Microwave Reflectometry Based Electrical Characterization of Milk for Adulteration Detection

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Abstract

The knowledge of dielectric properties such as dielectric constant and loss factor may hold a potential to develop a new technique for detection of adulteration in milk. In this paper, the measured results for dielectric properties of cow’s milk adulterated with water, sugar, starch and soda at 25 °C for frequencies ranging from 300 to 13500 MHz using open-ended coaxial-line probe technology are reported and discussed.

Keywords: Adulteration, coaxial-line probe, loss factor, permittivity.

1. Introduction

Milk forms an integral part in our daily diet. Unfortunately there have been cases of adulteration of milk which degrades its nutrient value to a great extent and in some cases can cause food poisoning or serious complication. Thus detection of adulterants in milk is very important. There are several lab detection methods for milk adulteration detection (Harding, 1995), but these methods are tedious and time consuming. The reflection based electrical characterization method where the dielectric properties of the material are used to determine their characteristics paves a way for easier and quick techniques which can be applied for in situ or online measurements. Reflection based method refers to the use of open ended coaxial–line probe method associated with network analyzers or impedance analyzers which determine dielectric constant, loss factor and loss tangent of materials, especially liquid foods, according to the reflection coefficient at the material-probe interface. Several studies (Nunes et al, 2006; W Guo
et al, 2010; Kudra et al, 1992) have been done on milk for quality detection, but thorough study on dielectric property of adulterated milk using reflectometry techniques were not found. Therefore a study was done over a wide range of frequency for adulteration of milk with most common adulterants like water, sugar, starch and soda.

2. Materials and Methods

2.1 Sample
Fresh untreated cow’s milk was used for the experiment. The temperature was maintained at 25°C. Milk is mostly adulterated using water to increase quantity, sugar is used to increase the sweetness of diluted milk, starch gives thickness to the adulterated milk and sodium bicarbonate is used to prevent the spoilage of milk by neutralizing the natural acidity of milk and acidity due to bacteria responsible for causing milk spoilage. So, adulterants used were water at room temperature, sugar, wheat flour as starch and sodium bi carbonate.

2.2 Dielectric Property Measurement
The dielectric properties were measured with an Agilent Technologies N5221A PNA network analyzer and Agilent Technologies 85070E open ended coaxial-line probe. Dielectric constant and loss factor were calculated with Agilent Technologies 85070E dielectric probe kit software according to the reflection coefficient of the material in contact with the active tip of the probe. Settings were made to provide measurement on a logarithmic scale from 300 to 13500 MHz which was the upper frequency limit of the measurement system. The port of the network analyzer was calibrated with open, short and 50Ω matched load followed by calibration of the coaxial probe with open, short and deionized water at 25°C. Thereafter subsequent calibration was done using the electronic calibration or the Ecal Module.

2.3 Procedure
Case1: Predetermined amount of water was added to 50ml of milk to prepare solution with different milk concentrations.
Case 2: Predetermined amount of sugar measured by electronic weighing system was added to milk and solution thus produced was tested.
Case3: Synthetic milk was prepared by adding water, sugar, starch and soda and solution thus obtained was tested.

3. Results and Discussion

3.1 The Results of the Experiment are tabulated in Table 1

<table>
<thead>
<tr>
<th>Adulterants</th>
<th>Permittivity</th>
<th>Frequency (GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh milk</td>
<td>er'</td>
<td>0.3 0.5 1 2.45 5.81 10 13.5</td>
</tr>
<tr>
<td></td>
<td>72.35 71.73 70.29 69.55 66.13 60.87 56.20</td>
<td></td>
</tr>
</tbody>
</table>
3.2 Effect of water on permittivity and loss factor of milk

When water was subsequently added to milk, the dielectric constant increased compared to the raw milk over the frequency range 300-13500 MHz frequency as shown in Fig. 1. The results obtained matched to findings of (W Guo et al, 2006). While loss factor decreases up to the frequency of 2GHz and then subsequently increases. This behavior can be explained by the phenomena that ionic concentration decreases with increasing water content. At higher frequencies the effect of ionic polarization on loss factor decreases. Thus explaining the behavior.

![Diagram](image-url)

Fig. 1: The frequency dependent (a) dielectric constant (er’) and (b) loss factor (er”) of fresh milk (100%) and milk diluted with water over the frequency from 300 to 13500 MHz at 250 C.
3.3 Effect of sugar permittivity and loss factor of milk
When sugar is added the permittivity of the adulterated milk so obtained is less, as shown in Fig. 2(a) and the loss factor first decreases and then increases after 1 GHz, as shown in Fig. 2(b). These Phenomena too can be explained by the contribution of ionic polarization to the dielectric constant and loss factor of a material.

![Fig. 2: The frequency dependent (a) dielectric constant (er’) and (b) loss factor (er’”) of fresh milk (100%) and milk adulterated with sugar over the frequency from 300 to 13500 MHz at 25° C.](image)

3.4 Effect of synthesized milk on permittivity and loss factor
The dielectric constant of synthesized milk is more than pure milk up to 2GHz and then decreases as evident from Fig. 3(a). And the loss factor increases, as shown in Fig. 3(b)

![Fig. 3: The frequency dependent (a) dielectric constant (er’) and (b) loss factor (er’”) of fresh milk (100%) and milk adulterated with sugar, water, starch and soda over the frequency from 300 to 13500 MHz at 25° C.](image)
4. Conclusion

It is evident from the study that microwave reflectometry based electrical characterization provides a way for quick and easier adulteration detection in milk. With addition of water, permittivity of milk increases but when sugar is added permittivity decreases. In case of loss factor, with addition of water it first decreases up to 2 GHz and increases thereafter, while for sugar loss factor increases up to 1 GHz and then subsequently decreases. At last the comparison made between synthetic milk and pure milk shows that for pure milk permittivity is lower for frequencies up to 2 GHz and after that permittivity increases while loss factor is lower than synthetic milk. Thus further confirming the use of electrical characterization using reflection based microwave technique for predicting the possible presence of adulterants in milk.

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References


