DIELECTRIC PROPERTIES OF VARIOUS HUNGARIAN HONEYS

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Abstract. The real and the imaginary part of complex electric pertmittivity of various Hungarian honeys (nine acacia, six lime, six sunflower) was obtained with an Agilent E4991A impedance analyser in the frequency range from 2 MHz up to 3 GHz. The total soluble solids (Brix) were determined with an Atago refractometer. The electrical conductivity was measured with a Mettler-Toledo conductivity meter. The real part of complex permittivity (dielectric constant) is decreasing if the frequency is increasing in 2 MHz – 3 GHz range. Generally for the investigated Hungarian honey variety the dielectric constant has negative linear regression with increasing total soluble solids content which can indicate the dielectric constant is decreasing if the sugar content is increasing. The dielectric loss factor at critical frequency does not show linear connection with electrical conductivity.

Keywords*:* honeys; complex electrical permittivity spectrum; total soluble solids; water content

Introduction

Honey is a natural sweet, viscous, fluid food. It is produced from the nectars of flowers by honeybees. It contains sugars, organic acids, various amino acids and biological active compounds: α-tocopherol, ascorbic acids and flavonoids (Turhan at al., 2008). The bee-honey is a natural food and does not allow the addition of any other substances (Diacu and Tantaveanu, 2007). The adulteration of honey is a common phenomenon with addition water or sugar. Currently the quality of honeys is measured by sensory and chemical methods. These measurements are often long-term and expensive. In the industry there is a demand for a quick, relative cheap and reliable method in quality control of honeys. In the last years there were published some experimental works about the dielectric properties of honeys (Guo at al., 2010; 2011).

The dielectric properties can be used for characterization the quality of various agricultural objects: the fruits, vegetables (Nelson, 2005) and meats (Kaltenecker et al. 2013). The relative electrical permittivity determines the interaction of investigated material with electromagnetic field and it is considered as a complex quantity: $\varepsilon^* = \varepsilon_1 - j\varepsilon_2$. The real part (dielectric constant), ε_1, can describe the energy storage in the material and the imaginary part (loss

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factor), ε_2, is associated with energy dissipation in the form of heat (Grimnes and Martinsen, 2008).

The dielectric properties of honey-water system were obtained with time–domain reflectometry in frequency range from 10 MHz up to 10 GHz (Puranik et al., 1991). The sugar and water content in yellow locust honey, jujube honey and rape honey were investigated with dielectric measurements (Guo, 2010). A strong linear correlation between the dielectric constant and the total soluble solids and water contents was observed. On the bases of these results it is interesting to reply the question whether is there any connection of dielectric permittivity with the total soluble solids or with the electrical conductivity at Hungarian honey varieties.

In present work the complex electric permittivity spectrum, the total soluble solids and the electric conductivity of some varieties of Hungarian honeys: acacia, lime, sunflower and some acacia honeys from European Community were measured. The connection of dielectric constant with total soluble solids was determined and the dielectric loss factor was presented as the function of electrical conductivity.

Materials and methods

The nine acacia samples from Nyírbogát, Hajdúsámson, Jászszentandrás, Erdőtelek, Nyírség, Kisköre, Tura, Salgótarján, and Ősagárd, the seven acacia honeys from European Community, the six lime honeys from Kisköre, Tiszanána, Hargita, Zselic, Zalacsány, Erdély and the six sunflower honeys from Rákhát (four producers), Békésszentadrás, Nógrád megye were purchased. Each honey was storage at room temperature in closed vial not to lose the natural water content.

The total soluble solids (Brix) were determined with an Atago refractometer. The electrical conductivity was measured with a Mettler-Toledo conductivity meter.

The dielectric spectrum, the real and the imaginary part of complex electric pertmittivity was obtained with an Agilent E4991A impedance analyser in the frequency range from 2 MHz up to 3 GHz. Before measurement the 85070D open-ended coaxial line probe system was open and short corrected and calibrated with distilled water.

All measurement on one sample was repeated three times. The correlation between the averages values was investigated.

Results

Typical dielectric spectrum of various sunflower honeys in the frequency range from 10 MHz to 3 GHz can be seen on Fig. 1. The real part of permittivity, the dielectric constant (Fig. 1.A) was monotonically decreased. At 20 MHz the maximum value of dielectric constant was varied between 30 and 40 and the minimum value at 3 GHz was fluctuated in range from 11 to 14. The imaginary part, the dielectric loss factor (Fig. 1 B) had a maximum in frequency range 500-1100 MHz. The critical frequency was changed in range from 550 MHz up to 1093 MHz.

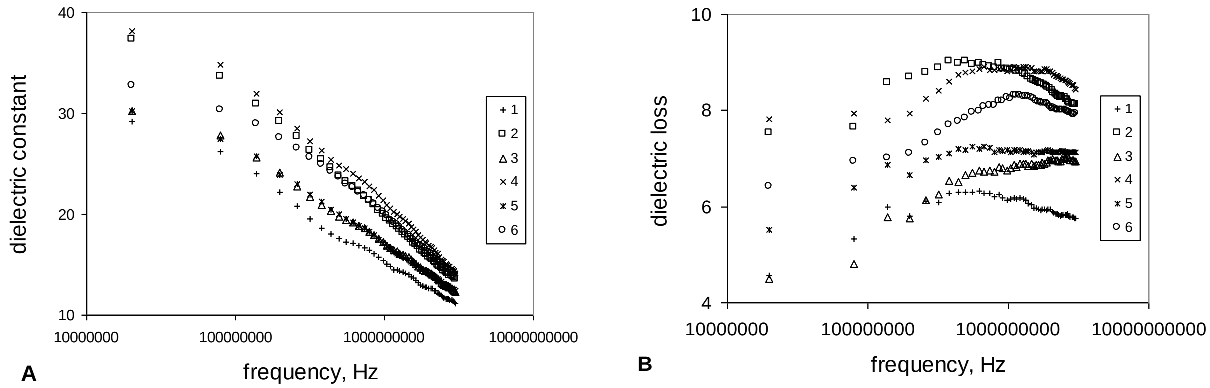

Fig. 1. Dielectric constant (A) and dielectric loss (B) of sunflower honey from various place (1-4: Rákhát, 5: Békésszentadrás, 6: Nógrád megye) as the function of frequency.

The dielectric spectrum of lime and both Hungarian and European acacia honeys was in own tendency very similar to spectra in Fig. 1. The critical frequency, the place of maximum in dielectric loss spectrum was varied for various honeys.

The dielectric constant in the function of total soluble solids (Brix) showed a linear regression for all investigated honeys (Fig. 2A, 3A, 4A and 5A).

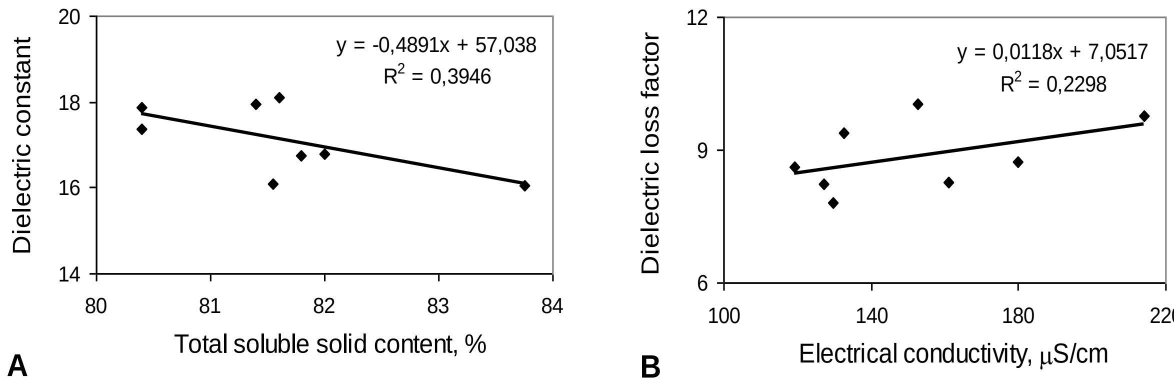

Fig. 2. Dielectric constant (A) at 915 MHz as the function of total soluble solids and dielectric loss factor (B) at critical frequency as the function of electrical conductivity for various Hungarian acacia honeys.

The dielectric loss factor as the function of electrical conductivity showed different tendency for the investigated honeys (Fig. 2B, 3B, 4B and 5B).

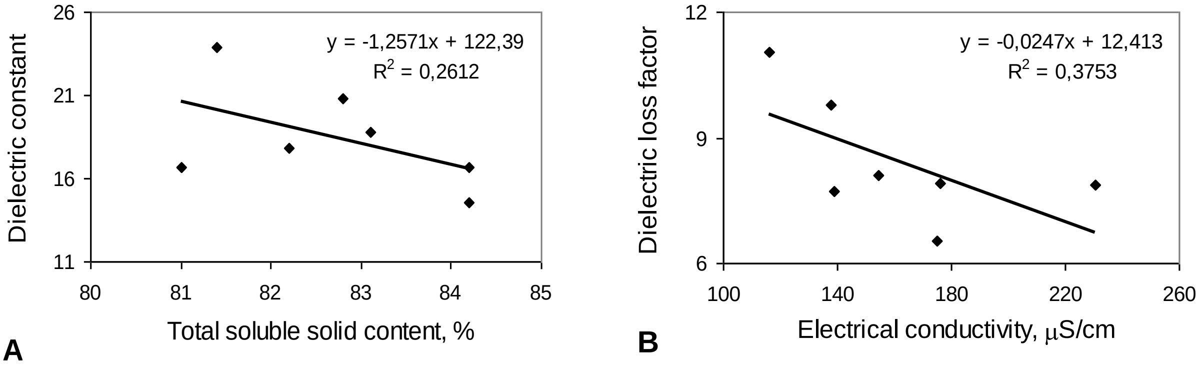

Fig. 3. Dielectric constant (A) at 915 MHz as the function of total soluble solids and dielectric loss factor (B) at critical frequency as the function of electrical conductivity for various European acacia honeys.

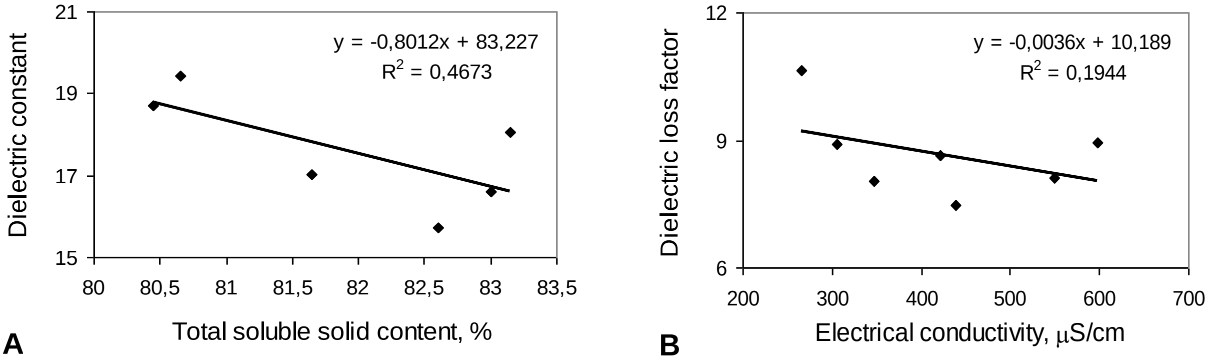

Fig. 4. Dielectric constant (A) at 915 MHz as the function of total soluble solids and dielectric loss factor (B) at critical frequency as the function of electrical conductivity for various lime honeys.

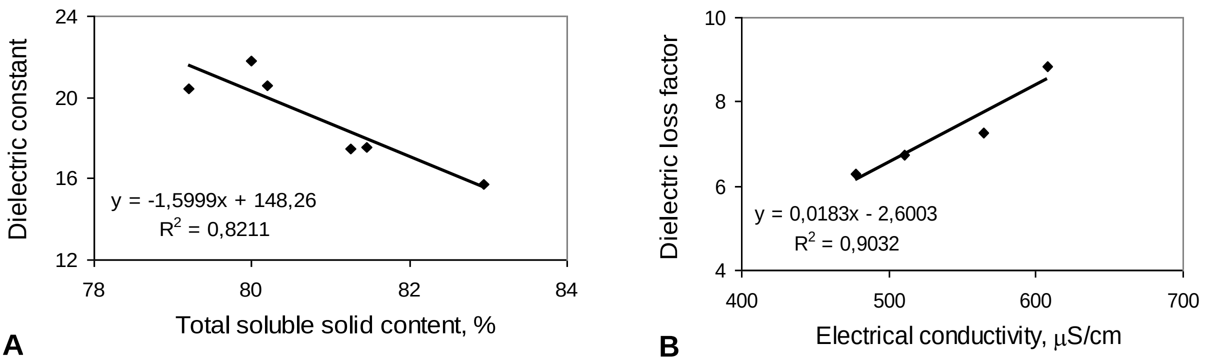

Fig. 5. Dielectric constant (A) at 915 MHz as the function of total soluble solids and dielectric loss factor (B) at critical frequency as the function of electrical conductivity for various sunflower honeys.

Similar linear regression between the total soluble solids and real part of complex permittivity was observed at all other frequencies of spectrum (not shown). In Fig. 2-5. each point represents various honey originated from various place of Hungary.

Discussion

The dielectric spectrum (Fig.1) of all investigated honeys is similar to each other, and to the spectrum obtained for other honeys in various scientific literatures (Guo et al., 2010; Ahmed et al. 2007). The similarity is expressed both in tendency as the function of frequency and in values of dielectric constant and dielectric loss factor.

The observed band (Fig. 1B) in loss factor can be caused by various processes - as polarization, electron conductivity, Maxwell-Wagner effect, - in electromagnetic field (Grimnes and Martinsen, 2008). The bound water gives a band of its loss factor in the range of critical frequency for our measured honeys (Hasted, 1973). Presumably the band in loss factor spectrum of honeys can be caused by several processes in addition to the bound water.

Considering a given honey the decrease of dielectric constant (Fig. 2A, 3A, 4A, 5A) was observed at increasing total soluble solids (Guo et al., 2010). The Brix can be considered as the total soluble solid which is proportional with total sugar content. The various value of Brix may reflect the difference in water content. The slope of trend lines in Fig. 2A, 3A, 4A and 5A are in the same range which was obtained for jujube, rape and yellow locust honeys: (-1,54) (Guo et al., 2010). For our honeys the change of total soluble solids was in a very thin range: 79-84%. The low regression coefficient may indicate, that the dielectric constant is determined not only by the water content, but the other chemical components of honey also effect on it.

The various critical frequencies (place of maximum) in the loss factor spectrum can show on the various ion environments, and on the various ion contents. The loss factor depends on the electrical conductivity (Grimnes and Martisen, 2008). It can be expected, that the electrical conductivity linearly depends on the loss factor at a given frequency. Our results (Fig. 2B, 3B, 4B and 5B) show not clear tendency in relation of loss factor at the critical frequency to the electrical conductivity. It seems, that loss factor contains not only energy loss caused by current, but contains the polarization energy loss, too. The electrical conductivity was measured only a single frequency and not in a frequency range, and the electrical conductivity itself depends on the frequency.

Conclusions

The dielectric spectrum of Hungarian honeys is similar to the spectrum of honeys from over the world. The real part of complex permittivity (dielectric constant) is decreasing if the frequency is increasing in 2 MHz – 3 GHz range. Generally for the investigated Hungarian honey variety the dielectric constant has negative linear regression with increasing total soluble solids content which can indicate the dielectric constant is decreasing if the sugar content is increasing. The dielectric loss factor at critical frequency does not show linear connection with electrical conductivity.

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