PERGA'S ELECTRICAL CHARACTERISTICS ELEKTRIČNE OSOBINE PERGE

Tomáš REGRUT*, Zuzana HLAVÁČOVÁ*, Ján NOVÁK*, Monika BOŽIKOVÁ*,
Peter HLAVÁČ*, Ján BRINDZA***, Vladimír CVIKLOVIČ**, Veronika ARDONOVÁ*

*Department of Physics, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A Hlinku 2, SK-949 76 Nitra, Slovakia

**Department of Electrical Engineering, Automation and Informatics, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A Hlinku 2, SK-949 76 Nitra, Slovakia

***Faculty of Agrobiological and Food Resources, Slovak University of Agriculture in Nitra, Tr. A Hlinku 2, SK-949 76 Nitra, Slovakia
e-mail: tregrut@gmail.com

ABSTRACT

The aim of this study was to measure the electrical properties of perga. We measured the capacitance, resistance and impedance. Each property was measured at all frequencies three times. Average value and standard deviation has been computed from these ones. The resistance, impedance, and capacitance decreases with frequency according to power function. The impedance has a slightly higher value as resistance, which is caused by the capacitance of perga. It was determined that the dielectric constant of perga increases when the moisture content of perga increases. The minimal decrease is at higher frequencies. The measurements indicate that perga must be included in the organic heterogeneous multi-component dielectrics or semi-conductors.

Key words: perga, electrical properties, moisture content, frequency.

REZIME

Cilj istraživanja bio je merenje električnih osobina perge. Izmereni su kapacitivnost, otpornost, impedansa. Svako svojstvo mereno je na svim frekvencijama tri puta. Prosečna vrednost i standardna devijacija i izračunati su iz ovih merenja. Otpornost, impedansa i kapacitivnost smanjuju se frekvencijom u skladu sa funkcijom snage. Impedansa ima nešto veću vrijednost kao otpornost, što je uzrokovano kapacitivnošću perge. Utvrđeno je da se dielektrična konstanta perge povećava kada se vlažnost perge povećava. Minimalno smanjenje je na višim frekvencijama. Merenja ukazuju na to da perga treba da bude svrstana u organske heterogene višekomponentne dielektrike ili poluprovodnike.

Ključne reči: perga, električna svojstva, sadržaj vlage, frekvencija.

INTRODUCTION

Bees products like honey, pollen, royal jelly, propolis, bee venom have immense medical importance. Honey is useful for healing the wounds, helps to build up haemoglobin, used as laxative blood purifier, preventive against cold, cough, sore throat, eye ailments, burns and gastrointestinal disorder etc. Honey has antibiotic property and is effective in reducing the risk of heart disease, cancer and diabetes. Pollen lowers blood pressure, increases haemoglobin and erythrocyte content, useful in pernicious anaemia, sterility, hypertension, in complaints of the nervous and endocrine system. Royal jelly has antimicrobial, anti-inflammatory, antiaging, vasodilate and hypotensive, antioxidant, antihypercholesterolemic and antitumor property (Waycar and Alquadhi, 2016). Bee bread – also called "Perga" – are fermented bees pollen in the comb, which store bees as protein supply. It was found that bees preferentially consume fresh pollen stored for less than 3 days. Newly collected pollen contained few bacteria, values which decreased significantly as pollen were stored more than 96 h (Anderson et al., 2014). The bee bread is harvested by hand from the honeycomb and thus is not only the most valuable, but also the most expensive bee products (McIntyre and Snyder, 1978). Bee bread is considered the most perfect of all natural foods – used by the Greeks as ambrosia. It includes many vitamins (A, B1, B2, B6, B12, C, D, E, P, PP) and trace elements (potassium, magnesium, calcium, copper, iron, sili-con, sulphur, chlorine, manganese) (McIntyre and Snyder, 1978). In the perga there is everything that is required for the normal growth and existence of a live organism. Good results are noted by specialists at treatment of patients with many diseases (Georgiev et al., 2004, Waycar and Alquadhi, 2016). Bee bread is of benefit not only for the materials of health food diets, but also for in patients undergoing various diseases such as cancer, cardio-vascular diseases, diabetes, and hypertension (Nagai et al., 2005).

The electric properties of foods and biological products have become valuable parameters in food engineering and technology. The measurement of electrical properties of food can be used to get information about many other characteristics of this material; in addition, there are some food processes which are based on electrical effects (Venkatesh and Raghavan, 2005). An electric current flowing through a food material causes a temperature rise due to energy dissipation by the electric resistance of the food. An extensive review of the literature on dielectric properties of agricultural materials was published by Nelson and Trabelsi (2008) that includes a number of potential applications in which the dielectric properties of such products are of interest.

The properties of honey are described in the literature, e.g. thermophysical and rheologic (Hlaváč and Božiková, 2012). Electrical properties of honey are utilized at the sugar and water contents (Guo et al., 2010), and floral origin determination (Scandurra et al., 2013).

It is obvious that Perga was examined in terms of its chemical composition, microbiological activity, and the effects on the human body. Information on its physical properties is scarce in the literature. Mechanical properties of perga were examined by Kubík et al. (2016). The aim of this study was to measure the electrical properties of perga.

Nomenclature:

C (F)	– capacitance of testing capacitor with a sample
C ₀ (F)	– capacitance of empty testing capacitor free of interconnector capacitance
C _x (F)	– capacitance of interconnector,
C ₁ (F)	– capacitance of tuning capacitor by resonance and by non-connection of testing capacitor
C ₂ (F)	– capacitance of tuning capacitor by

	resonance and by connection of testing capacitor
f (Hz)	– frequency
f_0 (Hz)	– reference frequency
k	– constant
l (m)	– electrodes distance
R (Ω)	– resistance
R_0 (Ω)	– resistance
R^2	– coefficient of determination
S (m ²)	– electrode area
Z (Ω)	– impedance
Z_0 (Ω)	– reference impedance
w (%)	– moisture content wet basis

Greek symbols

ε_r	– relative permittivity
ε_{r0}	– reference relative permittivity
ρ (Ω .m)	– resistivity
ρ_0 (Ω .m)	– reference resistivity

MATERIAL AND METHOD

Perga samples of different plant species were collected by beekeepers from selected regions of Ukraine (Poltava and Dnepropetrovsk) according to a new patented technology developed by the research team of the Department of Apiculture at the National University of Life and Environmental Sciences of Ukraine, with offices in Kiev.

All samples were polyfloral Perga (Regrut et al., 2016).

Average height of perga pellets was 9.713 mm and average width 5.459 mm.

Fig. 1: Sample of perga

All measurements were carried out under an air temperature of 20 °C and of 60 % relative humidity. Bulk density was determined by the mass of constant sample volume. We used two methods of electrical properties measurement by LCR meter and Q meter.

Low-frequency electrical properties of perga were measured by an instrument GoodWill Instek LCR meter 821 at different frequencies using four-electrode (tetra polar) system. The sample was placed in the sensor with parameters: diameter of electrode 37.8 mm, electrodes spacing 49.2 mm, mass of empty sensor 208.89 g. We measured capacitance, resistance and impedance. Each property was measured in the frequency range from 0.1 kHz to 200 kHz, at all frequencies three times. Average value has been computed from these ones and standard deviation was calculated. The measured values were loaded by PC using programme LRC Data Collector (created by V. Cviklovič). The resistivity ρ of perga sample was calculated as

$$\rho = \frac{RS}{l} \quad (1)$$

where R – resistance, S – electrode area, l – electrodes distance.

The capacitance of the testing capacitor was at higher frequencies measured by the Q-meter TESLA MB 560. The device was connected with the testing coaxial capacitor, which was used as a sample holder. The radius of capacitor outer electrode is 33 mm, radius of inner electrode is 8 mm and length of capacitor is 60 mm. The measurement was performed in a frequency range from 1 MHz to 16 MHz. Relative permittivity ε_r was calculated according to following relations

$$\varepsilon_r = \frac{C - C_x}{C_o} \quad (2)$$

$$C = C_1 - C_2 \quad (3)$$

where C – capacitance of testing capacitor with a sample, C_o – capacitance of empty testing capacitor free of interconnector capacitance, C_x – capacitance of interconnector, C_1 – capacitance of tuning capacitor by resonance and by non-connection of testing capacitor, C_2 – capacitance of tuning capacitor by resonance and by connection of testing capacitor.

Moisture content wet basis w was determined by gravimetric method. The samples were weighed by Sartorius Basic electronic analytical and precision balance (Sartorius AG) on the beginning and after drying and reaching constant mass.

RESULTS AND DISCUSSION

From measured values at initial moisture content are constructed graphical dependencies of electrical quantities on frequency. For illustration, the resistance and impedance versus frequency curves are shown on Fig. 2 and for resistivity on Fig. 3. These electrical properties of perga sample decreases in this frequency range. The regression equation has the shape of decreasing power function, e.g. for resistance

$$R = R_0 \left(\frac{f}{f_0} \right)^{-k} \quad (4)$$

where R – resistance, R_0 – reference resistance, f – frequency, $f_0 = 1$ kHz, k – constant.

Fig. 2. The resistance (●) and impedance (▲) versus frequency curves

The similar equation can be write also for impedance and resistivity. The coefficient of determination has high value. The change of resistance, impedance, and resistivity at low frequency is significant, compared to the higher frequencies. The impedance has slightly higher values as resistance, which is caused by the capacitance of perga. We had obtained similar result for other product, e.g. for dried apricots (Hlaváčová et al., 2007). Also, the resistivity (Fig. 3) and capacitance decrease with frequency according to power function. We can conclude that sample is created as a mixture of perga and air. The resistivity values show that perga belongs to semiconductors. The values of capacitance measured by Q-meter were used for calculation the relative permittivity applying the equations (2) and (3). The effect of moisture content on relative permittivity of perga is shown on Fig. 4. In Tab. 1 the coefficients of regression equation (4) are presented.

Fig. 3. The resistivity versus frequency curve

Table 1. Coefficients of regression equation (4) and coefficient of determination

Value	Reference value	k	R ²
R (kΩ)	158.98	1.131	0.9089
Z (kΩ)	159.7	1.112	0.9427
ρ (kΩ.m)	3.625	1.131	0.9089

Fig. 4. The relative permittivity versus moisture content curves at four frequencies, 1 MHz (◇), 6 MHz (□), 11 MHz (Δ), 16 MHz (○)

Also in this case, we can use the power function for modelling these dependencies

$$\varepsilon_r = \varepsilon_{r0} w^k \quad (5)$$

where: ε_{r0} – reference relative permittivity, k – constant.

Table 2. Coefficients of regression equation (5) and coefficient of determination

Frequency (MHz)	ε_{r0}	k	R ²
1	0.5526	0.7113	0.9726
6	0.508	0.6928	0.9905
11	0.2964	0.8353	0.9512
16	0.2293	0.9176	0.9645

Coefficients of regression equation (5) and coefficient of determination are displayed in Tab. 2. Also for equation (5), it can be seen that the coefficient of determination has a high value. Values of dielectric constant increase when the moisture content of samples increases. This effect is the consequence of a very high magnitude of water relative permittivity in comparison with other components of perga (Nelson and Trabelsi, 2008, Guo et al., 2010).

CONCLUSION

The measurements indicate that perga must be included in the most complex objects. It is an organic heterogeneous multi-component semiconductor or dielectric. We found out that the resistance, impedance, and resistivity decrease with frequency according to the power function. The change of these electric

properties at low frequency is significant, compared to the higher frequencies. The impedance has a slightly higher value as resistance, which is caused by the capacitance of perga. Also, the capacitance decreases with frequency powerfully. It was determined that the relative permittivity of perga increases when the moisture content of perga increases. The minimal difference is at higher frequencies. These relationships are caused by the dipole moment of water molecules and may be the orientation of charged groups of macromolecules. In this case, an orientation polarisation occurs in the electric field. This type of polarisation is highly dependent on frequency. Dipole macromolecules are not able to follow changes in the polarity of the electric field.

ACKNOWLEDGEMENT: This work was co-funded by the European Community under the project No 26220220180: Building the Research Centre AgroBioTech.

REFERENCES

- Anderson, K.E., Carroll, M.J., Sheehan, T., Mott, B.M., Maes, P., Corby-Harris, V. (2014). Hive-stored pollen of honey bees: Many lines of evidence are consistent with pollen preservation, not nutrient conversion. *Molecular Ecology*, 23 (23), 5904–5917.
- Georgiev, D.B., Goudev, A.G., Manassiev, N. (2004). Effects of an herbal medication containing bee products on menopausal symptoms and cardiovascular risk markers: results of a pilot open–uncontrolled trial. *MedGenMed* [online], 4 (46), 1–12. Available at: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1480585/>.
- Guo, W., Zhu, X., Liu, Y., Zhuang, H. (2010). Sugar and water contents of honey with dielectric property sensing. *Journal of Food Engineering*, 97, 275–281.
- Hlaváč, P., Božiková, M. (2012). Influence of temperature and storing time on flower honey rheologic and thermophysical properties. *Journal on Processing and Energy in Agriculture*, 16 (2), 52–56.
- Hlaváčová, Z., Babić, L., Babić, M., Kertész, Á. (2007). Some electrical properties of dried apricots *Prunus Armeniaca* L. *Journal on Processing and Energy in Agriculture*, 11 (3), 75–78.
- Kubík, L., Božiková, M., Brindza, J., Brovarskyi, V.D., Velychko, S.M. (2016). Behaviour of perga under compressive loading. International Conference: Biosystems and Food Engineering. Szent István Egyetem, Gödöllő, Hungary, 8 p.
- McIntyre, P., Snyder, A.W. (1978). Light propagation in twisted anisotropic media: application to photoreceptors. *Journal of the Optical Society of America*, 68 (2), 149–157.
- Nagai, T., Nagashima, T., Suzuki, N., Inoue, R. (2005). Antioxidant activity and angiotensin i-converting enzyme inhibition by enzymatic hydrolysates from bee bread. *Verlag der Zeitschrift für Naturforschung*, 60, 133–138.
- Nelson, S.O., Trabelsi, S. (2008). Dielectric spectroscopy measurements on fruit, meat, and grain. *Transactions of the ASABE*, 51 (5), 1829–1834.
- Regrut, T., Novak, J., Hlavacova, Z., Brindza, J., Brovarskyi, V.D., Velychko, S.M. (2016). Selected electric properties of perga. International Conference: MendelNet, Mendel University in Brno, Czech Republic, 628–633.
- Scandurra, G., Tripodi, G., Verzera, A. (2013). Impedance spectroscopy for rapid determination of honey floral origin. *Journal of Food Engineering*, 119, 738–743.
- Venkatesh, M.S., Raghavan, G.S.V. (2005). An overview of dielectric properties measuring techniques. *Canadian Biosystems Engineering*, 47 (7), 15–30.
- Waycar, B., Alquadhi, Y.A. (2016). Beekeeping and bee products; boon for human health and wealth. *Indian Journal of Pharmaceutical and Biological Research*, 4 (3), 20–27.

Received: 09. 05. 2017.

Accepted: 31. 05. 2017.