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MICROWAVE DIELECTRIC CHARACTERIZATION OF TURMERIC

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ABSTRACT

Dielectric properties of turmeric were measured at frequencies 0.2 to 20 GHz and temperature 26°C using the HP-85070B open-ended coaxial line probe coupled with a computer controlled Automated Network Analyzer (ANA). For all samples the dielectric constant decrease with increasing frequency. There is a sudden drop in the dielectric loss factor at 0.2 GHz due to ionic losses. At 1.5 GHz, the loss factor increases gradually to a constant value. The penetration depth is dependent on the evaporated moisture in the low frequency region.

Keywords: dielectric properties; turmeric;

INTRODUCTION

Microwaves have a special property in which it is able to penetrate into non-metallic materials. Two types of mechanisms occurred which are dipole interaction and ionic interaction. These produce volumetric heating which have many advantages such as reducing the time process [1], produce more quality product and allows substantial saving of energy [2]. Thus, microwave was used in dehydration, blanching, thawing, pasteurizing and sterilizing of foods [1].

The relationship between interactions of microwaves with food material can be determined by measuring its dielectric properties. From the dielectric properties, the penetration depth, power absorption and heating performance can be calculated [3]. Complex permittivity can be expressed as, $\varepsilon^* = \varepsilon' - j\varepsilon''$ where ε' is the dielectric constant, which is the ability of a material to store electromagnetic radiation whereas ε'' is the dielectric loss factor, which is the ability of a material to dissipate electrical energy into heat [4].

The dielectric properties of several foods especially at microwave frequencies have been measured in previous works. Other measurement parameters include temperature and moisture content. Reports have been made about the dielectric properties of garlic at 2450 MHz as a function of temperature and moisture content [1], dielectric properties of six different types of starch at 2450 MHz [4], dielectric behavior of apples (Granny Smith) at different moisture contents, effect of vacuum impregnation [3], osmotic dehydration on the dielectric properties of carrots and strawberries [8], dielectric spectroscopy of osmotic solutions and osmotically dehydrated tomato products [6], and others have also been reported.

The objective of this study is to measure the dielectric properties of turmeric in the frequency range between 0.2 to 20 GHz at various evaporated moisture. A non-destructive measurement technique using a combination of the HP-85070B open-ended coaxial line probe with a computer controlled Automated Network Analyzer (ANA) were used. Besides, the same sample can be use for other measurements, it is also a fast measurement technique and sample preparation is not necessary [2].

MATERIALS AND METHOD

Turmeric was bought from the wet market and to maintain its freshness, it was stored in a refrigerator around 4°C. The skin was removed and cut into 7 slices where each slice was about 20 ± 0.001 g with 30 mm thickness. All slices of turmeric were put in the oven at a fixed temperature (70°C). To obtain different moisture content, one sample was taken out from the oven at each hour until the 7^{th} sample (7 hours). All samples were then placed in a desiccator for 10 minutes. This is to cool down the samples to 26°C and to ensure uniform moisture content. The samples are weighed using an electronic balance (± 0.001g).

Using the open-ended coaxial line probe (OECP) coupled with a computer controlled software automated network analyzer (ANA), the dielectric properties of turmeric which was dried from one to seven hours were measured from frequencies 0.2 to 20 GHz. The sensor was calibrated using three different types of loads: (i) open circuit (air), (ii) short-circuit (metallic short block) and (iii) distilled water at room temperature (26°C). After calibration, the measurement of the dielectric properties of turmeric was taken at least three times for each sample to prevent erroneous values.

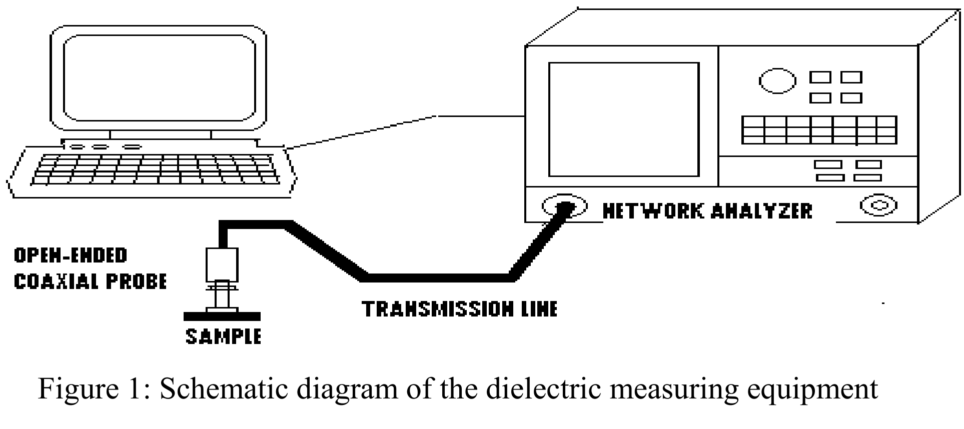

Figure 1: Schematic diagram of the dielectric measuring equipment

To get more accurate values, the flat surface of the open-ended probe which conducts all the measurements must have good contact with the surface of the sample during measurements. This is to ensure that the presence of air between probe and the sample surface can be avoided or minimized.

RESULTS AND DISCUSSION

The evaporated moisture of turmeric as a function of drying hours is shown in Figure 3. The evaporated moisture was found to be linear with the drying hours and it fits the following linear equation below:

$$EM = A\,T + B \quad (1)$$

where *EM* is the evaporated moisture, *T* is the drying hours, *A* (0.0714) is the slope and *B* (0.076) is the value when the drying hours is zero. The value of R^2 is 0.9778 which indicate that the evaporated moisture increases smoothly and consistently.

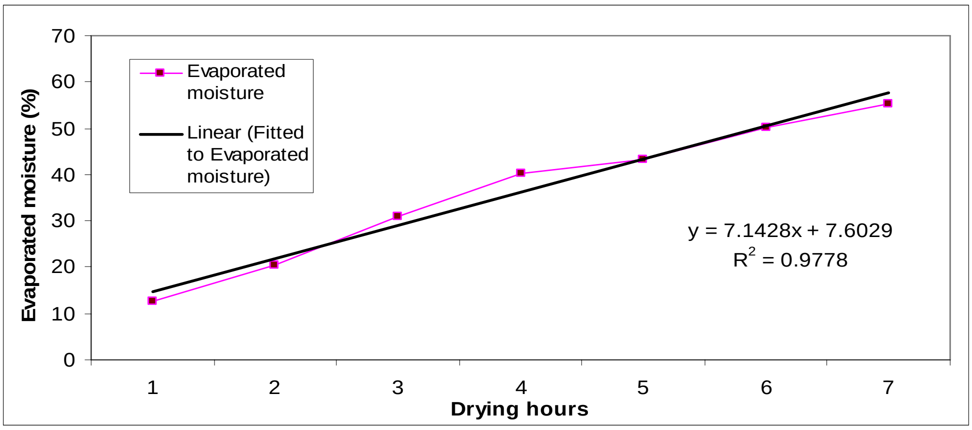

Figure 2: Evaporated moisture of turmeric at various drying hours

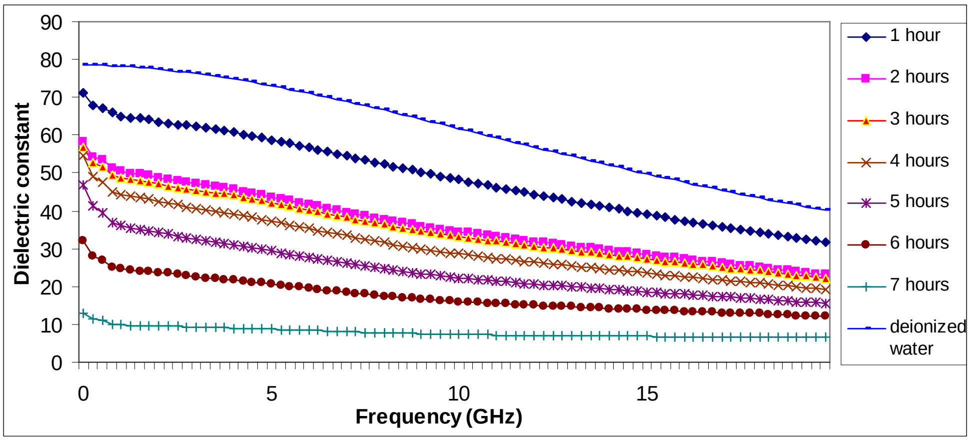

Figure 3: Dielectric constant of turmeric as a function of frequency with respect to the drying hours

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The dielectric constant of turmeric as a function of frequency with respect to the drying hours is shown in Figure 3. The dielectric constant of all the samples is below that of water while the dielectric constant for turmeric which is dried at 7 hours is almost constant. This result has been expected since water is the main contributor to the dielectric constant [7]. The dielectric constant decreases as frequency increases. At high frequencies, the movement of water dipoles called polarization is not able to follow the changing electromagnetic field or in other words polarization mechanisms "die out". This means at infinity, the dielectric constant approaches one [8].

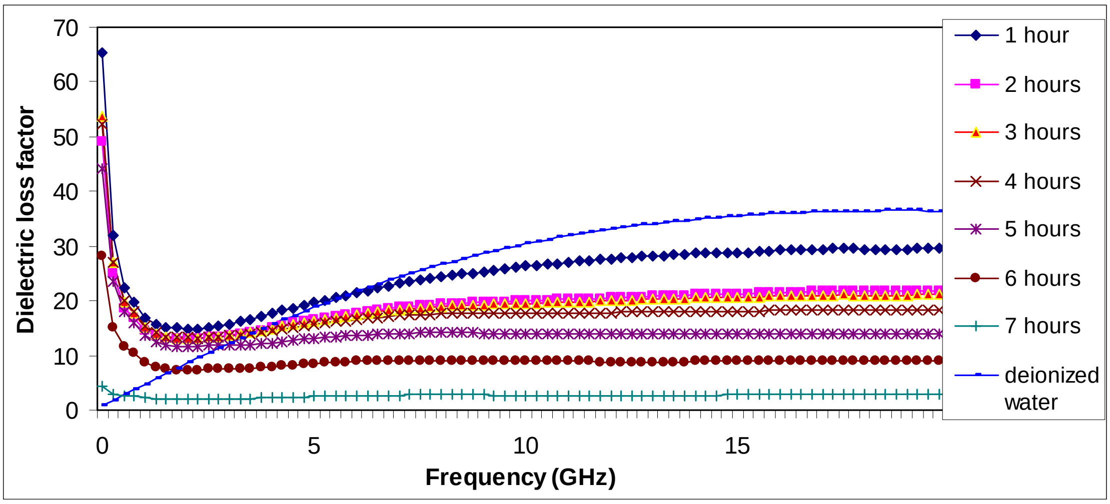

Figure 4: Dielectric loss factor of turmeric as a function of frequency with respect to the drying hours

The loss factor of turmeric as a function of frequency with respect to the drying hours is show in Figure 4. Initially, the dielectric loss factor decreases but it starts to increase at 1.5 GHz and above, following the trend of the deionized water. This implies that dipolar polarization is the predominant mechanism occurring in frequencies above 1.5 GHz. At low frequencies (< 1.5 GHz) it indicates the existence of ionic species in the turmeric. The decrease in the dielectric loss factor is predominantly due to the ionic interaction. The loss factor of turmeric which was dried for 7 hours is constant maybe because there is no water molecule to be polarized.

Table 1: Values of λ_o at 2.45, 10 and 18 GHz

Frequency (GHz)	Wavelength, λ_o (cm)
2.45	12.237
10	3.000
18	1.670

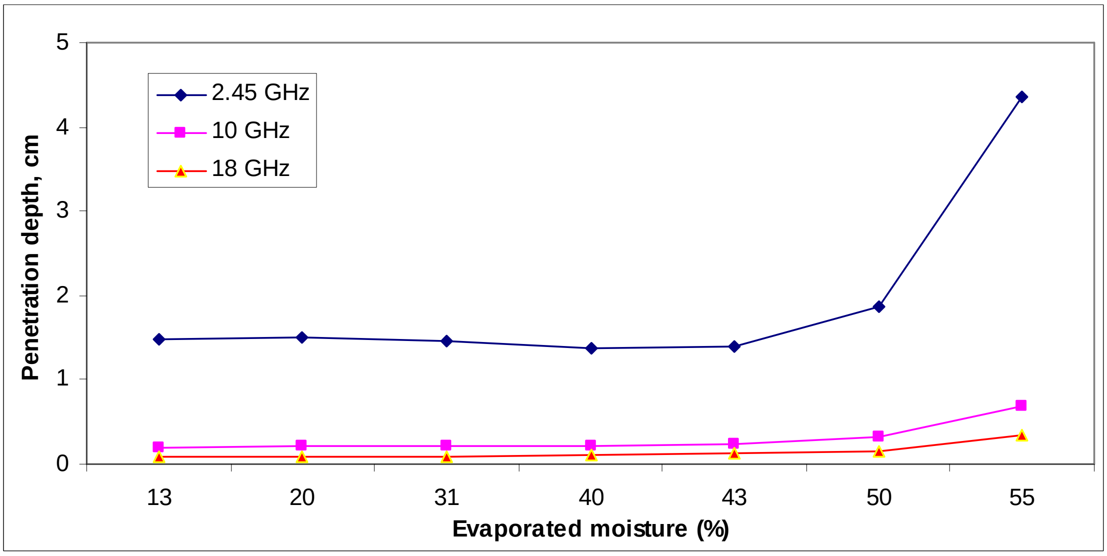

Figure 5: Penetration depth of turmeric as a function of evaporated moisture at 2.45, 10 and 18 GHz

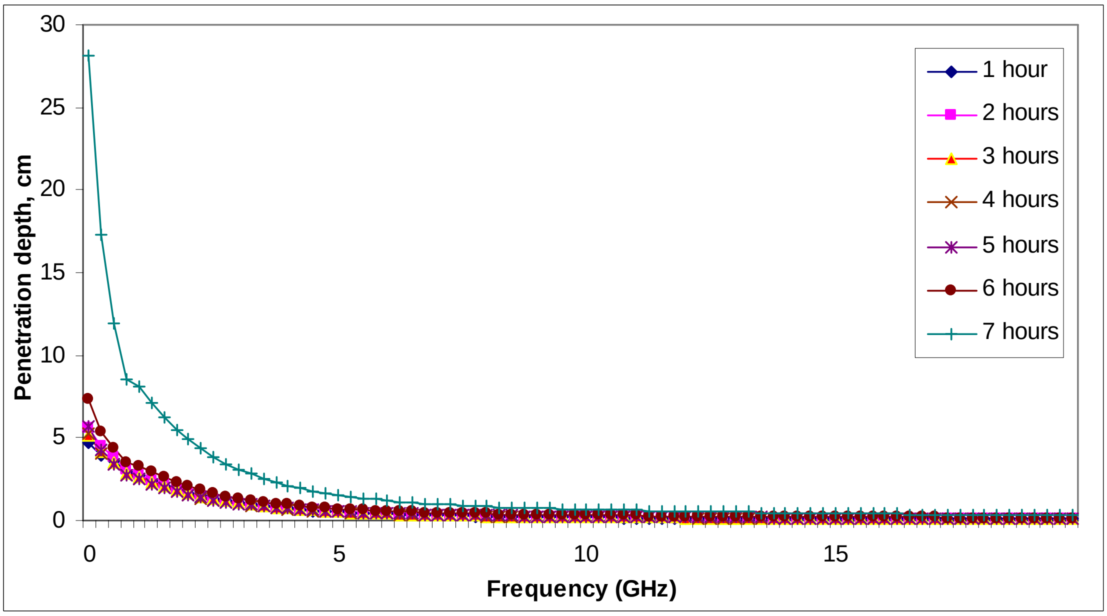

Figure 6: Penetration depth of turmeric as a function of frequency with respect to the drying hours

Penetration Depth

Penetration depth is an important parameter in characterizing microwave heating. It is the distance for a wave to penetrate into the sample material before it reduces to 1/*e* of its intensity [4]. When the penetration depth increases, automatically it increases the uniformity in microwave heating. Penetration depth for the sample was calculated using the following equation [1].

$$D_P = \frac{\lambda_0}{2\pi(\varepsilon')^{0.5}}\left[\left\{1 + (\varepsilon''/\varepsilon')^2\right\}^{0.5} - 1\right]^{-0.5} \qquad (2)$$

where D_P is the penetration depth (cm), λ_0 is the wavelength of the frequency used as shown is Table 1.

The variation of the penetration depth for turmeric as a function of evaporated moisture at 2.45, 10 and 18 GHz and penetration depth as a function of frequency with respect to the drying hours are given in Figs. 5 and 6, respectively. At low frequencies (< 10 GHz), the penetration depth is affected by moisture. However, the penetration depth is independent with moisture at higher frequencies (> 10 GHz).

CONCLUSION

The dielectric properties of turmeric have been successfully tabulated. The dielectric constant decreases with increasing frequency. The dielectric loss factor decreases rapidly at frequency below 1 GHz due to ionic losses while it increases at 1.5 GHz and above because of the dipolar polarization. The dielectric properties follow the trend of the deionized water. The penetration depth depends on moisture content in the low frequency region.

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