Dielectric Properties of Drugs at Lower Frequency Range from 3 KHz to 5 MHz by using Impedance Analyzer

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ABSTRACT: Study of dielectric properties of medicinal compounds is useful for pharmaceutical industries for design, development, and modification of dosage-form. In view of this, we selected five different medicinal compounds of importance in medicine to study their dielectric properties in terms of dielectric constant, dielectric loss, and tangent loss. We used the LCR-Q meter (impedance analyzer model IM3570) for the determination of dielectric properties. Drugs were procured (A R Grade) in powder form for making Pallets. The findings in terms of the measured values of dielectric constant, dielectric loss, and tangent loss at different frequencies are presented in graphical form and result discussed.

Keywords: LCR-Q meter, Herbal plants, Dielectric properties, Pallets, High-pressure pallets instrument.

INTRODUCTION:

Microwave heating is very common in cooking and pharmaceutical industries. It has lot of advantages over the traditional and electrical heating and is easily controlled. In medical field drugs are prepared in three phases. Primary, secondary and final phase, each phase require controlled heat treatment. Overheating and under heating are dangerous for the drug, drug damages occurs due to overheating. The overheated material can get deteriorated or even burn in extreme cases and material properties and quality deviates from its expected values. Under heating also not good for drug production, in primary or secondary stages during the production of drug solvent and water are added in raw material, moisture and solvent remains cause of heating [1-3]. Dielectric constant gives us the information about how much energy absorbed and dielectric loss factor e” shows how much heat generated per unit time under the electromagnetic field i.e. when subjected to microwave heating [4].

Apart from this there are many researchers who have used dielectric properties to measure moisture content of material and agro-food. The measurement of dielectric properties of liquid materials at microwave frequencies can be used to determine some electrical properties and evaluation of biological effects in biological molecules. The dielectric constant is associated with the capability of a material to accumulate electrical energy in the presence of electric field while the dielectric loss factor is the dissipation of electrical energy in the form of losses [5]. The mechanisms that contribute to the dielectric loss in heterogeneous mixtures include polar, electronic, and atomic Maxwell- Wagner responses [6]. S. O. Nelson et al. [7] presented the systematic data of dielectric properties of the grain. Many researchers also have been reported the dielectric properties of agro-products, such as grain seeds or grain flours [8-12], fruits and vegetables [13- 16]. Many factors including temperature, frequency and moisture content, affects the dielectric properties of agricultural products and food materials [17-23]. The relation between frequency and dielectric properties is useful in determining the optimum frequency range in which the material in question has the desired dielectric characteristics for intended applications [24 – 27].

MATERIALS AND METHODS

Paracetamol plays an important role in drug medication which is used directly or indirectly in many treatments; it is used as painkiller in many cases. It is often used with combination of other ingredient for preparation of drugs for cold, fever and other disease. It is used for relief of many types of pain like cancer, pain after surgery and headache etc. Frequent and high dosage of paracetamol is dangerous for health; it causes a serious heath problem like rashes on skin, liver failure etc.

Aspirin is commonly known as acetylsalicylic acid, its chemical formula is $C_9H_8O_4$. Its solubility in water is 3 mg/mL at 20° C. It is used to treat many diseases like pain, fever, heart attack, colorectal, cancer and inflammation etc. Aspirin is used for long term and short term to prevent from heart attack. Stomach ulcers, stomach bleeding, and worsening asthma diseases occur due to frequent and more dosage of aspirin. Aspirin is generally not recommended to pregnant woman.

Microcrystalline cellulose (MCC) is obtained from refined wood pulp. Microcrystalline cellulose is a polymer; it is composed by glucose units connected by a 1-4 beta glycosidic bond. Solid drugs having crystal and amorphous form, it is difficult to prepare tablet form crystal drug it need some binder. Microcrystalline cellulose is used in many tablet/drug as a binder.

Sodium Starch Glycolate is the sodium salt of a carboxy-methyl ether of starch or of a cross-linked carboxymethyl ether of starch. Sodium starch glycolate is a white to off-white, tasteless, odorless, relatively free flowing powder. Sodium starch glycolate is used as a pharmaceutical grade dissolution excipient for tablets and capsules.

Fig- 1 shows the pallets prepared by different drug powder Standard tablet machine at constant pressure and dimension

Pallets of all the samples were prepared using standard high pressure pallet machine as shown in Fig-1. The dimensions of the pallets were kept constant at 1cm diameter and 2.5 mm thickness for all five samples for uniformity as shown in Fig-1. There are various methods or techniques available for measurement of dielectric properties, such as parallel plate capacitor method, time domain reflectometry method and frequency domain reflectometry. Parallel plate capacitor is very fundamental, basic and authentic technique for dielectric spectroscopy. Dielectric properties are measure by using LCRQ meter that works on the principle of parallel plate capacitor and measures the dielectric properties at different frequencies.

Fig- 2 LCR-Q meter (impedance analyzer model IM3570) with solid sample holder

Dielectric properties of all five drugs were measured over the frequency range from 3 KHz to 5 MHz at room temperature 27 °C by using impedance analyzer model IM3570. Parallel resistance, Series capacitance, series resistance and quality factor of sample were measured at 3 KHz to 5 MHz frequencies; these parameters were used for further analysis for estimation of dielectric properties.

Dielectric properties of samples were measured in terms of dielectric constant, dielectric loss and tangent loss. Dielectric properties were estimated by using given formula

Dielectric Constant = $$\varepsilon' = \frac{C_s d}{\varepsilon_0 A} \quad (1)$$

Where,

C_s is a capacitance measured in series

d is a thickness of the sample

A is Cross-sectional area of sample

ε_0 is a permittivity of free space

Dielectric loss = $$\varepsilon'' = \varepsilon' Tan\delta \quad (2)$$

Tangent loss = $$Tan\delta = \frac{1}{Q} \quad (3)$$

Result and Discussion

Dielectric properties depend on frequency, moisture and temperature. When electromagnetic field is applied to the polar or non polar molecules, induced dipole moment or molecular vibration occurs. It depends on the frequency of electromagnetic waves; the amounts of molecular vibration of samples are varying due to variation of frequencies. For measurement of dielectric properties, various sophisticated equipment are commercially available in market. Impedance analyzer is the most common, useful and reliable equipment, which is used for measurement of electrical properties at electromagnetic frequencies. This technique is very simple and easy in that quick results can be obtained, if the sample is available in the form of standard palette used in LCR-Q based dielectric properties estimation. LCR-Q meter provide the value of C_S, C_P, R_S and Q of sample, it is used for estimation of dielectric properties discussed in experimental techniques. We studied the dielectric constant for five different drug substances at different frequencies from 3 KHz to 5 MHz and the results is presented graphically in Fig- 3.

Dielectric properties of solid drug powder were estimated at frequency range from 3 KHz to 5 MHz by using LCR-Q meter at 27° C. For all the five materials studied the dielectric constant was found to decrease with increase in frequency as is shown in Fig- 3. Dielectric constant of five drug powder at different frequency and graph plotted log f versus dielectric constant is shown in Fig-3.

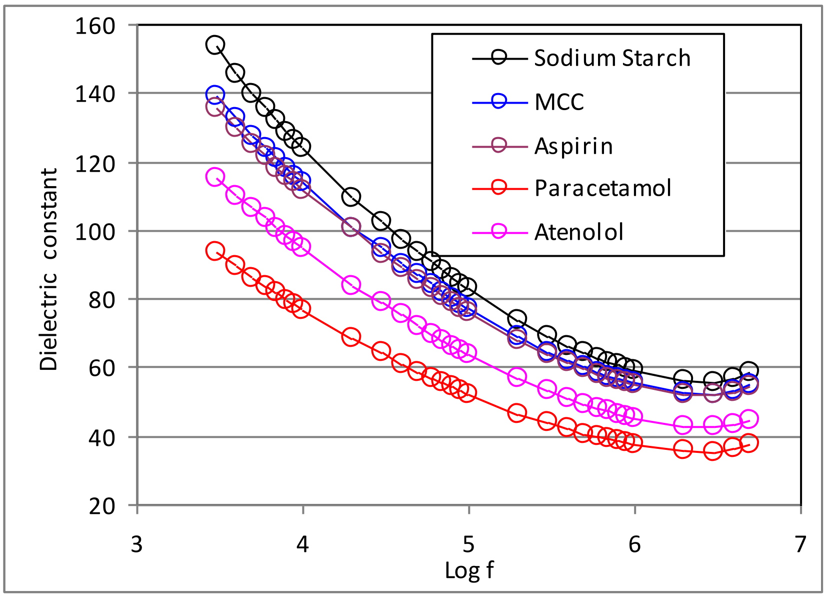

Fig- 3 Dielectric constant at frequency range from 3 KHz to 5MHz at room temperature

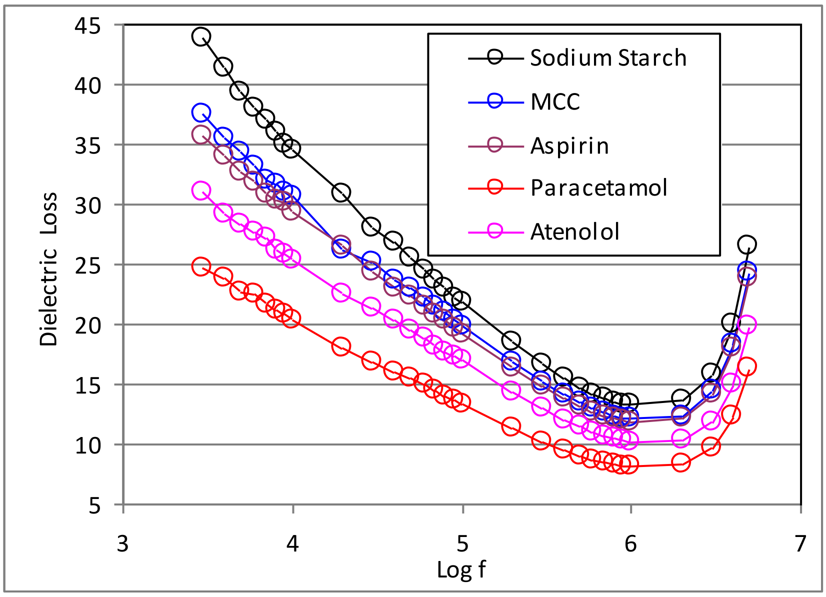

Fig- 4 Dielectric loss at frequency range from 3 KHz to 5MHz at room temperature

Dielectric constant of drugs gradually decreases with increasing frequency at constant temperature as shown in Fig-3. The dielectric constant gradually decreases with increase in frequency from 3 KHz to 0.7 MHz and after 0.7 MHz frequency it deviate its ideality and get lenient with frequency. Sodium starch has highest dielectric constant at all frequencies as compare to rest of four drugs and paracetamol has lowest dielectric constant, but all five drugs show same trend of dielectric constant with frequency.

Fig-4 shows that graphical representation of dielectric loss verses log f of five said medicinal drugs (tabular data is skipped to keep it brief). Dielectric loss was measured at frequency ranges from 3 KHz to 5 MHz at constant temperature (27° C). Dielectric loss of drugs decrease with frequency up to 1 MHz and then starts increasing and the increase becomes faster with increase in frequency. Dielectric loss of drugs had higher value at lower frequency region and lower values at higher frequency up to few MHz frequencies and again increases at higher frequencies. Sodium starch exhibits highest dielectric loss among the drugs studied at all given frequencies as compare to other drugs and paracetamol has lowest value.

Tangent loss of five drugs was estimated at frequency range from 3 KHz to 5 MHz at room temperature as shown in Fig-4. Fig-4 shows that tangent loss decreases slightly up to 100 KHz afterward suddenly rate of decreases of tangent loss with frequency increases up to 1 MHz. Tangent loss of five drugs drastically increases at the higher frequencies from 1 MHz to 5 MHz. Tangent loss of sodium starch is greater than other drugs studied up 30 KHz frequency and it is nearly same for all five drugs at frequencies from 30 KHz to 5 MHz.

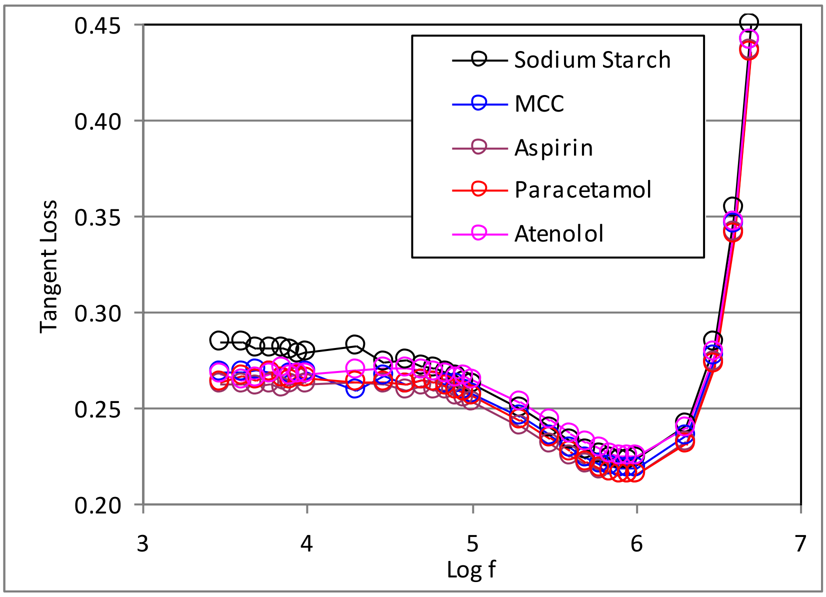

Fig- 5 shows tangent loss of drugs at frequency range from 3 KHz to 5MHz at room temperature

Conclusion

Dielectric properties in terms of dielectric constant, dielectric loss and loss tangent of five drugs are studied and systematic data presented over the frequency range 3 KHz to 5 MHZ at constant temperature of 27 ºC. This dielectric investigation is showing nonlinear variation of the said properties over the frequency range studied. It provides experimental data of dielectric constant of five drugs i.e. Paracetamol, Aspirin, Atenolol, MCC and Sodium Starch. It is observed that the dielectric constant, dielectric loss and tangent loss decrease with an increase in frequency up to about 1 MHz and there after it starts increasing, the rate of increase is very fast for tangent loss and dielectric loss.

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