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BASIC THERMAL PARAMETERS OF SELECTED FOODS AND FOOD RAW MATERIALS

Monika Božiková[1], Ľubomír Híreš[1], Michal Valach[1], Martin Malínek[1], Jan Mareček[2]

[1]Department of Physics, Faculty of Engineering, University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76, Nitra, Slovakia
[2]Department of Agricultural, Food and Environmental Engineering, Faculty of AgriSciences, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic

Abstract

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In general, processing and manipulation with foods and food raw materials have significant influence on their physical properties. The article is focused on thermophysical parameters measurement of selected foods and food raw materials. There were examined thermal conductivity and thermal diffusivity of selected materials. For detection of thermal parameters was used instrument Isomet 2104, which principle of measurement is based on transient methods. In text are presented summary results of thermal parameters measurement for various foods and food raw materials as: granular materials – corn flour and wheat flour; fruits, vegetables and fruit products – grated apple, dried apple and apple juice; liquid materials – milk, beer etc. Measurements were performed in two temperature ranges according to the character of examined material. From graphical relations of thermophysical parameter is evident, that thermal conductivity and diffusivity increases with temperature and moisture content linearly, only for granular materials were obtained non-linear dependencies. Results shows, that foods and food raw materials have different thermal properties, which are influenced by their type, structure, chemical and physical properties. From presented results is evident, that basic thermal parameters are important for material quality detection in food industry.

Keywords: thermal conductivity, thermal diffusivity, liquid materials, vegetables, fruits, flours

INTRODUCTION

For food industry is very important to protect high quality during processing of biological materials to final food products (Vozárová, 2007). According authors Kubík, Kažimírová (2015) and Kumbár – Strnková – Nedomová *et al.* (2015) food materials have complicated structure, which is main reason of great variability of their chemical, biological and physical properties. The basic task of food industry research is to know mechanical and thermophysiacal parameters because these are changed continuously during processing and manipulation (Blahovec, 1993). Food raw materials and food products are heated, cooled, dried, moisturised or they have mechanical manipulation, so it is necessary to know their thermophysical properties to choose optimal technological procedure.

Nowadays we know many methods and techniques of physical parameters measurement (Tye, 1991) Materials research and the rapid industrial development create a demand for experimental methods that give reliable data of the thermophysical properties of materials in a short time. Great number of experimental techniques has appeared in literature so far (Wechsler, 1992, Davis, 1984). The methods differ in basic principles of measurement; in number of thermophysical properties they allow to estimate simultaneously; they distinguish in suitability to test different materials and under various experimental conditions (Kubičár – Boháč, 1997). But in national standards are usually used transient methods. Transient methods represent a large group of techniques where measuring probes, i.e. the heat source and the thermometer, are placed inside the specimen (Maglić – Cezairliyan – Peletsky, 1992). This experimental arrangement suppresses the sample surface influence on the measuring process. The temperature of the specimen is stabilized and made uniform. Then the dynamic heat flow in the form of a pulse or step-wise function is generated inside the specimen. From the temperature response to this small disturbance, the thermophysical parameters of the sample can be calculated (Wakeham – Nagashima – Sengers, 1991).

MATERIALS AND METHODS

In our cause for detection of food materials thermal properties was used instrument Isomet 2104. Measurement with Isomet 2104 is based on the transient method principle. This instrument is used for quick and exact thermophysical parameters measurement of liquid, solid and bulk materials. We can use Isomet for measurement of thermophysical parameters as temperature, thermal conductivity, thermal diffusivity and volume specific heat. We used Isomet for measurements of thermal conductivity and thermal diffusivity of selected food products. We made relations of thermal conductivity λ, thermal diffusivity α to the temperature and for flours were measured also relations of thermophysical parameters to the moisture content.

The first group of measured samples were flours – sample 1 – corn flour and sample 2 – wheat flour. Measured samples was provided in storage boxes at the temperature from 2 °C to 3 °C and 90 % of the air moisture content during 24 hours before measurement and relations of thermophysical parameters to the temperature were measured during temperature stabilization of samples. For samples heating was used special laboratory heater. Different moisture content of flours was made by natural drying of samples in laboratory settings. All samples of flours were stabilized in room temperature 23 °C during 24 hours before measurements. We measured relations of thermal conductivity λ and thermal diffusivity a to moisture content for corn and wheat flour in range (2–18) % of moisture content.

The second group of measured samples were selected fruits, vegetables and especially there were examined thermal properties of apple products as: grated apple, dried apple and apple juice during temperature stabilisation in the temperature range (6–28) °C.

The third examined group of measured samples were different types of liquids like: beer, wine, juice, lemonade and milk. For all measured samples of liquids were obtained values of thermal conductivity and thermal diffusivity during temperature stabilisation in the temperature range (5–25) °C. Especially for milk samples were also measured relations of thermal parameters to the fat content.

Measured physical properties are described in next part of the text.

Thermal conductivity λ is definite as amount heat that penetrated in time isothermal area unit on temperature gradient unit. Thermal conductivity is related by pressure, temperature and moisture content, at dispersed materials are related by size of fragments, porosity and bulk density. The thermal conductivity characterized ability of material to conveyance heat. Biological materials with different structure have different mechanism of heat transfer (Childers, 1990). Heat transfer is characterized by the Fourier law (1).

$$q = \lambda \, grad \, T \tag{1}$$

q............ heat flow,
λ............ thermal conductivity,
$grad\ T$ ... temperature gradient.

Thermal diffusivity α is characterized as velocity equalisation of temperature in varied points of temperature field. This thermophysical parameter we can acquire from equation (2).

$$a = \frac{\lambda}{c\rho} \tag{2}$$

Where:
c.......specific heat
ρ..... bulk density of material
(Krempaský, 1999).

Thermophysical parameters were measured by instrument Isomet 2104, version made by Co. Applied Precision. It is used for quick and exact measurement of thermophysical parameters of various materials. Measurements were performed with spike probe and also for biological materials with compact, suspensoid and bulk structure was used surface probe with significant measurement range for different kinds of measured samples. Spike robe was inserted into the analyzed material and surface probe was located on the sample. For measurement with surface probe measured samples had cylindrical shape with diameter 63 mm. This diameter is the same like has surface probe. The theoretical description was published in literature (Božiková, 2006). Probe is generating a heat. Time process of temperature that is related by thermophysical parameters of sample is analysed. The process of temperature t in spike probe is define by equation $T(t) = A \ln(t) + B$, where A, B are constants, depending on parameters of sample and its thermal characteristics. Thermophysical parameters can be calculated from the time-temperature characteristics.

Because examined samples of flours have different bulk density and moisture content, we can define these parameters following: Bulk density ρ_S is define as the rate total weight of mass m and total bulk V of granular material (3).

$$\rho_S = \frac{m}{V} \quad (3)$$

Moisture content ω is definite as mass of water contained in biological material divided mass of dry substance of biological material (4).

$$\omega = \frac{m_1 - m_2}{m_2} 100\% \quad (4)$$

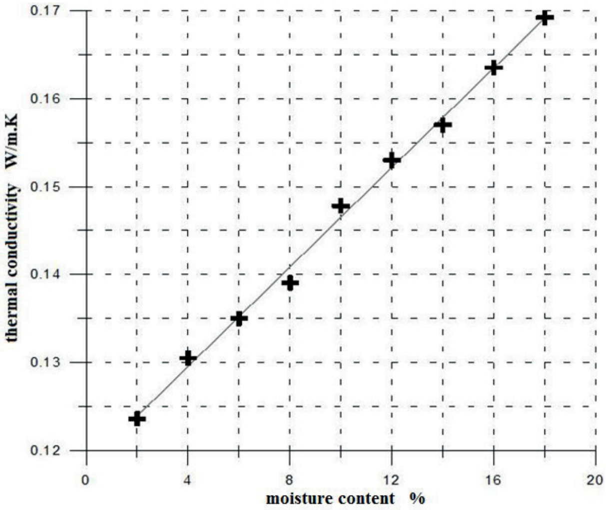
Where ω is the moisture content, m_1 is the mass of moisturised sample and m_2 is the mass of dry substance sample. We measured moisture content with instrument HE 50 Pfeuffer and there was use also standard ISO – STN 126000 (1998) – Basic concepts of food dehydration for control measured values.

RESULTS AND DISCUSSION

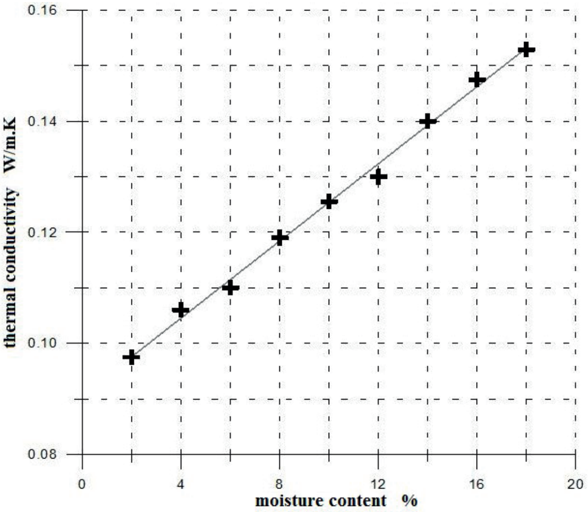
The results for relations of flours thermal conductivity λ and thermal diffusivity a to moisture content in range (2–18) % are showed on Figs. 1–6.

Sample 1 – corn flour had bulk density 510 kg.m^{-3}. Thermal conductivity in range (0.098–0.153) W.m^{-1}.K^{-1} and thermal diffusivity in range (15.1–15.7).10^{-8} m^2.s^{-1}.

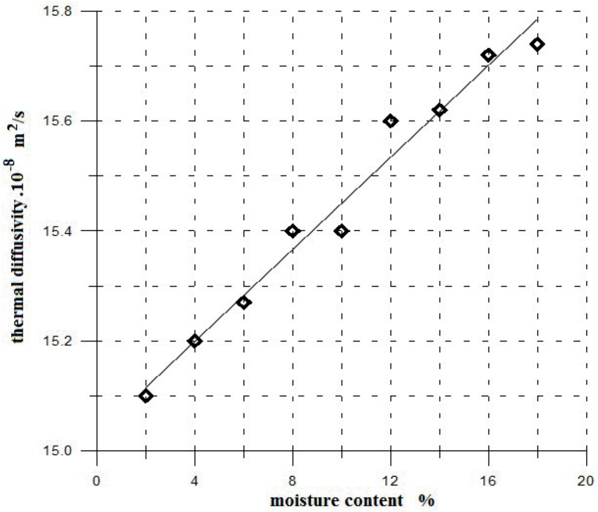
Sample 2 – wheat flour had bulk density 530 kg.m^{-3}. Thermal conductivity in range (0.124–0.169) W.m^{-1}.K^{-1} and thermal diffusivity in range (23.28–24.01).10^{-8} m^2.s^{-1}.



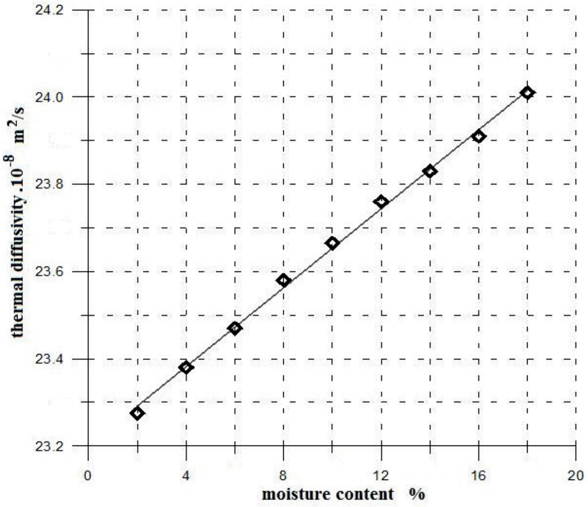
1: *Relation of thermal conductivity λ to moisture content ω for corn flour sample*



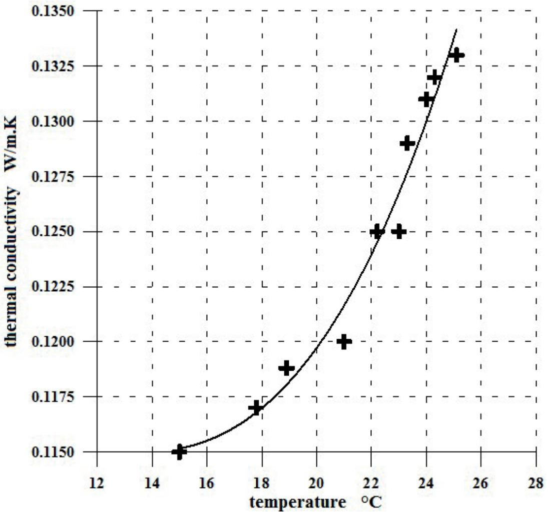
2: *Relation of thermal conductivity λ to moisture content ω for wheat flour sample*



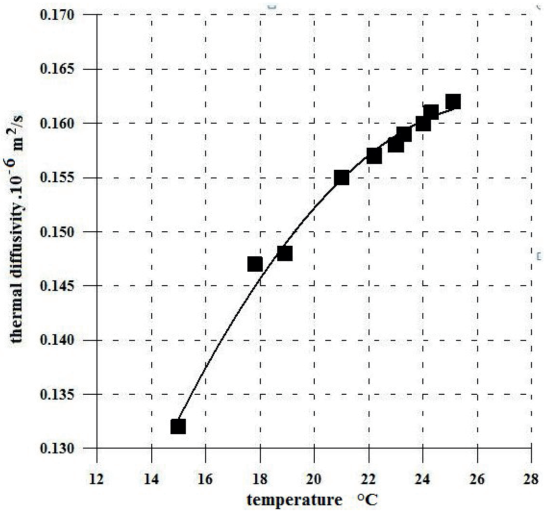
3: *Relation of thermal diffusivity α to moisture content ω for corn flour sample*



4: *Relation of thermal diffusivity α to moisture content ω for wheat flour sample*



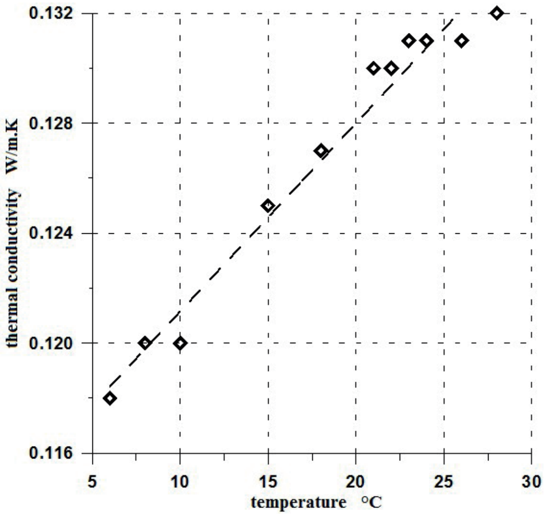
5: *Relation of thermal conductivity of wheat flour to temperature*



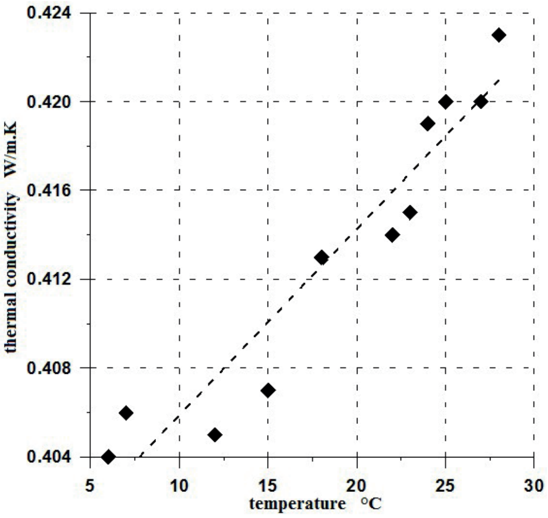
6: *Relation of thermal diffusivity of wheat flour to temperature*

All relations thermal conductivity and thermal diffusivity to moisture content had linear increasing progress for samples of corn flour and wheat flour. The relations between thermal conductivity, thermal diffusivity and temperature had polynomial progress for both measured samples of flour. There were also measured relations between thermal conductivity and thermal diffusivity to bulk density. In both causes they had polynomial decreasing progress for flour samples. From values of thermal conductivity λ and thermal diffusivity a is evident, that different sort of flour had different values of thermal parameters.

In the second series of measurement were measured trermophysical parameters for selected sorts of fruits and vegetables during temperature stabilisation and there were measured thermal parameters of apple products as grated apple, dried apple and apple juice. All obtained values are in great agreement with values presented in literature (Ginzburg *et al.*, 1985). We obtained values of thermal conductivity (Tab. I–III) and thermal diffusivity for samples – fresh apple, grated apple, dried apple and apple juice in temperature range (6–28) °C. Selected graphic relations are shoved on Figs. 7–10.



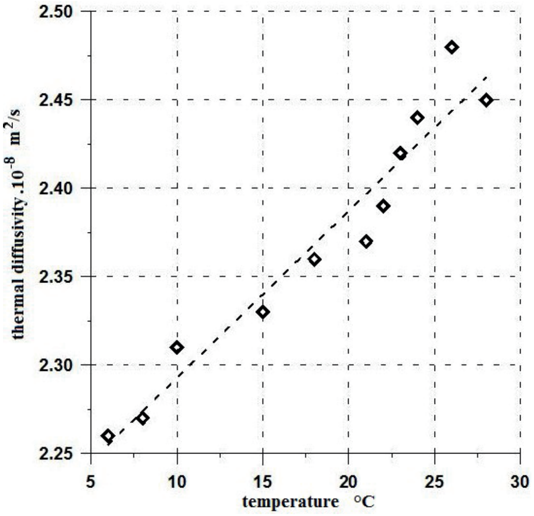
7: *Relation of thermal conductivity during the temperature stabilisation for sample of dried apple*



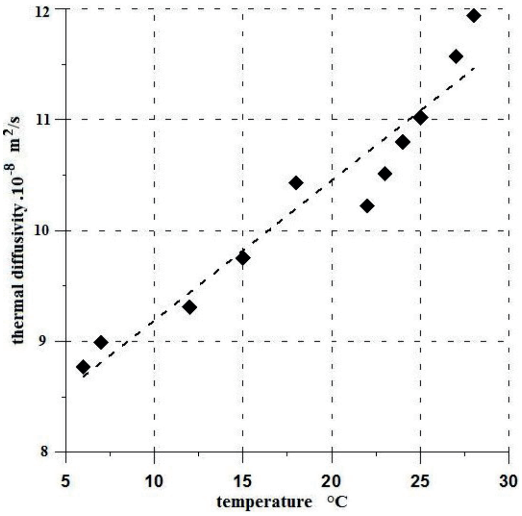
8: *Relation of thermal conductivity during the temperature stabilisation for sample of fresh apple*

I: *Thermal conductivity and diffusivity of dried apple, grated apple and apple juice during temperature stabilization in temperature range (6–28) °C*

Sample	Temperature range	Thermal conductivity [$W.m^{-1}.K^{-1}$]	Thermal diffusivity [$x\ 10^{-8}\ m^2.s^{-1}$]
dried apple	(6–28) °C	0.118–0.132	2.26–2.48
grated apple		0.553–0.575	12.80–13.81
apple juice		0.660–0.642	14.25–14.67



9: *Relation of thermal diffusivity during the temperature stabilisation for sample of dried apple*



10: *Relation of thermal diffusivity during the temperature stabilisation for sample of fresh apple*

II: *Thermal conductivity and diffusivity of selected fruits and vegetables during temperature stabilization in temperature range (6–28) °C*

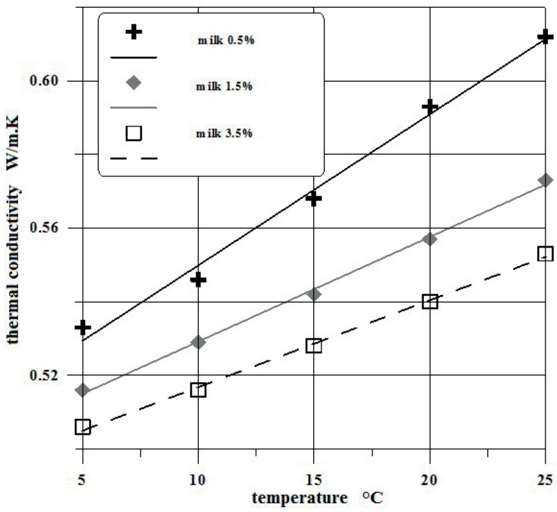
Sample	Temperature range	Thermal conductivity [W.m^{-1}.K^{-1}]	Thermal diffusivity [.10^{-8} m^2.s^{-1}]
Apples – variety Gala	(6–28) °C	0.492–0.525	14.5–14.8
Apples – variety Jonagold		0.514–0.529	15.5–15.8
Pears – I. variety		0.462–0.470	13.4–13.6
Pears – II. variety		0.510–0.524	13.6–13.8
Potatoes – I. variety		0.629–0.631	14.4–14.7
Potatoes – II. variety		0.640–0.652	14.5–14.8
Carrots		0.602–0.611	15.2–15.1

The third examined group of measured samples were different types of liquid food materials. The study of relationships between thermal conductivity, thermal diffusivity and temperature which results are showed on Figs. 7–10 and Tab. I demonstrate linear increasing relations between thermophysical parameters and temperature during temperature stabilization of samples for samples – fresh apple, grated apple, dried apple and apple juice. For data reliability protection there were realized series of measurements for every point in graphics characteristics with number of hundred measurements and results were obtained as valued averages.

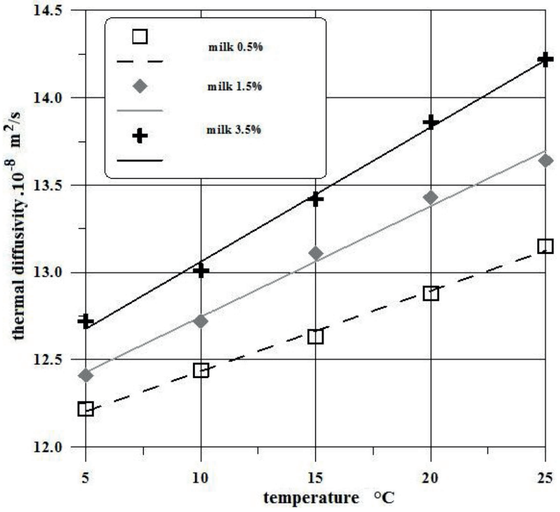
All obtained relations had linear increasing progress and from presented characteristics is evident that temperature and fat content had significant influence to thermophysical parameters. If the fat content increases, then thermal conductivity decreases and thermal diffusivity increases.

III: *Thermal conductivity and diffusivity of selected liquids during temperature stabilization in temperature range (5–25) °C*

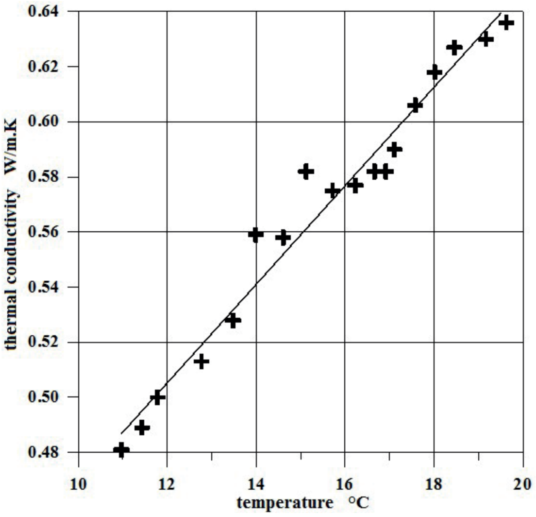
sample	Temperature range	Thermal conductivity range [W/m.K]	Thermal diffusivity range [.10^{-6} m^2/s]	Functional progress	
				λ	a
Alcohol-liquor	(5–25) °C	0.397–0.484	0.452–0.568	linear	linear
orange juice		0.432–0.574	0.130–0.179	linear	polynomial
wine		0.491–0.626	0.457–0.627	linear	linear
beer		0.481–0.636	0.147–0.203	linear	linear



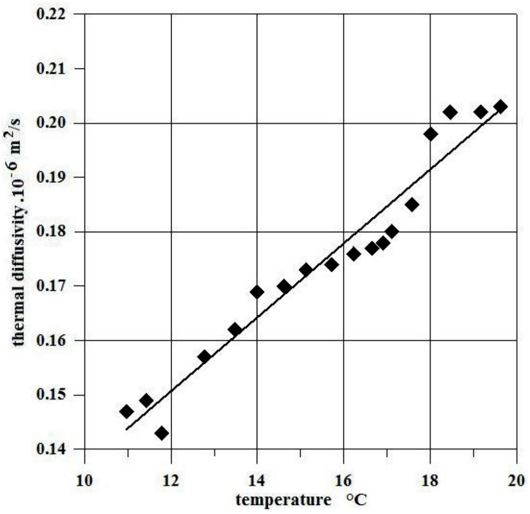
11: *Relations of thermal conductivity to temperature for milk with different relative fat content*



12: *Relations of thermal diffusivity to temperature for milk with different relative fat content*



13: *Relation of thermal conductivity to temperature for beer during the temperature stabilisation*



14: *Relation of thermal diffusivity to temperature for beer during the temperature stabilisation*

CONCLUSION

Summary presentation of measurements results refer to variability of thermophysical parameters during the changes of moisture content and temperature stabilization. Samples with liquid structure were measured by spike probe, granular materials were measured by spike and surface probe and for measurements of materials with compact structure was used surface probe. All results were obtained during the natural temperature stabilization process, because of practical reason. In food processing and storage are food materials exposed to premeditated or casual temperature changes. From obtained values is evident, that high water content and high content of fresh fruit ingredient is cause of non stability of biological materials. Results for granular materials are showed on Figs. 1–6, characteristics for thermal conductivity have linear increasing progress. The graphical characteristics for thermal diffusivity had polynomial progresses. During the measurement there was also found important relation between size of fragments and thermophysical parameters. .

Based on presented results physical parameters and development of physical characteristics can determine condition of food materials, so it is necessary to have knowledge of the dependence between physical parameters of food materials if we need to protect its quality during the manipulation, processing and storage.

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Contact information

Monika Božiková: Monika.Bozikova@uniag.sk
Ľubomír Híreš: Lubomir.Hires@gmail.com
Michal Valach: michalvalach.uniag@gmail.com
Martin Malínek: xmalinek@is.uniag.sk
Jan Mareček: marecekj@mendelu.cz