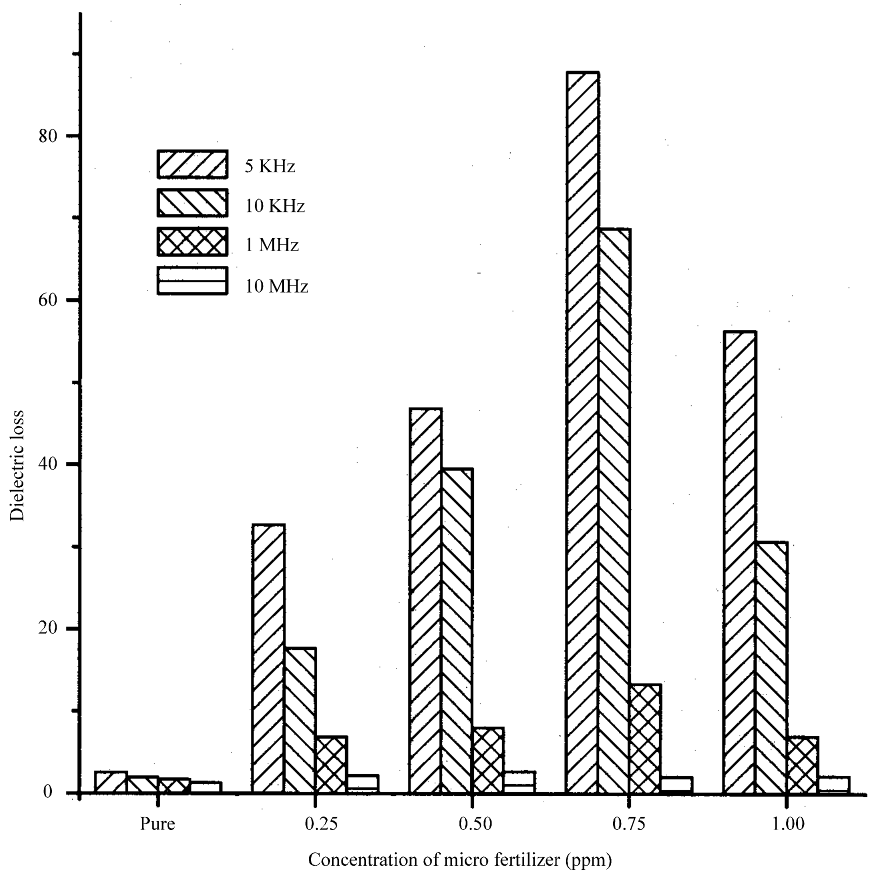

Fig. 9: Variation of dielectric loss with concentration of micro fertilizer at indicated frequency and temperature 35°C

Conclusions

- It can be concluded that the dielectric constant, dielectric loss and electrical conductivity increases with increase in moisture content for both the verities. These parameter decreases with increase in frequency.
- All the electrical parameter shows increasing trend with the increasing concentration of micro fertilizer.
- For the dead seed electrical parameter remains almost constant for both the verities and have lowest value indicating that moisture content and micro nutrients and electrical properties up to a large extent and can be used for the germination time determination

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