THERMAL PROPERTIES OF BIOLOGICAL AGRICULTURAL MATERIALS

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Abstract:
Thermal conductivity and specific heat capacity of several types of granular agricultural products, namely of spring oat, wheat mixture Axis, barley mixture Expres, corn mixture and soybean Evans is measured in dependence on moisture content from the dry state to the water fully saturated state. An impulse technique is used for the measurement. The obtained results will find use in the selection of suitable methods for processing of agricultural products, in a qualified assessment of optimal modes of technological processes, and in the development of modern fully automatic agricultural equipments.

Keywords:
Biological agricultural materials, thermal properties

INTRODUCTION

Biological agricultural materials consist of highly heterogeneous sets of different substances, mixtures and structural components, including complex organic structures. Their inhomogeneous composition and high variability affect their behavior and cause complicated and variable physical properties. Physical properties of biological agricultural materials are dependent on moisture and temperature of the studied material, and mostly show a considerable hysteresis.

Complete knowledge of physical properties of agricultural materials has a decisive importance for the realization of many technological processes, especially for monitoring their quality and health harmlessness during their production and storage. The quality assessment and guarantee of the safety of foodstuff belong to the main priorities in food industry.

HACCP – Hazard Analysis and Critical Control Point System [1] represents scientifically sophisticated approach to the problems of the protection of foodstuff quality. It is internationally accepted system guarantying the foodstuff safety aimed to the identification, evaluation and risks control in the whole technological procedure of foodstuff production. Its successful application is subject to the complete knowledge of physical properties of foodstuff.

From the point of view of optimization of a technological procedure the temperature and moisture have the crucial importance. They present the most important parameters having clear relation to the character of physical, chemical and physiological processes in biological agricultural materials. Physical processes, above all heat and moisture transport, affect the intensity of physiological processes, nominally of breath, germination, microorganisms progress and many others and in consequence determine the final quality of food sources. The modern trends in storage and subsequent processing of agricultural products are currently based on application of complex mechanization and automation. For their optimization, it is necessary to know physical material parameters and to relate them with the environmental conditions.

In this paper, determination of thermal properties of granular agricultural materials in dependence on moisture content, nominally of spring oat, wheat mixture Axis, barley mixture Expres, corn mixture and soybean Evans is presented.

EXPERIMENTAL

The thermal conductivity and volumetric heat capacity as the main parameters of heat transport and storage were determined using the commercial device ISOMET 104 (Applied Precision, Ltd.). ISOMET 104 is a multifunctional instrument for measuring thermal conductivity, thermal diffusivity, and volumetric heat capacity (see Tab. 1 for the measuring range and accuracy). It is equipped with various types of optional probes, needle probes are for porous, fibrous or soft materials, and surface probes are suitable for hard materials. The measurement is based on the analysis of the temperature response of the analyzed material to heat flow impulses. The heat flow is induced by electrical heating using a resistor heater having a direct thermal contact with the surface of the sample. The measurements in this paper were done in dependence on moisture content using the needle probe.

Table 1 Measuring ranges of ISOMET 104

Thermal conductivity [W $m^{-1}K^{-1}$]	0.015-1±10% of measured value + 0.005
Volumetric heat capacity [J m^{-3} K^{-1}]	3.10^3-5.10^6±15% of measured value + 3.10^3
Temperature [°C]	0-40

The material samples were provided by Slovak University of Agriculture in Nitra, Faculty of Agricultural Engineering, Department of Physics. The obtained materials were first dried according to instructions given in [2, 3]. The samples of wheat, barley and oat were dried for 120 minutes at 130°C, soybeans were dried for 240 minutes at 130°C and corn mixture was dried for 300 minutes at 130°C. After that the samples were cooled in the conditions near to 0% of relative humidity and the thermal properties of dry materials were measured.

Figure 1 Measuring setup

Thermal properties were measured in laboratory conditions at the average temperature of 25°C. The measurement of thermal conductivity in dependence on moisture content was done from the dry state to the fully saturated state. The samples were stored first in refrigerator at 4°C for ten days in plastic weighing bottles to distribute humidity homogeneously. Then, they were conditioned to 25°C for about six hours, moved to the measuring cylinder and measured using the needle probe (see Fig. 1). The dependence of specific heat capacity on moisture content was calculated by the mixing rule given in Eq. (1), where c is the specific heat capacity of moist material [J/kgK], c_0 the specific heat capacity of dry material [J/kgK], c_w the specific heat capacity of water (4181.8 J/m^{3}K), and u is the gravimetric moisture content by mass [kg/kg].

$$c = (c_0 + c_w u)/(1+u) \tag{1}$$

Since the apparatus ISOMET 104 provides determination of volumetric heat capacity, for the application of the mixing rule in Eq. (1) it was necessary to measure bulk density of the studied materials. The values of bulk density are presented in Tab. 2.

Table 2 Bulk density of granular agricultural materials

Material	Bulk density [kg/m^3]	Standard deviation [kg/m^3]	Variation margin [kg/m^3]
Wheat mixture Axis	827.69	13.75	47.6
Barley mixture Expres	665.63	7.12	24.6
Oat spring	466.39	14.83	50.6
Corn mixture	724.26	6.68	23.1
Soybean Evans	709.23	8.15	28.2

RESULTS AND DISCCUSION

The obtained results of the dependence of thermal properties on moisture content are given in Figs. 2 and 3. Looking at the results form the quantitative point of view, the highest value of thermal conductivity for dry materials exhibited the wheat mixture Axis. The results achieved for other materials were very similar each other.

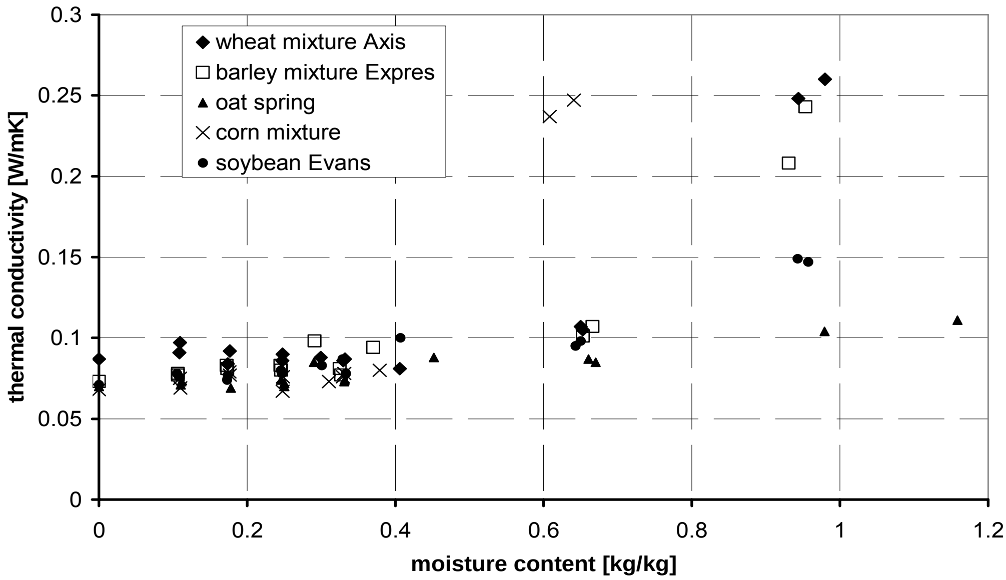

Figure 2 Thermal conductivity of granular agricultural materials

Taking into account the effect of moisture, the highest thermal conductivity was observed for the wheat mixture Axis, barley mixture Expres and corn mixture; for the saturated moisture content the values were typically about 0.25 W/mK. On the other hand the value of thermal conductivity of the soybean Evans at saturated moisture content was markedly lower. The oat spring has shown only slight dependence of thermal conductivity on moisture content.

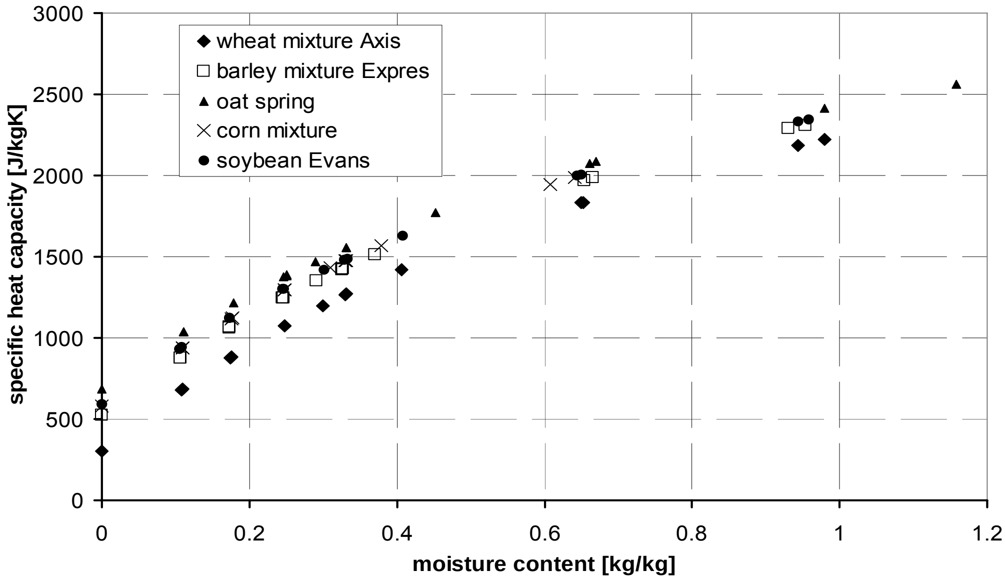

Figure 3 Specific heat capacity of granular agricultural materials

The values of specific heat capacity were for all studied materials very similar except for the wheat mixture Axis that had the lowest specific heat capacity. The effect of moisture on the specific heat capacity was quite remarkable, which is a consequence of the high specific heat capacity of water.

CONCLUSIONS

The results presented in this paper can find utilization in food industry in such processes where heat transport and storage properties of granular agricultural materials are indispensable. They can be applied for instance for the adjustments of drying rate, for the calculations of the economical drying time and for the determination of energetic balances of drying processes.

ACKNOWLEDGMENT

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