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DETERMINATION OF HEAT CAPACITY IN THE PILEUS AND STIPE OF AGARICUS MUSHROOM

The article proposes a discrete approach to preparing for storage of cultivated Agaricus mushroom based on data on the difference in the parameters of mushroom pileus and stipe. Experimental data that indicate a significant difference in the heat capacity of the mushroom pileus and stipe are presented. Considering the different biological value of the pileus and stipe tissues and basing on experimental data, recommendations on the choice of drying modes for the pileus and stipe of the cultivated Agaricus mushroom were developed. The data obtained allow the most efficient use of energy resources for the drying process, as well as maintaining a significant part of biologically valuable components in the finished drying object.

Keywords: *Agaricus mushroom, heat capacity, drying process.*

Relevance of research topic. Currently, Agaricus mushrooms are grown in more than 60 countries of the world. They account for almost 80% of all mushrooms grown under artificial conditions. This type of cultivated mushrooms contains 18 amino acids, including all essential for humans, as well as vitamins, micro and macro elements, with very few sugars, which makes it possible to determine this product as dietary [1].

It should be noted that cultivation of this type of mushrooms exceeds consumer ability of the population and about 35% of output is not distributed fresh before the end of the shelf life [2].

The most known method to advance the shelf life of Agaricus mushrooms is drying. Thereby, it is necessary to determine the drying parameters allowing to extremely preserve their beneficial properties.

Formulation of the problem. The article is devoted to the determination of the heat capacity values in the pileus and stipe of the cultivated Agaricus mushroom and the development of drying modes for this type of raw materials, in order to preserve useful substances, especially proteins.

Analysis of recent researches and publications. A lot of scientific works of domestic and foreign scientists are devoted to the study of heat capacity and the development of technological parameters of food drying. In particular, on this issue worked G. Brunner, K. Richardson, R. Wilson, Ru-Min Wang, Ya-Ping Zheng, A. V. Lykov, A. S. Ginsburg, S. A. Shevtsov. A lot of scientific works in Ukraine, there are Snezhkin Yu. F., Mikhaylik V. A., Dekusha L. V., Vorobyov L. I., Dmitrenko N. V., Ivanov S. A., and others [3].

Not only has the shelf life of a food product, but also its nutritional value, which affects the quantity and quality of nutrients, largely depended on the drying technology.

Presenting main material.

Separate determining of the exact heat capacity values of the mushroom pileus and stipe allows to choose the drying temperature at which the energy carrier is most rationally consumed, but at the same time, the useful properties of the product are preserved.

For complex heterogeneous substances, it is extremely difficult to determine the heat capacity by analytical methods, so it is advisable to conduct experimental researches to obtain exact data.

The most multipurpose is the experimental measurement of heat capacity, in which the temperature of the sample is changed, and the amount of heat expended in its heating is measured. To study the heat capacity of such inhomogeneous materials, the differential microcalorimeter-1 (DMC-1) was used. In DMC-1, the standard method of step-by-step scanning is used [3, 4].

To determine the value of mass heat capacity c, which depends on the drying temperature T and the current moisture content of the material W [5], it is convenient to use the step-by-step scanning method [4]. According to the method, the entire temperature range in which the study is conducted is divided into intervals. A sample of known mass is heated to the temperature of the current interval, while the amount of heat spent on heating the sample is measured. The heat capacity is determined by the formula:

$$c = \frac{\int_i^j Q(\tau)d\tau}{m(T_2 - T_1)} \qquad (1)$$

where: c – the mass heat of the material, kJ / (kg · K); m – the mass of the sample, kg; Q – the amount of heat, kJ; *i - j* – the duration of the interval, s; T_1, T_2 – temperature of the beginning and end of the interval, respectively.

For these purposes, the DMC-1 installation [3] (Fig. 1) was developed at the Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine, which makes it possible to determine the mass heat capacity from solutions and wet capillary-porous bodies.

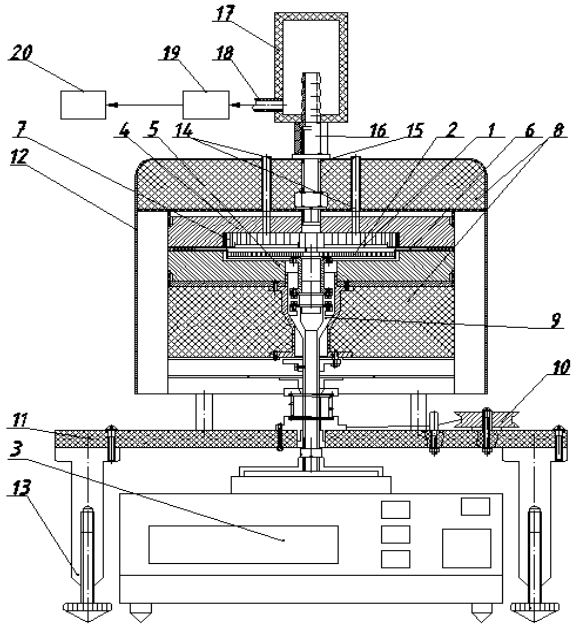

Figure 1. Structural scheme of DMC-1
1 – working chamber; 2 – calorimetric platform; 3– analytical scales; 4,5 – upper and lower thermostatical blocks; 6 – isolated ring; 7 – radial grooves; 8 – thermal insulation; 9 – coaxial rack; 10 – arresting device; 11 – base; 12 – cover; 13 – adjustable supports; 14 – holes for introducing a sample of liquid substance into the measuring cell; 15 – the central hole for the removal of evaporated moisture; 16 – fitting; 17 – separator; 18 – PVC pipe; 19 – receiver; 20 – compressor.

The device for determining the mass heat capacity of liquid and solid materials includes a calorimetric platform 2 with mounted calorimetric cells (Fig. 2). The calorimetric platform 2 and the coaxial rack 9 are not mechanically connected with other structural elements. The movable and fixed elements of the thermal unit are electrically connected loop-bent by soft copper conductors with a diameter of 0. 03 mm. The working chamber 1 is created by two thermostatical blocks 4 and 5, and isolated ring 6. Thermostatically controlled units have independent temperature control. The cover, thermostatically controlled units and the installation case are mounted on the base 11 with adjustable supports and a level gauge, which serves for precise positioning of the installation. Arresting device 10 located on the surface of the base 11 is designed to fix the calorimetric platform.

A separately located electronic unit is designed to set and maintain the temperature regime of the calorimetric block and convert the measurement information into digital form for subsequent transmission to a PC through the electronic unit.

To determine the relative humidity of the supplied air purge and exchange coefficient during the experiment, a Honeywell humidity sensor HIH-4021 is located at the entrance to the working chamber, and Honeywell air flow sensor AWM3300V is located behind the receiver. The signals from temperature converters, heat flow converters and analytical scales arrive through the electronic unit to the PC, where using the specially developed software the received data is processed and can be displayed on the screen in the form of graphs and tables.

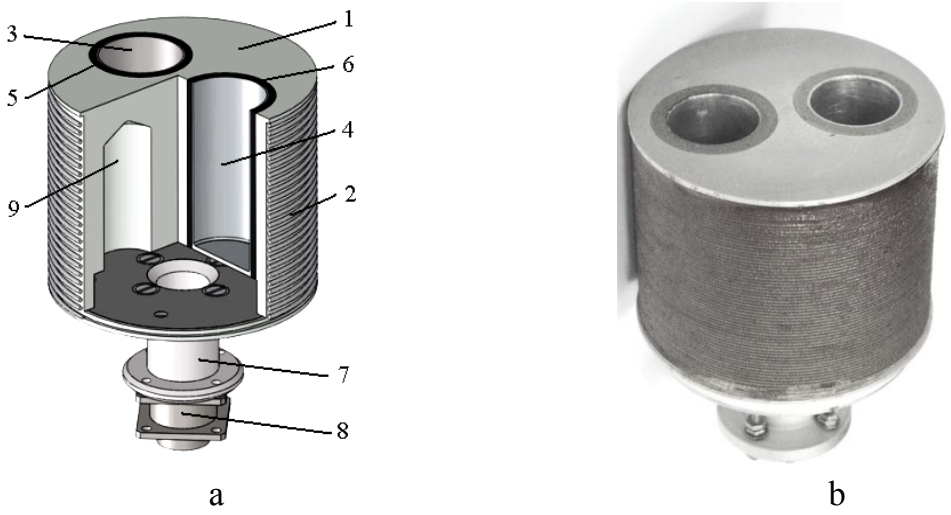

Figure 2. Calorimetric platform: a – scheme; b – appearance
1 – temperature balancing carcass; 2 – main heater;
3 – working cell; 4 – control cell; 5 – heat flow transducer of working cell;
6 – heat flow transducer of control cell; 7 – collar;
8 – output connector; 9 – hole

In the calorimetric platform, the control cell 4 remains empty, and a sample of the food product is placed in the working cell 3. For better thermal contact, the cell surface is hermetically sealed. After the covering of the platform with a lid a series of experiments is carried out sequentially over the entire operating temperature range of the device (30…90 °C) with a step of 5 °C, determining the numerical values of the heat electromotive force for each of the sensors. At the same time, the temperature of the calorimetric platform should be 5K higher than the temperature of the upper electric heater to create a positive heat flow through the calibrated and standard sensors. The temperature of the lower electric heater is maintained at room level in order to avoid parasitical heat flows.

In Figures 3 and 4 the heat capacity dependence of temperature for the pileus and stipe of the Agaricus mushroom is shown.

The study was conducted both for a fresh product (Fig. 3 curve 1 and Fig. 4 curve 3), the moisture content of the pileus was 92%, and for the stipe this indicator was 88%, when for a dried product (Fig. 3 curve 2 and Fig. 4 curve 4), the moisture content of the both pileus and stipe was 8%.

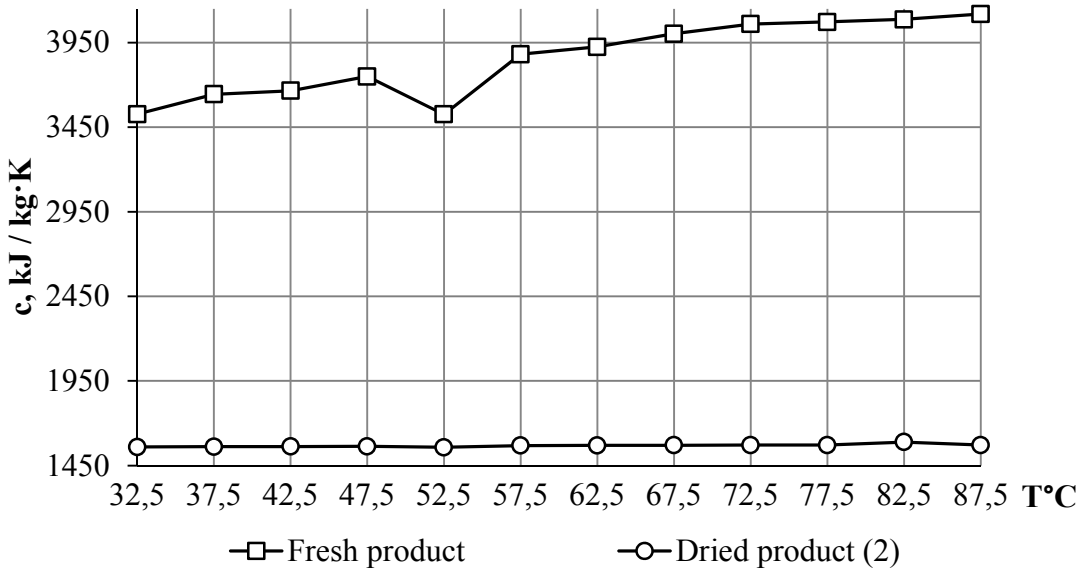

Figure 3. Heat capacity of the Agaricus mushroom pileus

As one can see in Figure 3, the protein chain breaks in a fresh pileus at a temperature of 52. 5 °C (curve 1). Thus, to preserve the protein structure of this product, it is necessary to dry it at a temperature of no more than ~ 52 °C for a given humidity. Examination of mushroom tissues at different humidity shows that the temperature of the tissue rupture peak increases with humidity decreasing. This allows choosing the most effective drying mode while maintaining the native protein structure depending on the moisture content of the material.

As one can see in Fig. 4, the protein chain breaks in a fresh pileus (curve 3) at a temperature of 57. 5°C. Since the temperature of the protein structures break for the pileus and stipe is significantly different, it is most rational to consider the pileus and stipe as separate objects of drying with different composition, parameters and requirements for the drying mode.

Moreover, in a dry product, the curve of the heat capacity of both the pileus and the stipe has the form of a straight line and is 2.5 times lower than the curve of the fresh product (Fig. 3…4), which indicates that the fresher mushroom, the more energy is needed to dry it.

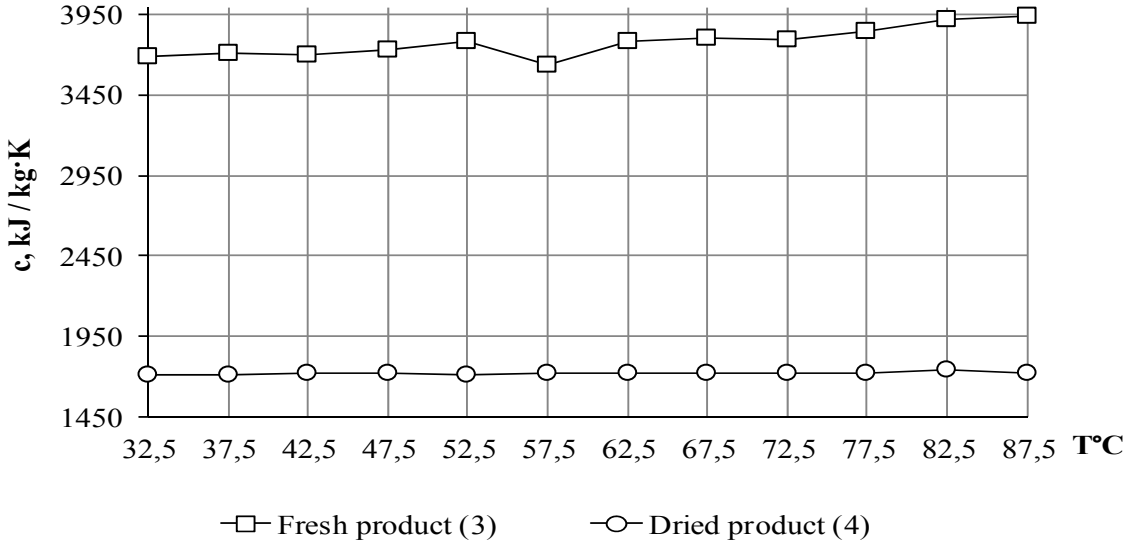

Figure 4. Heat capacity of the Agaricus mushroom stipe

On average, the heat capacity of the pileus before the breakdown of the protein structure is 11 % lower than the heat capacity of the stipe in the same range.

Conclusion. It was experimentally proved that the heat capacity of the pileus and the stipe differ by an average of 11 %, which can be used to save energy and preserve the nutritional properties of the product by dividing the mushroom into pileus and the stipe as separate drying objects.

The results of the heat capacity determination of the Agaricus mushroom pileus indicate that its drying temperature should not exceed 52° C, when for the stipe this temperature value rises to 57 ° C.

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