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METHODOLOGICAL ASPECTS OF TESTING ELECTRICAL PROPERTIES OF HONEY

Deta Łuczycka

Institute of Agricultural Engineering, Wrocław University of Environmental and Life Sciences
ul. Chełmońskiego 37-41, 51-630 Wrocław
e-mail: deta.luczycka@up.wroc.pl

Abstract. The aim of this work was to investigate the possibility of using various electrical and dielectric parameters to distinguish natural honeys and determine their authenticity. Electrical properties of honey were tested at temperatures between 10°C and 30°C, in an electromagnetic field frequency ranging from 50 Hz to 20 kHz. The determination of permittivity, dielectric loss factor and conductivity for honey makes it possible to distinguish types of honey and check their authenticity. The temperature of a honey sample has a significant effect on the values obtained for the measured electrical properties. Testing should be carried out within a temperature range of 15°C to 25°C. Further research, carried out on a greater quantity and variety of honeys, may lead to the introduction of new effective methods for evaluating the type and quality of natural honey.

Keywords: honey, electrical properties, dielectric properties

INTRODUCTION

The methods used to date for testing the authenticity of honey based on its conductivity are time-consuming and onerous – they require the preparation of an aqueous solution of the honey (Order of the Minister of Agriculture and Rural Development, 2009, PN-88/A-77626). Moreover, methods of obtaining fraudulent results are developed at a rapid pace, which makes it necessary to seek superior fast methods of honey inspection – those currently in use are becoming inadequate (Majewska and Delmanowicz 2008). Studies conducted by researchers, being aimed at identification of the origin of honey, are also based on honey solution testing (Popek 2002, Majewska and Delmanowicz 2008). Measurements of electric properties of honey are usually treated as one among many other methods – they are not a subject of separate detailed studies (Ahmed *et al.* 2007, Serrano *et al.* 2004). However, the development of electronics enables the use of new instruments for this purpose, that only a few years ago would have been ruled out on grounds of price.

The aim of this work was to investigate the possibility of using various electrical and dielectric parameters to distinguish natural honeys and determine their authenticity.

METHODOLOGY

The research was conducted on the following types of honey available on the market: nectar honeys – acacia (A), lime (L), multifloral (WK) – and heather (WR) and honeydew (SI) honey. For purposes of comparison, liquid artificial (surrogate) honey (SZ) was also tested.

For samples of honey, determinations were made of their electrical properties, such as:

- permittivity;
- dielectric loss coefficient;
- conductivity.

A measurement method was selected which enables results to be obtained rapidly, but also accurately. It is an indirect method, in which first a sample of honey is placed in the space between the electrodes of a measurement capacitor, and its capacitance (*C*) and resistance (*R*) measured, and next the capacitance of an air-spaced capacitor with the same geometry is measured. Based on the results obtained and the value of the frequency of the electromagnetic field in which the measurement was performed, it is possible to determine the permittivity (ε), the loss coefficient ($tan\ \delta$) and the conductivity (σ), these being the subject of the analysis itself (Lisowski 2004):

$$\varepsilon = \varepsilon_o \cdot \frac{C_r}{C_0}, \tag{1}$$

$$tg\delta = \frac{1}{\omega \cdot C_r \cdot R_r}, \tag{2}$$

$$\sigma = \frac{h}{S \cdot R_r}, \tag{3}$$

where: ε_o = permittivity of vacuum (F m^{-1}),

C_r = capacitance of capacitor with honey (F),

C_0 = capacitance of air-spaced capacitor (F),

ω = angular frequency of electromagnetic field (Hz),
R_r = resistance of honey sample (Ω),
h = distance between electrodes (m),
S = electrode surface area (m^2).

Measurements were performed using a FLUKE PM6304 impedance analyser. The measuring device was connected to a system of electrodes placed in an air-conditioned chamber. Measurements were performed using a flat system of measurement electrodes (Fig. 1). The tested material was placed between the electrodes in the form of a layer of thickness of 15 mm. Samples were maintained in measurement conditions in a WEISS WK 111 340 air-conditioned chamber – the investigators waited for the conditions to stabilise whenever the chamber had been opened or closed. The electrical properties of honey were tested at 10ºC, 15ºC, 20ºC, 25ºC and 30ºC, under the effect of electromagnetic field frequency in the range 50 Hz to 20 kHz. All results were statistically analysed by analysis of multi-factor variance. Differences were considered significant for $p < 0.05$.

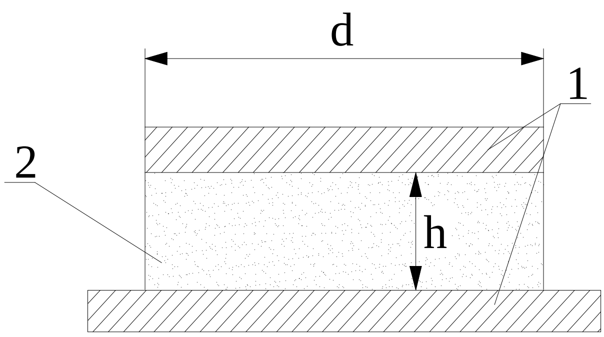

Fig. 1. Cheap, two-electrode measuring system: 1 – measuring electrode, 2 – grain, h – thickness of layer, d – diameter of the electrode

RESULTS

Multi-factor variance analysis was performed on the results, from which it was found that the type of honey and the temperature of the honey sample have a significant effect on all of the electrical properties determined. Moreover, the frequency of the electromagnetic field in which the measurements were performed has a statistically significant effect on the permittivity and dielectric loss coefficient (at a significance level of $\alpha = 0.05$).

An analysis was made of the effect of electromagnetic field frequency on the values of the electrical properties obtained for honey. Figure 2 shows the results obtained for the permittivity of the tested types of honey. The changes in this value as a function of frequency are of a similar nature for all of the varieties tested. It can be noted, however, that this physical property cannot be used either to distinguish nectar honeys from honeydew varieties, or to check whether honey has been falsified by the addition of artificial honey. For the frequency range of 2 kHz to 20 kHz the values of permittivity for the analysed honeys do not show statistically significant differences. Noteworthy is only the clearly deviating measurement result for heather honey. Possibilities of distinguishing honey based on this parameter can be sought only in a range of electromagnetic field frequency below 2 kHz, but confirmation of this supposition requires further research.

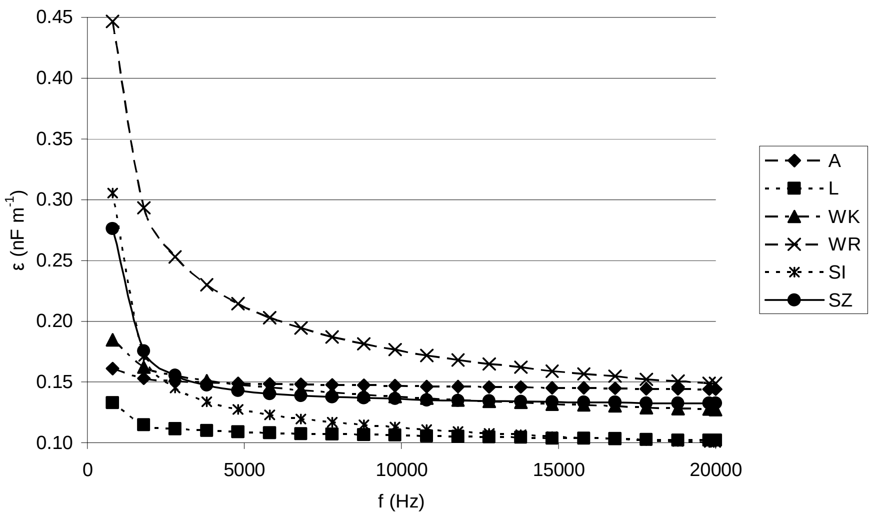

Fig. 2. Effect of frequency on permittivity values for tested honey varieties (at 20°C)

The effect of electromagnetic field frequency on the values of dielectric loss factor is shown in Figure 3. It can be clearly seen that over the entire frequency range the values of this parameter for artificial honey deviate significantly from those obtained for natural honeys. However, there are no significant differences between honeydew and nectar honey. At frequencies greater than 2 kHz the dielectric loss factor could be used to distinguish honeys in the tested categories.

The tested honeys are most clearly differentiated by the values obtained for their conductivity (Fig. 4). The electromagnetic field frequency has only a very small effect on the values of this parameter, with increases of 0.2% to 5% of the average value. Only for acacia honey is there a marked rise in conductivity with increasing field frequency, being 38% of the average value. The values obtained are completely different from those defined in the honey quality standards, because in these studies it was the conductivity of the liquid honey that was measured, not that of an aqueous solution of honey.

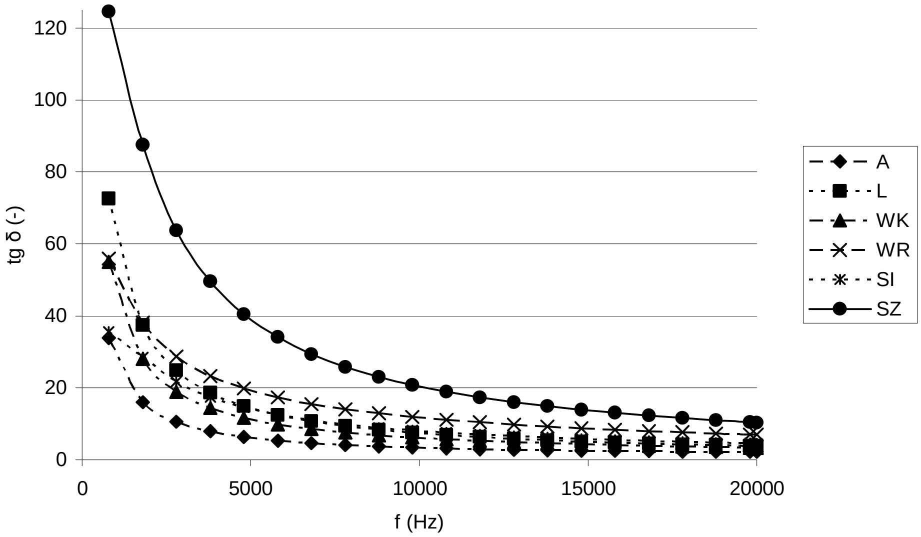

Fig. 3. Effect of frequency on loss coefficient values for tested honey varieties (at 20°C)

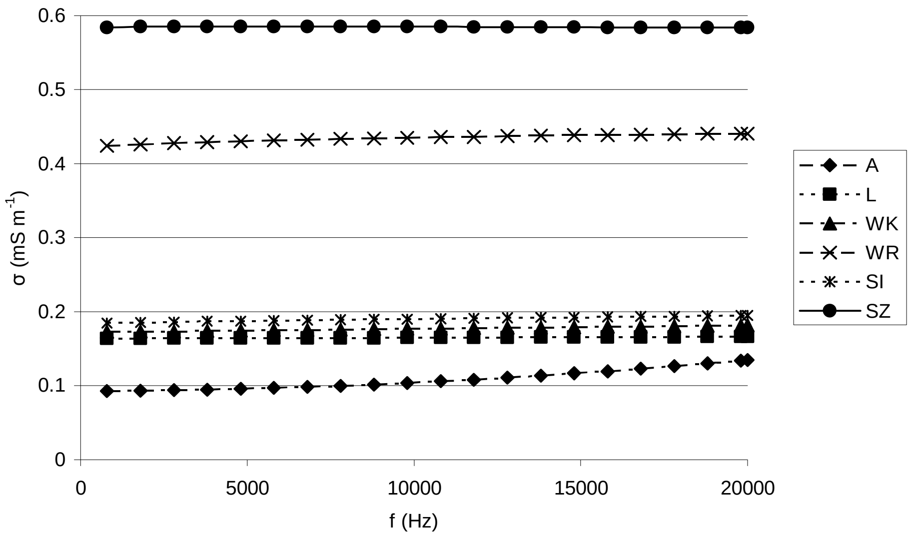

Fig. 4. Effect of frequency on conductivity values for tested honey varieties (at 20°C)

Next, an analysis was made of the effect of temperature on the measured electrical properties of honey. The diagrams show the effect of temperature on the values of permittivity (Fig. 5), dielectric loss coefficient (Fig. 6) and conductivity (Fig. 7), as measured at an electromagnetic field frequency of 800 Hz.

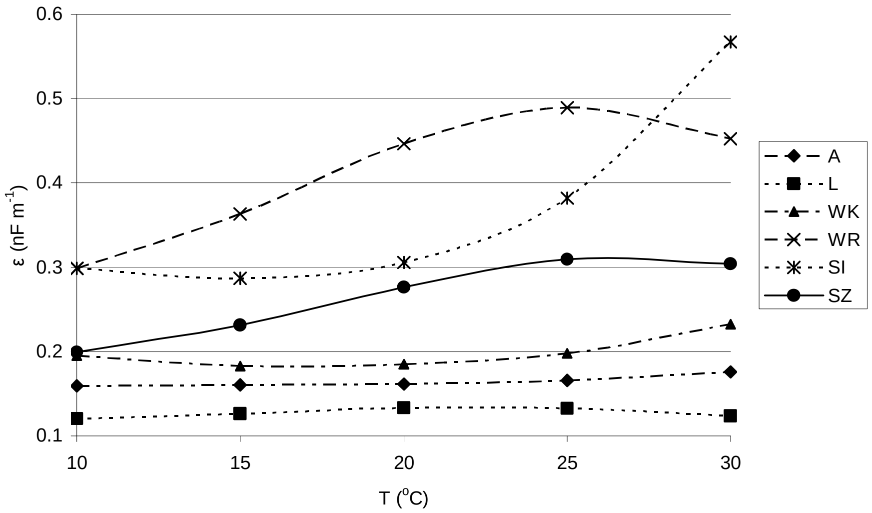

Fig. 5. Effect of temperature on permittivity values for the tested varieties of honey (frequency 800 Hz)

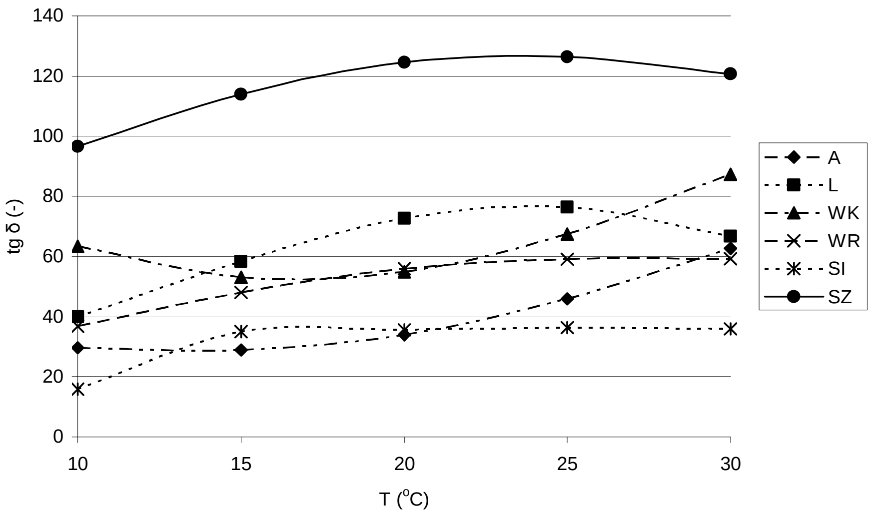

Fig. 6. Effect of temperature on loss coefficient values for the tested varieties of honey (frequency 800 Hz)

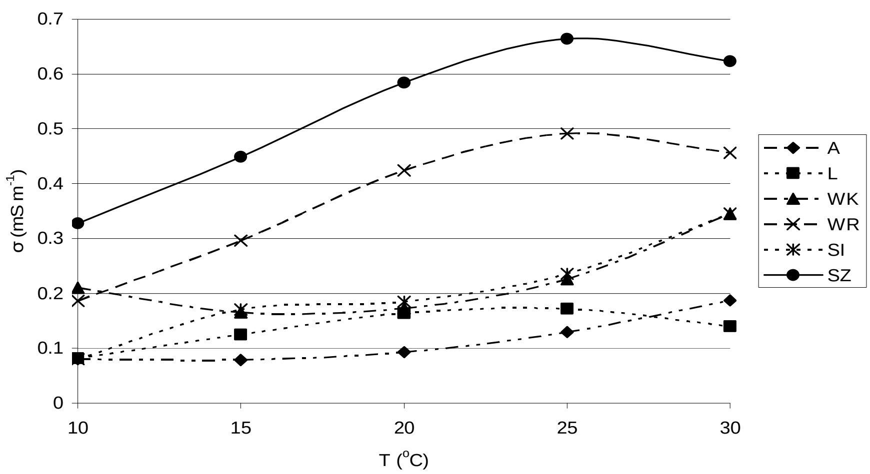

Fig. 7. Effect of temperature on conductivity values for the tested varieties of honey (frequency 800 Hz)

The measurement results shown in Figure 5 clearly indicate that at this frequency the permittivity may be a parameter permitting heather and honeydew honey to be distinguished from nectar honeys. Markedly deviating permittivity values were also obtained for artificial honey. For the avoidance of errors, however, it would be recommended that the range of temperature of honey samples be restricted to between 15ºC and 25ºC.

The dielectric loss coefficient makes it possible to establish unambiguously which sample is an artificial honey, and presumably also to detect additions of artificial honey to natural honey, since the values of the parameter for artificial honey are at least twice as great as those for natural honeys. For the dielectric loss coefficient it is also recommended that the temperature be kept within the range 15ºC to 25ºC to ensure unambiguous results.

The value of conductivity of honey is also affected markedly by the sample temperature (Fig. 7). The graph of this relationship is of a different character for the different types of honey tested. It would, therefore, be appropriate to limit the range of temperatures at which measurements are made to the range of 15–25ºC.

CONCLUSIONS

1. Determination of permittivity, dielectric loss coefficient and conductivity for honey makes it possible to distinguish types of honey and check its authenticity. Permittivity should be measured at electromagnetic field frequencies below 2 kHz, and the dielectric loss coefficient at frequencies higher than 2 kHz.

2. The temperature of a sample of honey has a significant effect on the values obtained for its electrical properties. Testing should be carried out between 15ºC and 25ºC.

3. Further research carried out on a greater quantity and variety of honeys may lead to the introduction of new effective methods for evaluating the type and quality of natural honey.

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METODYCZNE ASPEKTY BADANIA WŁAŚCIWOŚCI ELEKTRYCZNYCH MIODU

Deta Łuczycka

Instytut Inżynierii Rolniczej, Uniwersytet Przyrodniczy we Wrocławiu
ul. Chełmońskiego 37-41, 51-630 Wrocław
e-mail: deta.luczycka@up.wroc.pl

Streszczenie. Celem pracy było sprawdzenie możliwości wykorzystania różnych wielkości elektrycznych i dielektrycznych do różnicowania miodów naturalnych oraz określania ich autentyczności. Badano cechy elektryczne miodu w temperaturach od 10^{o}C do 30^{o}C, w polu elektromagnetycznym o zakresie od 50 Hz do 20 kHz. Określenie dla miodu przenikalności elektrycznej, współczynnika strat dielektrycznych oraz konduktywności pozwala na różnicowanie miodu i kontrolę jego autentyczności. Temperatura próbki miodu ma istotny wpływ na uzyskiwane wartości wyznaczanych cech elektrycznych miodu. Badania należy prowadzić w zakresie od 15^{o}C do 25^{o}C. Dalsze badania prowadzone na większej ilości i różnorodności miodów mogą doprowadzić do wprowadzenia nowych, skutecznych metod oceny rodzaju i jakości miodu naturalnego.

Słowa kluczowe: miód, właściwości elektryczne, właściwości dielektryczne