OPTIMUM FREEZING PARAMETERS FOR LOW-TEMPERATURE TREATMENT OF CULTIVATED CHAMPIGNONS AND COMMON OYSTER MUSHROOMS

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Abstract

The study investigates the effect of cold thermal treatment on the conditions and time of storage and quality parameters of mushrooms (using the example of cultivated champignon and common oyster mushrooms). The considered cold temperature treatment modes are -30°C, -60°C (natural convection), -25°C (forced convection), and freezing in liquid nitrogen. Thermograms of freezing at these temperature regimes and thermograms of defrosting at 20°C are plotted. The organoleptic characteristics of mushrooms upon defrosting immediately after freezing, as well as after 2 months of storage at -30°C and -60°C are determined.

Keywords: mushrooms, temperature, freezing process, defrosting, organoleptic properties

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Introduction

Important aspects in the processing and harvesting of plant raw materials are the longest possible preservation of components useful for human health in unchanged condition: vitamins, micro- and macronutrients, as well as qualitative organoleptic characteristics, shape, and structure. One of the methods of vegetable raw material preservation is the use of various technologies based on the process of freezing [1-3].

For the production of high-quality fast-frozen products, the source raw materials have to have high nutritional value (high content of dry substances, sugars, and vitamins) and good organoleptic and hygienic properties [4, 5]. Furthermore, microbiological parameters should not exceed the established norms. The raw material must be homogeneous in grade and ripeness. It is also important to use only raw materials undamaged by microorganisms for freezing [6].

The main task of freezing technology is to preserve the maximum of the product's initial properties, which define its nutritional value [7, 8]. Comprehensive research on the freezing of vegetable raw materials indicates that intensification of the freezing process contributes to better preservation of the marketable appearance and nutritional value of products [9].

Currently, intensification of the freezing process is achieved by lowering the temperature of the cooling medium, increasing the velocity of the medium, and using cooling media with high heat dissipation properties. A significant advantage of frozen products is the preservation of color, smell, and appearance of the products after defrosting. Since there are different ways of freezing vegetable raw materials, it is relevant to examine and compare the impact of these processes on the consumer parameters of products [10, 11]. Therefore, the study and research of the effect of low temperatures on various parameters of frozen and subsequently defrosted products is of great practical and scientific interest [12-14].

One of the products gaining popularity lately is cultivated mushrooms, such as champignons and oyster mushrooms. Their shelf life is not long, which does not allow retail chains to sell them widely in a refrigerated state [15, 16]. The use of various modern and, in some cases, innovative methods of freezing significantly increases the shelf life of mushrooms.

There are many variations of the freezing process. Among the advanced and modern methods of freezing are acoustic and shock freezing, which preserves the original appearance, taste, and useful properties of the products. In terms of structure, appearance, and taste, defrosted products are almost identical to the original [17-19].

Practical research and theoretical substantiation of these processes will provide a deeper demonstration of their impact on the object of study, which in turn will allow for the most rational use of these processes in the production of frozen foods [20].

The goal of the study is to investigate the effects of various parameters and low-temperature environments on the shelf life and quality parameters of cultivated champignons and oyster mushrooms.

Methods

The objects under study are cultivated mushrooms – champignons (*Agaricus bisporus*) and common oyster mushrooms (*Pleurotus ostreatus*). The research was conducted on standard mushrooms, selected from a batch of mushrooms offered by a retail chain [21]. The study was conducted at the Scientific and Educational Center of the Department of Heat and Cooling Engineering of Kemerovo State University (Russia).

Champignon mushrooms were frozen in whole, and oyster mushrooms were frozen as a cluster.

To plot freezing-defrosting thermograms, experiments were conducted under the following conditions:

- -30°C under natural convection;
- -60°C under natural convection;
- -25°C under forced convection;
- in liquid nitrogen at -195°C.

The experiment of freezing mushrooms at -30°C was carried out using a LIBHER MED LINE chest freezer. Freezing at -60°C was performed in a VESTFROST SOLUTIONS VT 78 low-temperature chest freezer, and forced convection at -25°C was performed in a universal bench laboratory unit at an air speed of 1 m/s. The velocity of air was measured with an anemometer. The mode for freezing in a liquid nitrogen medium was created in a thermostatically controlled unit.

For determining the organoleptic characteristics of mushrooms, frozen samples were placed in freezing chests at temperatures of -30°C and -60°C and stored for two months. The weight of the samples before and after freezing was measured with electronic laboratory scales Acom JW-1-200 RS232C.

A measuring complex was used to register the temperature inside the samples and the temperature of the freezing medium, as well as for automated data collection during the freezing and defrosting processes. In samples of champignon and oyster mushrooms (in a cluster), three chromel-copper thermocouples were placed on the surface, at the distance X from the surface, and in the center of the mushroom.

Results and Discussion. In the course of experimental studies, thermograms of freezing-defrosting of mushrooms under different mode properties and low-temperature environments were obtained. The results of the thermogram analysis of frozen mushrooms are presented in Table 1.

Table 1 – Results of thermogram analysis of samples: oyster mushroom (cluster) – 1 and champignon (whole mushroom) – 2

Characteristic	Mode							
	-30°C (natural convection)		-60°C (natural convection)		-25°C (forced convection)		-195°C (liquid nitrogen)	
	1	2	1	2	1	2	1	2
Time of freezing to the temperature in the center of the sample, min*	Temperature at the center,°C		Temperature at the center,°C		Temperature at the center,°C		Temperature at the center,°C	
	-18	-18	-18	-18	-18	-18	-18	-18
	56	69	46	38	11	29	22 (s)	70 (s)
Time of defrosting to the temperature in the center of the sample, min	Temperature at the center,°C		Temperature at the center,°C		Temperature at the center,°C		Temperature at the center,°C	
	0	0	0	0	0	0	-0,7	0
	65	61	49	67	8	54	30	32
Freezing rate, cm/h	4.7	2.1	9.1	3.7	20.3	3.4	-	-
Sample weight before freezing, g	25	14	56	16	6	13	9	21
Sample weight after freezing	23	12	55	14	5	11	8	18
Change in weight, g	2	2	1	2	1	2	1	3
Dimensions: length*, cap diameter, mm**	50*60	36*40	75*85	36*40	55*45	35*40	93*42-49	39*42-45

*for the mode of freezing in liquid nitrogen, the time is given in s

**for the sample of oyster mushrooms in a cluster, the dimensions of the cluster length by width

Analysis of Table 1 indicates that the time of mushroom freezing in a chamber at -30°C (natural convection), -60°C (natural convection), and -25°C (forced convection) up to -18°C at the center of the sample decreases and is two times shorter in the modes of -60°C (natural convection) and -25°C (forced convection) compared to the temperature of -30°C (natural convection). Freezing mushrooms in liquid nitrogen reduces the freezing time by 25-59 times compared to the modes described above.

The weight of mushrooms in the process of freezing decreased by 2-3 g at all freezing temperatures used in the chamber. The process of defrosting mushrooms to 0°C in the center for the modes of -30°C, -60°C, and -25°C with the temperature of 20°C in the chamber and natural air circulation takes about 54-67 min.

Considering the freezing time of common oyster mushrooms (in a cluster) at the temperatures of -30°C (natural convection), -60°C (natural convection), and -25°C (forced convection) in the chamber up to -18°C in the center of the sample, it is 4-5 times shorter in the mode of -25°C (forced convection) compared to -30°C (natural convection) and -60°C (natural convection). The freezing of common oyster mushrooms (in a cluster) in liquid nitrogen, however, takes 30-155 times less time than in the above modes. The weight of common oyster mushrooms (in a cluster) during freezing decreases by 1-2 g in all freezing modes.

After defrosting, the samples of oyster mushrooms (in a cluster) and champignons (whole mushroom) are firm and not moist in the modes of -30°C, -60°C, and -25°C. In contrast, the defrosted samples of the two types of mushrooms frozen in liquid nitrogen completely lose their sturdiness, and the structure becomes friable, loose, and soft, especially in the oyster mushroom sample.

Analysis of the parameter of velocity, as demonstrated in Table 1, suggests that the champignon sample freezes fast in the modes of -30°C, -60°C, and -25°C, while the oyster mushroom sample freezes superfast in the same modes, which reduces the migration of moisture in the product and ensures minimal loss of moisture after defrosting with less change in the consistency and taste of the product.

The organoleptic properties of the product affect consumer properties and demand to a greater extent than the chemical composition and nutritional value. Therefore, an important aspect of the study was an analysis of the effects of different freezing modes and the state of the samples after defrosting and storage specifically by the organoleptic properties.

The organoleptic properties of quality include appearance, color, taste, smell, and consistency.

The results of the study of organoleptic characteristics of mushroom samples defrosted immediately after freezing according to [21, 22] are presented in Table 2.

Table 2 – Organoleptic characteristics of defrosted samples of oyster mushroom (cluster) – 1 and champignon (whole mushroom) – 2

Parameter	GOST R 55465-2013 norm [14]	Study results							
		-30°C (natural convection)		-60°C (natural convection)		-25°C (forced convection)		-195°C (liquid nitrogen)	
		1	2	1	2	1	2	1	2
Appearance	Whole mushrooms or cut mushrooms of the same species, uniform in size, without	Whole mushrooms or cut mushrooms of the same species, uniform in size, without		Whole mushrooms or cut mushrooms of the same species, uniform in size, without		Whole mushrooms or cut mushrooms of the same species, uniform in size, without		Integrity is compromised, there are cracks, no traces of worm holes, no stains or burns	

	mechanical damage, no traces of worms, no stains or burns	mechanical damage, no traces of worms, no stains or burns	mechanical damage, no traces of worms, no stains or burns	mechanical damage, no traces of worms, no stains or burns	
Color	Uniform, characteristic of the correspondin g species of mushrooms in fresh or thermally prepared form	Uniform, characteristic of the correspondin g species of mushrooms in fresh or thermally prepared form	Uniform, characteristic of the correspondin g species of mushrooms in fresh or thermally prepared form	Uniform, characteristic of the correspondin g species of mushrooms in fresh or thermally prepared form	Uniform, characteristic of the correspondin g species of mushrooms in fresh or thermally prepared form
Taste and smell	In the defrosted state – well pronounced, typical of the relevant species of mushrooms without extraneous taste and smell	Well pronounced, typical of the relevant species of mushrooms without extraneous taste and smell	Well pronounced, typical of the relevant species of mushrooms without extraneous taste and smell	Well pronounced, typical of the relevant species of mushrooms without extraneous taste and smell	Well pronounced, typical of the relevant species of mushrooms without extraneous taste and smell
Consiste ncy	Slightly softened, close to the consistency of thermally prepared mushrooms	Elastic	Elastic	Elastic	Friable soft

Analysis of Table 2 indicates that upon visual analysis, the mushrooms frozen in liquid nitrogen are found to have lost their integrity and show multiple cracks, but no worm holes, stains, or burns. The consistency of samples frozen in this way is friable and soft. These indicators prove this batch of mushrooms to be unsuitable for storage. Mushrooms frozen at -30°C and -60°C with natural convection demonstrated the best results and were subsequently put into storage.

For the assessment of organoleptic characteristics in case of long-term storage of samples and their subsequent defrosting, the samples were placed in refrigerated chests with internal temperatures of -30°C and -60°C for two months. After that, an organoleptic analysis was conducted.

Organoleptic analysis of mass-produced public food products includes rating their appearance, texture (consistency), smell, and taste on a 5-point scale where: 5 points – excellent quality, 4 points – good quality, 3 points – satisfactory quality, and 2 points – unsatisfactory quality [22].

The results of the study of organoleptic characteristics of mushroom samples after storage are presented in Table 3.

Table 3 – Organoleptic characteristics of defrosted mushroom samples after storage

Parameter	Study results			
	-30°C (natural convection)		-60°C (natural convection)	
	champignon (whole mushroom)	oyster mushroom (cluster)	champignon (whole mushroom)	oyster mushroom (cluster)
	after 2 months of storage		after 2 months of storage	
Form	5	3	5	5
Surface state	5	4	5	5
Cut view	5	3	5	5
Color	4	4	4	4
Taste and smell	5	3	5	5
Texture	5	3	5	4

After two months of storage, changes in the organoleptic characteristics of champignons (whole mushrooms) under different storage temperatures are not found. The color of the mushroom became a deeper brown. Upon defrosting, the texture of the sample is unchanged. The taste and smell in the course of thermal processing correspond to those of a fresh mushroom.

All the organoleptic characteristics of oyster mushrooms (cluster) stored at -30°C changed significantly after defrosting. The mushroom poorly holds its shape and the texture is soft and watery. After thermal processing, the taste of the mushroom is poor and the sample is watery.

At a storage temperature of -60°C, the organoleptic characteristics of both types of mushrooms remain virtually unchanged after defrosting. They hold their shape well, and the texture is firm. During the heat treatment, the taste and smell correspond to a fresh mushroom.

Conclusion

The thermogram analysis demonstrates that the freezing process, namely its intensity and speed, is much more intense for the oyster mushroom (cluster) sample than for the champignon (whole mushroom) sample at -30°C (free convection), -60°C (free convection), and -25°C (forced convection) temperatures. Upon defrosting, all samples show good organoleptic properties. This indicates that the considered temperature modes do not affect the quality of the product defrosted immediately after freezing. However, freezing in liquid nitrogen at -195°C is not suitable for these product samples, as the mushrooms completely lose their shape and taste characteristics when defrosted.

The storage temperature mode of -60°C (free convection) for both types of mushrooms leads to virtually no changes in the organoleptic characteristics of this type of product after two months.

The storage temperature regime of -30°C (free convection) for the sample of champignons also entails no practical changes in organoleptic characteristics, while for common oyster mushrooms this mode of storage for 2 months is not suitable.

Proceeding from the above, the recommended most rational mode of freezing and storage for champignons (whole mushrooms) is -30°C, while the optimal mode for oyster mushrooms is freezing at -30°C in low-temperature chambers and storage at -60°C (free convection), which preserves the high quality of the mushrooms.

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