Int. Agrophysics, 2005, 19, 203-207

INTERNATIONAL
Agrophysics
www.ipan.lublin.pl/int-agrophysics

Thermophysical parameters of chosen granular samples[1,2]

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Received October 8, 2004; accepted January 24, 2005

A b s t r a c t. This article deals with the thermophysical properties of granary mass. It is necessary to know the thermophysical parameters of granular mass to ensure the quality of the technological processes. Granular mass is composed as a complex of specific kinds of grains. It is a non-uniform material with both microscopic and macroscopic structures. Biophysical and physiological processes are realized within grains. Heat transfer cannot be isolated from the solid transfer and from the heat-moisture transfer. It means that specification of granular mass and granular fragments is difficult to determine. We researched the thermophysical properties of granular mass.

Thermophysical parameters were measured by the Isomet instrument (made by the Applied Precision Comp.). It is used for quick and exact measurement of thermophysical parameters of various materials. Measurements were performed with a spike probe with the range of thermal conductivity of 0.015-0.2 $Wm^{-1}K^{-1}$. The spike probe was inserted into the analysed material. Heat was generated by the spike probe used. The time process of temperature which is related to the thermophysical parameters of samples was analysed.

The relations of thermal conductivity and thermal diffusivity to the temperature of chosen samples (wheat, malt barley and colza) were measured first. The moisture content of samples during the measurements was constant 6.5%. All the measurements were realized at room temperature. Because moisture content is one of the most important parameters which determine the thermophysical parameters of biological materials, we made a second series of measurements of the relations of thermal conductivity and thermal diffusivity to the moisture content.

K e y w o r d s: thermal conductivity, thermal diffusivity, temperature, moisture content

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[1]This work was supported by research projects VEGA 1/1321/04, VEGA 1/9079/02, and VEGA 1/0609/03 of Slovak Grant Agency for Science.

[2]The paper is published in the frame of activity of the Centre of Excellence AGROPHYSICS – Contract No. QLAM-2001-00428 sponsored by EU within the 5FP.

INTRODUCTION

Biological materials have a complicated structure. This complicated structure is the reason of great variability of their chemical, biological and physical properties (Blahovec, 1993). During processing, biological materials (specifically granary materials such as wheat, malt barley and colza) are heated, cooled, dried, moistened or subjected to mechanical manipulation. It is necessary to know the thermophysical properties of granular materials to choose optimal technological procedures. Nowadays, we know both many methods of measurement and a multiplicity of apparatus and instruments for thermophysical measurements. For our measurements we chose the Isomet. It is used for quick and exact thermophysical parameters measurement of various materials, like liquid, solid and bulk materials (Božiková, 2003). We can use the Isomet for the measurement of such thermophysical parameters as temperature, thermal conductivity, thermal diffusivity, *etc.* We used the Isomet for measurements of thermal conductivity and thermal diffusivity of wheat, malt barley and colza. We determined the relations of thermal conductivity, λ, thermal diffusivity, a, to the temperature and to the moisture content.

MATERIALS AND METHODS

Heat transport takes place in three ways: conduction, convection and radiation. Heat transport in grain mass is performed by conduction and by convection of air occurring between grains in dependence on the way of storage. In the case of no convection, the decisive mechanism of heat transport in grain is conduction.

Thermal conductivity, λ, is defined as the amount heat that penetrates in time isothermal area unit on temperature gradient unit. Thermal conductivity is related to pressure, temperature and moisture content; in dispersed materials it is related to size of fragments, porosity, and bulk density. Thermal conductivity characterizes the ability of a material to convey heat. Granular materials with different structure have different mechanism of heat transfer (Childers, 2003). Heat transfer is characterised by the Fourier law as:

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

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

Thermal diffusivity, a, is characterized as the velocity of equalization of temperature in various points of temperature field. We can acquire this thermophysical parameter from the equation:

$$q = \frac{\lambda}{c\rho}, \tag{2}$$

where: q – thermal conductivity, c – specific heat, ρ – density of material.

The Isomet instrument is used for measurement of thermophysical parameters. It works on the principle of the Hot Wire Method which is described in (Assael and Wakeham, 1992; Liang, 1995; Mardolcar and Nieto de Castro, 1992; Cheng *et al*., 1991). Measurements were performed with a spike probe with the range of 0.015-0.2 W $m^{-1}K^{-1}$. The spike probe was inserted into the analysed material. The probe generates heat. The time process of temperature which is related to the thermophysical parameters of samples was analysed. The process of temperature t in the spike probe is defined as:

$$T(t) = \mathrm{A} \ln(t) + \mathrm{B}, \tag{3}$$

where: t – is temperature; $T(t)$ – is temperature function; A,B – are constants which depend on parameters of a sample and its thermal characteristics.

Thermal conductivity, λ, is defined as:

$$\lambda = \frac{K_1}{A} + H, \tag{4}$$

and thermal diffusivity, a, is defined as:

$$a = \frac{\left[\left(\mathrm{K_2 A^2} e^{\frac{\mathrm{B}}{\mathrm{A}}}\right) + 4\mathrm{K_3 A} e^{\frac{\mathrm{B}}{\mathrm{A}}}\right]^{\frac{1}{2}} - \mathrm{K_2 A^2} e^{\frac{\mathrm{B}}{\mathrm{A}}}}{2}, \tag{5}$$

where: K_1, K_2, K_3, H – are constants of the spike probe used.

Moisture content, ω, is defined as the mass of water contained in a biological material divided by the mass of moistened sample (STN 12600 – Basic concepts of food dehydration for control of measured values):

$$\omega = \frac{m_1 - m_2}{m_1} 100\%, \tag{6}$$

where: ω – moisture content (%, mass), m_1 – mass of moistened sample, m_2 – mass of dry substance sample.

We measured the moisture content with the HE 50 Pfeuffer instrument and we also used the standard STN 12600. Thermophysical parameters which were measured by the Isomet were: temperature, thermal conductivity and thermal diffusivity.

The investigation were made in two series. In the first series we measured the relations of thermal conductivity, λ, and thermal diffusivity, a, to the temperature for wheat, malt barley and colza. Samples were stabilized in a special cooling box; before the measurement all the samples had

T a b l e 1. Moisture content (ω) and bulk density (ρ) during the harvest

No. of sample	Locality	Date of harvest	ω (%, mass)	ρ (kg m^{-3})	I series		II series	
					Range of thermal			
					conductivity (W $m^{-1}K^{-1}$)	diffusivity (10^{-8} m^2s^{-1})	conductivity (W $m^{-1}K^{-1}$)	diffusivity (10^{-8} m^2s^{-1})
					Wheat			
1	Rybany	17.07.2003	13.12	791	0.107÷0.128	0.240÷0.268	0.123÷0.179	0.232÷0.240
2	Šaľa	24.07.2003	6.66	805	0.094÷0.117	0.215÷0.235	0.129÷0.178	0.233÷0.241
					Malt barley			
1 (Expres)	Šaľa	28.07.2003	7.46	658	0.160÷0.181	0.161÷0.175	0.098÷0.153	0.151÷0.157
2 (Jubilant)	Šaľa	28.07.2003	7.59	663	0.161÷0.174	0.160÷0.175	0.129÷0.175	0.152÷0.158
					Colza			
1	Hont. Nemce	10.07.2003	6.75	631	0.142÷0.163	0.145÷0.164	–	–
2	Hont. Nemce	12.09.2003	7.78	635	0.127÷0.148	0.131÷0.148	–	–

temperature in the range of 2-20°C and their moisture content was 6.5% (Table 1).

In the second series we measured the relations of thermal conductivity, λ, and thermal diffusivity, a, to the moisture content. All the samples were stabilized at room temperature (20°C) during 24 h before the measurements, in a special laboratory glass box. The samples had moisture content in the range of 2÷18%. Because the natural moisture content of the samples was 6.5% and we needed moisture content in the range of 2÷18% we had to use drying and moistening for the measured samples.

RESULTS AND DISCUSSION

The values of thermophysical parameters which are presented on Figs 1-6 were obtained as arithmetical averages from one hundred measurements for every sample.

The relation of thermal conductivity, λ, and thermal diffusivity, a, showed a linear character for wheat, malt barley and colza. The functions $\lambda = f(t)$ and $a = f(t)$ had linear increasing progression with increasing temperature in the range of 220°C. Our results are in good agreement with the values which are presented in literature (Ginzburg, 1985).

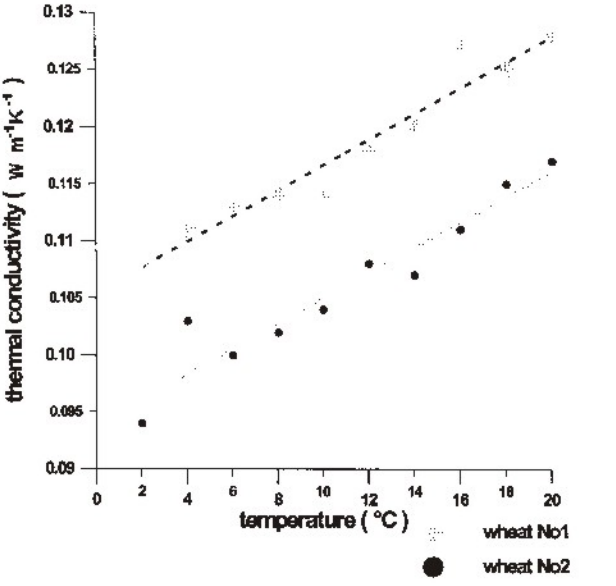

Fig. 1. Relations of thermal conductivity to temperature for wheat samples.

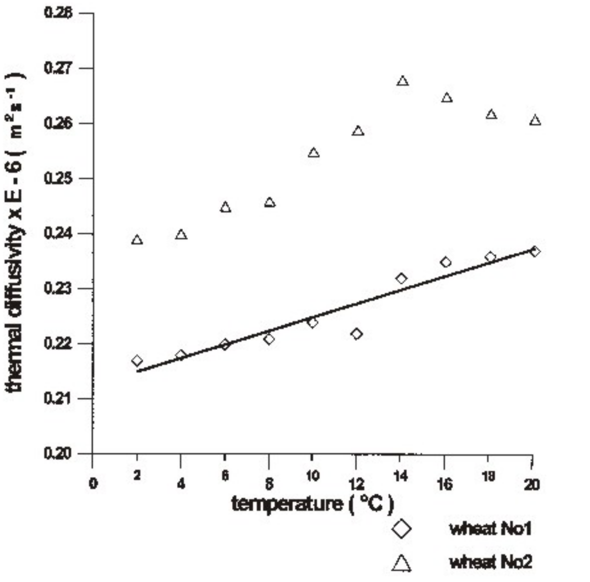

Fig. 2. Relations of thermal diffusivity to temperature for wheat samples.

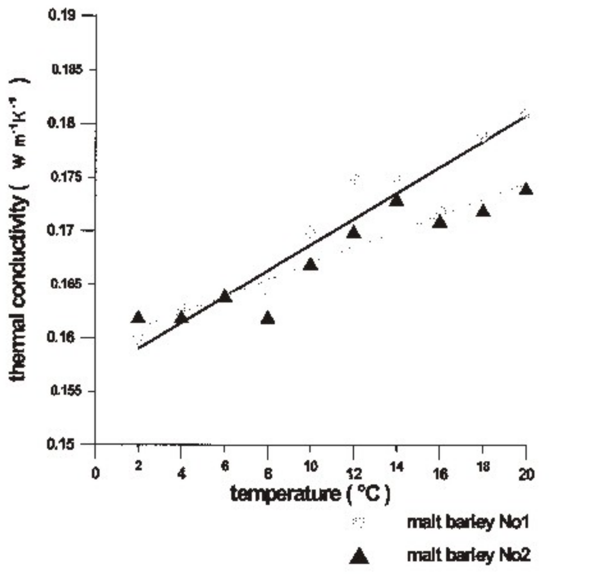

Fig. 3. Relations of thermal conductivity to temperature for malt barley samples.

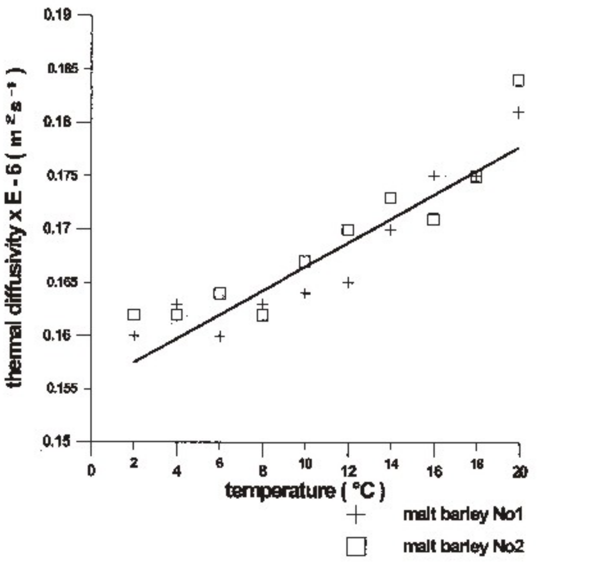

Fig. 4. Relations of thermal diffusivity to temperature for malt barley samples.

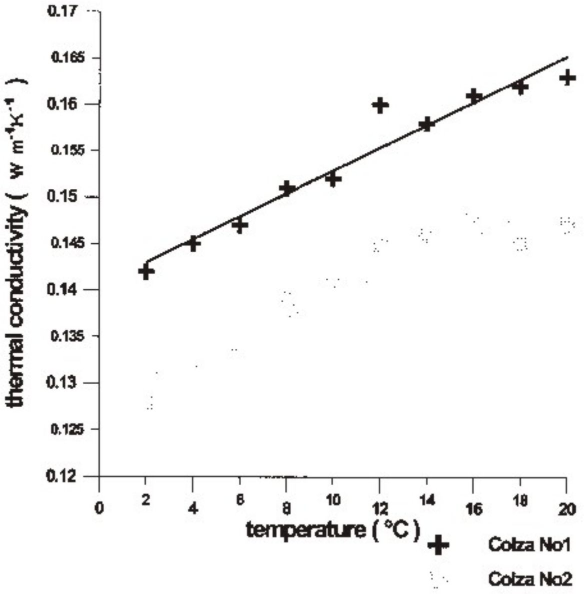

Fig. 5. Relations of thermal conductivity to temperature for colza samples.

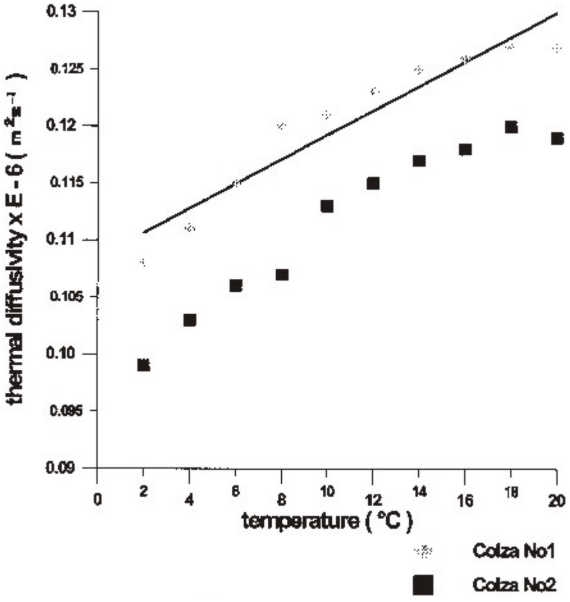

Fig. 6. Relations of thermal diffusivity to temperature for colza samples.

The results of measurements for the relations of thermal conductivity and thermal diffusivity to the moisture content are presented in Figs 7-10. All values were obtained as arithmetical averages from 100 measurements for every wheat and malt barley sample. The thermophysical parameters were measured for moisture content in the range of 2-18%. Because the moisture content during the harvesting was not such as we needed for the experiments, we had to simulate the necessary moisture content with artificial wetting of all measured samples. In the consideration of thermophysical parameters values for water, we expected increases of thermal conductivity values and thermal diffusivity values with increasing moisture content. Figures 7-10 shows that the relations observed had a linear increasing character.

Moisture content and temperature are very important parameters which determine the thermophysical parameters of granular mass like nutritive raw materials. During such process as wetting or drying and cooling or heating, the thermophysical parameters of granary mass are changed meaningfully, which affects subsequent technological processes.

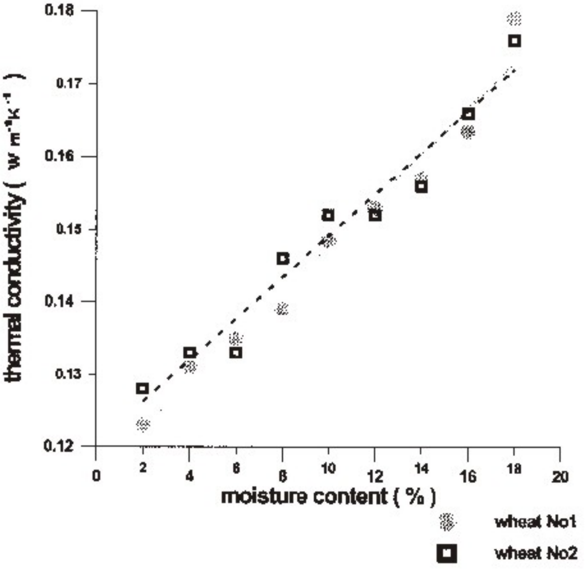

Fig. 7. Relations of thermal conductivity to moisture content for wheat samples.

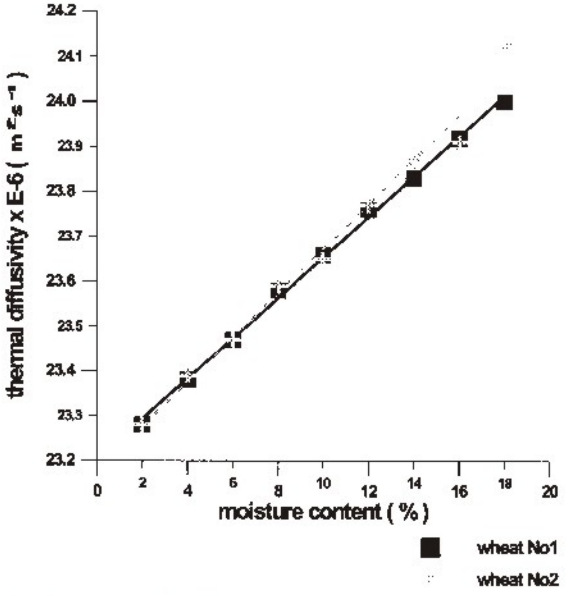

Fig. 8. Relations of thermal diffusivity to moisture content for wheat samples.

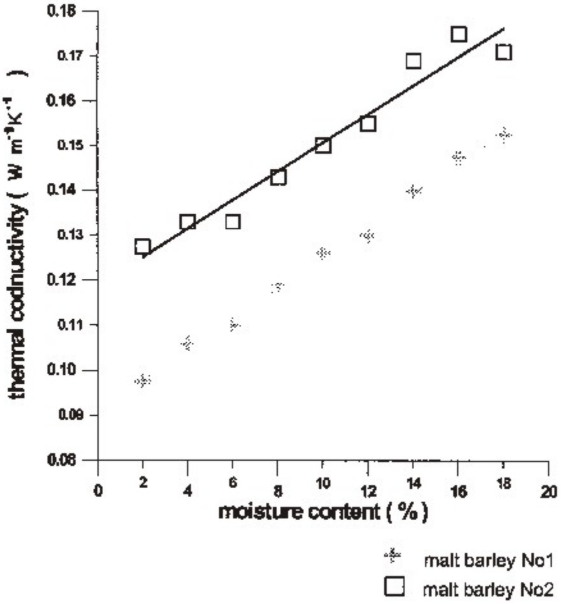

Fig. 9. Relations of thermal conductivity to moisture content for malt barley samples.

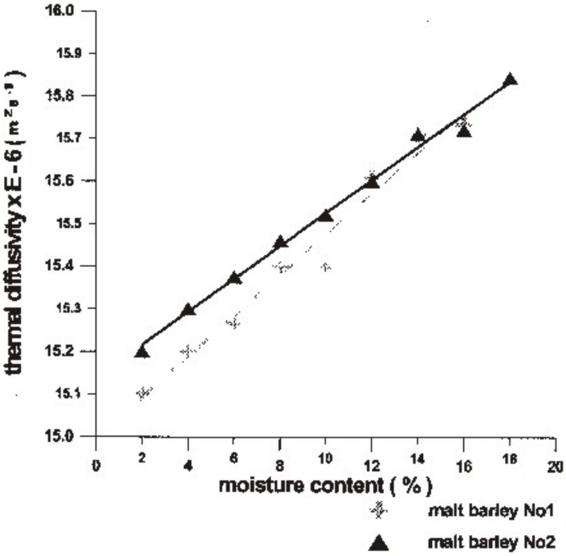

Fig. 10. Relations of thermal diffusivity to tmoisture content for malt barley samples.

CONCLUSIONS

1. Thermophysical parameters of granular materials are utilized in agricultural and food-processing industry.

2. Thermophysical properties of granular materials are influenced by many factors. The most important factors are temperature and moisture content because of their non-uniform distribution in granular materials.

3. Relations of thermal conductivity and thermal diffusivity to the temperature for wheat, malt barley and colza have linear character. Thermal conductivity of granular samples increases with temperature in the temperature range of 2-20°C.

4. Relations of identical thermophysical parameters to the moisture content for all samples had expected linear increasing character in the range of moisture content of 2-18%.

5. Temperature and moisture content are among the main factors affecting other thermophysical parameters, so heat transfer cannot be isolated from the solid transfer and from the heat-moisture transfer.

6. We have to know the thermophysical parameters of granular mass to protect the quality of technological processes for achieving optimal results.

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