Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2001
Volume 4
Issue 2
Series
AGRICULTURAL ENGINEERING

KRAMKOWSKI R., KAMIŃSKI E., SEROWIK M. 2001. EFFECT OF MOISTURE AND TEMPERATURE OF GARLIC ON ITS SPECIFIC HEAT **Electronic Journal of Polish Agricultural Universities**, Agricultural Engineering, Volume 4, Issue 2.
Available Online http://www.ejpau.media.pl

EFFECT OF MOISTURE AND TEMPERATURE OF GARLIC ON ITS SPECIFIC HEAT

Ryszard Kramkowski, Eugeniusz Kamiński, Małgorzata Serowik
Institute of Agricultural Engineering, Agricultural University of Wrocław, Poland

ABSTRACT

The method of Differential Scanning Calorimetry (DSC) was used for determination of the garlic specific heat. The measurements were carried out in the range of material moisture from 17 to 87% and in the temperatures from 283 to 333 K (10-60°C). The analysis of measurement results, aided with the methods of mathematical statistics, summarises the complex behaviour of the change in specific heat versus moistening of garlic and its temperature, and compares it with reference data.

Key words: specific heat, garlic, scanning calorimetry DSC

PRINT

INTRODUCTION

Specific heat capacity (specific heat) is a thermal property which has essential importance in many technological processes. The knowledge of the property of agricultural products and foods enables the quantitative analysis of thermal processes.

Differentiated structure and composition of plant products causes that specific heat depends on numerous factors, especially moisture, temperature, phase transitions of components and the composition of solid phase [1].

Besides moisture, the temperature of the product has an important influence on the value of specific heat. Investigations showed that the dependence of specific heat of a product on its temperature can have different character. It follows from the fact that water, contained in the cells and micro- capillaries, features with high pressure resulting in changing the properties of the material [2].

In the most simplified statement, agricultural products consist of water and dry solid. Therefore, their specific heat depends mainly on the mass content of water. Specific heat of mixtures is calculated under the assumption of additivity of particular components:

$$c_p = \sum c_{pi} \cdot x_i \quad (1)$$

where: c_{pi} – specific heat of i-th component, x_i – mass contribution of i-th component.

However, the results of studies on bound water point out that it has much lower heat capacity than free water. Under the assumption that free water makes up the total moisture contained in the product, specific heat increases gradually, according to the principle of additivity, from the specific heat of dry solid to specific heat of pure water. It follows from the works by Riedel [3] that the specific heat of biological materials changes, depending on moistening level, according to quite complex rules. In the layout of measurement points of specific heat versus water content, two straight-lined sections can be distinguished. One of them, corresponding to higher values of the heat, features with higher inclination angle. Riedel worked out a universal equation for the calculation of specific heat of solid food products with the water content above 25%, neglecting the initial straight-lined section at low moisture level in material. The equation has the following form:

$$c_p = 1{,}675 + 0{,}025 \cdot w \quad [\text{J/g} \cdot \text{K}] \quad (2)$$

where: w – material moisture [%].

Many researchers, among others Ginzburg and Gromov [4], dealt with investigation of thermal-physical properties of fruit and vegetables. They derived a generalised dependence of specific heat of root vegetables on their moisture:

$$c_p = 1{,}401 + 0{,}02786 \cdot w \quad (3)$$

The equation is valid in the whole range of humidity w, but only at the temperature of 293 K (20°C). The aim of the work was to determine and characterise specific heat of common garlic in relation to its moisture and temperature.

PRINT

MATERIALS AND METHODS

The material employed in the investigation was common garlic (*allium sativum*), the annual plant, commonly available on the market.

The slices of garlic were dried by freeze drying method [5], at the heating plate temperature of lyophilising cabinet equal to 313 K (40°C). The material was ground into homogenous powder and then moistened in order to obtain the required moisture level.

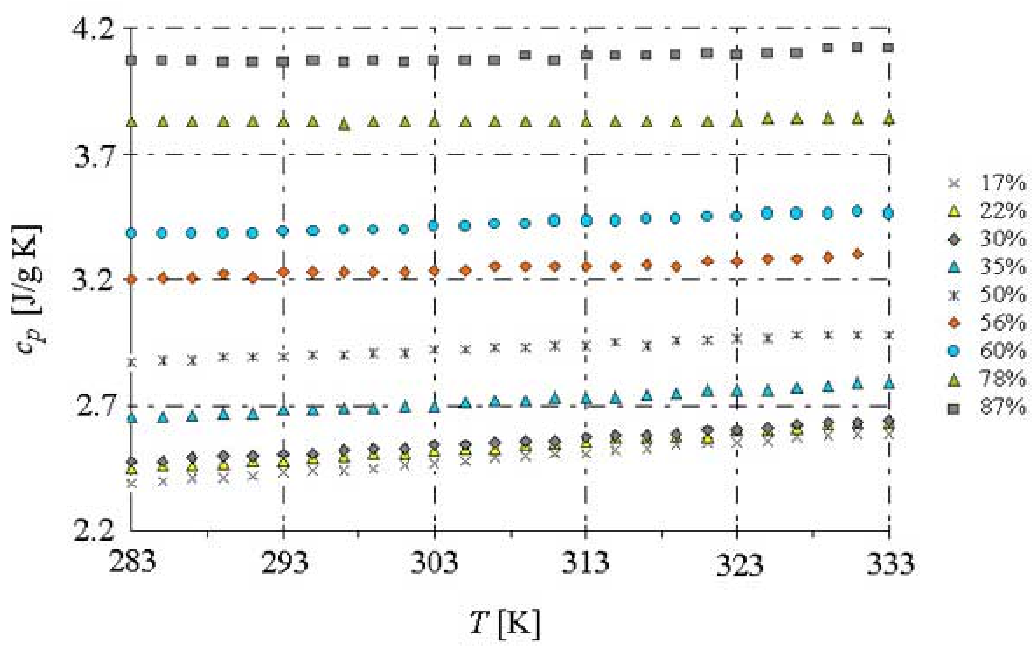
The studies on specific heat of garlic were carried out using Differential Scanning Calorimetry Method – DSC. The method enabled testing the changes in physical and chemical properties of the examined material versus temperature, by registering the occurring thermal alterations. Determination of specific heat by Differential Scanning Calorimetry Method consists in comparison of heat flux introduced to an empty container or a container with a standard material, whose specific heat value is known at a given temperature, with the heat flux introduced to the container filled with tested material, whose specific heat should be evaluated [6].

The measurements were carried out with Mettler Toledo DSC 821 set within the temperature range from 283 to 333 K (10-60°C) at the scanning rate of 5 K/min. In the calculations, the average values of specific heat, determined at three different runs for the sample with the same moisture level, were taken into account. Results of measurements were analysed using mathematical statistics methods, especially by linear regression.

RESULTS

Results of the measurements of the specific heat of garlic depending on its temperature at different moisture levels is shown in Figure 1. The layout of points, representing the measurement results, suggests the occurrence of straight-lined dependencies of the specific heat of garlic at all examined moisture levels. With the growth of water content in the material, the value of specific heat of garlic increases in every case.

Figure 1. Results of measurements of specific heat c_p of garlic versus its temperature T and moisture w



PRINT

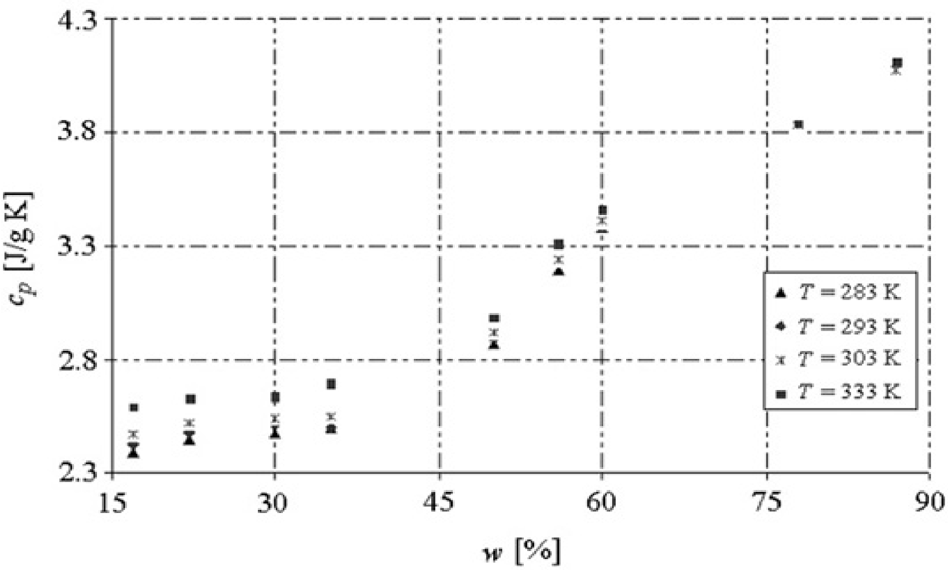
In Table 1, the regression equations, characterising the tested dependencies and corresponding regression coefficients R^2 are collected.

Table 1. The relation of specific heat c_p of garlic to its temperature *T* and assumed moisture value *w*

Moisture [%]	$c_p = f(T)$	Regression coefficient R^2
17	$c_p = 0.0041 \cdot T + 2.3476$	0.9973
22	$c_p = 0.0037 \cdot T + 2.4111$	0.9930
30	$c_p = 0.0032 \cdot T + 2.4430$	0.9952
35	$c_p = 0.0028 \cdot T + 2.6201$	0.9927
50	$c_p = 0.0023 \cdot T + 2.8484$	0.9869
56	$c_p = 0.0017 \cdot T + 3.1861$	0.9454
60	$c_p = 0.0020 \cdot T + 3.5130$	0.9795
78	$c_p = 0.0002 \cdot T + 3.8246$	0.4272
87	$c_p = 0.0010 \cdot T + 4.0444$	0.7706

Figure 2 displays the calculated values of specific heat of garlic with different moisture and selected temperatures.

Figure 2. Results of measurements of specific heat c_p of garlic versus its moisture *w*, for different values of temperature



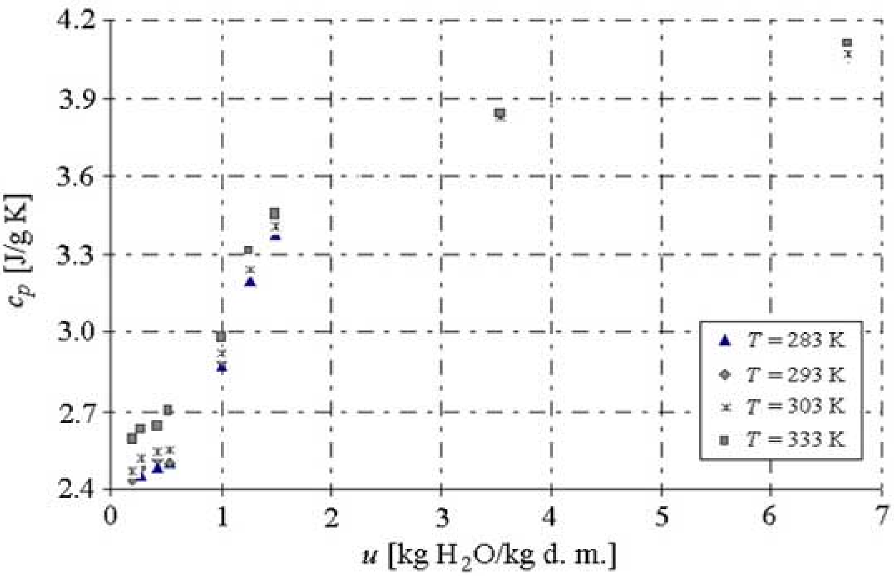
The results of earlier works by Riedel, concerning the multi-directional influence of moisture on the specific heat of biological materials at different moistening levels, gained confirmation in the results of the present investigations. After a short straight-lined section of the

PRINT

dependence, characteristic of the samples with low water content (about 35%), an abrupt increase in specific heat value occurs, which is also linear in character, but with a significantly higher slope.

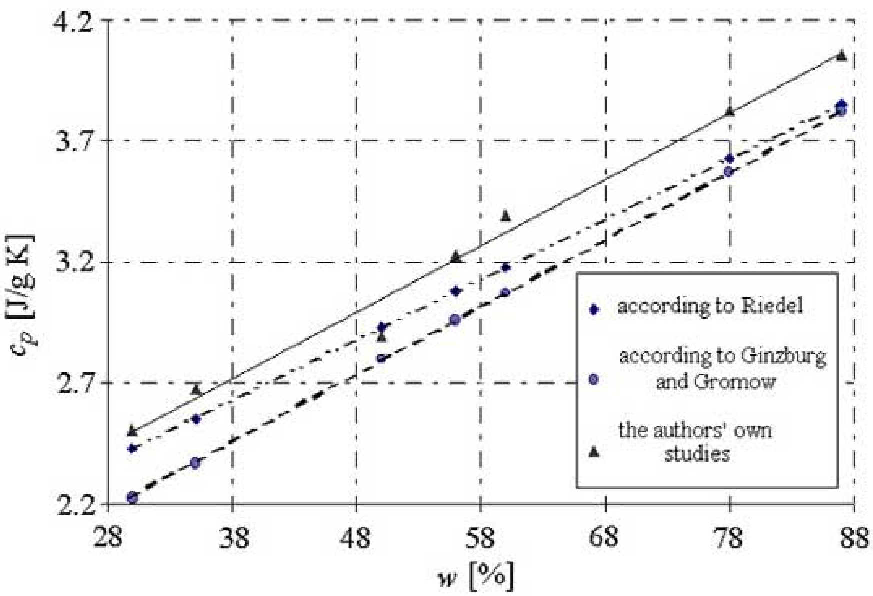
In the calculations concerning the balance of the drying process, the use of water content *u* (kg H_2O/kg d.m), determining the moistening state of material is much more convenient. The dependence of the calculated value of the specific heat of garlic on water content is shown in Figure 3.

Figure 3. Dependence of the specific heat of garlic on its water content at different temperatures



In Figure 4, a comparison of the authors' own experimental results with the results by Riedel and Ginzburg is presented. For the comparison, the values of specific heat, estimated at the temperature of 293 K (20°C) were exclusively used. The comparison concerns the range of higher moisture content (>25%), for which the run of the specific heat of garlic can be approximated with a straight-lined section.

Figure 4. Dependence of the specific heat c_p of garlic on its moisture *w*, according to the reference data and the results of the authors' own investigations



PRINT

Specific heat values, obtained from the authors' own investigations in changing moisture level, are slightly higher than the ones obtained by Riedel and Ginzburg in the same conditions.

CONCLUSIONS

1. The value of specific heat of garlic increases significantly with the increase in moisture, and slightly with the increase in material temperature.
2. The dependence of the specific heat of garlic on its temperature can be approximated quite well with a linear function.
3. The run of the dependence of specific heat on the moisture of examined material can be divided into two straight-lined sections, connected with abrupt growth of the property of garlic.
4. The values of specific heat of garlic obtained in the investigations are slightly higher than the values from which the property was evaluated, given by Riedel or Ginzburg and Gromow.

REFERENCES

1. Hwang C. H., Heldman D. R., Taylor T. A., Cao R. R., 1999. Changes in Specific Heat of Corn Starch Due to Gelatinization. Journal of Food Science 64, 1, 141-149.
2. Pabis S., 1982. A Theory of Convector Drying of Agricultural Products. PWRiL, Warszawa [in Polish].
3. Riedel L., 1966. Versuche zur Bestimmung der Spezifischen Wärme des gebundenen Wassers, Kältetechnik – Klimatisierung 18, 193-199.
4. Ginzburg A. S., Gromow M. A., 1987. Thermophysical Characterization of Potato, Greenstuff and Fruits. VO. Agropromizdat, Moscow [In Russian].
5. Kramkowski R., Pasławska M., Peroń S., 2001. Estimation of the Effect of Sublimation Drying on the Persistence Properties of Root Celery. Inżynieria Rolnicza, Wrocław [in Polish].
6. Kramkowski R., Gawlik P., 2001. Specific Heat of Root Celery in the Function of Its Moisture. Inżynieria Rolnicza, Wrocław [in Polish].

Submited:

Ryszard Kramkowski, Eugeniusz Kamiński, Małgorzata Serowik
Institute of Agricultural Engineering
Agricultural University of Wrocław
37/41 Chełmońskiego Street, 51-630 Wrocław, Poland
tel. (+48 71) 320 57 14
fax (+48 71) 348 24 86
e-mail: kramkowski@imr.ar.wroc.pl
