INVESTIGATION OF THE FORMS OF MOISTURE BONDING IN CULTIVATED FUNGI BY THE METHOD OF DIFFERENTIAL THERMAL ANALYSIS

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Summary: The paper is devoted to the investigation of the character of moisture bonding with the determination of areas on which substances transform in the process of drying of cultivated oyster fungi. The forms of the state of water in fungi have been investigated by the method of differential thermal analysis. The periods of fungi dehydration and transformation of dry substances under thermal influence on cultivated fungi have been established.

The obtained scientific results can be useful and are employed in technologies of food fungi products.

Keywords: forms of moisture bonding, differential thermal analysis, cultivated fungi.

Introduction

Differential thermal analysis is efficiently used for obtaining information on the kinetics of the thermolysis process of various food products. Drying of fungi is one of the most important stages of the production process of food concentrates. The nutritive value and qualitative indices of finished products, which are the result of structural-mechanical, biological, and physicochemical transformations of substances, depend on the drying regime of fungi.

The technological drying regimes of fungi depend on the moisture content in them. For the efficient realization of the drying process of fungi, it is necessary to study the character of moisture bonding with the determination of areas on which substances transform with increase in the temperature.

The substantial influence of technological regimes on changes of carbohydrates, denaturation of proteins, oxidation of lipids, change of vitamins, and organic acids was established. The drying process of fungi includes complex reactions of transformation of substances, in each of which the following stages can be distinguished: supply of heat to the surface, transfer of moisture in the volume of the product, and biochemical reaction of its components.

The limiting stages that determine the rate of complex reactions is the internal diffusion of moisture in the product. This is why the problem of evaluating the capability of realizing biochemical reaction and determining the kinetic parameters can be stated on the basis of the construction of reliable kinetic models, which represent the features of realization of the drying process of fungi in time.

Materials and Methods

As an object of investigation, particles of oyster fungi with an oval cross-section and sizes 1.0 × 2.0 × 10.0 mm, which were preliminarily sorted to equalize the particle-size distribution and provide the homogeneity of the structure of the product, were used.

Derivatographic investigations of fresh and dried cultivated oyster fungi were performed by the method of nonisothermal analysis on a derivatograph of “Paulik-Paulik-Erdei” system at a constant rate of air heating of 3 °C/min to 300°C. To obtain the required accuracy of derivatograms, the following requirements to performance of experiments were chosen: the mean mass of samples of fresh and dry fungi of 200 mg; the temperature interval 20–300 °C. As a standard, Al_2O_3 calcined at a temperature to 2800°C was used.

Thermoanalytical curves used for a quantitative processing by the method of nonisothermal kinetics record simultaneously the change in temperature, the mass of a sample, the rate of change of the temperature and enthalpy, and change in the mass: ***TA*** is an integral curve of change in the temperature, ***DTA*** is a differential curve of change in the temperature, which is recorded with the help of two thermocouples connected in a differential thermocouple arrangement (one of the thermocouples is located in a crucible with an inert substance (Al_2O_3), and the other is located in a crucible with the investigated substance); ***TG*** is an integral curve of change in the mass; ***DTG*** is a differential curve of change in the mass.

Results and Discussion

In the process of drying, substantial physicochemical changes of fungi occur, as a result of which moisture is released, which determines the character of transformations of substances inside the product. Due to evaporation of moisture and decomposition of carbohydrates, cellulose, and other organic compounds, their mass decreases in the interval 80–92%. The fungi cell walls consist of a dense layer of fungine (replaces cellulose), which decomposes weakly during heat treatment. In drying, the structure weakens as a result of the partial hydrolysis of cellulose, hemicellulose, and other complex carbohydrates, of which cell walls and intercellular septa consist. Organic acids also undergo changes.

A quantitative evaluation of the forms of moisture bonding in the product was performed from experimental curves (*Fig. 1*) obtained by the thermogravimetry method. The segment of the curve of change in the mass corresponding to the dehydration process transforms into a dependence of the degree of transformation of the substance α on the temperature t. On the curve of change in the temperature ***TA***, segments that correspond to moisture release with different forms and energies of moisture were determined: ***AB*** corresponds to the heating and removal of weakly bound moisture, ***BC*** corresponds to the fracture of the bond of bound moisture, ***CD*** corresponds to the removal of adsorptionally bound moisture and partial decomposition of the substance, ***DE*** corresponds to the decomposition of the substance with the release of gaseous components and removal of chemically bound moisture.

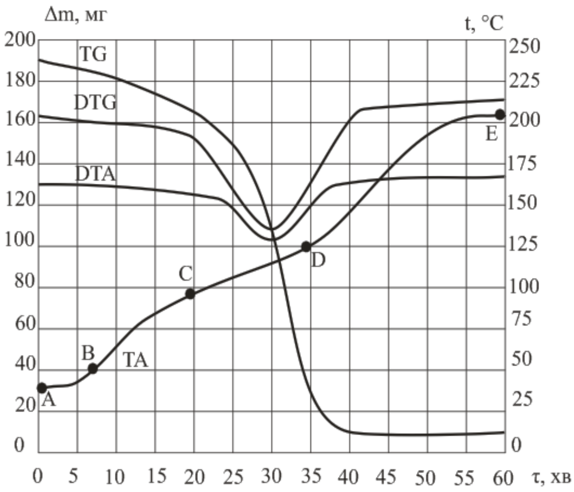

Fig. 1. Derivatogram of fresh oyster fungi

The derivatogram of oyster fungi has characteristic temperatures of degrees of hydration, destruction of substances, and temperature intervals of stability of intermediate compounds determined by peaks of endothermic effects, accompanied by the removal of moisture and gaseous fractions (*Table 1*).

Table 1. Kinetic temperature characteristics of the process

Kinetic temperatures of the process	Cultivated oyster fungi
Temperature of the beginning of the endothermic effect, °C	69–85
Temperature of the peak of the endothermic effect, °C	137
Temperature of the end of the endothermic effect, ˚C	170–200

On the ***DTA*** curve, significant endothermic minimums are observed at a temperature of 108°C. These minimums correspond to a maximum dehydration rate of products, are accompanied by an intensive mass loss of the sample, and are connected with the transformation of the substances of fungi and substantial release of the gaseous fraction. The segment of the curve of change in the mass corresponding to the dehydration process was transformed into a dependence of the degree of mass change or transformation of the substance on temperature. For this purpose, with an interval of 5°C, we found changes in the mass m_i of the sample, corresponding to the mass fraction of released water at a temperature t_i, on the ***TG*** curve. The degree of change in the mass (a) was calculated as the ratio of the mass m_i to the total mass fraction of water contained in the product (m), which is determined from the ***TG*** curve at the end of the dehydration process. The *TG* curve obtained on "a –T" coordinates has an S-like form, which reflects the complex character of the interaction of water with dry substances of fungi and assumes differences in the rate of release of water in different segments of this curve (*Fig. 2*). Thus, the curves of the temperature dependence of the degree of transformation of the components of fungi make it possible to study different kinetically nonequivalent forms of bonding of moisture and assume different rates of dehydration.

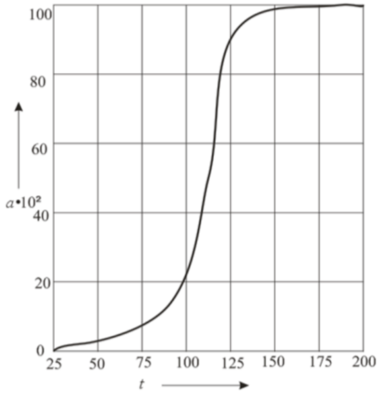

Fig. 2. Temperature dependence of the degree of transformation *a*.

The dependence of the change in the mass α on the temperature *t* (*Fig. 2*) in the temperature range for fungi from –28 to 200°C is characterized by an insignificant ($a < 0.1$) induction period, connected with the presence of the limiting stage of external diffusion retardation. Then an acceleration and monotonic increase in the degree of transformation $0.1 < a < 0.9$ occur, which reflects a substantial change in the mass connected with the release of water. Subsequent heating ($a > 0.9$) promotes an increase in the thermal decomposition of the substances of fungi. This conclusion is confirmed by the form of the ***TA***, ***DTA***, and ***DTG*** curves.

In the first stage (the segment ***AB***), the heating and removal of “free” water (mechanically and osmotically bound moisture) that have an insignificant energy of bond with the product occur. Released water forms a lacy network from associates of water molecules connected by hydrogen bonds with each other. In this case, desorption of capillary water is characterized by lower values of the activation energy as compared with desorption of water released in the second stage of the process.

In the process of heating, a part of osmotically bound moisture held in closed regions of protein micelles is released during unfolding of polypeptide chains at the temperature of evaporation of adsoptionally bound moisture as a result of the disturbance of micellar and hydrophobic interactions of proteins and carbohydrates with water.

In the temperature range about 74–80°C, the removal of the physicomechanically bound water ends, the release of the insignificant amount of weakly bound adsorption moisture of external polymolecular layers inside the product and the partial decomposition of substances begin, and in the temperature range 144–150°C, the destruction of substances is observed.

The deviation of the differential thermal curve from the basic line for oyster fungi 69– 85°C is caused by the endothermic effect as a result of the desorption of liquid from the product during its heating. On the ***DTA*** curve, the effect is accompanied by a change in the mass (the ***TG*** curve) and by the effect on the ***DTG*** curve, which enables us to establish the beginning and end of the change in the enthalpy.

The endothermic effect at a temperature of 137°C, which is accompanied by the end of the intensive mass loss, corresponds to the release of water molecules with a physicochemical bond and removal of gaseous fractions. At a temperature of oyster fungi of 170 to 200°C, the beginning of the decomposition of the substances of the product is observed. At a temperature above 200°C, the peak-like ***DTG*** curves are caused by the substantial destruction of substances, which is also noted on the ***TG*** curve as the mass of samples decreases, with subsequent carbonization of products. The total mass loss in heating of oyster fungi to a temperature of 220°C is equal to 68.96% (*Table 2*).

Table 2. Kinetic temperature characteristics of the process

Structural changes	Temperature characteristics of fungi, °C
Removal of the main mass of moisture	(69–85)…(170–200)
Removal of the last water molecule at the end of heating	220
Beginning of the destruction of the substances of the product	144–150

The third stage of dehydration (the segment ***CD***) corresponds to the removal of strongly bound moisture, hydrating active groups of dry substances.

In the fourth stage (the segment ***DE*** of the curves), the transformation and destruction of the structure of carbohydrates and organic acids end.

Thus, the analysis of the obtained data enabled us to distinguish four periods of fungi dehydration and transformation of dry substances under thermal influence on fungi and determine temperature zones that correspond to release of moisture with different forms and energies of bond.

Conclusions

The performed analysis of the obtained data made it possible to distinguish periods of fungi dehydration and transformation of dry substances under thermal influence on cultivated fungi and establish temperature zones that correspond to the removal of moisture with different forms and energies of bond, which will enable us to choose the most efficient regime of the drying process.

References

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