Chapter VI

Dielectric Study of Argemone (Argemone Mexicana) Seeds

6.1 Introduction

The dielectric studies of agricultural and edible products have been of interest for many years (1). These properties are used to describe the behavior of materials when subjected to high frequency electric fields, dielectric heating applications and as indicators of their use for rapid methods of moisture content determination (2). The dielectric properties of these products are finding increasing applications as new technologies are adopting them for use in their respective industries and research laboratories (3, 4). The dielectric study of agricultural materials is also important in the designing of electrical and electronic equipments and is a suitable technique for measuring these properties for various applications (5). The moisture dependent electrical properties of mechanically and nutritionally important poppy seeds have been reported by Kumar et al. (6). Dielectric constant, dielectric loss and conductivity of some oil 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. (7). 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 is discussed by Nelson (1). The dielectric properties of apples were measured at different frequencies with varying maturity by Thompson et al., (8). The dielectric constant and loss of meats and vegetables at varying temperatures has been reported by Mudgett et al., (9). The frequency and moisture dependence of the dielectric properties of hard red winter wheat has been reported by Nelson et al., (10). The Prediction of banana quality during ripening stage using capacitance sensing system has been reported by Soltani et al., (11).

The dielectric properties of seeds are important for many applications such as, control from insects through radio frequency, dielectric heating (12) and sorting and cleaning of seed mixtures by dielectric methods (13). Dielectric parameters are also useful in improving germination of seeds (14). Govindarajan reported the dielectric properties of bulk wheat samples using reflection and transmission techniques (15), and a study of...
The water relation in neem (Azadirachta indica) seed characterized by complex storage behavior has been reported by Scande et al., (16).

Dielectric data has also been utilized for measuring the oil content in Soya bean and Sunflower by Brandenburg et al., (17) and study of metabolic mechanism by Hunt et al., (18). Funebo et al. showed that dielectric properties of fruits and vegetables also depends upon the temperature, and moisture content as well as on frequency of the applied field (19). The electrical properties of many agricultural materials are influenced by ionic conductivity, water relaxation effects and presence of micro-fertilizers by Wendel (20). The electrical parameters for many agricultural materials are influenced by ionic conductivity (21) and water retention of cell (22), but with the development of practical application of microwave energy, need of data on dielectric properties of seeds have gained much importance. The dielectric properties of opium poppy seeds has been reported by Sacilik et al. (23). The effect of nonequilibrated moisture on microwave dielectric properties of wheat and the free-space measurement of dielectric properties of moist granular materials at microwave frequencies was reported by Trabelsi et al., (24, 25). Moisture content and bulk density dependence of dielectric properties of safflower seed in the radio frequency range have been reported by Sacilik et al., (26), and determination of dielectric properties of corn seeds from 1 to 100 MHz have also been reported recently by Sacilik et al., (27). Dielectric study of wheat in powder form at microwave frequencies has been reported by Sharma et al., (28), moisture determination in coffee seeds by the capacitance method at radio frequencies has been reported by Berbert et al., (29), dielectric properties of soybean has been reported by Kanjana et al., (30), dielectric properties of common bean has been reported by Berbert et al., (31), some physical and mechanical properties of fennel seeds, sunflower seed, beniseed, lentil seed, simarouba fruit and kernel, chickpea seeds, cotton seed, watermelon seed, wild pistachio nut and kernel, tiger nut have been reported by many researchers in last decade (32, 33, 34, 35, 36, 37, 38, 39, 40). Dielectric properties have also been used for evaluation of shell eggs quality during storage (41), effect of moisture content on physical properties of wheat has been reported by Karimi et al., (42), three dielectric models for estimating common bean moisture content has been reported by Berbert et al., (43), Pozeliene showed that the treatment of rape (brassica napus l.) seeds with the
help of electrical field speeds up seed germination by 2-3 days and increases germination reliability (44).

Argemone seeds contain 22–36% of a non-edible oil, called katkar oil, which contains the toxic alkaloids sanguinarine and dihydrosanguinarine (45). The Seri of Sonora, Mexico use the whole plant both fresh and dried. An infusion is made to relieve kidney pain, it help to expel a torn placenta, and in general to help cleanse the body after parturition (46).

Although a lot of work has already been done in the field of physical properties of seeds but the dielectric study for the argemone seeds has not been reported 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 oil seeds cultivated in India, it was considered interesting to study electrical properties of oil seeds produced in India. The present paper reports dielectric properties of argemone seeds in the temperature range of 30-45°C 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.

6.2 Materials and Methods

6.2.1 Argemone seed

Classification of argemone seeds

<table>
<thead>
<tr>
<th></th>
<th>English Name</th>
<th>Mexican prickly poppy</th>
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<tr>
<td>2</td>
<td>Hindi Name</td>
<td>Satyanashi</td>
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<tr>
<td>3</td>
<td>Botanical Name</td>
<td>argemone. mexicana</td>
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<tr>
<td>4</td>
<td>Family</td>
<td>Papaveraceae</td>
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The word argemone is derived from the Greek word argema meaning cataract in 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.
6.2.2 Experimental Details
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 plated to reduce dissipation losses. It was calibrated by using standard liquids (Benzene and Methanol) and error in measurement for dielectric constant ($\varepsilon'$) was found to be 1% and for dielectric loss ($\varepsilon''$) was 1.5%. The dielectric parameters and conductivity have been calculated with the help of the mathematical relations already been discussed in chapter II.

6.2.3 Moisture Content
Moisture contents in argemone seeds were determined on 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 24 hours before the measurements were made. The moisture contents of the samples have been determined by approved oven method (47) and have prepared samples for the measurement of dielectric properties. Temperature of the argemone seed have been varied by placing sample holder in 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 ±0.01ºC.

6.3 Results and Discussion
6.3.1 Behaviour of Dielectric Constant and Dielectric Loss Factor
6.3.1.1 Frequency Dependence
It has been observed from the figure-(6.1) and figure-(6.2) that both the dielectric constant and dielectric loss decrease with increase in the frequency. 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 Magario and Yamaura (48).

As we go towards the lower frequency side the ionic loss ($\sigma_i/2\pi\varepsilon\varepsilon_0$) 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 in Corn for the moisture range 5 to 10% and frequency range 1 to 11 GHz have been reported by Nelson (5). In other studies on wheat (49), Corn and Soybean over the frequency range 1 to 200 MHz range and also for corn seed similar types of behaviour have been reported (27). The complex dielectric relaxation and dispersion phenomena may be one of the causes in the irregularity in loss factor.

![Fig.6.1: Frequency dependence of dielectric constant of argemone seeds at indicated moisture content and 30°C.](image-url)
6.3.1.2 Moisture Dependence

It is clear from the figure-(3.3) and figure-(3.4) 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 ($\varepsilon'$) 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 ($\varepsilon''$) 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 6%, bound water changes state from first (monolayer) to second (multilayer) type and add to the complex permittivity, which shows a sharp increase in ($\varepsilon'$) and ($\varepsilon''$) 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 (22) 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 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 (27).
Fig. 6.3: Moisture dependence of dielectric constant of argemone seeds at indicated frequency and constant temperature 30°C.

Fig. 6.4: Moisture dependence of dielectric loss of argemone seeds at indicated frequency and constant temperature 30°C.

6.3.1.3 Temperature Dependence

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. Sipahioglu et al. reported the dielectric constant of fruit and vegetables decreased with increasing temperature because the majority of water within the chemical composition exists as free water (Sipahioglu and Barringer, 2003). 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 figure -6.5 and figure-6.6 show temperature dependence of (ε') and (ε'') in the range of 30-45°C. 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 (50) has been reported the same for fruits while similar behavior for pecan has also been reported (52).

As temperature increases the behavior of molecules to rotate with electric field changes the permittivity (22) 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 (53). Therefore, the peaks of both, the dielectric constant ($\varepsilon'$) and dielectric loss ($\varepsilon''$) 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 ($\varepsilon'$) and dielectric loss ($\varepsilon''$) 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 ($\varepsilon'$) and ($\varepsilon''$) 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.

Fig.6.5: Temperature dependence of dielectric constant of argemone seed at indicated moisture content and constant frequency 50kHz.
Fig. 6.6: Temperature dependence of dielectric loss of argemone seeds at indicated moisture content and constant frequency 50 kHz.

6.3.2 Behavior of Electrical Conductivity

Figure-(6.7) and figure-(6.8) show that the electrical conductivity for argemone seeds increases with increase in frequency and for all the moisture content at 30º C temperatures. Figure-(6.7) 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.
Variation of the electrical conductivity with the temperature of argemone seed at a given moisture content and frequency is shown in the figure-(6.9). From figure-(6.9) 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. 6.7: Frequency dependence of electrical conductivity of argemone seeds at indicated moisture content and constant temperature 30ºC.
Fig. 6.8: Moisture dependence of electrical conductivity of argemone seeds at indicated frequency and constant temperature 30°C.

Fig. 6.9: Temperature dependence of electrical conductivity of argemone seeds at indicated content and constant frequency 50 kHz.

6.4 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 as indicator of the seed quality. It can also be concluded that the dielectric constant, dielectric loss increases with increase in moisture content for the sample. These parameters decrease with increase in frequency.

6.5 References


