

# Study of Dielectric Properties of Adulterated Milk Concentration and Freshness.

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**Abstract.** The knowledge of dielectric properties may hold a potential to develop a new technique for quality evaluation of milk. The dielectric properties of water diluted cow's milk with milk concentration from 70 percent to 100 percent stored during 36hour storage at 22°C and 144 hour at 5°C were measured at room temperature for frequencies ranging from 10 to 4500 MHz and at low , high & at microwave frequencies using X band bench and open-ended coaxial-line probe technology, along with electrical conductivity. The raw milk had the lowest dielectric constant ( $\epsilon'$ ) when the frequency was higher than about 20M.Hz, and had the highest loss ( $\epsilon''$ ) or deceptation factor  $\tan(\delta)$  at each frequency. The penetration depth ( $d_p$ ) increased with decreasing frequency, water content and storage time, which was large enough to detect dielectric properties changes in milk samples and provide large scale RF pasteurization processes. The loss factor can be an indicator in predicting milk concentration and freshness.

**Key Words:** Dielectric Constant, Radiofrequency, Microwave frequency, open-ended coaxial-line probe technique, von - hippel technique.

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## 1. Introduction

1.1 Pure Milk (Unadulterated Milk): A glass (250ml) of unadulterated whole milk will give around 146 k.cals, 8gms of fat and protein with 257mg of calcium. Calcium and other vitamins and minerals in milk make it an important part of a healthful diet for people of all ages. The benefits of drinking milk include strengthening bones, improved cardiovascular and oral health.

1.2 Impure Milk (Adulterant Milk): Milk is most commonly diluted with water this not only reduces its nutritional value, but contaminated water can also cause additional health problems. The other adulterants used are mainly starch, sodium hydroxide (caustic soda), sugar, urea, hydrated lime, sodium carbonate, formalin, and ammonium sulfate etc.



The Indian Council of Medical Research (ICMR) has reported that milk adulterants have hazardous health effects. “The detergent in milk can cause food poisoning and other gastrointestinal complications. Its high alkaline level can also harm the body tissue & destroy proteins. Other synthetic components can cause heart problems, cancer or even death. While the immediate effect of drinking milk adulterated with urea, caustic soda and formalin is gastroenteritis, the long-term effects are far more serious. Urea can lead to vomiting, nausea and gastritis. Urea is particularly injurious for the kidneys, and caustic soda can be dangerous for people suffering from hypertension and heart disease. Formalin can cause more severe damage to the body like liver damage. The health impact of drinking milk adulterated with these chemicals is worse for children. Caustic soda troubles the mucosa of the food pipe, especially in kids. The chemical which contains sodium, can act as slow poison for those suffering from hypertension and heart disease”.

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In our daily life milk is one of the most important foods; provide rich nutrients to the body. But Milk adulteration leads to economic losses, deterioration of the quality of end products, and a risk to consumers' safety<sup>1</sup> therefore, it is important for the milk industry to confirm the quality of raw milk supplied by dairy farmers and for consumer agencies to verify the quality of fresh milk purchased from the market.

Dielectric properties, are the properties that determine the inter-action of electromagnetic energy with milk when subjected to dielectric heating. Knowledge of dielectric properties is essential

Since traditional methods for evaluating milk quality are lengthy, labor-intensive, and expensive The advanced technique Open-ended coaxial-line probe method associated with net-work analyzers or impedance analyzers is an useful technique to determine dielectric properties. Much information is available at low frequencies but permittivity at microwave (MW) range was not studied much. Therefore, the understanding on dielectric properties over a wide range of frequency is considered necessary to establish complete relationships of concentrations of milk in water diluted solution.

The objectives of this research were (1) to study the influence of added water content or milk concentration and freshness during 22°C and 5°C storage on the dielectric spectroscopy starting 10Hz to 4500 MHz with the open-ended coaxial-line probe technology, (2) to determine useful frequencies where the dielectric properties are sensitive to milk concentration and freshness.

## **2. Materials and methods**

*2.1. Sample:* The fresh untreated raw cow milk (raw milk) was obtained from a local stock farm half hour before experiment in the morning, and was filled in two plastic bottles of 2500 ml sterilized with boiling water. The milk had 2.90% fat, 2.37% protein, and 8.42% non-fat solids in mass.

*2.2. Dielectric properties measurement:* The dielectric properties were measured with an vector network analyzer open-ended co-axial line probe and X band (von-Hippel technique). Dielectric constant and loss factor were calculated with Matlab program dielectric probe kit software according to the reflection coefficient of the material in contact with the active tip of the probe.

Then electrical conductivity was determined using a conductivity meter.

*2.3. Procedure:* Predetermined amounts of deionized water were added to 70 ml of raw milk to prepare milk solutions with different milk for quality control of milk based on dielectric properties measurements.

The masses were measured by an electronic balance with a precision of 0.0001 g. The raw milk obtained from the farm, was stored in two covered bottles in an incubator at 5°C and at room temperature, 22°C, respectively. The milk samples were used for measurements every 12 h for storage at 5°C and every 2 h for storage at 22°C until the sample was deteriorated to study the influence of milk spoilage on dielectric properties. Before each measurement, the milk in bottles was shaken evenly. For the milk stored at 5°C, it was warmed to room temperature by circulating warm water at 25°C for 5 min around the beakers, to reach equilibrium before permittivity measurement. The temperature of samples was determined with a high accuracy mercury laboratory thermometer. Care was taken in sample temperatures as the dielectric properties of food materials were found to be dependent on temperature. Each beaker filled with milk solution in 15 ml was placed on a platform of 50 mm in diameter, and was raised up until the downward open-ended coaxial-line probe was completely immersed in the sample. Care was also taken to eliminate bubbles between the probe and the sample during measurements, since air bubbles might interfere with proper permittivity determinations. Dielectric properties measurements were repeated three times for each sample. Between replications, the probe was washed with water and wiped dry.

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#### *2.4. Dielectric properties, electrical conductivity and penetration depth*

At RF and MW heating, loss mechanisms of foods and agricultural products with high moisture content are dominated by ionic conduction and dipole polarization<sup>3</sup>. This can be mathematically expressed as

$$\epsilon^n = \epsilon_d^n + \epsilon_\sigma^n \quad (1)$$

where  $\epsilon_d''$  and  $\epsilon_\sigma''$  are dielectric loss due to dipole rotation and ionic conduction, respectively.  $\epsilon_\sigma''$  is further expressed as:

$$\epsilon_\sigma'' = \frac{\sigma}{2\pi f \epsilon_0} \quad (2)$$

By taking the logarithm on both sides of equation (2), it becomes:

$$\log \epsilon_\sigma'' = \log \frac{\sigma}{2\pi \epsilon_0} - \log f \quad (3)$$

where  $\sigma$  is ionic conductivity of a material in S/m;  $f$  is frequency in Hz; and  $\epsilon_0$  is the permittivity of free space ( $8.854 \times 10^{-12}$  F/m). Equation (3) expresses a negative linear relationship between the dielectric loss factor contributed by ionic conductance and the frequency in a log–log plot. To evaluate the influence of ionic conductivity on the loss factor, the electrical conductivity of fresh raw milk was used to calculate  $\epsilon_\sigma''$  according to equation (2).

Penetration depth of RF and MW power is defined as the depth where the power is reduced to  $1/e$  ( $e = 2.718$ ) of the power entering the surface. The penetration depth  $d_p$  in m of RF and MW energy in milk was calculated according to von Hippel

$$d_p = \frac{c}{2\pi f \sqrt{2\epsilon' \left[ \sqrt{1 + \left( \frac{\epsilon''}{\epsilon'} \right)^2} - 1 \right]}} \quad (4)$$

where  $c$  is the speed of light in free space ( $3 \times 10^8$  m/s). subsequent to obtaining the dielectric properties at  $22^\circ\text{C}$ , the penetration ( $d_p$ ) was calculated as a function of frequency for milk concentrations of 70 percent and 100 percent, and in raw milk at storage periods of 0, 18, and 36 hours at room temperature

### 3. Results and discussion

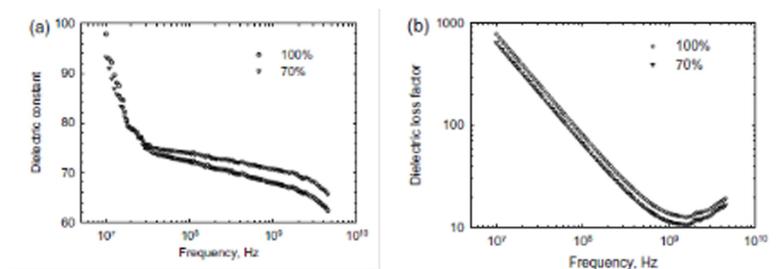
#### 3.1 The influence of milk concentrations on permittivities

The computed dielectric parameters such as dielectric constant & dielectric loss is tabulated in Table 1. for fresh raw milk and diluted milk with milk concentration of 70 percent over the frequency from 10Hz. to 4500 MHz .

**Table 1:** Dielectric parameters such as dielectric constant and dielectric loss for fresh raw milk and diluted milk with milk concentration of 70% over the frequency from 10Hz. to 4500 MHz

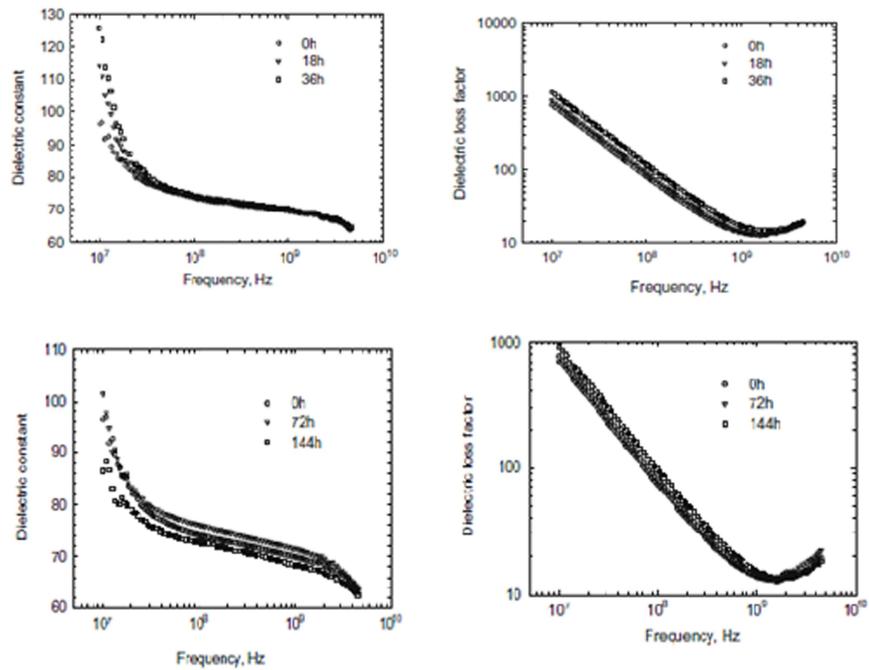
Milk Concentration	Permittivity	Frequency (MHz)			
		27	915	2450	4500
70%	$\epsilon'$	76.4	70.9	69.1	65.7
	$\epsilon''$	233.8	11.9	12.4	16.8
75%	$\epsilon'$	76.3	70.4	68.5	65.1
	$\epsilon''$	245.3	12.4	12.6	17.0
80%	$\epsilon'$	76.4	69.9	68.0	64.7
	$\epsilon''$	255.7	12.8	12.9	17.3
85%	$\epsilon'$	76.3	69.5	67.5	64.3
	$\epsilon''$	266.4	13.3	13.2	17.6
90%	$\epsilon'$	76.3	69.0	66.9	63.8
	$\epsilon''$	277.1	13.7	13.4	18.1
95%	$\epsilon'$	75.1	67.7	65.6	62.2
	$\epsilon''$	291	14.2	13.5	17.8
100%	$\epsilon'$	75.8	68.1	65.9	62.4
	$\epsilon''$	282.1	14.3	14.3	19.3

Variation of dielectric constant and dielectric loss with frequency for different concentration is as shown in figure 1

**Figure 1.** The frequency dependent permittivity's of fresh raw milk (100%) and diluted milk with milk concentration of 70% over the frequency from 10 to 4500 MHz.

### 3.2 Influence of Freshness on dielectric Properties:

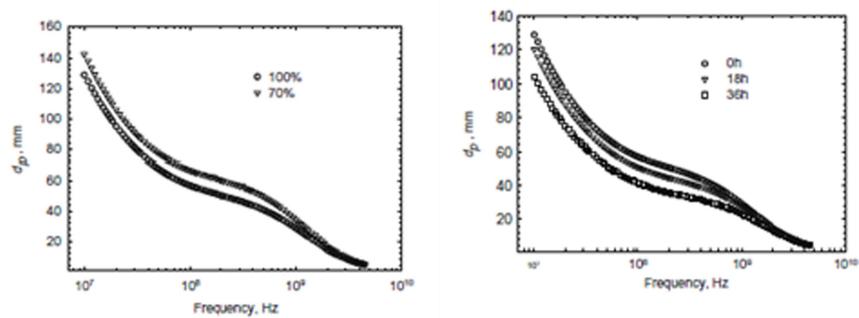
Influence of Freshness on dielectric Properties for varies frequencies and for different duration is as shown in figure 2.



**Figure 2** Dielectric properties of raw milk over the frequency from 10Hz to 4500 MHz . duration 0h, 18h, 16h, 36h, 72h, 144h at 22 °C.

3.3 Penetration depth :

Penetration depth increased with decreasing frequency, water content and storage time, which was large enough to detect dielectric properties changes in milk samples.



**Figure 3** Penetration depth of electromagnetic radiation into raw milk and adulterated (100 % and 70%) milk over the frequency from 10 to 4500 MHz . duration 0h, 18h, , 36h, at 22 °C.

#### 4. Conclusions:

The dielectric constant of milk decreased with the increasing frequency, and the loss factor had a minimum at about 1700 MHz over the frequency range from 10 to 4500 MHz at 22°C. The raw milk had lowest dielectric constant when the frequency was higher than about 20 MHz, and had the highest loss factor over the detected frequency range when compared with diluted milk. The penetration depth increased with decreasing frequency, water content and storage time, which was large enough to detect dielectric properties changes in milk samples and provide large scale RF pasteurization processes. The study provides some constructive information for developing a fast & simple milk concentration and freshness sensor in food processing industry.

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