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Effect of fungicide treatment on dielectric properties of sorghum seed

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ABSTRACT

Dielectric parameters, the dielectric constant and dielectric loss factor of hygroscopic materials such as seeds and grains vary with moisture content, temperature and the frequency of applied electric field. These variations are used to correlate moisture content of the material and the dielectric relaxation spectra in online moisture meter for the measurement of moisture content of seed lots during harvesting, processing, handling, storage and transportation. This paper presents the effect of fungicide treatment on dielectric parameters of sorghum (*Sorghum bicolour*) seed to detect any considerable change in its dielectric parameter under the applied electric field which necessitates the inclusion of effect in the model for accurate moisture determination. The effect was studied over the frequency range of 10 kHz - 10 MHz using Hewlett-Packard (HP-4194A) impedance/gain phase analyzer. This study showed that the effect of fungicide treatment on dielectric constant and dielectric loss factor was considerably high at low frequencies, but at frequencies higher than 10 MHz, the effects were negligibly small. Therefore, the fungicide treatment effect on dielectric parameters of seeds should be taken in to account if the operating frequency of the moisture meter is less than 10 MHz.

Keywords: Dielectric permittivity, Sorghum seed, Radio frequency, Dispersion

INTRODUCTION

The dielectric properties that describe the interaction of a material with an electric field are the dielectric constant (ε') and dielectric loss factor (ε''), the real and imaginary part of the relative complex permittivity (ε^*), expressed as

$$\varepsilon^* = |\varepsilon^*| e^{-j\delta} = \varepsilon' - j\varepsilon''$$

where, $\delta = \tan^{-1} (\varepsilon''/\varepsilon')$ is the loss angle.

The dielectric constant is a measure of electromagnetic energy stored in the material, while the dielectric loss factor gives the energy dissipation rate in the material (Gracia *et al.*, 2001). The loss tangent is used as dissipative parameter and dielectric properties dictate the behavior of the material when subjected to radio frequency or microwave.

The dielectric properties of biological material such as seed and grains are depending on the moisture content and upon the way the water is held in the seed or grains. The dielectric properties of hygroscopic materials vary greatly with the frequency of applied electric field. This variation over a frequency range is called dielectric dispersion or dielectric relaxation spectrum. The mechanism of such dispersion is referred as dielectric relaxation.

The much of interest in dielectric properties of a material is the frequency region where dispersion occurs and this dispersion has many applications in agro-industries. The values of dielectric parameters along with dielectric relaxation spectrum analysis are used in real-time moisture determination of seed and grains during harvesting, processing, handling and transportation (Hansen, 1992; Tang *et al.*, 2000, Nelson and Payne, 1982, Ikediala *et al.*, 1999; Wang *et al.*, 2002; Nelson *et al.*, 2002). The dielectric data for such potential applications can only be obtained by careful and direct measurement of dielectric parameters of seed and grains (Nelson and Wolf, 1964; Stetson and Nelson, 1972).

Further, the seed treatment refers to the application of fungicide, insecticide, or a combination of both, on seeds so as to disinfect and disinfest it from the seed borne or soil borne pathogenic organisms and storage insects. Therefore, for quality control during storage and marketing the agro-industries treat the seed and grain lots with an appropriate antifungal and insect repellents chemicals.

As dielectric properties of a material is well correlated with moisture content, temperature and bulk density and are used as indicators for different physical parameters by modeling. This modeling is generally done on the basis of large experimental data sets of dielectric properties of that material, and moisture meter predicts the parameter's value accordingly. But, the treatments of seeds with fungicides could alter the dielectric parameter values of seed and would be causing errors in determination of dielectric properties and real time physical properties. Therefore, necessary variation in parameter's value should be incorporated in the model to minimize the measurement error. Hence, to assess the effect of fungicide treatment on dielectric parameters at different frequencies and temperatures, four fungicides were selected and slurry method was used for treatment. The slurry method is a common and extensively used method.

MATERIALS AND METHODS

The sorghum (*Sorghum bicolor)* seed NSSG-1899 was selected for the study. In order to investigate the effect of fungicide treatment on dielectric properties the selected seed was divided into five parts, out of these five parts one part was left untreated, called reference sample, and other four parts were treated with four fungicides, namely the thiram (75% WS), carbendazim (50 % WP), captan (50% WP) and bagalol (MEMC, 6 % Hg, SD). Initial moisture content of each sample was determined by ASAE standard (1999) by drying triplicate samples, each of 10g, in a forced air-oven at 130 °C for few hours till the weight become constant. To obtain samples of desired moisture level the samples were conditioned either by adding moisture or by drying. For obtaining moisture level higher than the initial level distilled water was added to the samples in glass containers and then sealed to store it at 4 °C for at least 72 hours to equilibrate the moisture content (Agrwal, 1999). These jars were frequently agitated to facilitate uniform moisture distribution. For moisture level lower than the initial level, these samples were dried in open air to reach at lower desired moisture content. Before each measurement, the samples were allowed to equilibrate at room temperature for few hours.

The Hewlett-Packard (HP-4194A) impedance/ gain phase analyzer was used to determine the dielectric properties of samples. This instrument employed microprocessor controlled built-in bridges and resonant circuits. This instrument basically measured the resistance, capacitance, inductance and loss angle. This was also equipped with a test fixture (16047D) and a specially designed coaxial cylindrical sample holder. The sample holder was then filled with seed sample evenly and uniformly by following consistent filling procedure so that the kernels could get natural course of adjustment and normal course of density, leaving minimum air-filled space among them. The sample holder was then placed inside the temperature-controlled chamber with suitable adjustment. The capacitance and dissipation factor measurements were repeated at 30°, 35°, 40° and 45°C temperatures. This was forming one set of measurement for one sample at a given moisture content and density. After completion of measurement over the temperature range of interest, the seed sample was poured out of the sample holder and weighed to determine any change in bulk density of the samples. Sample holder filling and impedance measurements over the whole temperature range were replicated three times for each sample. The moisture determinations of samples were done before and after each series of measurement to detect any changes in moisture content, but found negligible in all cases. The dielectric constant and dielectric loss factor were recorded directly from the screen of the analyser.

RESULTS AND DISCUSSION

The experimentally determined values of dielectric constant, ε', dielectric loss factor, ε'', of reference and treated samples at given moisture content and bulk density, over the temperature range of 30-45 °C and at the frequency range of 10kHz - 10MHz. The outcomes are reported in Table 1.

From Table 1 it was observed that the dielectric constant ε' and dielectric loss factor ε'' both decreases with increase in frequency, however increases with

Table 1. Dielectric constant and dielectric loss factor of fungicide treated and untreated sorghum seed

Attribute	Bulk Density (gm/cc)	Moisture (%)	Dielectric constant (ε′)				Dielectric loss factor (ε″)			
			30 °C	35 °C	40 °C	45 °C	30 °C	35 °C	40 °C	45 °C
10 kHz										
Reference	0.795	9.8	6.238	6.582	6.894	7.976	2.359	2.492	2.89	3.627
Thiram	0.795	9.8	7.179	7.537	8.433	9.976	3.322	3.683	4.502	6.349
Carbendazim	0.795	9.8	6.607	7.299	7.317	8.186	2.41	2.217	2.965	3.959
Captan	0.795	9.8	6.356	7.07	7.802	9.077	2.56	3.055	3.61	4.669
Bagalol	0.795	9.8	8.321	8.81	9.704	11.572	4.06	4.416	5.394	7.131
100 kHz										
Reference	0.795	9.8	4.586	4.682	4.842	5.106	0.91	0.981	1.156	1.458
Thiram	0.795	9.8	5.115	5.222	5.476	5.904	1.11	1.266	1.556	2.136
Carbendazim	0.795	9.8	4.726	4.83	5.051	5.399	0.929	0.998	1.229	1.564
Captan	0.795	9.8	4.798	4.958	5.155	5.517	1.014	1.138	1.421	1.856
Bagalol	0.795	9.8	5.136	5.279	5.541	6.01	1.579	1.722	2.087	2.793
1 MHz										
Reference	0.795	9.8	4.063	4.136	4.201	4.3	0.41	0.416	0.464	0.561
Thiram	0.795	9.8	4.517	4.564	4.663	4.815	0.483	0.498	0.586	0.743
Carbendazim	0.795	9.8	4.079	4.254	4.349	4.469	0.411	0.429	0.505	0.612
Captan	0.795	9.8	4.245	4.294	4.385	4.515	0.452	0.482	0.555	0.69
Bagalol	0.795	9.8	4.307	4.419	4.507	4.651	0.617	0.629	0.719	0.899
10 MHz										
Reference	0.795	9.8	3.835	3.878	3.939	4.029	0.481	0.499	0.503	0.577
Thiram	0.795	9.8	4.126	4.187	4.264	4.366	0.549	0.563	0.576	0.61
Carbendazim	0.795	9.8	3.838	3.928	4.004	4.085	0.484	0.503	0.513	0.598
Captan	0.795	9.8	3.873	3.928	3.997	4.097	0.632	0.65	0.657	0.668
Bagalol	0.795	9.8	3.838	3.99	4.056	4.149	0.648	0.685	0.691	0.727

increase in temperature. To assess the changes in these parameters due to fungicide treatment bar plots were drawn for percentage change in dielectric constant and for dielectric loss factor at 30°C and 45°C at discrete frequencies:10 kHz, 100 kHz, 1 MHz and 10 MHz (Fig. 1 & Fig. 2 for dielectric constant and Fig. 3 & Fig. 4 for dielectric loss factor). The interpretation of Fig.1 & Fig. 2 shows that the fungicide treatment makes substantial change in the dielectric constant, particularly at low frequency. The degree of change was depending on the type of fungicide used. At 30°C, and at 10 kHz, the percentage change in dielectric constant for thiram, carbendazim, captan and bagalol treated samples was 15, 5.9, 1.9, and 33.4%; respectively; however, at 10 MHz the percentage changes were 7.6, 0.0,

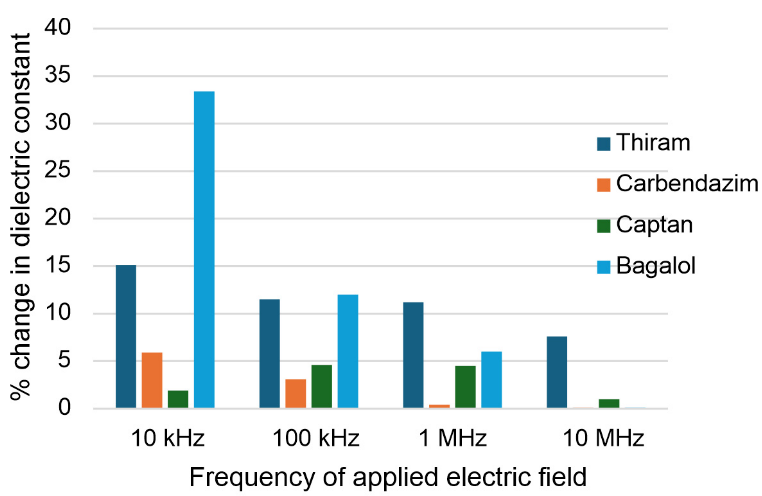

Fig. 1. Percentage change in dielectric constant due to fungicide treatment of sorghum seed at 30 °C

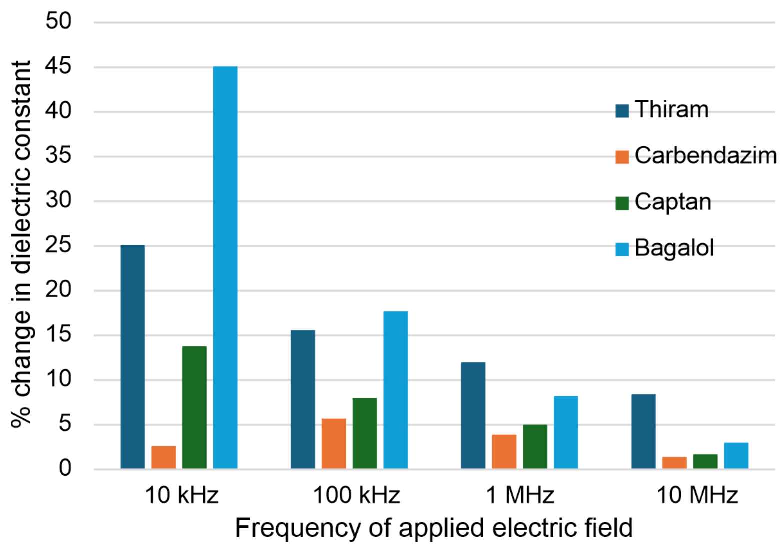

Fig. 2. Percentage change in dielectric constant due to fungicide treatment of sorghum seed at 45 °C

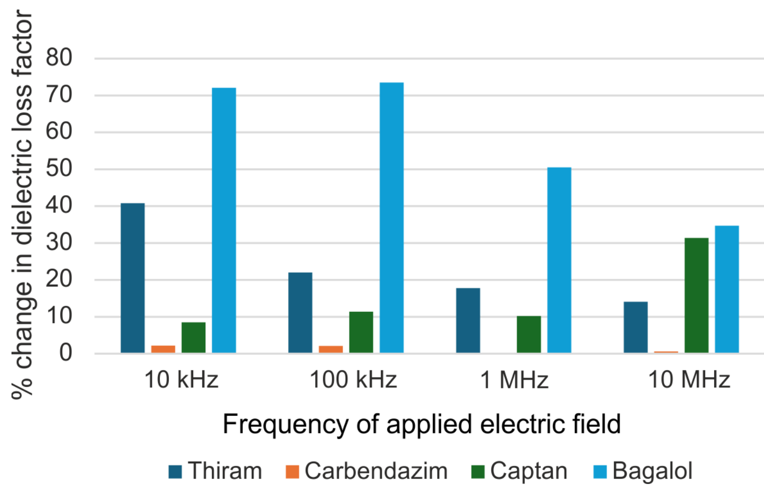

Fig. 3. Percentage change in dielectric loss factor due to fungicide treatment of sorghum seed at 30 °C

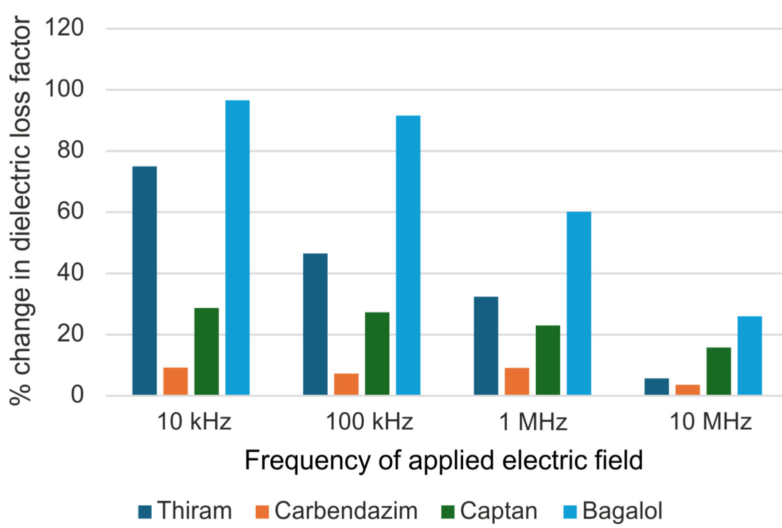

Fig. 4. Percentage change in dielectric loss factor due to fungicide treatment of sorghum seed at 45 °C

1.0, and 0.1%, respectively. At 45^{0}C and at 10 kHz, the corresponding variations were 25.1, 2.6, 13.8, and 45.1%; but at 10 MHz the changes were 8.4, 1.4, 1.7, and 3.0%, respectively. These changes shown that, in general, the fungicide treatment were affecting the dielectric constant considerably at low frequencies and low temperatures, but tended to be small at higher frequencies.

Similarly, from Fig. 3, at 30^{0}C and at 10 kHz, the percentage changes in dielectric loss factor were 40.8, 2.2, 8.5, and 72.1%; but at 10 MHz the changes were 14.1, 1.1, 31.4, and 34.7%, respectively with thiram, carbendazim, captan and bagalol. At 45°C and at 10 kHz, changes were 75.0, 9.2, 28.7, and 96.6 %; and at 10 MHz the changes were 5.7, 3.6, 15.8, and 26.0% (Fig. 4). This shows that the effect of fungicide treatment on dielectric loss factor is considerably high at low frequencies but decreased with increase in frequency at all temperatures.

The variation of mean temperature coefficient of dielectric constant and dielectric loss factors over the temperature range 30-45°C and at discrete frequencies: 10 kHz, 100 kHz, 1 MHz and 10 MHz are shown in Fig. 5 and Fig. 6. Interpolation of these figures shows that the mean temperature coefficient of dielectric constant and dielectric loss factor both vary with temperature and fungicide treatments. The changes in mean temperature coefficients of dielectric constant ($\Delta\varepsilon'/\Delta T$) at given moisture content and bulk density, over the frequency range of 10 kHz- 10 MHz and temperature 30 - 45 °C, was ranging from 0.116 - 0.013 for refence sample, 0.186 -0.016 for thiram, 0.105 - 0.016 for carbendazim, 0.181 - 0.015 for captan and 0.217 - 0.021 for bagalol

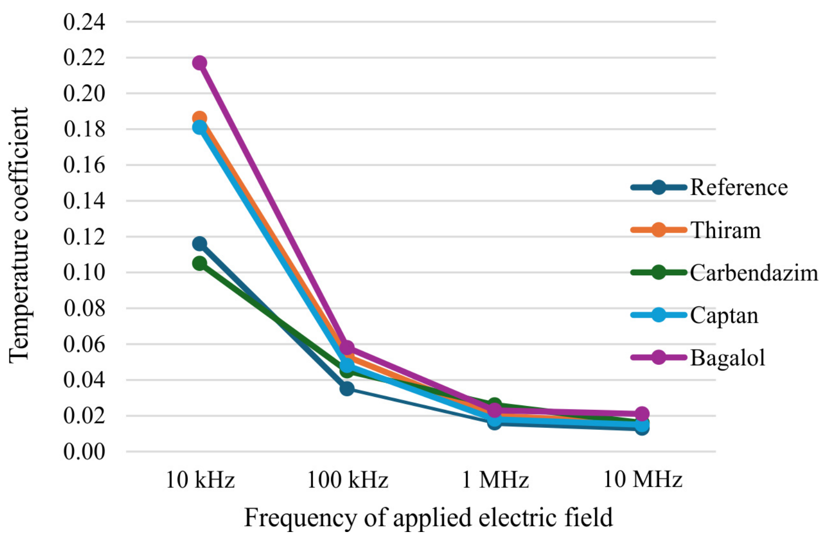

Fig. 5. Variation of mean temperature coefficient in dielectric constant of different samples with frequency

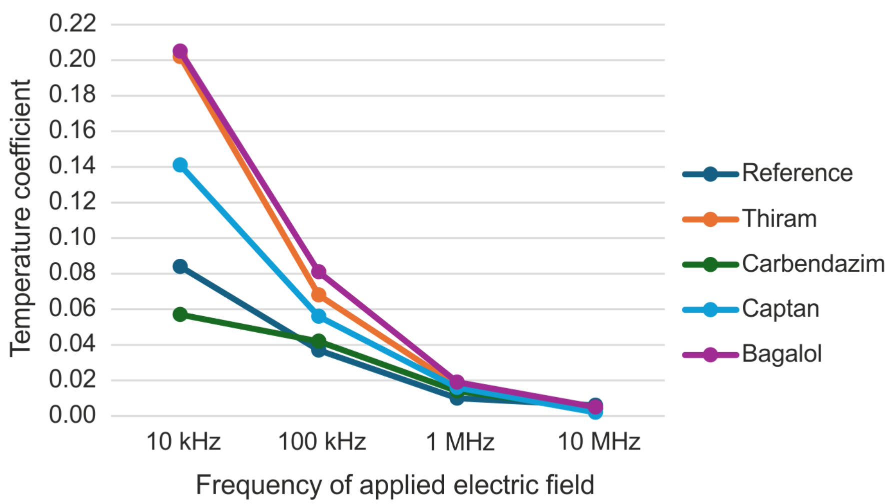

Fig. 6. Variation of mean temperature coefficient in dielectric loss factor of different samples with frequency

treated sample. Similarly, the changes in mean temperature coefficients in dielectric loss factor ($\Delta\varepsilon''/\Delta T$) was ranging from 0.084 - 0.006 for reference sample, 0.202 - 0.004 for thiram, 0.057 - 0.004 for carbendazim, and 0.205 to 0.005 for bagalol treated sample. These variations showed that fungicide treatment not only changes the values of dielectric parameter, but also influences their temperature coefficient.

CONCLUSION

Study shows that that the fungicide treatment considerably affects the dielectric properties of seed and their variation with temperature. Therefore, for accurate online moisture determination of seeds lots, the effect of fungicide treatment on dielectric parameter should be taken into account, especially the cases where moisture meter is operated in the radio frequency and the operating frequency is below 10 MHz.

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