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INNOVATIVE SOLUTIONS IN DRYING TECHNOLOGYOF MUSHROOM RAW MATERIALS

Prospects for the use of dried cultivated champignons (Agaricus bisporus) and shiitake (Lentinula edodes), progressive ways of drying mushrooms are analyzed. The rational parameters of convective mushroom drying under oscillatory mode are grounded and new solutions in A. bisporus and L. edodes drying technology are proposed in order to intensify the process, increase its energy efficiency and obtain a dried product with high quality indicators.

Keywords. *Mushroom raw material, convective drying, oscillating mode, energy efficiency, quality.*

Relevance of the research topic. A promising area for the development of modern food production and restaurant facilities is the development of energy-efficient raw material drying technologies, which are subsequently widely used for food production, cooking and culinary products. The efficiency of the drying process and the quality of the dried raw material will depend on the demand for the finished product and its sale and, as a consequence, the competitiveness of domestic production.

The market of dried food raw materials in Ukraine is represented mainly by vegetable raw materials: onions, greens, garlic, spicy vegetables, paprika, carrots, beets; to a lesser extent – powdered milk raw materials (powdered milk, whey, concentrate of milk and whey proteins) and fish raw materials (ready-to-cook fish products, fishmeal). Particularly important among these products are dried mushrooms, which are traditionally represented by *Boletus mushrooms*, *Honeysuckle, Chanterelles*.

Cultivated mushrooms: champignons (*Agaricusbisporus*) and shiitake (*Lentinulaedodes*) have been of high demand in the past few years. The great interest in cultivated mushrooms is explained by the fact that they are much safer than wild plants and have high taste properties. The chemical composition of dried *A. bisporus* and *L. edodes* is similar to animal products, they carry up to 20% of complete proteins, with 30-40% of the total weight of fungal protein amino acids being essential, especially great amount of lysine, threonine, valine, leucine and isoleucine, which are little in vegetable products. Mushrooms contain a lot of lecithin (fatty substance) and glycogen (animal starch), B vitamins up to 1,2 mg/100g, niacin up to 20 mg/100g and phenolic substances up to 1,5%; high content of zinc and phosphorus [1]. Mushrooms of *A. bisporus* and *L. edodes* have therapeutic, prophylactic, tuberculous and oncostatic effect [6]. Modern scientific researches have added new facts of the high ability of chitin (the main compound of the cell wall of fungi and the chemical compound of chitosan, substance close to it) to purify biologically the human body from radionuclides and various toxic substances [8]. The advantage of cultivated mushrooms is the fact that their yield does not depend on seasonal changes, so, in cultivated structures they are grown during the year, regardless of soil and climatic conditions, harvesting up to 11 thousand h/he per year [7].

Formulation of the problem. A specific drawback of the sale of fresh cultivated fungi A. bisporus and L. edodes is the limited shelf life. Thus, fresh *A bisporus* mushrooms are stored for no more than 4 days at 4… 7°C and up to 10 days at 0… 4°C and 85…90% relative humidity without air access, *L. edodes* up to 10 days [4]. Thus, fresh mushrooms belong to perishable products - this is due to the peculiarities of the chemical composition and high activity of tissue enzymes, as well as the intense development in the fruiting bodies of microorganisms. The shelf life of fresh mushrooms is limited by the hours during which special treatment (preservation) must be carried out, which changes their properties.

Special treatment includes the preservation of mushrooms: pickling, drying, freezing. The most convenient and popular way to extend the shelf life of mushrooms is through drying. Therefore, the search for innovative solutions in the drying technology of *A. bisporus* and *L. edodes* in order to obtain a high-quality product for further use in the food technology (first and main courses, sauces, salads, mince for culinary products, etc.) is a relevant and promising topic of research.

Analysis of recent researches and publications.

Drying is one of the most common ways of removing moisture from the material, which contributes to the transportability of mushroom raw materials, the storage stability. The modern search for innovative modes and methods of drying mushroom raw materials in order to obtain high-quality dried product is highlighted in the scientific works of such scientists as Tarasenko T. A., Shapar R. A., Dabizha N. A., Butkevich T. A., Popovich V. P., Zinchenko I. M., SevikS., AktasM., Lidhoo C. K., Agrawal Y. C., Xiao fei Wu, Min Zhang, et al. [2].

The following methods are used for drying mushrooms: contact, thermo-radiation, dielectric, acoustic, sublimation, sublimation vacuum, convective. In modern industries, the convective method is most often used, but it is energy-consuming and long-lasting. The process of convective drying can be intensified to increase its energy efficiency through the use of additional driving forces: the use of pulsed drying mode, combining convection with infrared rays, microwave and electromagnetic irradiation of the product, the use of oscillatory convective drying.

The most progressive methods of drying plant materials are;

– thermoradiation-convective drying method at a drying agent temperature of 40… 55°C with the combination of infrared irradiation with dark and light TENs. Thermoradiation convective drying of mushrooms saves considerable time and energy, but the disadvantages of this method of drying are insufficient amount of specialized industrial equipment for drying – thermo radiation dryers, high cost of these installations, lack of competent personnel for operation and care of the equipment [3].

– Oscillating convective drying with a cyclic oscillating alternation of heating and cooling with air convection speed in the drying chambers being within 5,5. . 6,0 m/s [5], which also significantly saves time and energy resources and does not require specialized equipment.

– Sublimating drying at 60°C provides the maximum possible degree of storage of thermally labile raw materials, is highly energy-efficient, but time- and cost-consuming (the cost of specialized drying installations, the lack of competent staff).

The oscillating method of drying does not require special equipment, so it is easy to implement in the modern production with traditional convective drying installations. However, this method is currently limited: mainly for the drying of solid varieties of wood, medicinal plants, grains and certain vegetables (artichoke, carrots), as for the drying of mushrooms, in particular *A. bisporus* and *L. edodes*, no scientific developments on this subject have been covered in modern scientific literature.

Taking into consideration the lack of the scientific researches on the development of innovative propulsion in the technology of convective drying of *A. bisporus* and *L. edodes* in order to maximize the preservation of the content of biologically active substances, natural taste properties while ensuring the energy efficiency of the process, the search for technological solutions and scientific substantiation of rational parameters of ossification *A. bisporus* and *L. edodes* are relevant and promising.

Outline of the main research material.

To substantiate the rational parameters of the oscillating convective drying process of *A. bisporus* and *L. edodes*, the cultivated fungi *A. bisporus* and *L. edodes* were used according to TU 9164-082-37676459: 2012 and TU 01. 1-16304966-047-

2002. Drying of all prototypes of mushrooms was preceded by their sorting, cleaning, grinding.

To study the effect of the size of the mushroom particles on the intensity of drying, a trial of *A. bisporus* was carried out, whole mushrooms, crushed into cubes of size 10x10mm and slices with a thickness of 4. . . 5mm. The mushrooms were dried at 60°C, because according to the studies of the specificity of the convective method of drying plant materials, this temperature provided a high degree of preservation of their biologically active substances [3]. Since *L. edodes* has the same morphological structure as *A. bisporus*, it was decided not to carry out studies with them to establish rational grinding parameters.

The data on the effect of drying duration on the degree of grinding of mushroom raw materials are summarized in Fig. 1.

During the experiments, it was found that the fastest drying occurs when grinding mushrooms with slices with thickness of 4… 5mm, τ = 280·60s, during grinding with a cube of 10x10mm, the drying time increases by 40·60s, while drying with whole mushrooms – by 180·60s. Therefore, it is rational to grind the mushroom raw with slices of 4… 5mm thick.

After grinding, the mushrooms were laid on perforated sheets 10…15 mm thick, to increase the area of contact with the drying agent, and sent to the drying cabinet.

In order to substantiate the rational mode of convection of the fluid during drying, convective drying of *A. bisporus* at 60°C and υ_{air} = 1…7m/s was carried out. These studies are summarized in Fig. 2.

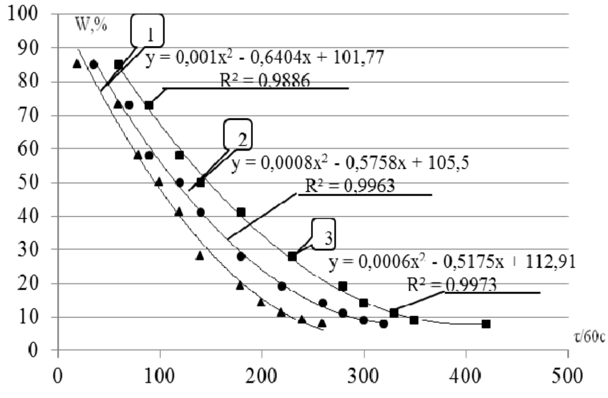

Fig. 1. The influence of the duration of drying of A. bisporus on the degree of grinding, where 1 – slices of 4. . . 5 mm, 2 – cubes 10x10mm, 3-wholemushrooms

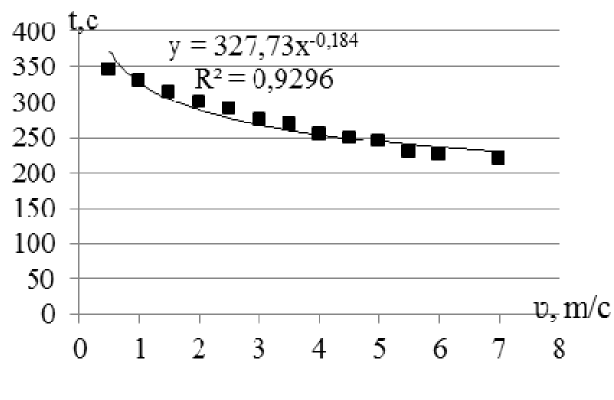

Fig. 2. The in fluence of the velocity of the convection of the coolanton the dry in gtime of A. bisporus

Analyzing the data of the study, we can conclude that the samples are most rapidly dried at υ_{air} = 3… 7 m/c. However, when the velocity of convection of the coolant in the chamber of the oven was over 6,0m/s, there was a slight swelling of slices of mushrooms, so we do not consider it to be advisable to increase the velocity of convection of the coolant over 6,0m/s. The convection velocity within 3. . 5m/sis is rational. However, during the test drying with constant convection of the coolant 3. . . 5m/s, the surface of the mushroom plates and their darkening were observed. Therefore, we consider it to be rational to dry mushroom raw materials at the rate of convection of air in the chamber of the drying cabinet 1,5m/s with a periodic increase of υ_{air} to 5,5m/s for a short period to create a difference of temperature and humidity gradients, with the purpose of intensification of drying.

The next stage of the study was convective oscillation drying, which was performed alternately by alternating two cycles:

1) The first drying cycle: t = 60°C; distance from TENs to the product – (15…16)·10mm; υ_{air} = 1,5m/s. The process continued until the humidity in the drying chamber was increased to 80%, τ = (40… 60)·60c. The humidity level in the chamber was recorded with a moisture meter mounted in the drying chamber of the cabinet.

2) Second cycle of drying - convective drying of mushrooms at υ_{air}= 5,5m/c without heating of the chamber of the drying cabinet (with TEN heater off). The process continued until the humidity in the drying chamber was reduced to within 45…55%, τ = (10… 15)·60c.

The drying time of the mushroom raw material was recorded by a timer. These drying kinetics are summarized in Fig. 3 and 4.

The control was the traditional industrial method of drying mushrooms - one-stage convective, at υ_{air} = 1,5m/c and a temperature of 80°C.

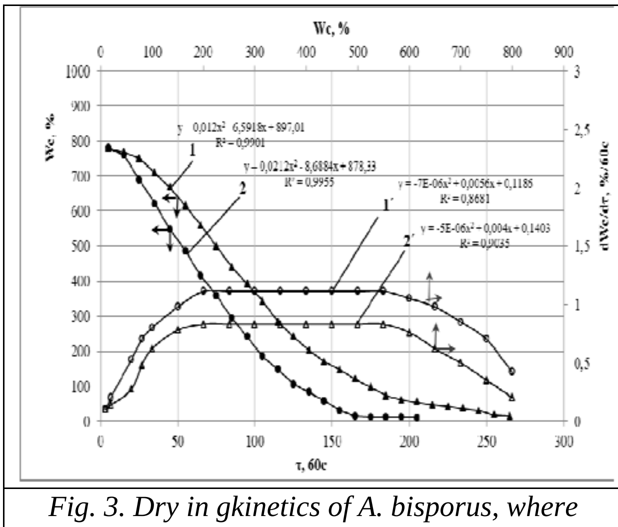

Fig. 3. Dry in gkinetics of A. bisporus, where
1 - t = 60ºC,
2 - t =80ºC

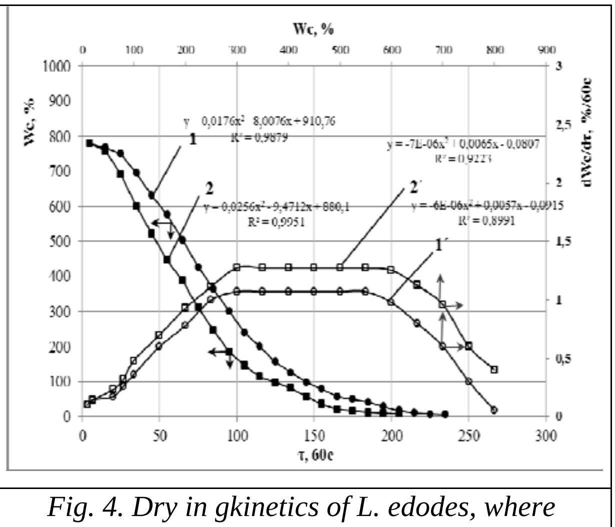

Fig. 4. Dry in gkinetics of L. edodes, where
1 - t = 60ºC,
2 - t = 80ºC

According to the study data, the drying time of *A. bisporus* is reduced by 45·60c when applied to the oscillation mode, compared to the control, with the energy consumption level being 6,3kW/h·kg, thus saving energy up to 12%, the drying time *L. edodes* is reduced by 30·60c, with energy consumption of 5,9 kW/h·kg, energy savings – 10%.

The mushrooms dried according to the proposed technology had high organoleptic properties: the surface is light cream color, smooth without cracks and dark spots caused by the melanin formation reaction, with a pronounced mushroom aroma.

Conclusions. As a result of the studies of the parameters of drying of the mushroom raw material *A. bisporus* and *L. edodes*, rational parameters of convective drying under the oscillatory mode were established: the form of grinding – slices with a thickness of 4…5mm, drying t – 60°C, υ_{air} – with cyclic changes of 1,5 and 5,5 m/c, drying = (200… 220) 60c. This drying mode saves time by (35… 45) 60c and saves energy by 10… 12%. Thus, the technology of cultivation of cultivated fungi *A. bisporus* and *L. edodes* was improved in order to increase the energy efficiency of the process, to obtain a dried product with high organoleptic quality indicators for further use in the food technology for modern restaurants.

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