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THE USE OF ULTRASONIC METHODS IN THE IDENTIFICATION OF HONEY TYPES

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Key words: ultrasound, identification, honey.

Abstract

The objective of this study was to determine the correlations between the viscosity and temperature of honey and the velocity of ultrasonic wave propagation, and to investigate the use of ultrasonic methods in the identification of different honey types. Within the analyzed temperature range, a significant correlation was found between ultrasound propagation velocity and the viscosity of honey. The results of this experiment suggest that the velocity of ultrasonic wave propagation measured at a temperature of 25°C may be a factor discriminating between different types of honey.

WYKORZYSTANIE METOD ULTRADŹWIĘKOWYCH DO IDENTYFIKACJI RODZAJU MIODU

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Słowa kluczowe: ultradźwięki, identyfikacja, miód.

Abstrakt

Celem pracy było określenie zależności między lepkością miodu i temperaturą a prędkością propagacji fali ultradźwiękowej oraz zbadanie możliwości identyfikacji rodzaju miodu z wykorzystaniem metod ultradźwiękowych. W badanym zakresie zmian temperatury stwierdzono istnienie zależności między prędkością propagacji fali ultradźwiękowej a lepkością miodu. Przeprowadzone badania pozwalają przypuszczać, że wartości prędkości propagacji fali ultradźwiękowej zmierzone w temperaturze 25°C mogą być czynnikiem dyskryminującym badane rodzaje miodu.

Symbols:
A – constant
B – activation energy [kJ mol^{-1}]
R – gas constant R = 8.314 J mol^{-1} K^{-1}
T – temperature [K]
V – velocity of ultrasonic wave propagation [m s^{-1}]
s – distance between heads [m]
t – ultrasonic wave passage time [s]
GE – global approximation error [%]
Ve – empirical value
Vm – modeled value
τ – shear stress [Pa]
γ – shear rate [s^{-1}]
μ – apparent viscosity [Pa s]

Introduction

Honey is a natural food product made by bees from flower nectar and honey-dew. The viscosity of honey is a crucial parameter in the processing and storage of honey. Viscosity is determined by the moisture content of honey, the content and type of sugars and the applied thermal processing method (ABU-JDAYIL et al. 2002).

There are various techniques for determining the viscosity of honey. According to Polish Standard PN-87/A-89291/20, the viscosity of aqueous honey solutions is determined using a Ubbelohde type viscometer. BHANDARI et al. (1999) analyzed the rheological properties of Australian honey with the application of a Brookfield viscometer featuring a spindle rotating with a set speed in the studied sample. YANNIOTIS et al. (2006) determined the viscosity of honey based on a measurement of shear forces in the gap between two coaxial cylinders. A similar technique involving a rotational viscometer and concentric cylinders was used for measuring the viscosity of honey by LAZARIDOU et al. (2004). STEFFE (1996) presented the results of honey viscosity measurements with the use of a falling sphere viscometer.

Ultrasound is increasingly often used in food tests as a nondestructive carrier of information about the analyzed material. In a series of experiments performed by MIZRACH, the velocity of ultrasonic wave propagation was correlated with changes in the physical and chemical properties of ripening fruit and vegetables. The experimental material comprised avocados (MIZRACH 2000), plums (MIZRACH 2004) and tomatoes (MIZRACH 2007). LLULL et al. (2002) used ultrasound to evaluate the share of various fractions in meat stuffing. Ultrasound is also applied to test food liquids. AY et al. (1994) investigated the process of milk coagulation, and the measured attenuation coefficient was used to estimate process time. By relying on an empirical mathematical model, ZHAO et al. (2003) described the correlations between the viscosity of liquids and wave propagation velocity in the process of diluting orange juice and tomato puree.

Objective

The objective of this study was to determine the correlations between the viscosity and temperature of honey and the velocity of ultrasonic wave propagation, and to investigate the use of ultrasonic methods in the identification of different honey types.

Materials and Methods

The experimental material consisted of oilseed rape honey (H1) and mixed honey (H2) comprising multifloral honey and buckwheat honey at a 1:1 ratio. Honey was harvested in 2004 in a private apiary kept by one of the authors. To reduce the degree of crystallization, the studied honey was stored for 10 hours in an incubator at a temperature of 50°C. The rheological properties of each sample were analyzed using a Haake RheoStress1 rotational rheometer with a cone and plate system with a diameter of 35 mm and an angle of 2°. Honey samples were subjected to shear force with shear rate $\dot{\gamma}$ of 0 to 300 s^{-1} for 180s. Measurements were performed at four honey temperatures: 25°C, 28°C, 33°C and 39°C, using a Haake DC 50 heating circulator with a water bath. The viscosity of the analyzed substances was determined using Newton's model:

$$\tau = \mu \cdot \dot{\gamma} \tag{1}$$

The application of the Arrhenius equation:

$$\mu = A \cdot e^{\frac{B}{R \cdot T}} \tag{2}$$

supported the determination of correlations between the studied samples' viscosity and temperature.

Acoustic measurements were performed using a PC equipped with the UMT-12 ultrasonic defectoscope card. Two longitudinal wave heads with a frequency of 2 MHz were applied. The heads operated in the wave transmission system, and the distance between their frontal surfaces reached 10.38 ± 0.01 mm. The time of wave passage through the analyzed material was measured when honey was cooled within the temperature range of 25 ÷ 45°C. The velocity of wave propagation was determined based on the below dependency:

$$V = \frac{s}{t} \tag{3}$$

The time of wave passage through the material was measured within an accuracy of 0.014 μs. The distance between the frontal surfaces of ultrasound heads was determined within an accuracy of 0.01 mm. The above data were used to determine the maximum measurement error which reached ± 4.4 m s^{-1}.

The goodness of fit between the model and measuring points was evaluated with the use of the global approximation error:

$$BG = \sqrt{\frac{\sum_{i=1}^{n}(We_i - Wm_i)^2}{n}} \cdot 100 \tag{4}$$

Results and Discussion

The dynamic viscosity of honey was determined using Newton's fluid flow model (1) based on flow curves. Flow curves and fluid flow models are exemplified in Figure 1. In all cases, minor deviations of measuring points from a straight line could point to the presence of undissolved sugar crystals. The viscosity values produced by the applied model are presented in Table 1.

Table 1

Viscosity values determined based on Newton's model

Honey H1			Honey H2		
Temperature [°C]	Viscosity [Pa s]	GE [%]	Temperature [°C]	Viscosity [Pa s]	GE [%]
25.2	6.6	1.5	25.3	5.3	1.7
28.3	5.1	1.5	28.4	4.8	4.6
32.2	3.7	3.7	31.7	3.5	1.4
36.2	2.8	1.4	36.2	3.0	1.5

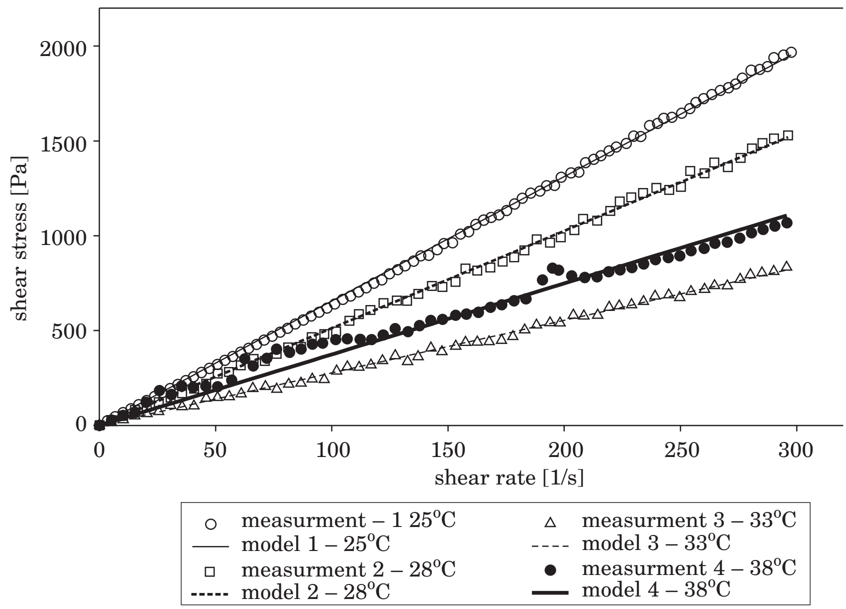

Fig. 1. Honey flow curves – experimental and model values (Newton's model [1])

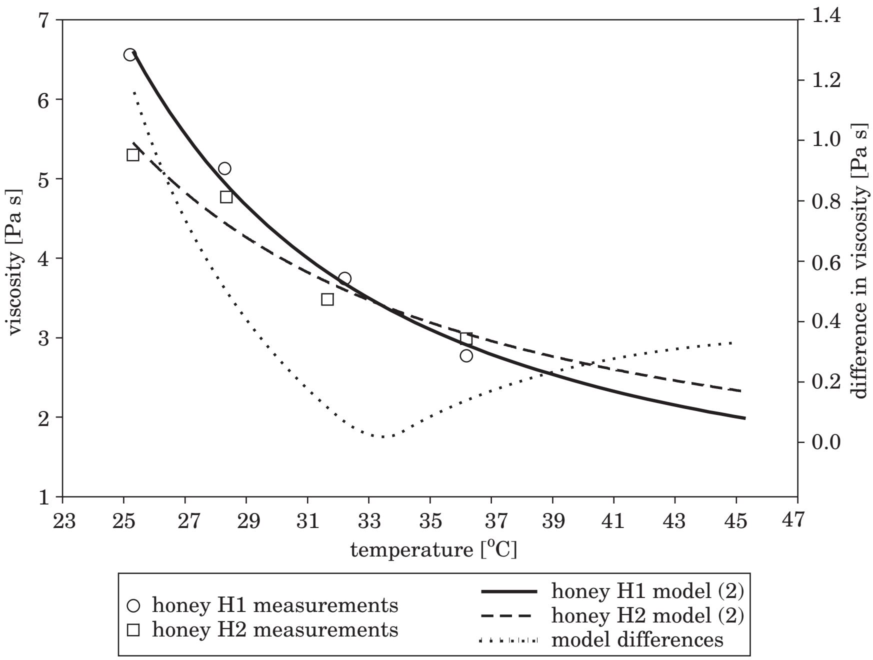

Fig. 2. The viscosity of honey as a function of temperature

The correlations between the viscosity of honey and temperature, based on experimental data and the Arrhenius-Guzman model (2), are presented in Figure 2. Although flow curves were plotted at the maximum temperature of 36.2°C, the results were extrapolated to 45°C to ensure that the temperature range is consistent with the range of ultrasonic measurements. The values of model coefficients and global approximation errors are presented in Table 2.

Table 2
Model coefficients based on the Arrhenius--Guzman equation

A	B	GE[%]
Honey H1		
0.434	572.8	2.1
Honey H2		
0.788	407.0	5.4

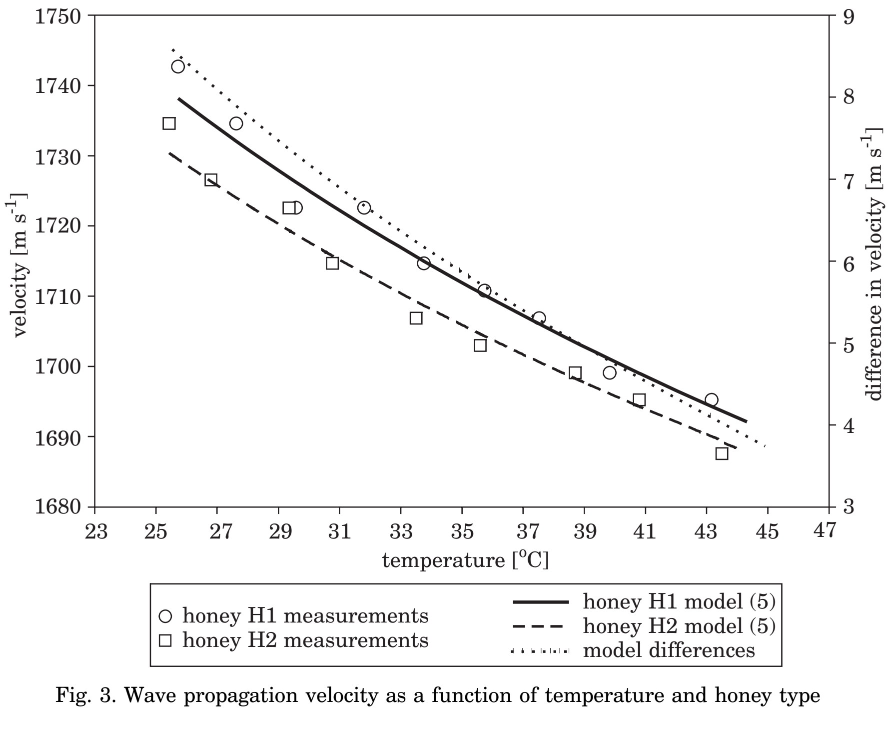

Fig. 3. Wave propagation velocity as a function of temperature and honey type

The noticeable difference in curve shapes and the values of constants A and B in the model probably resulted from variations in the composition of the studied honey due to its different origins. The modeled differences in the viscosity of honey H1 and H2 within the temperature range of 25 to 31°C reached 1.1 to 0.2 Pa s. The above differences suggest that viscosity (within the studied temperature range) could be a factor discriminating between different types of honey.

Based on ultrasonic measurements of wave propagation velocity (V) and temperature (T), a diagram illustrating the correlations between wave velocity and material temperature was developed (Fig. 3). The investigated dependency was modeled using equation (5):

$$V = c \cdot T^{d} \tag{5}$$

The estimated values of model coefficients are presented in Table 3.

Table 3
Model coefficients describing changes in wave propagation velocity as a function of temperature

c	d	GE[%]
Honey H1		
2040.3	-0.0494	0.122
Honey H2		
1998.9	-0.0446	0.111

Within the studied temperature range, the differences between the modeled wave velocity values were insignificantly below the maximum measurement error. Maximum measurement error values are unlikely to be attained, therefore, it can be assumed that significant differences in wave propagation velocity are observed at the lowest temperatures.

Conclusions

Significant correlations between the velocity of ultrasonic wave propagation and the viscosity of honey were determined within the analyzed temperature range. The results of this study suggest that if the difference in the viscosity of honey analyzed at a temperature of 25°C reaches approximately 1.1 Pa s, viscosity could be a factor discriminating between various types of honey.

The accuracy of the applied method could be improved (due to minimizing the error in velocity measurements) by increasing the distance between heads, but this approach would require larger quantities of experimental material.

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