ORIGINAL PAPER

ELECTRICAL PROPERTIES OF ARGEMONE SEEDS AT VARIABLE MOISTURE CONTENTS

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Abstract. *Dielectric constant and dielectric loss of argemone seeds have been measured over the range of temperature 30ºC-45ºC with varying frequency from 5 kHz to 10MHz. The effects of change in moisture level on dielectric properties have also been studied. Both, the dielectric constant and dielectric loss were found to increase with increase in moisture level while the same show a decreasing trend with increase in frequency. In order to investigate the effect of moisture content on the dielectric properties of argemone seeds, the measurements have been taken at five different moisture levels.*

Keywords: *Dielectric constant, dielectric loss, moisture, argemone.*

1. INTRODUCTION

The preservation and quality control of food materials including seeds and grains is an important concern for the people long back. The quality of these items can be maintained by controlled heating, by the application of radio or microwave frequencies. The main concern of applying these frequencies is to destroy the insects and other living organism or pathogens present without affecting the quality of host material. That is why the dielectric studies of agricultural and edible products have been of interest for many years. The use of dielectric properties of agricultural products for sensing moisture in grains and seeds and their application in radio-frequency and microwave dielectric heating has been discussed by many researchers [1-5]. The dielectric properties of these products have many applications as new technologies are adopting them for use in their respective industries and research laboratories [6]. Dielectric constant, dielectric loss and conductivity of some oil seeds and poppy seeds have been measured over the range of temperature 15°-45°C within the frequency range 5 kHz to 10 MHz by Singh *et al.* and Kumar *et al.* [7-8]. Govindarajan *et al.* reported the dielectric properties of bulk wheat samples using reflection and transmission techniques [9]. The dielectric properties of different seeds like opium poppy seeds, flaxseeds, safflower seed and corn seed have been reported by Kamil Sacilik *et al.*[10-13]. The effect of moisture on microwave dielectric properties of wheat and the free-space measurement of dielectric properties of moist granular materials at microwave frequencies have been reported by

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Trabelsi *et al.* [14-15]. Dielectric study of common bean, three dielectric models for estimating common bean moisture content and moisture determination in coffee seeds by the capacitance method at radio frequencies have been reported by P. A. Berbert *et al.* [16-18].

Although a lot of work has already been done in the field of physical properties of seeds but the dielectric study for the seeds have not been reported much and in view of above mentioned applications, study of dielectric properties of seeds (argemone) have become more important. As very few information is available on dielectric properties of seeds cultivated in India, it was considered interesting to study electrical properties of seeds produced in India.

2. MATERIALS AND METHODS

The word argemone is derived from the Greek word 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. Oil seeds namely argemone have been obtained from fields near district Basti, U.P., India.

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 dielectric constant was found to be less than 1% and for dielectric loss *was* 1.5%. The dielectric parameters and conductivity have been calculated with the help of the following relations:-

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

$$\tan\delta = \frac{C_M D_M - C_0 D_0}{C_M - C_0} \quad (2)$$

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} \quad (3)$$

$$\varepsilon'' = \varepsilon''_d + \frac{\sigma_i}{\omega \times \varepsilon_0} = \varepsilon''_d + \frac{\sigma_i}{2\times\pi\times f\times\varepsilon_0} \quad (4)$$

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[$C_G = q/v = 2\pi\varepsilon_0 h/\log_e(b/a)$]where a and b are the internal and external radii, respectively, ε_0 is the permittivity of free space, while ω is 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 in the Physics department, Lucknow University, Lucknow, India.

The present paper reports dielectric 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 dielectric properties of argemone seeds the measurements have been taken at five different moisture levels. Moisture contents in argemone seeds were determined on wet basis. The moisture contents were maintained 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 samples 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 hours before the measurements were conducted. The moisture contents of the samples have been determined by approved oven method [19] and samples have been prepared for the dielectric measurement.

The experimentally determined values of dielectric constant, dielectric loss of argemone seed, over the frequency range of 5 kHz to 10 MHz at different discrete frequencies of 5, 10, 30, 50, 130, 330 kHz, 2, 4 and 10 MHz and for moisture levels 0%, 2%,4%,6%,8% between the temperature range 30 to 45ºC has been analysed in the present study.

3. RESULTS AND DISCUSSION

The present study reports electrical properties of oil seeds with different levels of moisture content. It has also been investigated whether the dielectric properties can be used as a strong indicator of percentage of moisture content, as it is very important for seed germination as well as preservation.

It has been observed from the Fig. 1 and Fig. 2 that both the dielectric constant and dielectric loss decrease with increase in the frequencies. This exhibits dielectric dispersion in the material at different frequencies. The high values of dielectric constant at lower frequencies (5, 10, 30, and 50 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 has already been reported by Singh *et al.* [7].

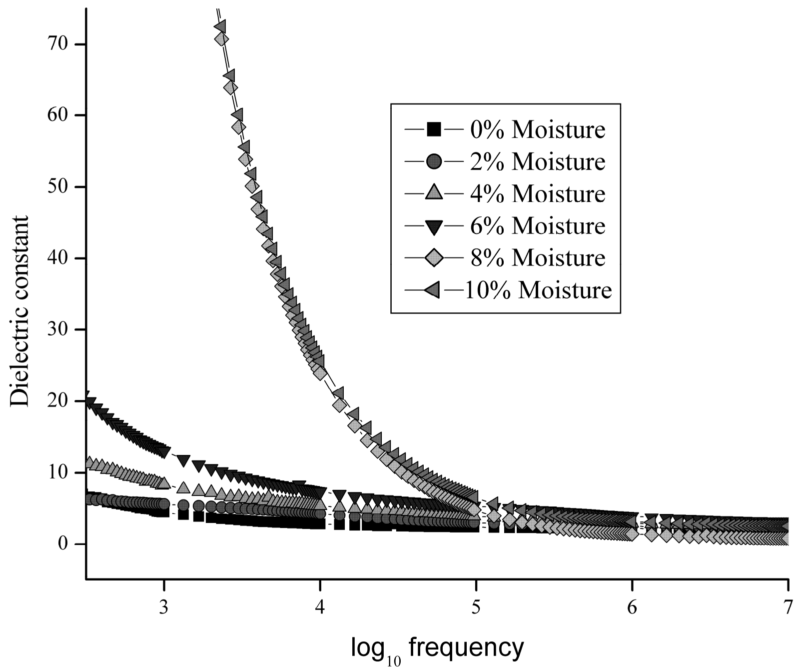

Fig. 1. Variation of dielectric constant of argemone seeds with $\log_{10}$ frequency.

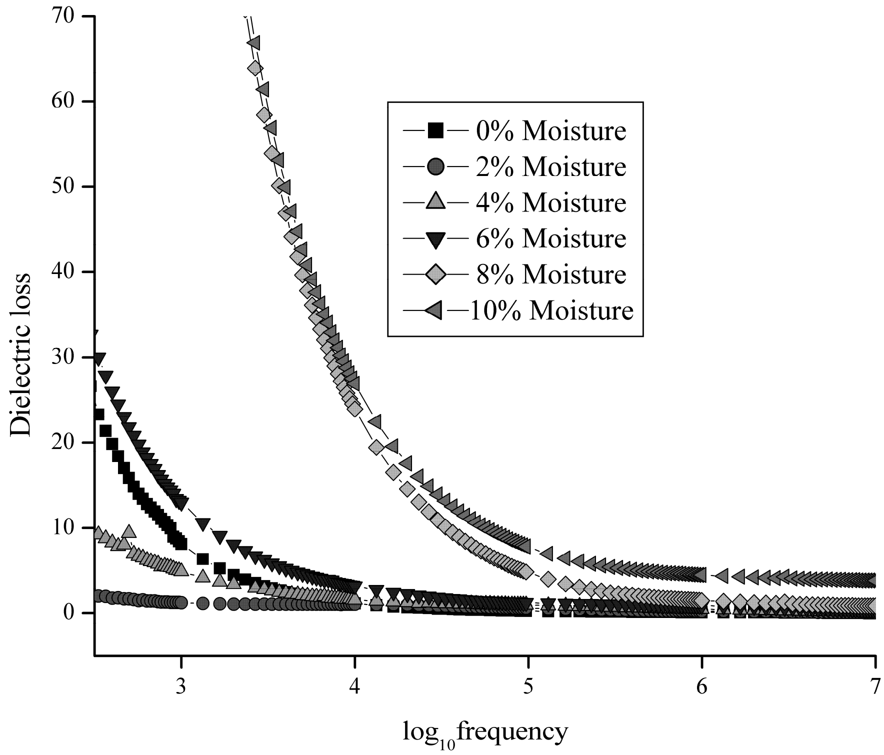

Fig. 2. Variation of dielectric loss of argemone seeds with $\log_{10}$ frequency.

As we go towards the lower frequency side the ionic loss ($\sigma_i / 2\pi f\varepsilon_0$) is inversely proportional to frequency and it becomes almost absent at the 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 show that the changes in the loss factor are less regular than the change in dielectric constant. The similar behaviors have been reported by P. A. Berbert *et al.* and Kamil Sacilik *et al.* [10-13, 16-17]. The complex dielectric relaxation and dispersion phenomena may be one of the causes in the irregularity in loss factor.

It is clear from the Fig. 3 and Fig. 4 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 $\varepsilon''$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 $\varepsilon'$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.

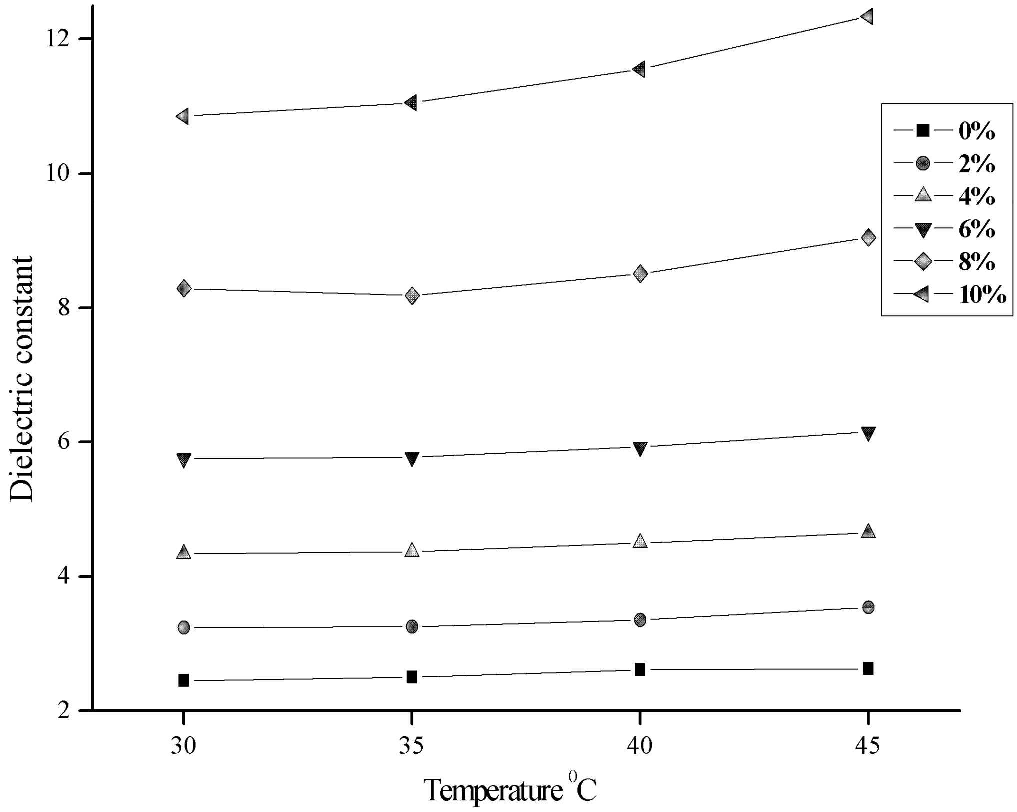

Fig. 3. Variation of dielectric constant of argemone seeds with moisture.

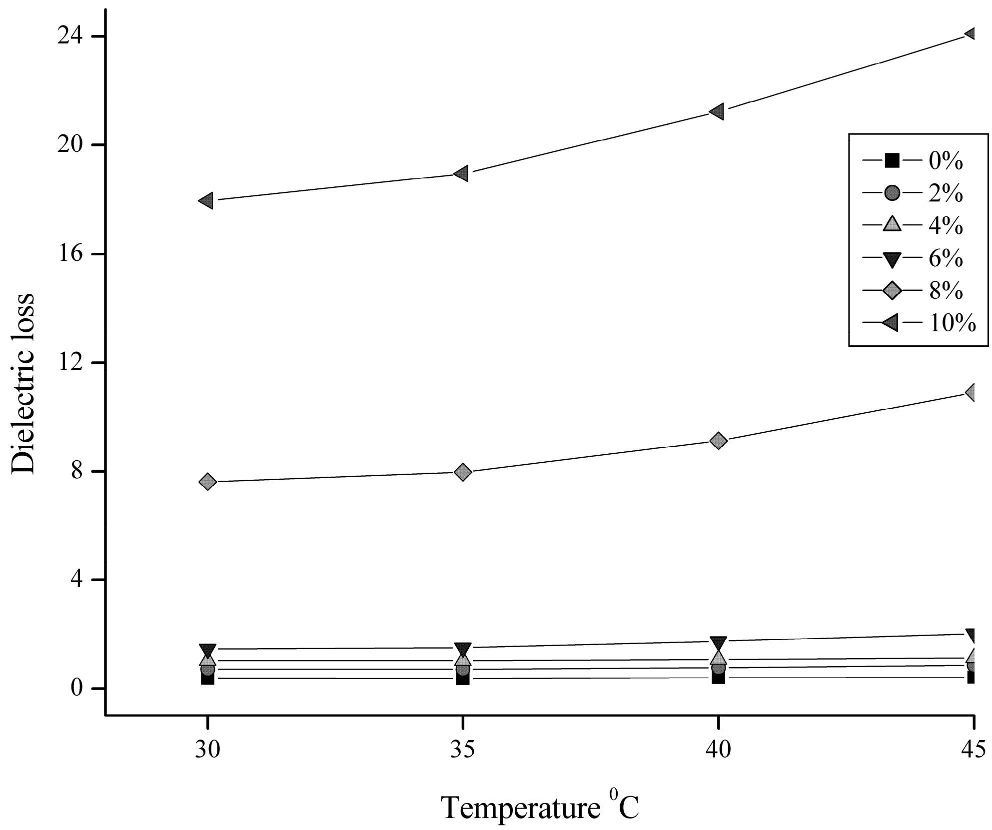

Fig. 4. Variation of dielectric loss of argemone seeds with moisture.

When the moisture content increases beyond 6%, 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. This type of behavior could be attributed to transition of bound water state second (multilayer) to third state due to osmotic tension [20] 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. In a recent study for corn seed Sacilik Kamil *et al.* has shown that for high frequency region the variation of dielectric constant as well as in dielectric loss is non linear while for lower frequency region it is almost linear [13].

Dielectric properties are also dependent on temperature in relation to dielectric relaxation at the higher frequency. The relaxation time decreases as temperature increases as it is associated with time required for the dipoles to revert to random orientation when the electric field is removed. Dielectric constant will decrease with increasing temperature as a result of the dielectric relaxation. Temperature has shown in many studies to have an effect on the dielectric properties. For the dielectric loss factor, initial decrease with temperature is followed by an increase because of the temperature dependence on the dipole and ionic loss components.

The fig-5 and 6 show temperature dependence of dielectric constant and dielectric loss in the range of 30-45ºC. At 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 8% and 10% moisture content (and low frequency, particularly at 50 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 [11-13, 16].

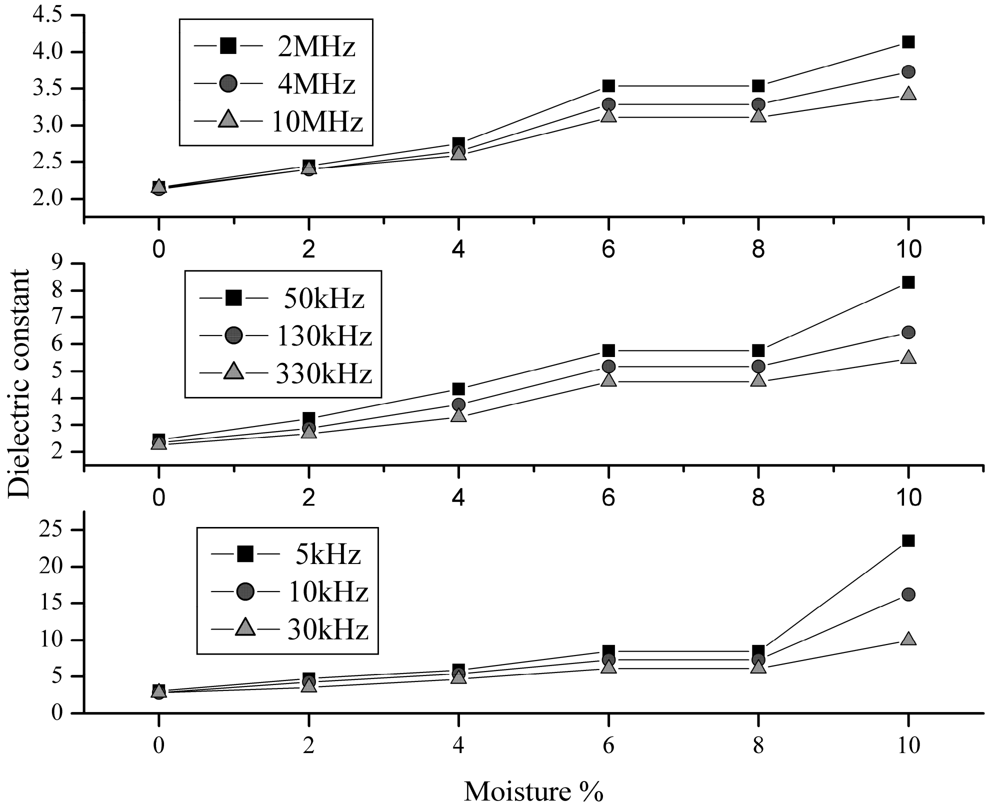

Fig. 5. Variation of dielectric constant of argemone seeds with temperature (^{0}C) at 50kHz.

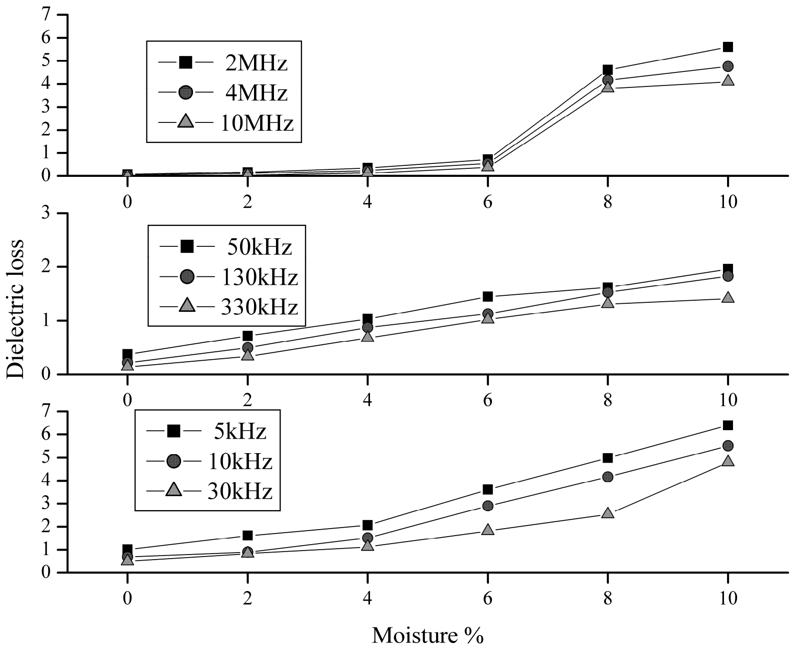

Fig. 6. Variation of dielectric loss of argemone seeds with temperature (^{0}C) at 50kHz.

As temperature increases the behavior of molecules to rotate with electric field changes the permittivity [20] and hence change in effective complex permittivity results in increases or the decreases of the water molecules contribution to the polarization of the medium.

Increase in the temperature also increases the molecular mobility which ultimately increases relaxation frequency, as it is strongly related to the molecular mobility [21].Therefore, the peaks of both, the dielectric constant and dielectric loss shifts to the higher frequency. Increase in the temperature also increases the ionic conduction, leading to increase in the dielectric loss. Thus, as temperature increases both dielectric constant and dielectric loss increase. 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 dielectric constant and dielectric loss 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.

4. CONCLUSIONS

The results of this paper indicate that dielectric properties can be used as indicator of the seed quality and its moisture level. 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.

The changes in the dielectric constant, dielectric loss with variation in the moisture content for the sample are similar to those reported by other workers for different samples.

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