EFFECT OF HEATING ON ELECTRICAL IMPEDANCE PARAMETERS OF ACACIA HONEY

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Abstract Processing of honey contains heating procedures. If the temperature is too high during this process, the structure of honey can be changed, and the quality of honey can be reduced. The aim of this work was to answer the question: are the electrical impedance parameters enough sensitive to evince the overheating. Acacia honey of 20 g in plastic box with cover was put into a laboratory oven Venticell for 2 and for 4 hours at 40, 50 and 60 °C. The electrical impedance spectra were measured with precision LCR meter in frequency range from 30 Hz up to 1 MHz before heating and 0, 2, 20, 43, 90, 164, 360 and 523 hours after heating at room temperature. The impedance spectra after open and short correction were approached with distributed circuit element in serial connection with a resistance. The two resistances and the relaxation time of model increased, and the exponent parameter decreased in the whole investigated period. These changes practically were the same after both 2- and 4-hours heating time. Nevertheless, the rate of change increased with increasing the heating temperature after long time storage. These results can be explained with the recrystallization process after heating.

Keywords: honey, heating, electrical impedance

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 et al., 2008, Wijaya et al., 2015). Generally, acacia honey has a pale yellow or even clear colour, with a mild vanilla taste and herbaceous flavour, like liquid glass. The origins of Acacia honey are the black locust and false acacia tree, gathered only from acacia blossoms (Varga, 2006).

To be more specific, the saccharides part mainly contains fructose, glucose, maltose and sucrose, it takes up the most of the honey products, around 80%. The water part, it should be less than 20% of the products. And it also contains 0.1–5% protein, 0.1–2% ash and negligible

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amounts of amino acids, enzymes and vitamins, phenolic antioxidants and some trace minerals (Buba, 2013).

During heat treatment the spoilage microorganisms can be eliminated, and the level of the moisture content is not enough for the fermentation process after heat treatment (Subramanian et al., 2007). The high temperature can decrease the activity of enzymes and the quality of honey. Heat processing can influence the crystallisation tendency of honey, too (Kowalski et al., 2012). On the bases of our earlier experiments the electrical impedance parameters – as resistance and relaxation time – can show the former heating of honey (Vozáry et al., 2018). Nevertheless, the changes of parameters were depended on the time period after heat processing, presumably because of recrystallization process of honey.

The aim of this work is the determination of electrical impedance spectrum of acacia honey as a function of time elapsed after heat processing.

Materials and methods

Acacia honey from Kiskunsági Nemzeti Park was used in thermal processing. In each thermal processing a fresh (unprocessed) sample of 20 g was placed into a plastic box with cover. The box was placed into a laboratory drying oven – Venticell - for heating.

The temperature of the oven was set 40, 50 and 60 °C, respectively and the samples were placed into the oven for 2 hours or 4 hours. After heat treatment, the samples were left to cool for two hours at room temperature and they were stored at room temperature up to electrical impedance measurements. Electrical impedance spectrum of various honey samples was determined at room temperature before heating and after heating when the sample was cooled down for room temperature and after 2, 20, 43, 90, 164, 360 and 500 hours storage time. For all hear treatments and for all storage time there were measured three samples and one sample was measured three times after each other.

The magnitude and the phase angle of impedance were determined in frequency range from 30 Hz up to 1 MHz with a HP 4284A precision LCR meter. Two Ag/AgCl electrodes (World Precise Instrument) one cm away from each other were inserted into the honey in 1 cm deep and the voltage between the two electrodes was 1 V. The measured spectra were open and short corrected – according to HP method – for eliminating the stray capacitance and inductance. The open and short corrected spectra were approached with a model consisting of serial connection of a resistance and a distributed element (Grimnes,and Martinsen, 2008):

$$, \qquad (1)$$

where R_0 and R are resistances, i is the imaginary unit, πf is the angular frequency, f is the measuring frequency, τ is a relaxation time and ψ is an exponent. The model parameters were determined with the Solver function of Excel program. For all heat processing and storage time the nine measured spectra were approached, and the nine parameters were averaged, and the standard deviation was calculated.

Results

The all measured impedance spectra of honey samples were approached with the model circuit (1) and the model parameters – R_0, R, τ and ψ - were determined. Generally, the measured honey impedance spectra were similar to a typical open-short corrected impedance magnitude and phase angle spectrum on the Fig.1A. The representation of this spectrum with its approaching curve on the complex plane can be seen on the Fig.1B.

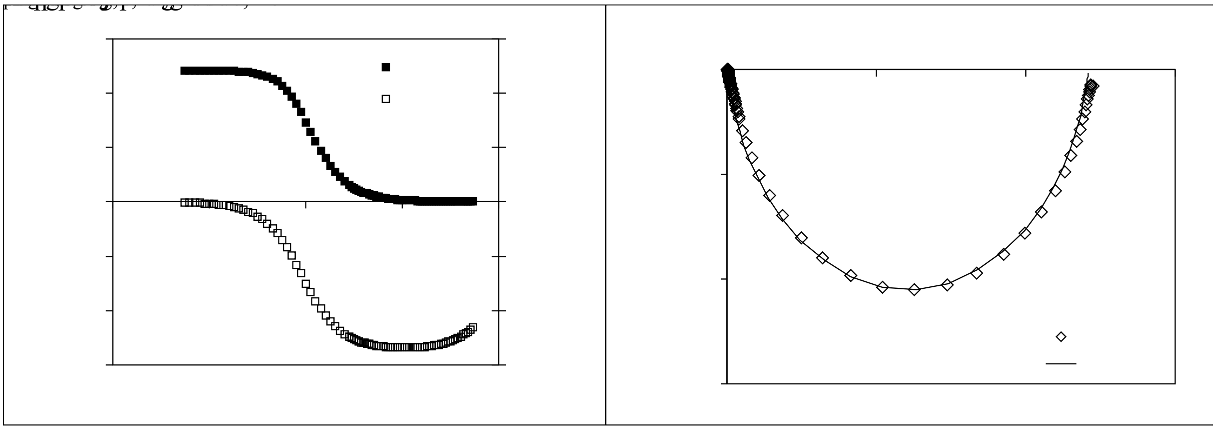

Figure 1. A typical (first measurement of a control sample) measured impedance magnitude and phase angle spectrum after open-short correction (A). Representation of this spectrum on the complex plane with the approaching curve (B).

The value of R_0 parameter practically was remained constant for all heating and for all storage time. Its fluctuation was not higher than 10-15 % of the average (not shown).

The R parameter showed a slight decrease after immediately cooling down (on Fig.2, Fig.3 and Fig.4 the R parameter at zero storage time). However, the storage time is increased, the R value increased at first slightly and then faster after two-three weeks storage. The the initial growth will gradually become slower as the heat treatment temperature increases.

The changes of relaxation time parameter, τ, is very similar to the changes of R parameter (Fig.2, Fig.3 and Fig.4 the tau parameter).

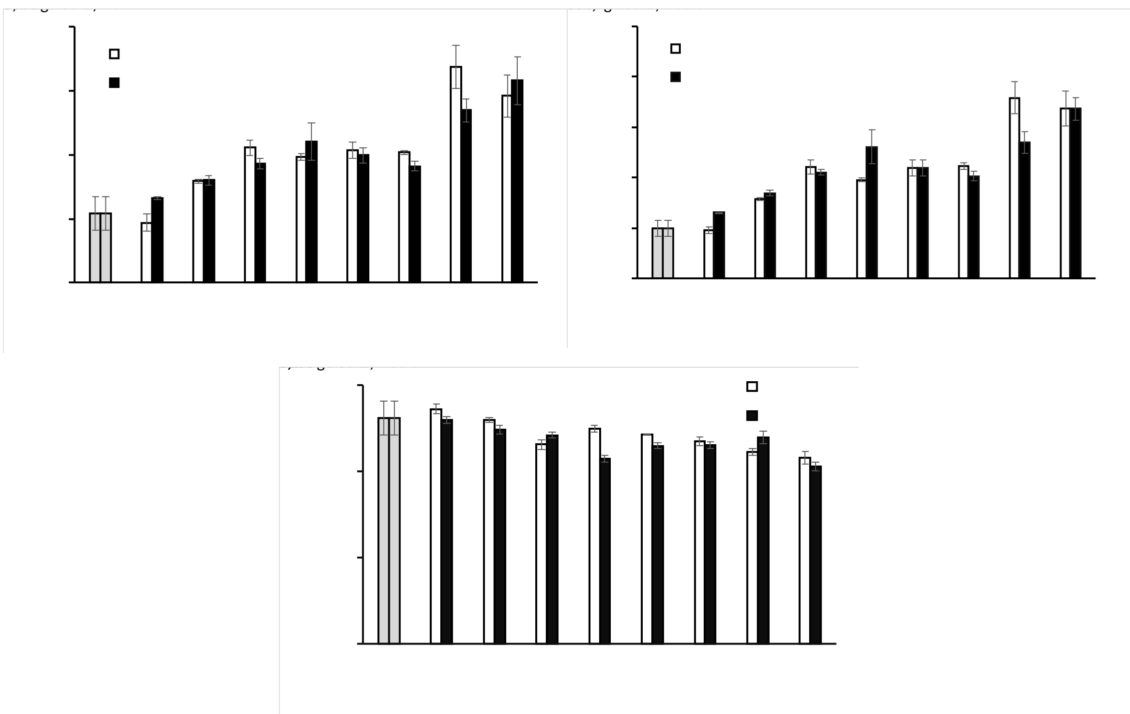

Figure 2. The resistance (R), the relaxation time (τ) and the exponent (ψ) impedance parameters of honey kept at temperature 40°C during 2 and 4 hours as a function of the storage time after heat processing. The average values with standard deviation.

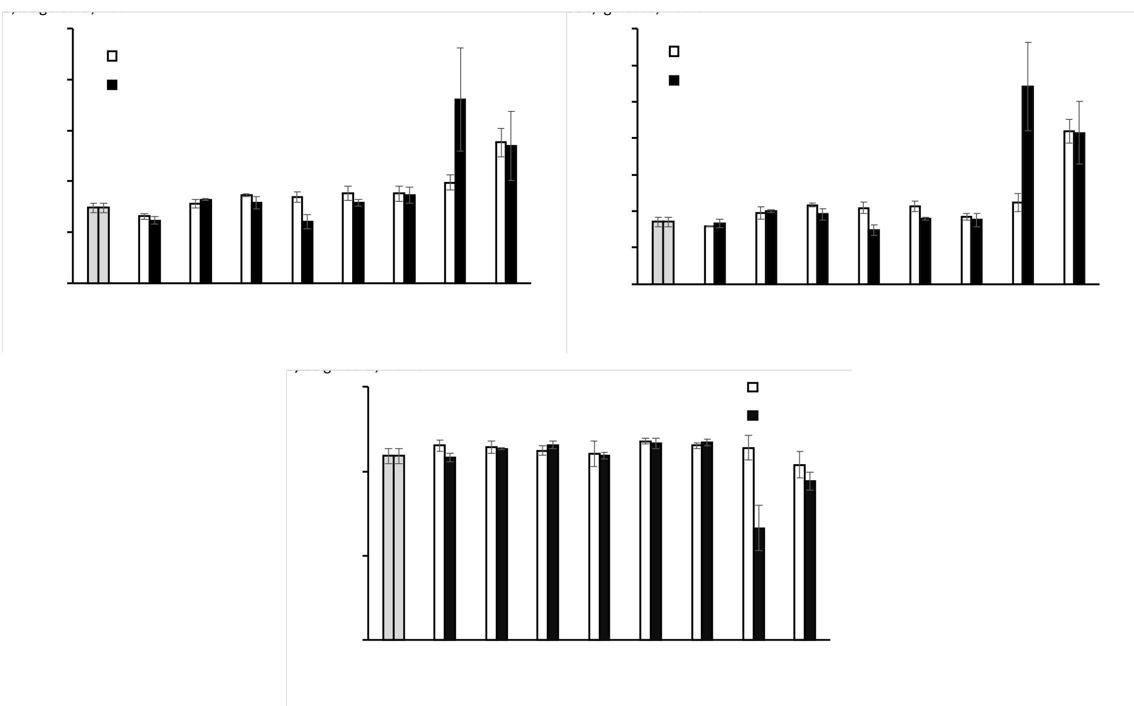

Figure 3. The resistance (R), the relaxation time (τ) and the exponent (ψ) impedance parameters of honey kept at temperature 50°C during 2 and 4 hours as a function of the storage time after heat processing. The average values with standard deviation.

The exponent parameter, ψ, continuously decreased after heating up to 40 °C temperature (Fig.2). This parameter practically remained constant after 50 °C heat treatment (Fig.3) and slightly decreased after two to three weeks storage (Fig.3). After heat processing at 60 °C temperature the exponent practically slightly decreased during the first week storage and significantly decreased in the second and the third week (Fig.4).

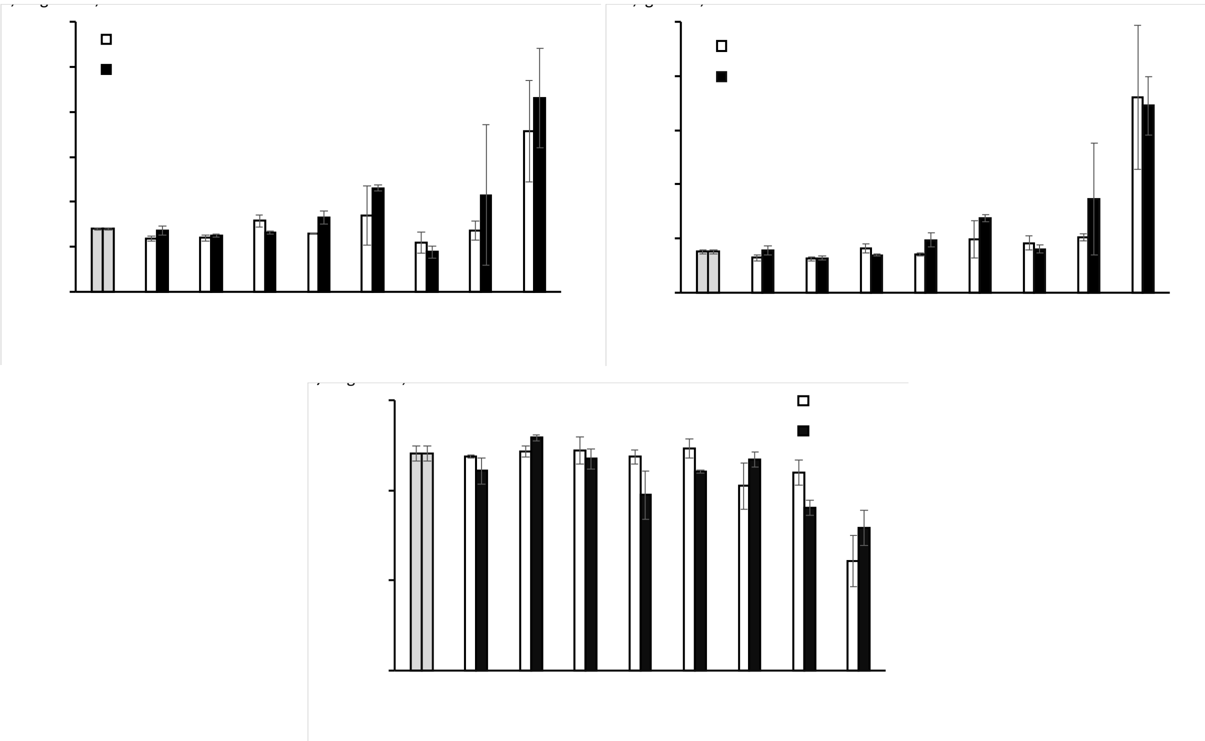

Figure 4. The resistance (R), the relaxation time (τ) and the exponent (ψ) impedance parameters of honey kept at temperature 60°C during 2 and 4 hours as a function of the storage time after heat processing. The average values with standard deviation.

The heating time of two or four hours did not make a significant difference in the parameter values, so the parameters after two- and four-hours heating were averaged and as a function of storage time after heat process were graphically represented (Fig.5).

Both R parameter and τ parameter were increased quicker after heat treatment of 40 °C temperature, than after processing at 50 °C and 60 °C. These parameters reached the highest value after heating up 60 °C and after three weeks storage time. The exponent, ψ, parameter after heating up to 40 °C temperature practically continuously decreased as the storage time increased (Fig.5) and reached the lowest value after highest temperature processing.

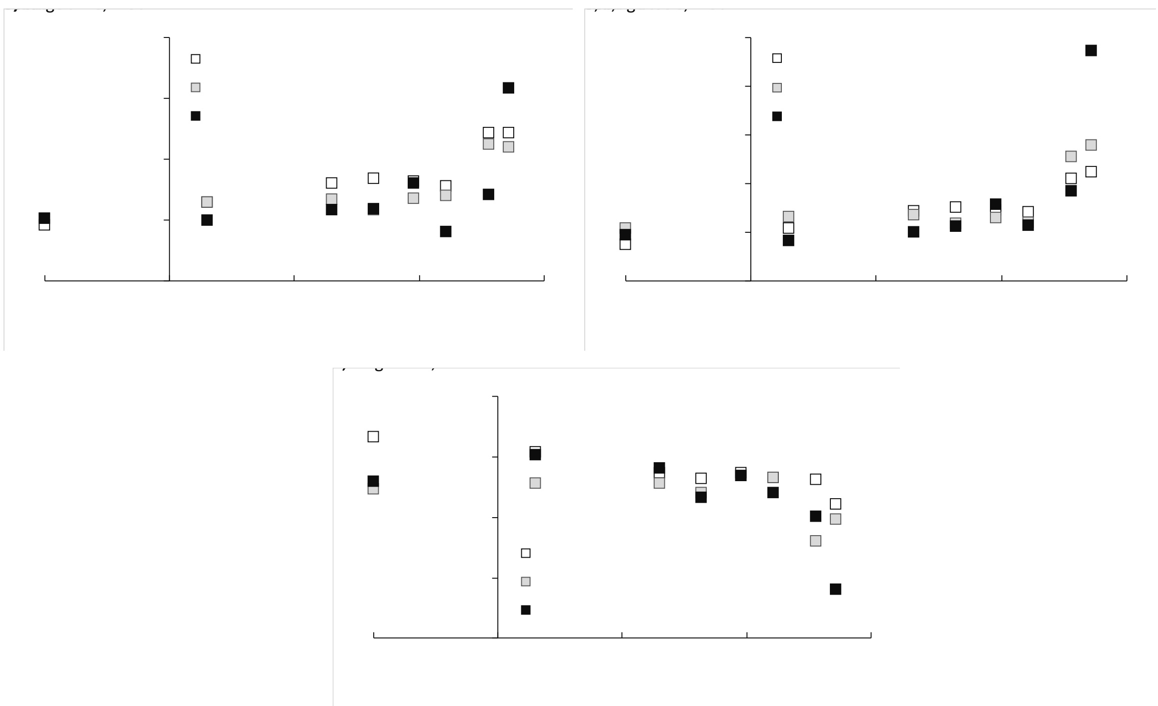

Figure 5. The resistance (R), the relaxation time (τ) and the exponent (ψ) impedance parameters of honey kept at temperature 40 °C, 50 °C and 60°C as a function of the storage time after heat processing

Discussion

The unchanged parameter R_0 can represents the resistance of honey at very high frequency which does not change during the heat treatments.

The decrease of the R and τ parameters immediately after heat treatment can show to the melting of microcrystals in honey. The melting can result charges with high mobility, that is low resistance. The low relaxation time also can give higher polarizability. In the melted crystals the charged groups can freely follow the changes in electric or magnetic field.

During the storage of the honey after the heat treatment the microcrystals begin to re-form and the resistance and the relaxation time increase. The R and τ parameters increase during the storage time. With the formation of new microcrystals, the mobility and the polarizability decrease. It is interesting that the process of increasing of R and τ parameters depend on the temperature of heat treatment. It seems that at lower temperature - at 40 °C -not the all crystals were melted during the heat treatment and the recrystallization is slower. Probably after heat treatment at higher temperature – 50 °C and 60 °C – more microcrystals were melted and during the recrystallisation larger crystals are formed causing higher resistance and lower polarizability.

The decrease in ψ parameter can be explained by an assumption that in the newly formed crystals the order is not as high as in the original crystals.

Conclusions

The results of this work show, that the all the three impedance parameters – R, τ and ψ – can reflect the changes in microcrystal structure of honey caused by heat treatment. These parameters are sensitive to reflection of new structures forming during the storage time after heat processing. The changes of these parameters depend on the temperature of the heating.

References

Buba, F. (2013) Physicochemical and Microbiological Properties of Honey from North East Nigeria. *Biochemistry & Analytical Biochemistry*, *02*(142): 61–67.

Grimnes, S., Martinsen, O.G. (2008) *Bioimpedance and bioelectricity basics*. Elsevier, Amsterdam, New York, London.

Kowalski, S., Lukasiewicz, M., Bednarz, S., & PaNuś, M. (2012) *Diastase Number Changes During Thermal and Microwave Processing of Honey*. *Czech J. Food Sci* (Vol. 30).

Subramanian, R., Umesh Hebbar, H., & Rastogi, N. (2007) Processing of Honey: A Review. *International Journal of Food Properties*, *10*(1): 127–143.

Turhan, I., Tetik, N., Karhan, M., Gurel, F., Reyhan Tavukcuoglu, H. (2008) Quality of honeys influenced by thermal treatment. LWT-*Food Sci. Techn*. 41(8): 1396-1399.

Varga, L. (2006) Effect of acacia (Robinia pseudo-acacia L.) honey on the characteristic microflora of yogurt during refrigerated storage. *International Journal of Food Microbiology*, *108*(2): 272–275

Vozáry, E., Ignácz, K. and Gillay, B. (2018) Dielectrical properties of Hungarian acacia honeys. *Proc. 2nd Int. Conf. Biosystem and Foodengineering* Budapest, Hungary

Wijaya, C. H., Wijaya, W., & Mehta, B. M. (2015) *General Properties of Major Food Components*. *Handbook of Food Chemistry*. Berlin, Heidelberg: Springer Berlin Heidelberg.