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REHYDRATION OF NAMEKO (*PHOLIOTA NAMEKO*) AND SHIITAKE (*LENTINUS EDODES*) FRUITBODIES DRIED CONVECTIONALLY AND SUBLIMATICALLY

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ABSTRACT

The reconstitutional properties of mushroom fruitbodies dried convectionally and sublimatically were analysed. The fruitbodies of nameko (*Pholiota nameko*) and shiitake (*Lentinus edodes*) which differ in the structure, chemical composition and growth rate were examined. It was found that the most important influence on the rehydration rapidity (time of rehydration) was exterted by the method of drying. The differences between these two species of mushrooms were also distinctive and dependent on individual features of raw substrate and was closely connected with the examinated mushroom species.

Key words: rehydration, drying, *Pholiota nameko*, *Lentinus edodes*

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INTRODUCTION

For many years an increasing demand for mushrooms was the result of their taste and flavour values, which enable the preparation of various products in food industry and house keeping. Due to their seasonal occurence in nature, the crops from natural habitats cover only a small part of market demand. Therefore, the indoors cultivation and the processing of new species of mushrooms have gained a greater importance. Mushrooms cultivated indoors are the products characterized by high nourishing quality and low costs of production. Mushroom fruitbodies have nourishing significance in spite of their high water content (85-92%). The dry substance of fruitbodies consists mostly of carbohydrates (11-33%), while proteins are the second component occuring in quite high amounts and containing all exogenic aminoacids. Mushroom proteins are digestable by humans in 80-90%. The amount of fats, as compared to other foods, is not high and makes 2-6% of dry substance. Ash content makes 5-13%. Mushrooms are rich in alkaligenous substances in contrast to the majority of food products [5, 6, 16].

The search for new methods of processing and preservation of products assuring the achievement of high quality food has a special significance. Fresh mushrooms belong to the group of products which are characterized by limited shelf life. Their longer storage require preserving treatments. Lyophilization is a very good method of preservation because of good maintenance of organoleptic features and rehydration ability of product. Food products preserved by this method are characterized by a high level of retention of flavour compounds. The principles of lyophilization is based on drying of frozen product. The removal of water from the product takes place by sublimation. The aim of lyophylization is the same as in the case of other drying methods – biological preservation of product by reducing the water activity. The decrease of water content slows down or inhibits metabolism biologically, biochemically or chemically extending the period of food persistence.

This process should take place in conditions preventing irreversible changes, which could lower the quality of products. These changes are mostly connected with protein denaturation and starch colloidization because of intensive heating of the material while drying it. During the convectional drying the temperature of the dried material and water content are the subject of constant changes. The air warmed by the source of heat comes to the material, delivers heat required for warming the product up and evaporation of water and consequently cools down. The air is a heat carrier conveying heat and evaporating water together with dissolved compounds, e.g. aroma substances. The most important causes of the dried food quality changes decreasing its ability to dehydration are oxydation of fats, vitamins, pigments and flavour-taste substances as well as crystalization of some components [1, 2, 3, 11].

Osmotic dehydration is proposed as a pretreatment before convectional drying of fruit and vegetables. This process has an evident influence on the chemical composition and chemical and physical properties of the final product. The investigations showed that dehydration in sugar solutions is the surface process, which generates only inconsiderable changes in the structure of materials. The carbohydrate layer occurring at the surface decreases the losses of the water soluble compounds mostly volatile, it protects carotenoids, restrains the processes of nonenzymatic browning, modifies the taste and influences the structure of the dried substrates.

Until now, there is not much information about the reconstitutional properties of mushrooms. The investigations of the rate of reconstitution of chemical and physical properties of products during rehydration also include changes in the volume, consistency and rheological properties of materials. Variability of these features can result from the properties of the dried material, the method of pretreatment and the drying parameters, which was confirmed in the investigations conducted on vegetables and fruit. The pretreatment and the drying method of onion have an essential influence on its reconstitutional properties. The soaking in water and dipping in amylose syrup solution improved these properties. Increasing the temperature of the drying air using infra-red radiation slightly improved the reconstitutional properties of dried onion as compared with the product obtained by convectional drying in 60°C. The rate of dehydration of carrot samples dried in temperature 25°C and 65°C was similar. Natrium chloride addition did not substantially influence the rate of rehydration but caused the reduction of the speed irrespectively of the temperature of soaking. A high influence on the decrease of the rate of water content changes during carrot rehydration is exerted by osmotic dehydration as a pretreatment before convectional drying. The amount of water in convectionally dried carrot after three hours of rehydration is about twice as high as in the samples dried osmotically. The rate and effect of rehydration also depends on individual features of the raw material. A high amount of water after soaking of dried apple samples results from the loose structure of fruit tissue containing large empty spaces and a large amount of pectines and fibre, which are able to keep water while swelling [4, 8, 9, 12, 13, 15, 17, 18].

Aroma is the main factor of the food quality. A constant and high demand for mushrooms result from their flavour and taste values. It has to be emphasized that conventional methods of drying of fungi fruitbodies can cause many defects resulting from deep changes occurring in raw material during technological process. The classic drying process taking place in elevated temperatures and strong aeration of the material brings out its contraction, changes of consistency as a result of denaturation of protein cell membranes and decomposition of pectines. The digestibility of proteins, decrease in savouriness, colour changes, the amount of vitamins and aroma substances specific for mushroom also change. Susceptibility of some chemical components of mushroom tissue to higher temperatures constrains the use of such technical solutions that lower the temperature of drying to 40-70°C. Higher temperatures cause a crust formation on the surface of fruitbodies, which makes the water evaporation difficult. The overheating of the material in the last phase of drying causes the substrate burning. The most important feature of lyophilization in the case of mushrooms is the possibility of long storage at room temperature if the method of packaging is proper. An indication of the quality of food dried sublimatically is the retention of aroma substances. Drying of frozen food assures a high level of retention of aroma and colour without essential changes of compounds making up the aroma. The presence of ice crystals in tissues in the first phase of the process assures the maintenance of the shape of the mushroom fruitbodies. Products dried sublimatically can be reconstituted to their original shape at any time by water addition (rehydration). They can also be dissolved in salt solutions or other physiological liquids making new, interesting products. Lyophilization is most often applied for producing instant type food from meat, vegetables and fruit [5, 6, 15].

Reconstitutional properties of product depend on the internal structure of the tissues and the surface of the sample. One of the most important features of the sublimatically dried food is the ability of fast and total rehydration. A wide use of this process is limited by its high costs of investment and energy. It is necessary to search for the new instrumentation and improve the process parameters, which would result in higher profitability [20].

Mushroom fruitbodies have been known as a food source for several thousands of years. The use of mushrooms as a substrate in vegetable processing create a possibility of preparation of many products such as: pickles, mushroom-vegetable salads and suplements to canned vegetable-meat food. Dried mushrooms are used in catering and food industry to obtain soups, sauces and concentrates. Proteins soluble and nonsoluble in water are important nutritional component of mushrooms. Nitrogen fraction consisting of soluble and water insoluble compounds contain aminoacids, amines, peptides, chitin and nucleic acids. Many of them are biologically active [10, 14].

The aim of the investigations was to evaluate the rate of rehydration of mushroom fruitbodies differing in the speed of growth and development. The samples for rehydration were prepared by two different methods: classical convectional drying and sublimatical drying, which that allows mushroom components to keep up the biological activity.

MATERIALS AND METHODS

In the experiments two species of mushrooms: nameko (*Pholiota nameko*) and shiitake (*Lentinus edodes*) from the collection of the Department of Fruit and Vegetable Processing were used.

The fruitbodies of the analysed species were collected at their full physiological maturity. Caps of the fruitbodies were cut into 2 mm-thick slices, frozen at –18°C and then dried convectionally and sublimatically.

Drying was conducted in one layer. The rate of air flow in conventional drying was constant and equal to 1.6 m/s.

The degree of rehydration of the dried mushrooms was determined according to a modified method of Lenart [8]. Dried samples with a defined weight were soaked in 100 cm^3 of distilled water in 20°C. The rehydration kinetics was examined in the time ranging from 1 to 5 hours for samples dried convectionally and from 1 to 6 minutes for lyophilized samples. After a definite time the samples were drained and weighted and the dry substance of the sample was determined by Drzazga [1] and Strumiłło [9] methods.

During the rehydration (30 min-6 hours for convectionally dried samples and 0-6 min for sublimatically dried samples) the weight gain of the sample was determined three times. The amount of water in samples was calculated according to the formula:

$$W = \frac{m_p - m_s}{m_p} \cdot 100\%$$

where:
W – water content of rehydrated sample,
m_p – sample weight during rehydration,
m_s – sample dry weight.

The results were subjected to statistical evaluation using regression analysis and appropriate software (Curv +) optimizing mathematical description of the relation of moisture and dry mater of the product on the one hand and the time of reconstitution on the other.

RESULTS

The results were presented on the figures 1-16. The basic parameters necessary for graphic presentation of data are shown in the table 1. The calculation were done according to the equation:

$$W = a \cdot e^{(\ln(t)-b)^{\frac{1}{c}}}$$

Table 1. Parameters of the equations for *W*

Figure	*a*	*b*	*c*	Corelation coefficient
1	2.7153	-9.0939	189.3967	0.8631
2	0.9863	-7.9471	102.3704	0.9708
3	5.3503	-13.5547	519.7943	0.9891
4	0.5786	-9.8496	56.9854	0.9605
5	1.5838	-10.0951	60.3096	0.9957
6	2.2487	-11.6781	78.9904	0.9938
7	2.6287	-11.8850	51.7731	0.9969
8	2.4421	-12.9900	59.7805	0.9985
9	2.8109	-11.1019	93.0739	0.9719
10	0.3758	-8.4306	42.1822	0.9189
11	3.6102	-11.6634	89.8904	0.9926
12	1.8702	-11.2861	66.9646	0.9948
13	40.4845	23.6580	-80.0413	0.9998
14	127368.87	48.8933	-150.1646	0.9990
15	9.5925	17.1751	-61.2666	0.9994
16	65166.258	39.8130	-114.9321	0.9997

The studies showed that sublimatical drying facilitates and accelerates the rehydration of nameko (*Pholiota nameko*) and shiitake (*Lentinus edodes*) fruitbodies. During the 3 minutes of soaking the lyophilized fruitbodies of nameko and shiitake gained similar amounts of water as convectionally dried fruitbodies of these mushrooms during 2 and 3 hours respectively. Besides, the lyophilized samples of nameko and lyophilized samples of shiitake 3 and 4 minutes after soaking were characterized by the amount of water close to equilibrium (fig. 1 and or 2 and 4). Evaluating the way of absorbing water by fruitbodies of two biologically different species, it was shown that the tissue structure of fruitbody and the amount of fibre substances differ substantially. Fruitbodies of nameko, growing and maturing faster, have a looser structure of flesh tissue than shiitake which grows slowlier and forms fruitbodies later. It was apparent in faster absorption of water by tissue of nameko fruitbodies (fig. 1 and 2 or 3 and 4). After the defined time of rehydration, the evaluation of the amount of water absorbed by the unit of dry substance showed fewer differences between fruitbodies of these two fungi (fig. 3 and 5 or 6 and 7). Such a way of hydration during the time of soaking can be explained by the high amount of fibre substances, which have the ability to swell and accumulate water. Figures 5 and 7 or 6 and 8 show the increase of water content absorbed by the unit of dry substance of fruitbodies during rehydration. The influence of the method of preparing and drying was evident. Slow freezing to –18°C and then convectional drying in comparison to sublimatical drying considerably decrease the possibility of absorbing water by both mushrooms. The evaluation of the way of absorbing water by these two species of mushrooms showed more essential differences in the amount of the absorbed water when samples were dried convectionally (fig. 5 and 6) than sublimatically (fig. 7 and 8). During rehydration two different periods of soaking could be distinquished: the first one was characterized by fast increase of water content and the second in which changes were more uniform and the increase of water content with time was constant (figures 9 and 11 or 10 and 12).

Fig. 1. The water content changes during rehydration of *Pholiota nameko* fruitbodies dried convectionally

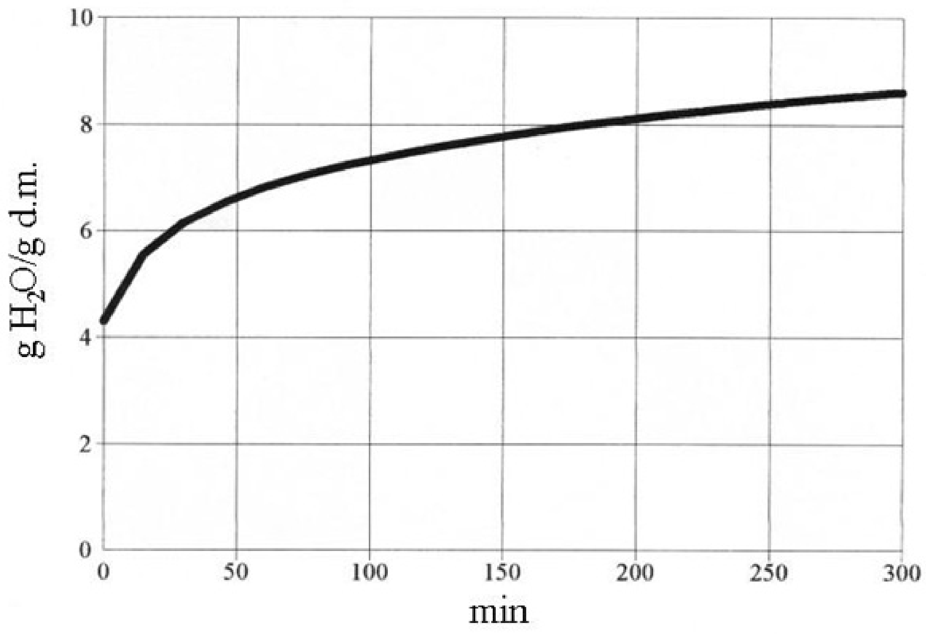

Fig. 2. The water content changes during rehydration of *Lentinus edodes* fruitbodies dried convectionally

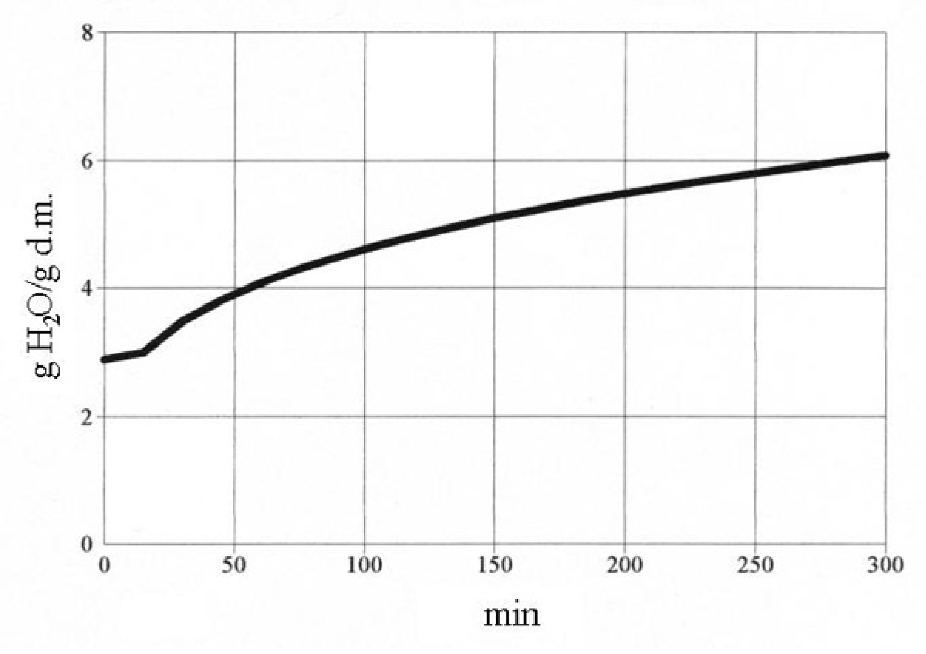

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Fig. 3. The water content changes during rehydration of *Pholiota nameko* fruitbodies dried sublimatically

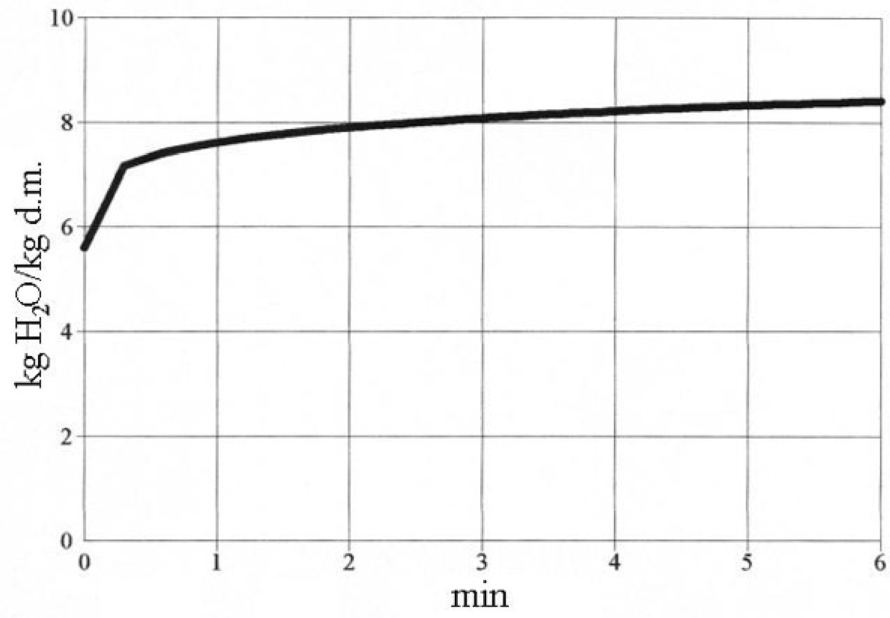

Fig. 4. The water content changes during rehydration of *Lentinus edodes* fruitbodies dried sublimatically

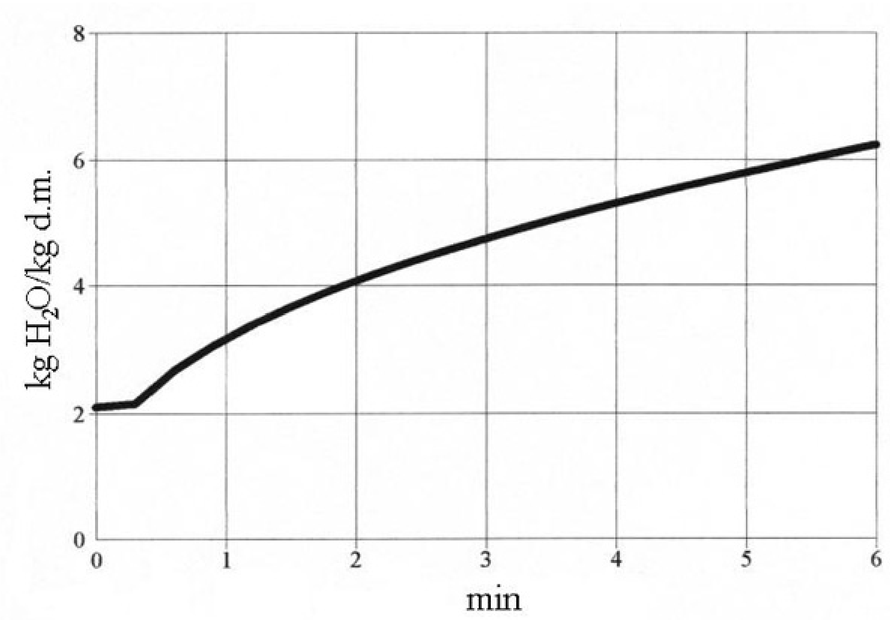

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Fig. 5. The relation of *W = f(t)* during rehydration for *Pholiota nameko* fruitbodies dried convectionally

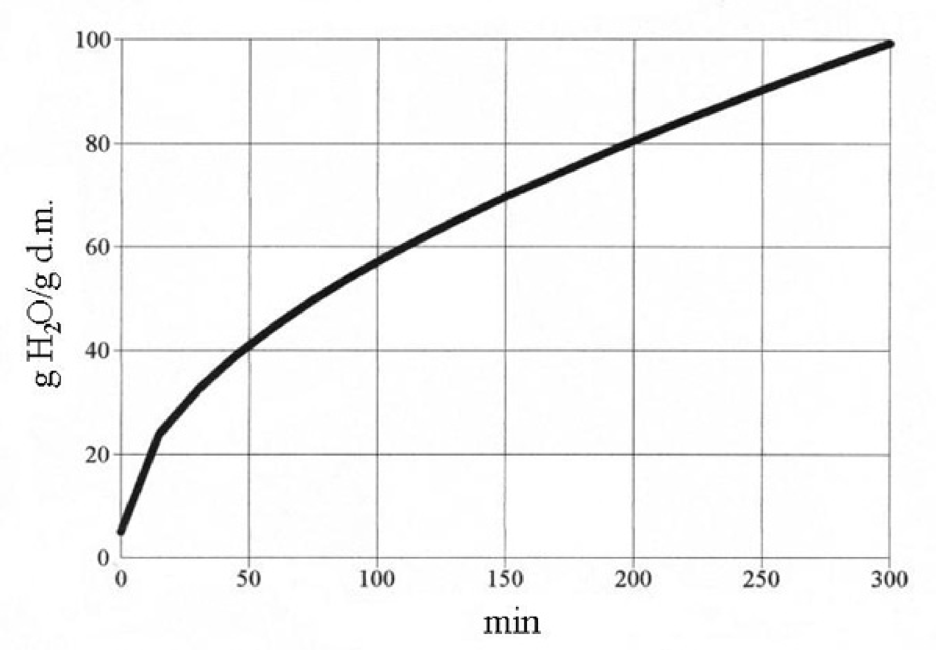

Fig. 6. The relation of *W = f(t)* during rehydration for *Lentinus edodes* fruitbodies dried convectionally

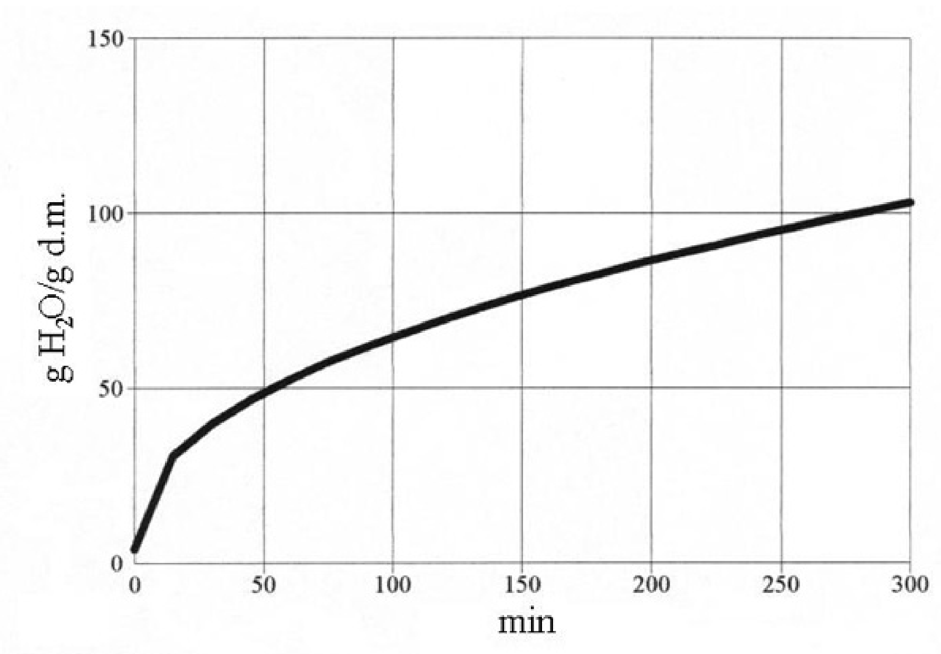

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Fig. 7. The relation of *W = f(t)* during rehydration for *Pholiota nameko* fruitbodies dried sublimatically

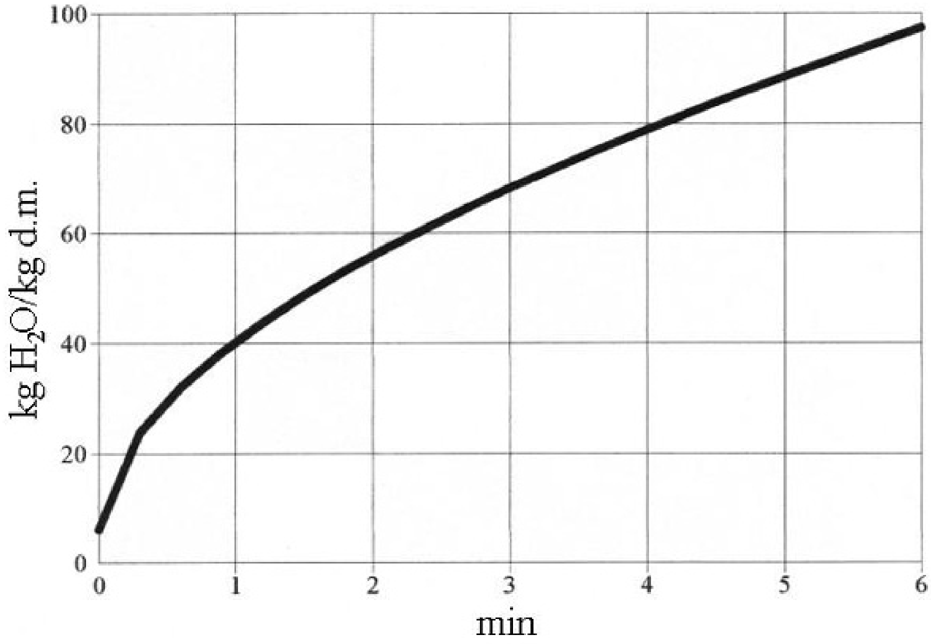

Fig. 8. The relation of *W = f(t)* during rehydration for *Lentinus edodes* fruitbodies dried sublimatically

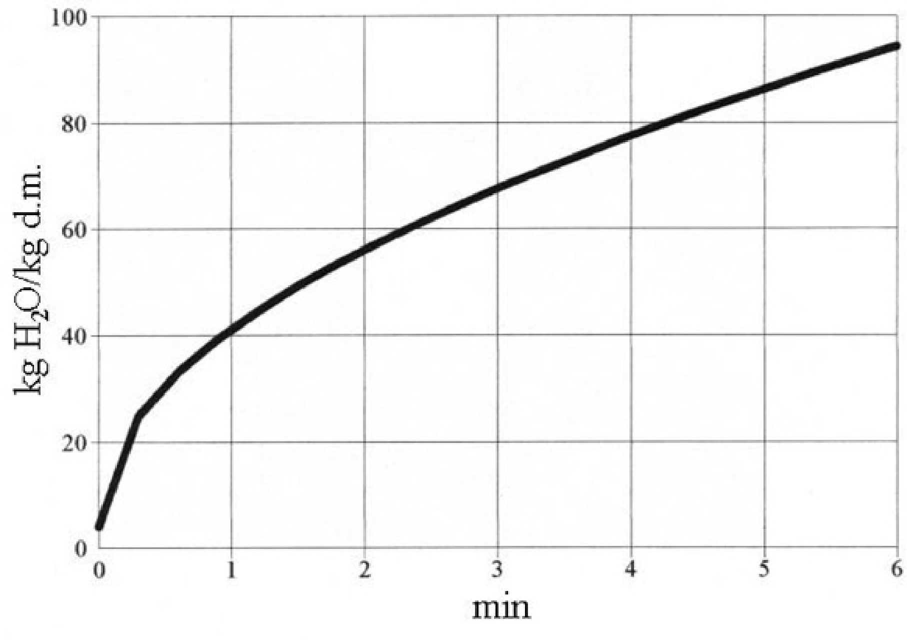

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Fig. 9. Rehydration curve for *Pholiota nameko* fruitbodies dried convectionally

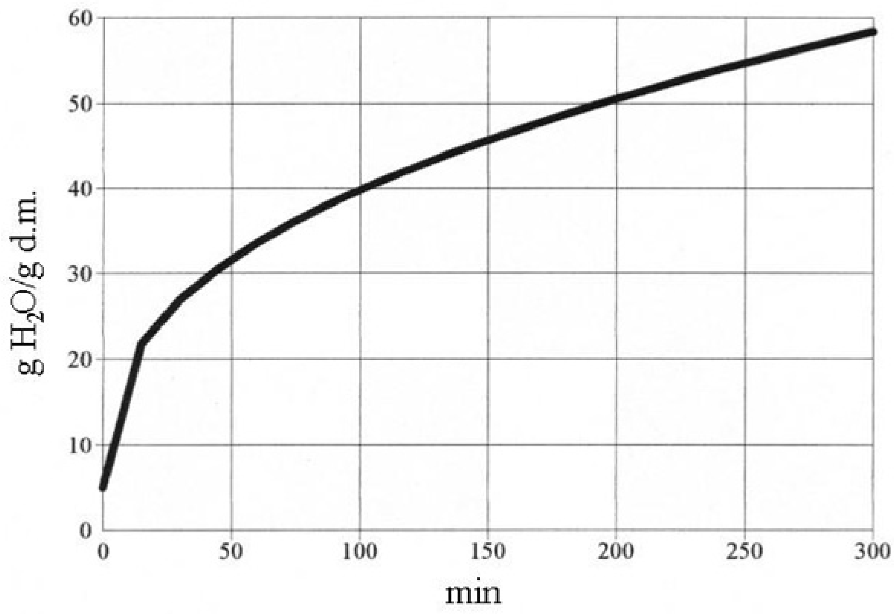

Fig. 10. Rehydration curve for *Lentinus edodes* fruitbodies dried convectionally

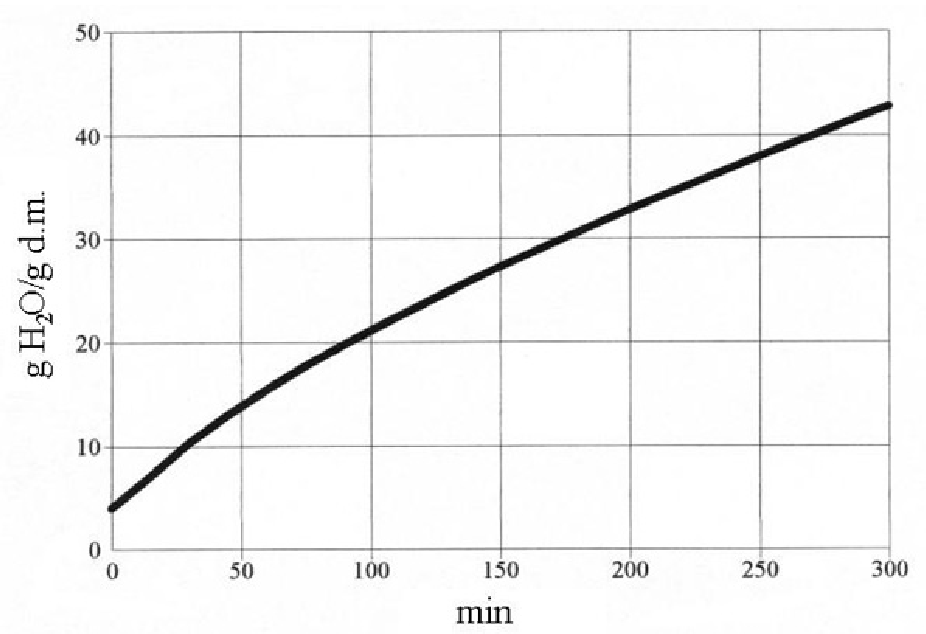

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Fig. 11. Rehydration curve for *Pholiota nameko* fruitbodies dried sublimatically

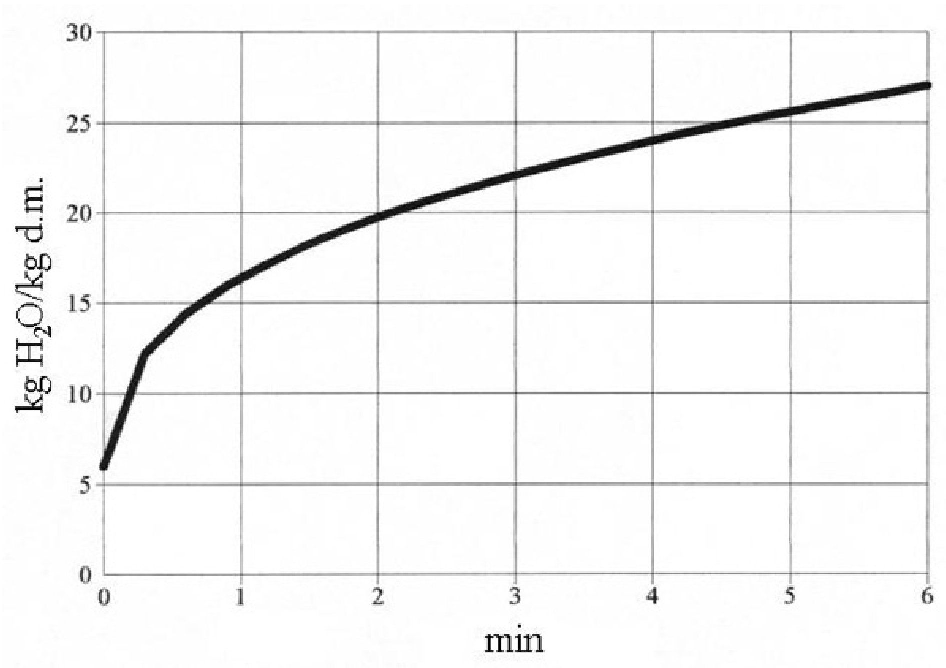
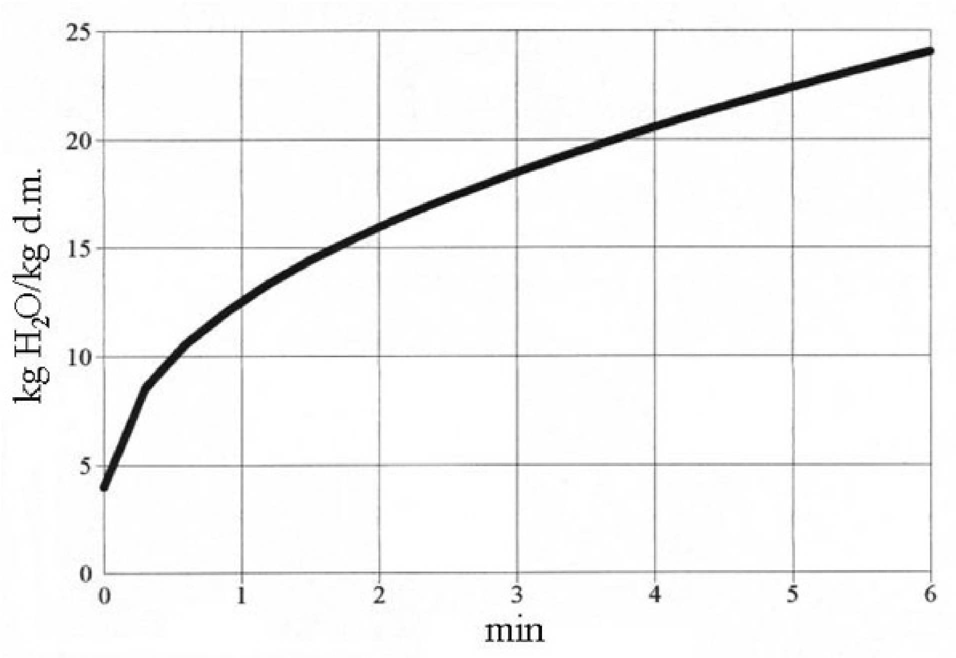


Fig. 12. Rehydration curve for *Lentinus edodes* fruitbodies dried sublimatically



Mushroom fruitbodies differ from higher plants by a higher activity of enzymes. Injury of fruitbodies while cutting caused an increase of activities of enzymes and chemical reactions. Soaking of fruitbodies, which were cut into thin slices caused dissolving of soluble substances during rehydration. Figures 13 and 15 or 14 and 16 show the losses of dry substance during rehydration. The speed of solubilization and the quantity of dry substance loss were dependant on the time of rehydration and the species of mushrooms.

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Fig. 13. The loss of dry matter content during rehydration of *Pholiota nameko* fruitbodies dried convectionally

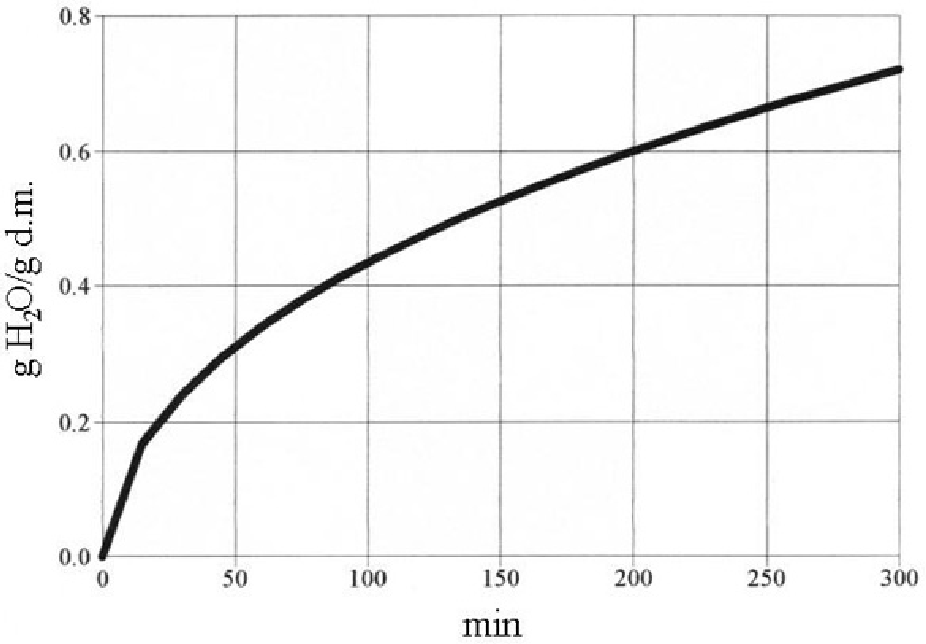

Fig. 14. The loss of dry matter content during rehydration of *Lentinus edodes* fruitbodies dried convectionally

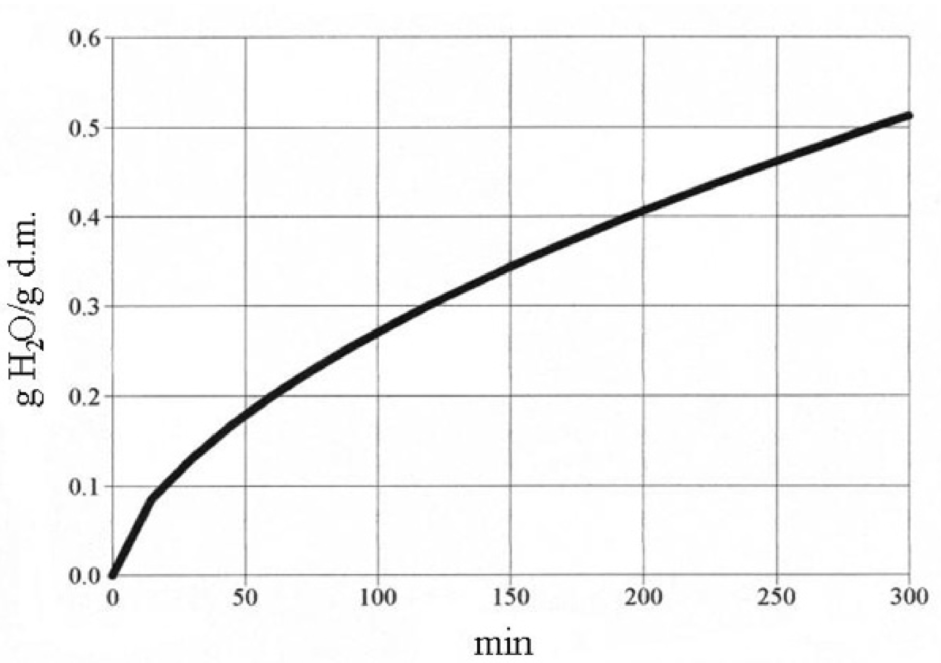

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Fig. 15. The loss of dry matter content during rehydration of *Pholiota nameko* fruitbodies dried sublimatically

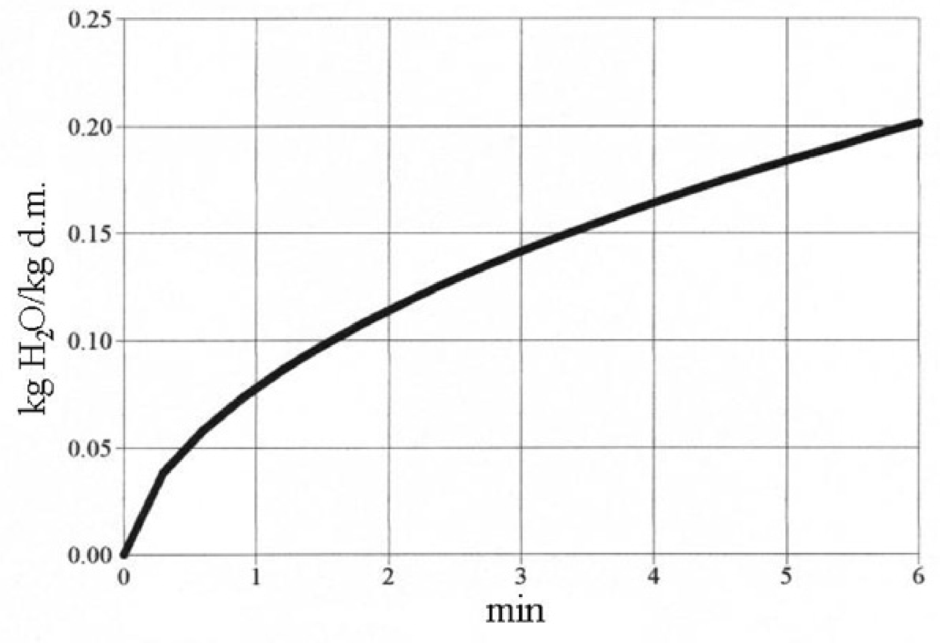
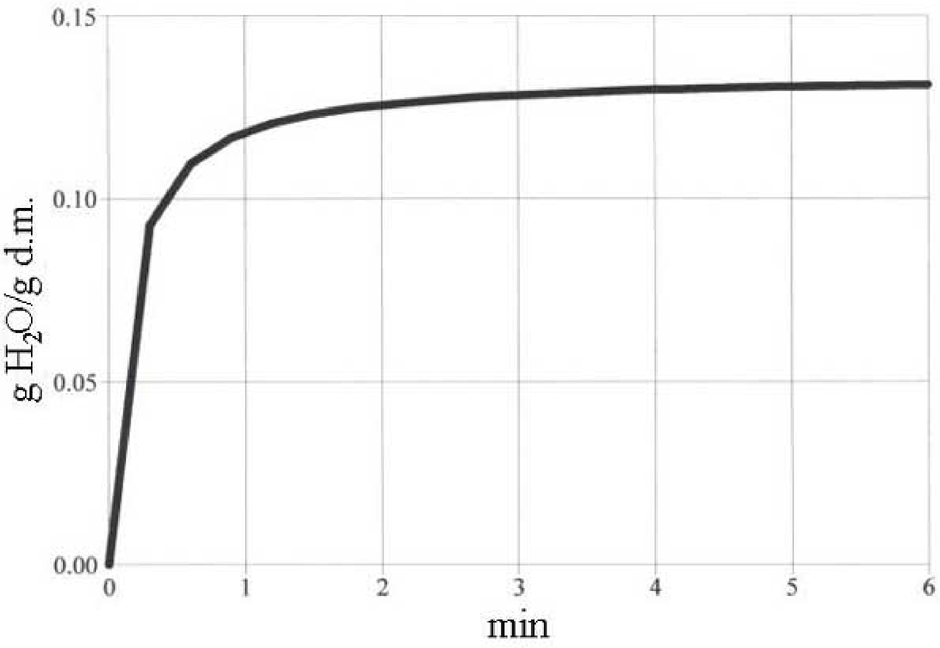


Fig. 16. The loss of dry matter content during rehydration of *Lentinus edodes* fruitbodies dried sublimatically



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CONCLUSIONS

1. Reconstitutional properties of dried mushrooms depended on the method of drying. The process of lyophilization made the rehydration of fruitbodies of both examined fungi easier.
2. Sublimatical drying of fruitbodies caused that during rehydration the water was taken much faster, i.e. 3 min than after convectional drying of the samples (120 min) of the same mushroom.
3. Soaking caused losses of dry substance. The longer time of rehydration was, the higher losses of dry substances were caused by dilution of soluble compounds. The convectional method of drying mushrooms caused twice as many losses during rehydration as the sublimatical method of drying.
4. Few studies on the mushroom rehydration call for more detailed examinations of the process.

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