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Effect of Temperature Changes to Dynamic Viscosity and Thermal Conductivity

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Abstract: *This article deals with thermophysical properties of wheat and malt barley. If we want to protect high standard of agricultural materials quality we need to know physical parameters, which can evaluate the quality. The most important for agricultural materials are mainly mechanical and thermophysical parameters, which can determine the state of material. The contribution presents results from thermophysical parameters measurements of granular samples during the temperature stabilisation and also relations of thermal parameters and moisture content for wheat and malt barley. For our measurements was used Extended Dynamic Plane Source method (EDPS) which is classified as transient methods. The results of measurement show that temperature and moisture content have significant influence on thermophysical parameters of granular material.*

Keywords: *dynamic viscosity, thermal conductivity, temperature, biooil*

INTRODUCTION

This article deals with thermophysical properties of granary mass. Biological materials have complicated structure. This structure is a reason of great variability of their chemical, biological and physical properties (Vozárová, 2007). During processing of biological materials (specifically granary materials) they are heated, cooled, dried, moisturised or they have mechanical manipulation, so it is necessary to know physical, especially thermophysical properties of granary materials to choose optimal technological procedures.

Granular mass is composed as complex of specific varieties of grains. It is non - uniform material in microscopic and macroscopic structure. Biophysical and physiological processes are realised within grains. Heat transfer can not be isolated from the solid transfer and from the heat – moisture transfer (Božiková, 2003). It means that specification of granular mass is difficult to determine. It was the main reason to observe thermal parameters of selected granary samples.

MATERIALS AND METHOD

We measured relations of thermal conductivity λ and thermal diffusivity a to the temperature for wheat and malt barley. Samples were stabilised in special cooling box, before the measurement all samples were examined in temperature range (2 – 20) ºC and their moisture content was 6.5 %. Basic parameters of samples during harvest are presented in table 1.

Table 1 Moisture content (ω) and bulk density (ρ) during the harvest

Sample (Date of harvest)	**ω, %**	**ρ, kg.m^{-3}**
Wheat № 1 10.7.2014, Locality – Nové Zámky	9.26	792
Wheat № 2, 13.7.2014, Locality – Nové Zámky	7.61	801
Malt barley № 1, 18.7.2014, Locality - Galanta	7.63	656
Malt barley № 2, 17.7.2014, Locality - Galanta	8.11	668

For detection of thermal conductivity and thermal diffusivity was used Extended Dynamic Plane Source (EDPS) method. This dynamic transient method is described in following text.

We need two identical samples of measured material which have disc form and two metal blocks with sufficient geometrically size. Theory expects these experimental conditions:

- ideal thermal source,
- ideal contact between source and measured sample,
- zero thermal resistance between surface of measured sample and contact material,
- zero thermal losses from flank of sample (Liang, 1995; Assael – Wakeham, 1992).

Thermal source is located between two identical samples with thickness L. In time *t=0 s* thermal source starts affect with constant thermal power *q* on unit area, than we can express relation of temperature to time by equation (1) :

$$\Delta T(x,t) = \frac{qL}{\lambda\sqrt{\pi}}\sqrt{\frac{t}{\Theta}}\left[1 + 2\sqrt{\pi}\sum_{n=1}^{\infty}\beta^n ierfc\left(n\sqrt{\frac{\Theta}{t}}\right)\right], \qquad (1)$$

where:

$$\beta = \frac{\frac{\lambda}{\sqrt{a}} - \frac{\lambda_M}{\sqrt{a_M}}}{\frac{\lambda}{\sqrt{a}} + \frac{\lambda_M}{\sqrt{a_M}}}, \qquad (2)$$

$$\Theta = \frac{L^2}{a}, \qquad (3)$$

and: Θ - is characteristic time defined by equation (3),

a - is thermal diffusivity of measured sample,

a_M - is thermal conductivity of metal blocks,

β – parameter defined by equation (2) describes the heat sink imperfection,

ierfc - is error function integral for short time $t < 0{,}3\Theta$ equation (1) have simplified form (4) (Beck – Arnold, 2003)

$$\Delta T(x,t) = \frac{q\sqrt{a}}{\lambda\sqrt{\pi}}\sqrt{t} \qquad (4)$$

The principle of method resides in fitting of the theoretical temperature function given by (1) over the experimental points. In case of the best fit, both parameters λ and *a* can be determined. The method of fitting based on least-squares procedure was described in detail (Karawacki at all, 1992).

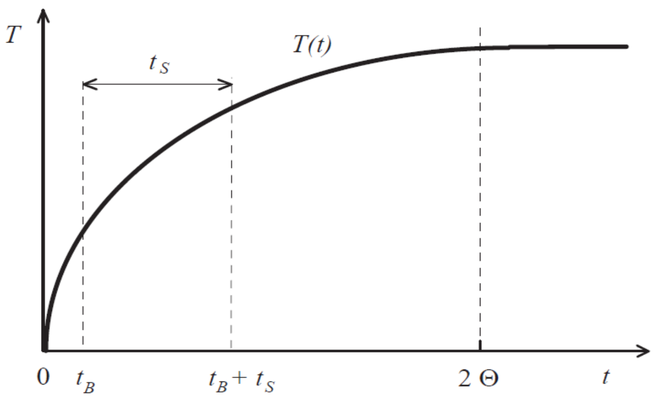


Fig. 1 Temperature function – temperature increase as a function of time (Labudová – Vozár – Malinarič, 2000)

RESULTS AND DISCUSSION

All measured samples were provided in laboratory storage boxes at the temperature 5°C during 24 hours before measurement and measurements were made in laboratory settings.

At the 1st series of measurements were detected the relations of thermal conductivity and thermal diffusivity to the temperature during temperature stabilization in temperature range (2 - 20) °C for wheat and malt barley samples. The moisture content of samples during the measurements was at the same level 6.5 % stored in special containers. Obtained results are presented on Fig. 2 - 5.

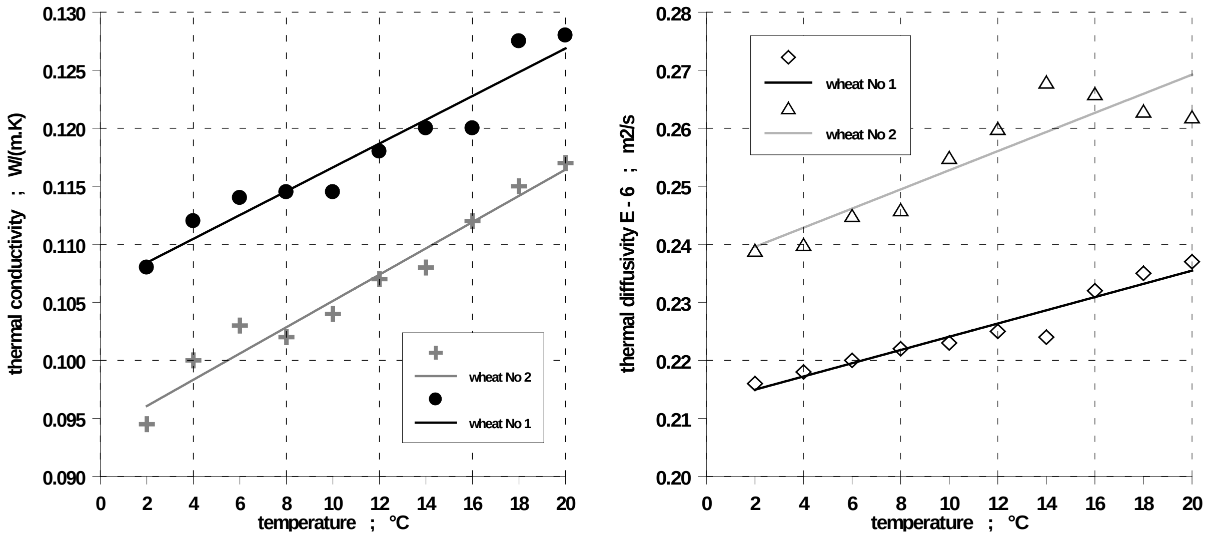
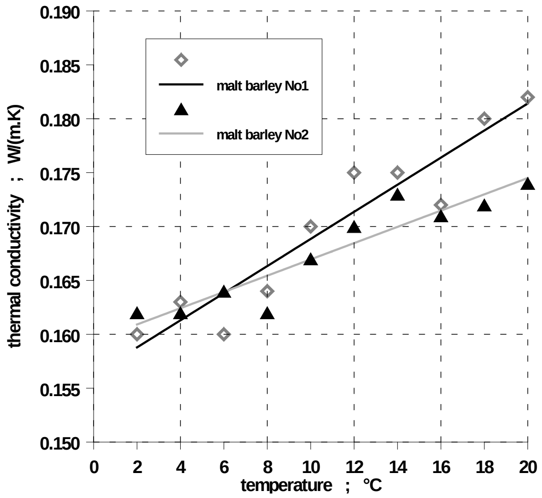


Fig. 2 and **3** Relations of thermal conductivity and thermal diffusivity to temperature for samples of wheat № 1 and № 2

For measured samples were obtained values summarized in the following text:

- wheat sample № 1 had bulk density 792 $kg.m^{-3}$ and thermal conductivity in range (0.106 - 0.127) $W.m^{-1}.K^{-1}$ and thermal diffusivity in range (0.241 - 0.267).10^{-8} $m^2.s^{-1}$.
- wheat sample № 2 had bulk density 801 $kg.m^{-3}$ and thermal conductivity in range (0.095-0.116) $W.m^{-1}.K^{-1}$ and thermal diffusivity in range (0.216 - 0.238).10^{-8} $m^2.s^{-1}$.
- malt barley № 1 had bulk density 656 $kg.m^{-3}$ and thermal conductivity in range (0.161 - 0.182) $W.m^{-1}.K^{-1}$ and thermal diffusivity in range (0.162-0.176).10^{-8} $m^2.s^{-1}$.
- malt barley № 2 had bulk density 668 $kg.m^{-3}$ and thermal conductivity in range (0.161-0.174) $W.m^{-1}.K^{-1}$ and thermal diffusivity in range (0.160- 0.175).10^{-8} $m^2.s^{-1}$.

In the 2nd series of measurements were detected relation between thermal parameters and moisture content, because the moisture content is one of the most important parameter which determines thermophysical parameters of biological materials. The moisture content of measured samples was in range (2 - 18) %. Moisture content was measured by instrument HE 50 Pfeuffer and we also used gravimetric measurement method of moisture content according to standards STN 12600. All samples were stabilised in room temperature 20 ºC during 24 hours before the measurements in special laboratory glass box. Samples had moisture content in range (2 - 18) %. Because the natural moisture content of samples was 6.5 % and we needed moisture content in range (2 - 18) %, so we had to use drying and moisturising for preparation of measured samples.



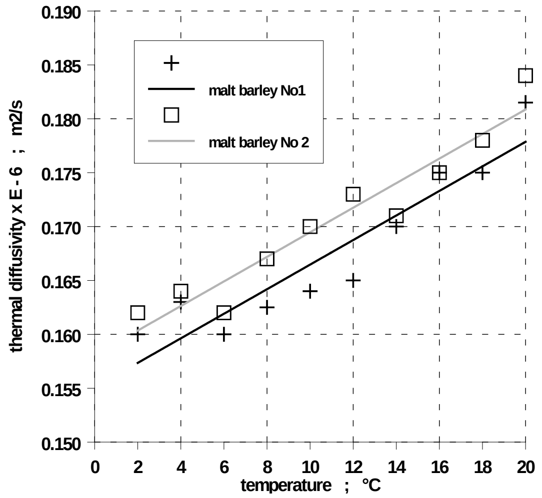
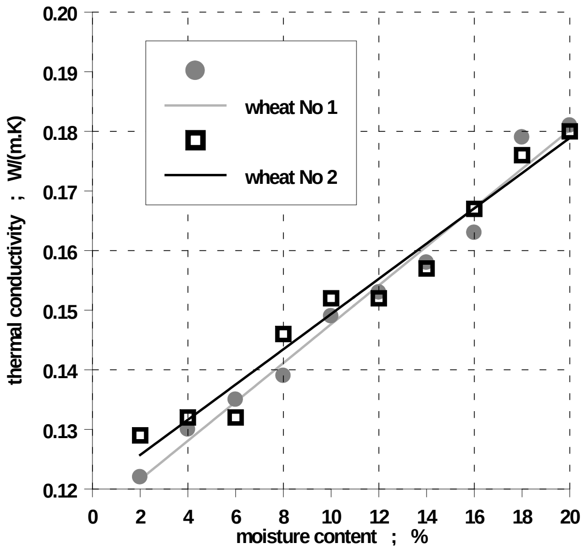


Fig. 4 and **5** Relations of thermal conductivity and thermal diffusivity to temperature for samples of malt barley № 1 and № 2

All experiments at 2nd series of measurements were made in laboratory settings. For wheat and malt barley were observed next results:

- wheat sample № 1 had bulk density 792 kg.m^{-3}, temperature 20 ºC, thermal conductivity in range (0.122 - 0.180) W.m^{-1}.K^{-1} and thermal diffusivity in range (0.233 - 0.241).10^{-8} m^{2}.s^{-1}.
- wheat sample № 2 had bulk density 801 kg.m^{-3} and thermal conductivity in range (0.129 - 0.178) W.m^{-1}.K^{-1} and thermal diffusivity in range (0.233-0.241).10^{-8} m^{2}.s^{-1}.
- Malt barley № 1 had bulk density 656 kg.m^{-3} and thermal conductivity in range (0.099 - 0.160) W.m^{-1}.K^{-1} and thermal diffusivity in range (0.161-0.1697).10^{-8} m^{2}.s^{-1}.
- Malt barley № 2 had bulk density 668 kg.m^{-3} and thermal conductivity in range (0.128-0.180) W.m^{-1}.K^{-1} and thermal diffusivity in range (0.162-0.169).10^{-8} m^{2}.s^{-1}.



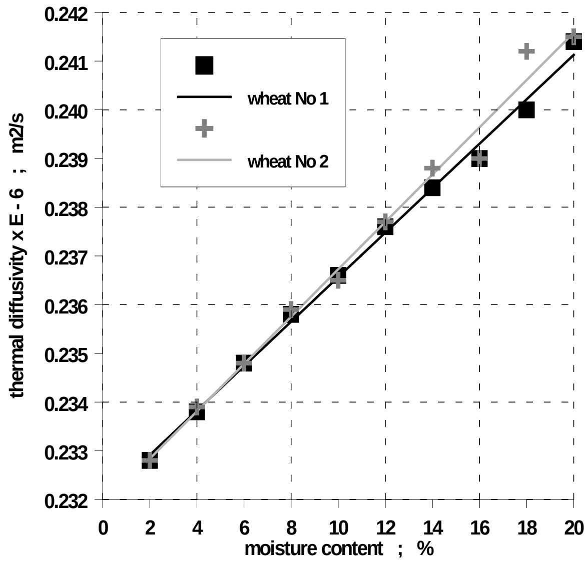


Fig. 6 and **7** Relations of thermal conductivity to moisture content for samples of wheat № 1 and № 2

The values of thermophysical parameters which are presented on figures (2 – 9) were obtained as arithmetical averages from one hundred measurements for every sample. The coefficients of determination were from 0.565 to 0.991 for obtained regression equations. Functions $\lambda = f(t)$ and $a = f(t)$ had linear increasing progresses. Thermal conductivity and thermal diffusivity increased with increasing temperature in range (2 – 20) °C. Our results are in good agreement with the values which are presented in literature (Figura – Teixeira, 1985).

The measurement results for relations of thermal conductivity and thermal diffusivity to the moisture content are presented on figures (6 – 9). There were observed also linear increasing progresses for relations $\lambda = f(\omega)$ and $a = f(\omega)$ in all causes. In consideration of thermophysical parameters values for water, were expected increases of thermal conductivity values and thermal diffusivity values with increasing of moisture content - Figures (6 – 9).

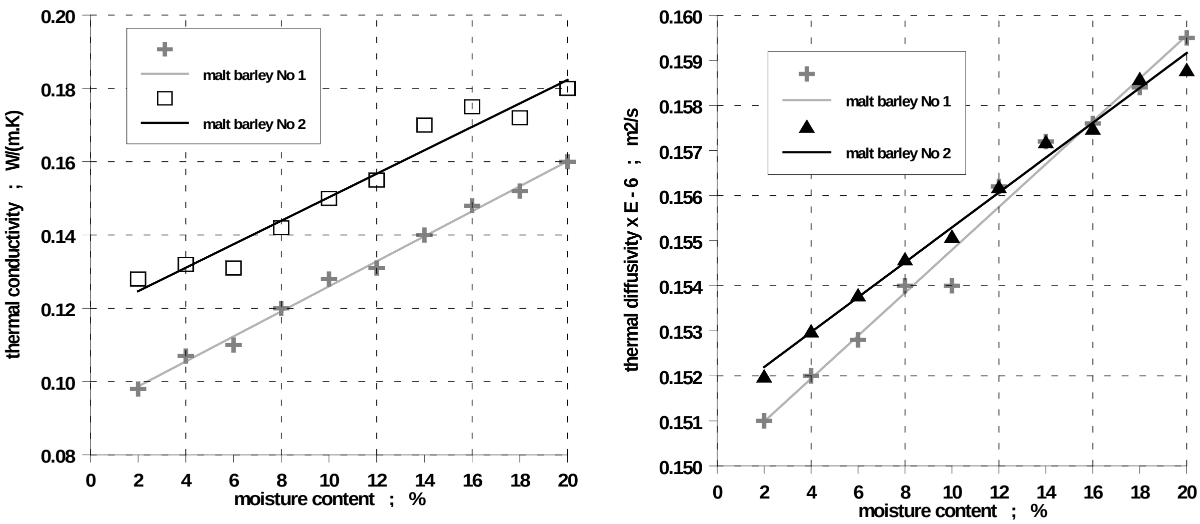


Fig. 8 and **9** Relations of thermal conductivity to moisture content for samples of malt barley № 1 and № 2

CONCLUSION

For many structural materials, including also granular materials, it is important to know the relationships between their physical parameters. For these reasons, in most of experimental observations were performed measurements of dependencies for the selected physical parameters. In our case were examined two basic thermophysical parameters - thermal conductivity and thermal diffusivity in temperature range (2 - 20) °C and also in the moisture content range (2 - 20) %. The temperature range and moisture range were chosen in the point of view on the measured sample characteristics and also with regard to the purpose of obtained results usage. From presented results (Table 1 and Fig. 2 - 9) is clear, that moisture content and the temperature are very important parameters which determine thermophysical parameters and status of granular materials. During processes as moisturising or drying, cooling or heating are mainly changed physical parameters especially thermophysical parameters of granary mass which can affect technological processes. In generally if we want to protect quality during the manipulation, processing and using it is necessary to have knowledge of the physical parameters dependences and also knowledge of their influence on granular materials behavior.

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