Agronomy Research **14**(4), 1293–1299, 2016

Modification of the rheological properties of the honey in the honeycombs prior to its extraction in the production conditions

T. Jehlička[1,*] and J. Sander[2]

[1]Czech University of Life Sciences Prague, Faculty of Engineering, Department of Technological Equipment of Buildings, Kamýcká 129, CZ 16521 Prague 6 – Suchdol, Czech Republic
[2]Czech University of Life Sciences Prague, Faculty of Engineering, Department of Technological Equipment of Buildings, Kamýcká 129, CZ 16521 Prague 6 – Suchdol, Czech Republic
[*]Correspondence: jehlickat@tf.czu.cz

Abstract. This paper addresses the issue of honey extraction in difficult conditions (prevailing cold weather) and the extraction of highly viscous honey from the honeycombs. The objective was to design and validate a technology that will reduce the viscosity of honey in the honeycombs by warming up by infrared radiation and shorten the total time of honey extraction. To verify the proposed procedure three groups of samples of the capped honeycombs were selected that contained honey of different botanical origin and rheological properties. The honeycombs were warmed up to the targeted temperature (from 15 °C to 40 °C). Warming was carried out by two low-temperature emitters of the infrared radiation. The time dependence of honey extraction on the temperature of the pre-heated honeycombs was monitored. The measured values indicate that the dependence of the rheological properties of honey on temperature is technologically significant. Operational monitoring shown that the optimal rheological properties for the processing of the honeycombs are at a temperature above 30 °C as the time necessary for the honeycombs extraction reaches its minimum value. The optimal temperature for the honeycomb extraction can be considered the temperature above 30 °C which corresponds to the extraction time for about 4 minutes. The evaluation of the obtained results demonstrates the operational reliability of the proposed technology. Measurements proved that the infrared radiation is suitable for warming up of the honeycombs, warming up is quick and results in time reduction of honey extraction from honeycombs is dependent on temperature.

Key words: honey, honey extraction, infrared radiation heating, viscosity.

INTRODUCTION

This paper addresses the issue of honey extraction from the capped honeycombs during adverse climatic conditions, obtaining highly viscous or partly crystallized honey. The objective was to verify the possibility of changing the rheological properties of honey in the honeycombs in the production conditions by infrared radiation heating and thus achieve higher productivity and yield of honey during its separation from the honeycombs.

Honey is a sweet substance produced by honey bees from the nectar or honeydew which the bees transform by the secretion of their pharyngeal glands and store in honeycombs. Honey is a liquid which is difficult to process from the technological point of view. It is influenced by the chemical composition and physical properties (Fischer & Windhab, 2011). Technologically significant are the rheological properties of honey. They influence the honey processing technology, i.e honey extraction from the honeycombs, pumping, churning, straining, filtration, mixing and filling honey into consumer packaging (Escriche et al., 2009).

Rheological properties are mostly influenced by the degree of crystallization and the viscosity of honey. The degree of crystallization is dependent on several factors of which the most important is the glucose / fructose ratio and the presence of pollen grains (Escuredo et al., 2014). Honey viscosity is dependent on water content in honey, chemical composition and temperature (Gleiter et al., 2006). Water content and chemical composition of honey is determined by the botanical origin of honey and cannot be changed in the operation conditions for honey processing. It would cause irreversible changes in the quality of honey. Given the fact that some properties (e.g. water content) are at the same time the indicators of product quality their technological change would be in breach of the legislation (Turhan et al., 2008). On the other hand, the influence of temperature change on the viscosity of honey is technologically feasible and is regularly used in practice.

The temperature dependence of honey viscosity is described by the Arrhenius model, this model is also used for sugar syrups or fruit juices (Smanalieva & Senge, 2009). The temperature dependence of viscosity is a logarithmic function - there is a big change in viscosity at low temperature change (Gomez–Diaz et al., 2009). Honey viscosity (regardless the botanical origin) decreases with increasing temperature and such decrease reaches its maximum at a temperature around 40 °C. In the temperature range 10–40 °C viscosity of honey gradually decreases from 100 Pa s to 2 Pa s (Yanniotis et al., 2006). The above values show that the temperature at which the viscosity of honey is low is technologically advantageous for honey extraction from the honeycombs, mixing and other processing procedures.

Technologically, there are several ways to extract honey form the honeycombs. In practice, gravitational force, pressure force or centrifugal force are used for honey extraction. In all cases, the effectiveness and efficiency of the process depend on the rheological properties of honey. Well-established practice is to extract honey by centrifugal force on honey extractors of various constructions. Extraction efficiency is dependent on centrifugal force and the properties of honey. Increasing efficiency by increasing the centrifugal force, i.e. the speed increase and the radius of rotation of the drum of the honey extractor, is limited by the firmness of the wax comb (the risk of damage and contamination of honey by wax). Therefore in the production conditions for honey extraction a change in honey's rheological properties is sometimes used before the uncapping of the honeycombs. It's about the increase of temperature by the conventional warming and thus reducing viscosity, which affects the efficiency and speed of honey extraction (Oroian et al., 2013). This procedure is time consuming and laborious.

The proposed technology solves the problem of reduction in the viscosity of honey by warming up the capped honeycombs by infrared radiation. It is based on the assumption that the infrared radiation warms the honeycombs evenly to a depth of a few millimetres; is faster compared to the conventional heating and is friendly for the honey quality (Hebbar et al., 2003). The goal is to propose and validate a technology that will reduce in adverse climatic conditions the viscosity of honey in honeycombs by heating by infrared radiation, shorten the total time of honey extraction from the honeycombs and increase efficiency, i.e. the total amount of honey extracted. A chamber with infrared radiators was assembled for warming up the honeycombs. For the measurement several samples of the filled honeycombs were selected which contained honey of different rheological properties. It was measured how the temperature of the pre-hated honeycombs impacts the time of honey extraction.

MATERIALS AND METHODS

The following procedure was used to verify the possibility of changing the rheological properties of honey in the honeycombs by warming up by infrared radiation in the operating conditions.

Three groups of samples of the capped honeycombs that contained honey of different botanical origin and came from different periods of honey brood were selected. Thus the requirement of different rheological properties of honey was fulfilled. The honeycombs were warmed up to the targeted temperature (from 15 °C to 40 °C, always by 3 °C). Warming up was carried out always for four honeycombs by two low-temperature emitters of the infrared radiation. Once the target temperature was reached, honey was extracted from the honeycombs on honey extractors with automatic control. The overall time required to extract all the honey from the honeycombs was measured. Honeycombs were extracted to reach the complete extraction of honey (level of such honey extraction from honeycombs was assessed subjectively.) The foregoing measurement was carried out at a bee farm during the summer honey brood.

Honeycombs samples

In order to verify the assumption, three samples of the capped honeycombs were selected. (As used herein, sample means a few tens of capped honeycombs coming from the beehives which were in immediate proximity in the period of honey brood and contained honey of the same chemical composition and the same physical properties). Each sample of the honeycombs came from a different period of honey brood and contained honey of different botanical origin. Thus the assumption that each sample contained honey of different rheological properties was met.

Sample 1: nectar honey, brood period – June.

Sample 2: honeydew honey, brood period – June.

Sample 3: honeydew honey, brood period – July.

Warming up of the honeycombs

A device was created to warm up the honeycombs which consisted of a holder of honeycombs, two low-temperature infrared panels, thermometers and switching regulator controller with a thermostat to adjust the temperature.

Two low-temperature emitters IT AG–600 (Termowell) were used to warm up the honeycombs. Base panel consists of carbon thermocouple equipped on their surface with silicon grains with a white surface finish. Input 600 W, voltage 230 V, frequency 50 Hz, size 1,200 x 600 x 50 mm. The efficiency of electrical energy transformation into heat radiation energy is 92%.

Four honeycombs were always attached to the honeycombs' holder (two and two superimposed). The holder with the fixed honeycombs was placed between two heating surfaces of the infra-panels facing each other. The warming up from both sides was opted in order to achieve a homogeneous temperature field. The distance from the infrared radiation heating to the surface of the honeycomb was set at 0.5 m. Thermometers were inserted to a depth of honeycomb so that the temperature was measured inside of the honeycomb. The targeted temperature was set on the thermostat of the control unit. Once reached, the regulatory control unit switched off both infra-panels and the heating was interrupted.

Honey extraction

Honey extraction from the honeycombs was performed on a commercially produced honey extractor. Honey extractor EWG 4 Comfort of Heinrich Holtermann brand is a four-frame reversible tangential honey extractor with automatic control. During extraction, the control mechanism was adjusted so that the process corresponded to normal operational practice of honey extraction. The tangential reversible honey extractor worked in two phases. The first phase of honey extraction was conducted using low speed rotation (30 min^{-1}) to one and the other side – for 1 minute each. The second phase of honey extraction was conducted using high speed rotation (60 min^{-1}) for one and the other side – for the time necessary to extract all the honey from the honeycomb.

RESULTS AND DISCUSSION

To verify the assumption that the infrared heat radiation can be utilized to change the rheological properties of honey in the operating conditions, the time dependence of honey extraction on the temperature of the pre-heated honeycombs was monitored. Table 1 shows the values measured, i.e. the targeted temperature of the honeycombs and the time required for their complete extraction at the preset temperature.

Table 1. The temperature of the honeycombs and the extraction time

Sample 1 time, min	Sample 2 time, min	Sample 3 time, min	Temperature, °C
10	12	10	15
8	8	10	18
8	8	10	21
6	6	8	24
4	6	6	27
2	4	4	30
2	4	4	33
2	2	4	36
2	2	2	40

Dependence of the measured factors shows Fig. 1. In Fig. 1 the values from Table 1 are laid out in a graph and they are interlaid with a trend connecting line. The curves thus obtained show progress of the time dependence of honey extraction on the temperature of the pre-heated honeycombs. The time figure represents the minimum time of the extraction required to extract all the honey from the honeycombs.

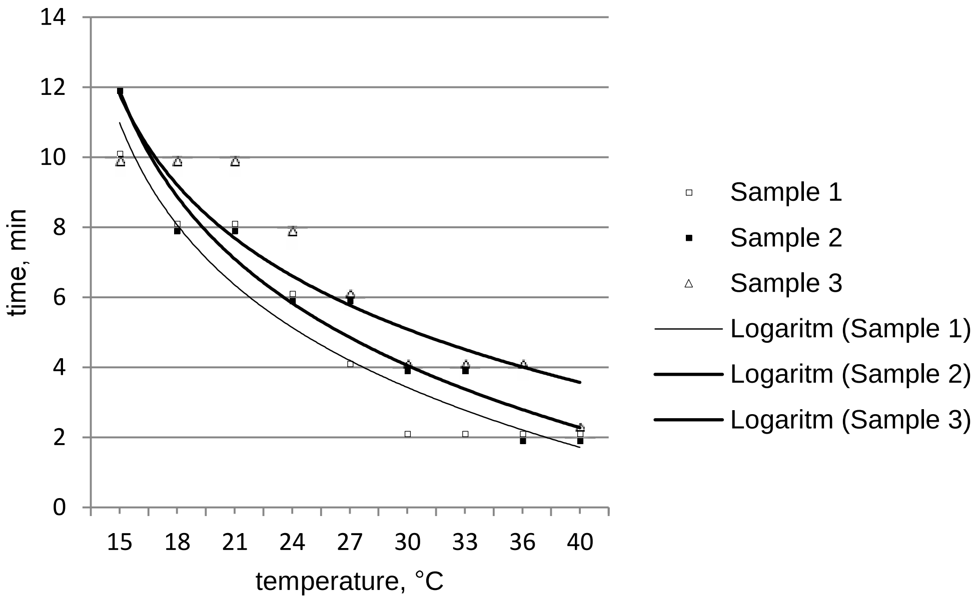

Figure 1. Time dependence of honey extraction on the temperature of honeycombs.

For plotted dependencies of all three samples of the honeycombs was used logarithmic trendline. This one most closely represents the actual time reduction of the extraction depending on the rising temperature. The coefficient of reliability correlation was in all samples around 0.95.

Summing up the above analysis, it is possible to demonstrate that the time required to extract the honeycombs in all samples is directly dependent on the temperature. For all samples, i.e. for nectar and both honeydew honeys, the trendlines of extraction time and temperature are very similar. This demonstrates that the course of dependency is only minimally influenced by the botanical origin of honey, but depends mainly on temperature. Botanical origin of honey, respectively rheological properties of honey defined by its chemical composition impact in all samples only mutual shift of the plotted dependencies, but the course remains the same. As follows from Table 1, and then from Fig. 1, this shift of the set temperature causes the difference of maximum of two minutes to achieve complete honey extraction. The plotted curves indicate that the rheological properties dominantly depend on the temperature and that the botanic origin of honey (chemical composition of honey) is operationally less significant factor.

From a technological point of view, the optimal temperature for the extraction of the honeycombs can be considered a temperature at which the honeycombs are extracted in a short period of time. This is important in terms of process performance, but also in terms of the extent of the honeycombs wax damage. The extraction time is affected by the construction of the honey extractor (radius and speed of the drum) and by rheological properties of honey. The design and setting of the honey extractor was constant during the measurement. Then, the plotted dependencies on Fig. 1 imply that extraction time depends mainly on honey temperature. It reaches its minimum at all observed samples after reaching a temperature of about 30 °C. The optimal temperature for the honeycombs extraction can be considered a temperature above 30 °C, which corresponds to the extraction time of 4 minutes.

Besides an objective assessment of the impact of the honeycombs' warming by infrared radiation on the rheological properties of honey during processing, secondary technological factors were observed. The average time of the warming up to reach the targeted temperature and the extent of damage to the honeycombs wax during the extraction on the honey extractor were observed in indicative terms. Both factors were not monitored objectively, but for reference purposes only. The specific values are not provided because the measurement methodology did not allow the precise detection (due to the thermostatic temperature control of the heating).

The extent of damage of the honeycombs can be indirectly estimated by the amount of wax in the extracted honey. Subjectively, it was observed that at the time of extraction over 6 minutes its presence in the extracted honey increases. Wax pollutes extracted honey. The second interesting operating figure is the warming time by infrared radiation. Infrared radiation penetrates the honeycombs to a depth of a few millimetres. According to the methodology used the warming up was both-sided (honeycombs were placed between two heating surfaces of two infra-panels facing each other). This allowed even and rapid heating of the honeycomb. Warming time from 15 °C to 30 °C was an average of 5 minutes, warming to 40 °C about 8 minutes. When comparing the extraction time and the warming time of the honeycombs it is clear that the warming period of the honeycombs corresponds approximately to the time of their extraction. This is technologically advantageous. The honeycombs can gradually warm up and then extract without unnecessary loss of time. In comparison with the convectional heating at the warming chambers the infrared radiation heating allows to work operatively i.e. to eliminate the long-term warming and work with less honeycombs during the honey extraction procedure.

CONCLUSIONS

Based on the measured values it can be determined that infrared radiation can change the rheological properties of honey and such change can be utilized to increase efficiency and probably also effectiveness of honey extraction technology.

The proposed technology utilizes for warming up two low-temperature emitters of infrared radiation. The honeycombs were placed between two heating surfaces facing each other and warmed up by infrared radiation to the targeted temperature. Warming up from both sides was opted in order to achieve a homogeneous temperature field. Warming time from 15 °C to 30 °C was an average of 5 minutes.

The measured values indicate that regardless of the botanical origin of honey (nectar and both honeydew honey), the dependence of the extraction time on the temperature is very similar in all observed samples. This means that the dependence of the rheological properties of honey on the temperature is technologically significant. The technological significance of the botanical origin of honey affects its rheological properties only minimally. Operational monitoring has shown that the optimal rheological properties for the processing of the honeycombs are at the temperature above 30 °C as the time necessary for the honeycombs extraction reaches its minimum value. The optimal temperature for the honeycomb extraction can be considered the temperature above 30 °C which corresponds to the extraction time for about 4 minutes.

According to the proven results, the possibility of heating the honeycombs by infrared radiation can be assessed as operationally efficient technology. In comparison with the convectional way of heating at the tempering chambers, the use of infrared heating is faster, not space consuming, does not require investment to acquire the tempering chamber and further it can be assumed that it is less energy-intensive.

REFERENCES

Escriche, I., Visquert, M., Juan–Borrás, M. & Fito, P. 2009. Influence of simulated industrial thermal treatments on the volatile fractions of different varieties of honey *Food Chemistry* **112**(2), 329–338.

Escuredo, O., Dobre, I., Fernández–Gonzáles, M. & Seijo, C. 2014. Contribution of botanical origin and sugar composition of honeys on the crystallization phenomenon, *Food Chemistry*, **149**, 84–90.

Fischer, P. & Windhab, E.J. 2011. Rheology of food materials. *Current Opinion in Colloid & Interface Science* **16**(1), 36–40.

Gleiter, R.A., Horn, H. & Isengard, H.D. 2006. Influence of type and state of crystallization on the water activity of honey. *Food Chemistry* **96**(3), 441–445.

Gomez-Diaz, D., Navaza, J.M. & Quintans–Riveiro, L.C. 2009. Effect of temperature on the viscosity of honey. *International Journal of Food Properties* **12**(2), 396–404.

Hebbar, H.U., Nandini, K.E., Lakshmi, M.C. & Subramanian, R. 2003. Microwave and infrared heat processing of honey and its quality. *Food Science and Technology Research* **9**(1), 49–53.

Oroian, M., Amariei, S., Escriche, I. & Gutt, G. 2013. Rheological Aspects of Spanish Honeys. *Food and Bioprocess Technology* **6**(1), 228–241.

Smanalieva, J. & Senge, B. 2009. Analytical and rheological investigations into selected unifloral German honey. *European Food Research and Technology* **229**(1), 107–113.

Turhan, I., Tetik, N., Karhan, M., Gurel, F. & Reyhan Tavukcuoglu, H. 2008. Quality of honeys influenced by thermal treatment. *LWT – Food Science and Technology* **41**(8), 1396–1399.

Yanniotis, S., Skaltsi, S. & Karaburnioti, S. 2006. Effect of moisture content on the viscosity of honey at different temperatures. *Journal of food engineering* **72**(4), 372–377.