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DEVELOPMENT OF THE TECHNOLOGY OF MUSHROOM SAUCE WITH FUNCTIONAL INGREDIENTS

Об'єктом дослідження є грибні порошки з печериць (Agaricus campestris), рейші (Ganoderma lucidum), шиїтаке (Lentinula edodes) та соуси грибні з згущувачем.

В Україні все більше зростає рівень споживання культивованих грибів, а саме печериць, шиїтаке та рейші, про це свідчать й зростаючі обсяги вирощування даних грибів українськими господарствами. Однак у науковій літературі недостатньо висвітлене питання ефективних технологій отримання грибних порошкоподібних напівфабрикатів та готової продукції з них для харчових виробництв.

Використання грибних порошків з шиїтаке, рейші та печериць для приготування соусів грибних призводить до збільшення кількості незамінних амінокислот, вітамінів групи В, РР, екстрактивних речовин у готовій продукції. Внаслідок цього підвищується біологічна цінність, покращуються органолептичні показники якості грибних соусів. Це дозволить підвищити популярність соусів грибних серед сучасних споживачів продукції закладів ресторанного господарства.

В ході досліджень проаналізовано асортимент соусної продукції підвищеної біологічної цінності та специфіку фізіологічного впливу грибів шиїтаке, рейші та печериць на організм людини. Розроблено науково-обумовлену технологію соусу грибного підвищеної біологічної цінності з функціональними інгредієнтами – грибними порошками з печериць, рейші, та шиїтаке. Проведено оптимізацію рецептури новоствореного продукту та запропоновано оптимальний рецептурний склад соусу грибного з грибними порошками з співвідношенням грибних порошків у рецептурному складі як 1:1:2 (шиїтаке:рейши:печериці). Досліджено структурно-механічні властивості інноваційного соусу та порівняно їх з контрольним зразком соусу грибного, приготовленого за традиційною технологією. Так при швидкості зсуву 200 $с^{-1}$ в'язкість розробленого соусу становить – 0,38 Па·с, тоді як в'язкість соусу грибного приготовленого за традиційною технологією – 0,3 Па·с.

Встановлено, що соус грибний з грибними порошками має високу біологічну цінність, оптимальні реологічні та органолептичні показники якості.

Розроблений соус з грибними порошками дасть можливість розширити асортимент соусної продукції підвищеної біологічної цінності на рослинній сировині для закладів ресторанного господарства. Впровадження інноваційної технології значно заощадить час виробництва соусів власного виготовлення та фінансові витрати, оскільки розроблена технологія передбачає виготовлення грибних порошків з некондиційної грибної сировини.

Ключові слова: *грибний порошок, культивовані гриби, технологія соусу грибного, функціональні інгредієнти, динамічна в'язкість.*

1. Introduction

According to the scientific research of the structure of the food ration of the population of Ukraine, it is established that for the most part of the Ukrainian one is characterized by an unbalanced, polyinsufficient diet. Most diets are carbohydrate-fat components, as well as foods that contain nutritional supplements. This negatively affects human health, causes a number of nutritional diseases, can have a carcinogenic effect [1].

Obtaining products of increased nutritional and biological value with specified parameters is an important stage in the creation of innovative food products of healthy and balanced nutrition for modern restaurants. Sauces better allow to enrich the human diet with functional, useful ingredients.

Therefore, the development of scientifically-determined technologies for production of sauces with functional ingredients, namely with shiitake mushroom powders, reishi and champignons, as well as researching the technological properties of innovative products is urgent.

2. The object of research and its technological audit

The object of research is a sauce with mushroom powders of champignons (Agaricus campestris), reishi (Ganoderma lucidum) and shiitake (Lentinula edodes).

The subject of research is the rheological properties of mushroom sauces.

Solving the problem of expanding the range of sauces with increased biological value and optimizing their formulations is impossible without examining the rheological properties of the newly created product. And also the comparison of the obtained data with the control sample of the sauce, prepared according to the traditional technology.

The conduct of technological audit is aimed at defining the following tasks:

– expansion of assortment of sauce products of increased biological value for restaurants in the restaurant industry by obtaining products with the specified composition and consistency;

– obtaining data on the viscosity of the newly created product for the rational dosing of mushroom powders and thickeners;
– optimization of technological processes for the production of mushroom sauce with mushroom powders in order to obtain a product with specified rheological properties.

3. The aim and objectives of research

The aim of research is development of scientifically-determined technology for production of a mushroom high-biological value sauce with mushroom powders of champignons (Agaricus campestris), reishi (Ganoderma lucidum) and shiitake (Lentinula edodes) with predicted chemical composition and structural and mechanical properties.

To achieve this aim, it is necessary to perform the following tasks:

1. Analyze the assortment of sauce products of increased biological value for restaurants.

2. Propose the technology of production of sauce products from a given consistency and physicochemical quality indicators, namely, to develop a recipe and technology for the production of the «Mushroom Extra» sauce with mushroom powders.

3. Analyze the structural and mechanical properties of the innovative product for the purpose of further rational use in the technology of sauces for restaurants.

4. Research of existing solutions of the problem

Consumption of sauce products by the population of Ukraine every year becomes more and more popular, as evidenced by statistical data [2]. After all, sauces in modern restaurant business have become an integral part of not only hot dishes, but also snacks (both cold and hot), sweet dishes, desserts. Analysis of the market for consumption of restaurants in the restaurant industry allows to conclude that sauces are not only an integral part of a delicious meal, but also an additional source of biologically valuable substances. Sauces can reduce the nutrient deficiency necessary for the normal functioning of the human body.

The production of sauces based on champignons mushroom powder (Agaricus campestris), Reishi (Ganoderma lucidum) and shiitake (Lentinula edodes) is promising. After all, mushroom sauces are perfectly combined with both appetizers and basic vegetable and meat dishes.

Champignons, shiitake and reishi contain a whole complex of essential nutrients, such as essential amino acids, vitamins, flavonoids. The physiological and therapeutic effect of champignon mushrooms, shiitake and reishi as powerful immunostimulants and antioxidants has been proved by a number of scientists [3]. The chemical composition and physiological effect of shiitake and reishi mushroom on the human body, as well as the specificity of their cultivation, were studied in [4, 5]. The authors proposed the use of cultivated shiitake mushrooms, reishi, flamulins and others, as functional food products. The most important biologically active substances of cultivated mushroom have been analyzed [6], but the lack of labor is the lack of data on the biosafety of biologically active substances characteristic of cultivated mushroom. The rational consumption of cultivated mushrooms is justified, which will have a therapeutic effect on the human body [7] and the analysis of the positive effect on the human body of food additives from cultivated mashrooms [8], however, the authors do not cite technological aspects of the production of culinary products from cultivated mushrooms.

Separate aspects of the production of powdered mushroom semi-finished products are investigated [9], drafts of technical conditions and technological instructions are given: «Powdered semi-finished product made from mushrooms», «Dry mixtures. Fast food instant sauces». The composition of these sauces includes heat-treated semi-finished mushroom concentrate from oyster mushrooms. It is proved that the use of powder semi-finished product greatly simplifies the technological process in 6...23 times the duration of the process of preparation of finished products is reduced.

The technology of obtaining a mushroom powder semi-finished product is substantiated and its structural-mechanical properties are investigated [10], however, the high cost of equipment for the production of powder semi-finished products is a limitation of the introduction of the proposed methods into practice.

A technology is proposed for the use of mushroom powders from porcini and wild mushrooms in the production of restaurant facilities [11], but the author does not consider the possibility of using fungal powders from cultivated mushrooms.

The technology of meat products with the addition of mushroom powders [12] has been developed and scientifically substantiated and a positive effect on the organoleptic and technological properties of meat sausages with the addition of a mushroom powder from flammulina (winter mushroom) has been proved. The use of the proposed technologies is limited in the restaurant industry, since these technologies are developed for the meat processing industry.

The technology of sauces of increased biological value with the addition of fruit and berry raw materials for institutions of the restaurant economy was proposed and their structural-mechanical as well as organoleptic quality indicators were investigated [13]. However, the issues of scientifically-conditioned development of technology for producing sauces of increased biological value with mushroom powders from shiitake, reishi and champignons are not reflected in the literature. There are no data on the structural and mechanical properties of mushroom sauces with a thickener.

It is known that changes in the formulation of traditional mushroom sauces should lead to a change in their structural and mechanical properties. Therefore, in the process of developing the technology for the production of mushroom sauce with mushroom powders, it is necessary to take into account the ratio of the liquid portion of the sauce and the solid particles of mushrooms and fillers. This will make it possible to obtain an innovative sauce with quality indicators close to the control sample. After all, the production of food products of the established structure and consistency, ultimately, determines the quality of culinary products, their consumer characteristics, as well as the specificity of transportation and storage of finished products.

5. Methods of research

Experimental studies of the rheological characteristics of the «Mushroom Extra» sauce with mushroom powders

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and the «Mushroom Sauce» prepared according to the traditional technology according to the recipe No. 868 of the Recipe for Foods and Culinary Products [14] were determined according to ISO 9001:2008. A constant-voltage viscosimeter ВПН-0,2М (USSR) was used. And also using the technique described in [15]. The study was carried out in triplicate. Research results were processed using the methods of mathematical statistics. The error was determined with a confidence probability of $P=95$ %. Optimization of the sauce recipe was carried out by the method of full-factorial experiment according to the given criteria according to the compiled matrix of the rotatable central composite uniform design (RCCUD) by means of a computer, the function «Find solutions» of MS Excel, Statistica and MachCad software.

6. Research results

The development of scientifically-determined technology for production of mushroom sauce with increased biological value with mushroom powders of champignons (Agaricus campestris), reishi (Ganoderma lucidum) and shiitake (Lentinula edodes) was preceded by the optimization of recipes for food sauces with mushroom powders.

As input variables of the formula of the mushroom sauce of increased nutritional value, the following values were used:

x_1 – the amount of champignon mushroom powder added to the sauce;

x_2 – the amount of shiitake mushroom powder;

x_3 – the amount of reishi powder;

x_4 – the amount of flour;

x_1 – the amount of WPC (whey protein concentrate), as the thickener of the sauce.

The initial optimization parameter was the structural and mechanical properties of the developed sauce – viscosity at a shear rate of 50 s^{-1}.

According to the general theory of conducting experimental studies, the full-factor experiment was used to determine the coefficients. It was considered expedient to establish the following limits of change in input values:

$$10 \le x_1 \le 60,\ 1 \le x_2 \le 10,\ 1 \le x_3 \le 10,\ 20 \le x_4 \le 60,\ 5 \le x_5 \le 30.$$

The full-factor experiment was carried out according to the conditions given in Table 1.

Table 1

Planning of experiment to study the structural and mechanical characteristics of mushroom sauces (viscosity)

planning conditions	The limits of variation of the main factors				
	x_1	x_2	x_3	x_4	x_5
Basic level (0)	30	2	2	40	15
interval	5	1	1	10	5
The upper level (1)	60	10	10	60	30
The lower level (–1)	10	1	1	20	5
The upper arm of the «star point» (+2.0)	65	11	11	70	35
The lower arm of the «star point» (–2.0)	5	0	0	60	0

Each experiment was conducted three times. The mean values for each of the experiments were calculated by the formula:

$$\bar{Y}_i = \frac{1}{k}\sum_{i=1}^{k} Y_i, \quad (1)$$

where k – the number of parallel experiments ($k=3$); Y_i – measurement results.

In natural and coded values, the RCCUD matrix is presented in Table 2.

Table 2

RCCUD matrix of the active experiment on the study of the dependence of the viscosity variation of model compositions on the number of introduced prescription components

Natural values of factors						Coded values of factors					Y_2
No.	x_1	x_2	x_3	x_4	x_5	X_1	X_2	X_3	X_4	X_5	
1	10	1	1	20	30	–1	–1	–1	–1	1	0.98
2	60	1	1	20	5	1	–1	–1	–1	–1	1.13
3	10	10	1	20	5	–1	1	–1	–1	–1	0.75
4	60	10	1	20	30	1	1	–1	–1	1	1.09
5	10	1	10	20	5	–1	–1	1	–1	–1	1.14
6	60	1	10	20	30	1	–1	1	–1	1	1.44
7	10	10	10	20	30	–1	1	1	–1	1	1.73
8	60	10	10	20	5	1	1	1	–1	–1	1.70
9	10	1	1	60	5	–1	–1	–1	1	–1	1.60
10	60	1	1	60	5	1	–1	–1	1	1	1.79
11	10	10	1	60	30	–1	1	–1	1	1	1.53
12	60	10	1	60	30	1	1	–1	1	–1	1.91
13	10	1	10	60	5	–1	–1	1	1	1	1.21
14	60	1	10	60	30	1	–1	1	1	–1	1.91
15	10	10	10	60	5	–1	1	1	1	–1	1.58
16	60	10	10	60	5	1	1	1	1	1	2.01
17	5	2	2	40	30	–2	0	0	0	0	0.85
18	65	2	2	40	15	2	0	0	0	0	1.47
19	30	0	2	40	15	0	–2	0	0	0	1.42
20	30	11	2	40	15	0	2	0	0	0	1.51
21	30	2	0	40	15	0	0	–2	0	0	1.48
22	30	2	11	40	15	0	0	2	0	0	1.51
23	30	2	2	15	15	0	0	0	–2	0	1.36
24	30	2	2	70	15	0	0	0	2	0	1.87
25	30	2	2	40	0	0	0	0	0	–2	1.51
26	30	2	2	40	35	0	0	0	0	2	1.54
27	30	2	2	40	15	0	0	0	0	0	1.53
28	30	2	2	40	15	0	0	0	0	0	1.53
29	30	2	2	40	15	0	0	0	0	0	1.53
30	30	2	2	40	15	0	0	0	0	0	1.53
31	30	2	2	40	15	0	0	0	0	0	1.53
32	30	2	2	40	15	0	0	0	0	0	1.53

The dispersion of each parallel experiment was determined by the formula:

$$S_i^2 = \frac{1}{k-1}\sum_{i=1}^{k}(Y_i - \bar{Y}_i)^2. \quad (2)$$

The dispersion of reproduction was determined by the formula:

$$S^2(Y) = \frac{1}{N}\sum_{i=1}^{N} S_i^2. \quad (3)$$

To describe the response function of the optimization of the sauce formulation with the mushroom powders, a second-order polynomial was used:

$$Y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i\neq 1}^{k} b_{ij} x_i x_j + \sum_{i=1}^{k} b_{ii} x_i^2, \quad (4)$$

where b_0, b_i, b_{ij}, b_{ii} – regression coefficients of the equation; x_i – factors of experiment; k – the number of factors in experiment (k=5).

The significance of the coefficients of the obtained regression equations (4) was checked according to Student's t-criterion. The coefficients were considered to be statically significant provided that $b_i \geq tS(b_i)$, where the t-criterion selected from the table of critical values of Student's t-criteria for significance level 0.05 and degrees of freedom f_E, $S(b_i)$ – the error of the coefficients b_0, b_i, b_{ij}, b_{ii}.

The regression equation was also tested for adequacy with Fisher's F-test for degrees of freedom f_E and f_{ad} is equal to significance level α=0.05.

The response function, which reflects the dependence of the sauce viscosity on its formulation composition, according to the results of the experiment planning in the coded values of the variable factors, has the form (5):

$$Y = 0.488 + 0.083x_1 + 0.02x_2 - 0.12x_2^2 + \\ + 0.016x_3 - 0.0004x_4 + 0.043x_5, \quad (5)$$
$$R^2 = 0.96.$$

Thus, the process of modeling and optimizing the formulation of a mushroom sauce with mushroom powders according to specified structural and mechanical criteria allowed to obtain the optimal composition represented as a ratio of components to the total content of solids in the balance equation (6):

$$0.0275x_1 + 0.0135x_2 + 0.01x_3 + \\ + 0.019x_4 + 0.0164x_5 = 100. \quad (6)$$

Based on these calculations, a recipe was prepared for the mushroom sauce with mushroom powders of champignons, reishi and shiitake, which is presented in Table 3.

The technological process of production of the «Mushroom Extra» sauce is carried out in the following sequence:

Stage 1. Preparation of semi-finished mushroom powders: mushrooms (champignons, reishi and shiitake) are sorted, cleaned, washed, dried at a temperature of +20...+24 °C for 15...25·60 s. Then the mushrooms are mixed in a ratio of 2:1:1 (champignons, reishi, shiitake, respectively), cut into slices 3–4 mm thick. Shredded mushrooms are lined on perforated sheets and dried in drying cabinets (dryers) at a temperature of +35...+45±5 °C and moderate convection, alternately including heating (to 45 °C) and convection without heating (to reduce the temperature to 35 °C and removal of moisture from the drying chamber). Duration of drying is 6–8 hours. The resulting dried mushrooms are cooled to a temperature of 20...+24 °C, ground using a laboratory mill or a coffee grinder to the particle size of the ground mushroom powder of 0.05–0.002 mm. Sift through a sieve with a section of holes of 0.0025 mm^2 for the removal of unmilled residues [16].

Stage 2. Preparation of a suspension from mushroom powders and whey protein concentrate: the fungal semi-finished product from mushroom powders is mixed with a whey protein concentrate in a 1:1 ratio and soaked in cold boiled water (t=15 °C). Leave for swelling at 2..3·60 s.

Stage 3. «Roux» – preparation the butter is melted in a sauté pan on a small fire, add the sifted flour. Passed at a temperature of +120...+130 °C until the appearance of a golden hue and a delicate nutty flavor.

Stage 4. Preparation by vegetable sautéing: onion is cleaned, washed, cutted into small cubes, save on a mixture of butter and butter until the appearance of golden color.

Stage 5. Preparation of sauce: In a boiling mushroom broth or water, add a suspension of mushroom powders and WPC, boil for 10·60 seconds with slow boiling. Then enter «Ru», mix, cook until the desired consistency (τ=(20–25)·60 s), strain, bring to a boil, add salt, white ground pepper (if desired), and oil, to avoid the appearance of crust on the surface of the sauce.

The technological scheme of production of mushroom sauce with mushroom powders is shown in Fig. 1.

Table 3

Recipe composition of mushroom sauce with mushroom powders

Raw material	Net weight of raw materials, g	
	Control* «Mushroom sauce» rec. № 868	«Mushroom extra»
Dried porcini	40.0	–
Champignon mushroom powder	–	10.0
Shiitake mushroom powder	–	5.0
Reishi mushroom powder	–	5.0
Concentrate of whey proteins KSB-80	–	20.0
Wheat flour	38.0	20.0
Bulb onions	300.0	200.0
Butter	60.0	50.0
Oil	10.0	8.0
Water	860.0	800.0
Salt	8.0	8.0
White pepper powder	0.5	0.5
Yield	1000	

Note: * – the recipe of mushroom sauce No. 868 of the Collection of recipes of dishes and culinary products is used for the control.

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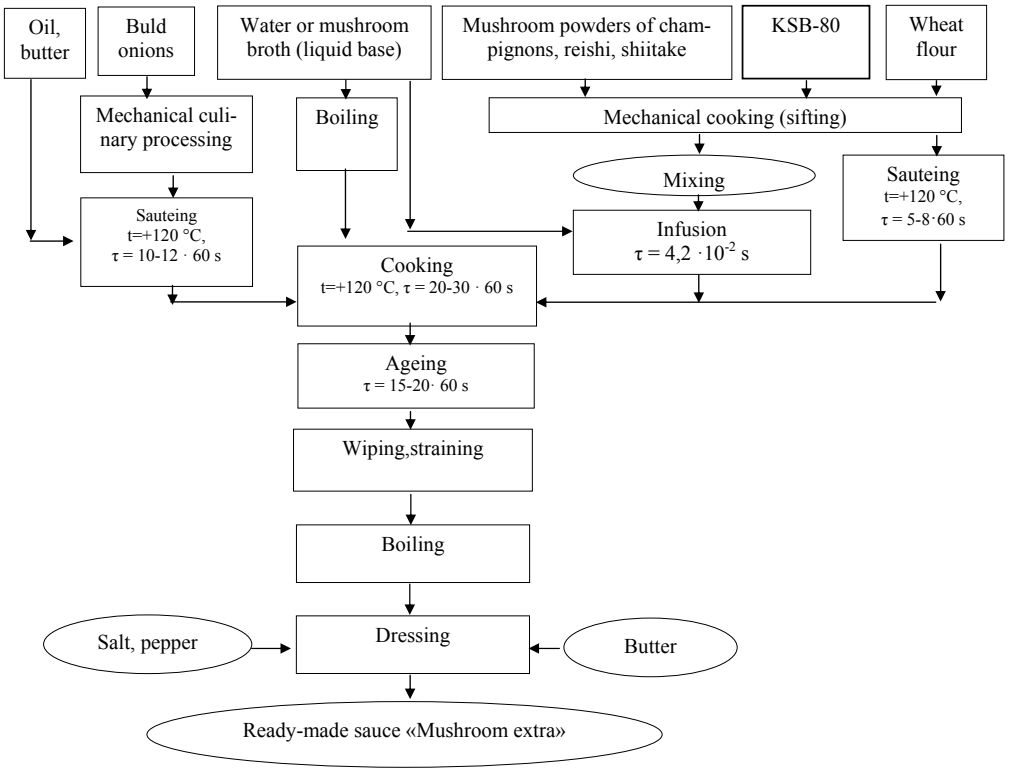

Fig. 1. Technological scheme of production of mushroom sauce with mushroom powders of champignons (Agaricus campestris), reishi (Ganoderma lucidum) and shiitake (Lentinula edodes)

One of the most important characteristics of the structural and mechanical properties of finished culinary products, including sauces, is viscosity. Viscosity is the ability of the body to create resistance when moving it one layer relative to others. When the fluid moves, some of its layers move relative to the others and at the same time an internal inhibitory force occurs between them, which is the force of internal friction and is determined by Newton's law:

$$F = -\eta \cdot s \cdot \frac{dv}{dl}, \qquad (2)$$

where η – the coefficient of internal friction, or absolute viscosity; s – area of contact of two layers, on which the force acts, m^2; dv/dl – velocity gradient per unit distance between two layers of liquid, 1/s.

Structural and mechanical properties of sauces are characterized by dynamic (effective) and kinematic viscosity.

According to experimental data, the dynamic viscosity of the «Mushroom Extra» sauce at a shear rate of 100 s^{-1} is 0.57 Pa·s. Whereas the viscosity of the mushroom sauce (control), prepared according to the traditional formulation, at a shear rate of 100 s^{-1} is 0.42 Pa·s. Thus, the «Mushroom Extra» sauce has a thick, more elastic consistency, which affects the improved organoleptic properties compared to the control.

Graphically, the dependence of the dynamic viscosity on the shear rate of the «Mushroom Extra» sauce and the mushroom sauce prepared according to the traditional recipe is shown in Fig. 2.

The adequacy of the dependence obtained in Fig. 2 was verified with the help of the Fisher criterion. The value of the coefficient of determination of the logarithmic regression = 0.93, according to the data of the dependence it follows that 93 % of the variations in the values of the dynamic viscosity of the mushroom sauces are explained by the magnitude of the shear rate, and the remaining 7 % is due to the influence of extraneous factors.

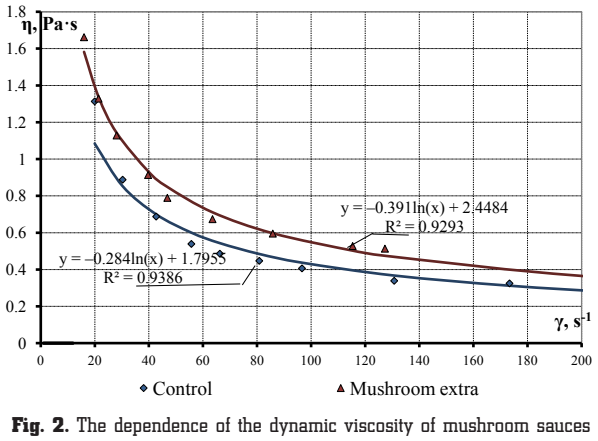

Fig. 2. The dependence of the dynamic viscosity of mushroom sauces on the shear rate

Analysis of the flow curves of the viscosity variation of the mushroom sauces on the shear rate proves that with an increase in the shear rate of the mushroom sauces, the dynamic viscosity decreases and gradually approaches a certain limit. Thus, at a shear rate of 200 s^{-1}, the dynamic viscosity for the «Mushroom Extra» sauce is 0.38 Pa·s, for a mushroom sauce prepared according to conventional technology, 0.3 Pa·s. This is due to the fact that the molecules of polysaccharides and protein sauces are partially destroyed, straightened and have less hydrodynamic resistance to fluid movement of the system. Structural and

mechanical changes in the «Mushroom Extra» sauce are similar to the control sample, however, the viscosity of this sauce is higher. This is due to improved wet content due to the increase in the protein component of this sauce, as well as the introduction of whey protein concentrate into the formulation. The dependence of the shear stress, (Pa) on the shear rate (s^{-1}) of the sauces under investigation looks as follows, Fig. 3.

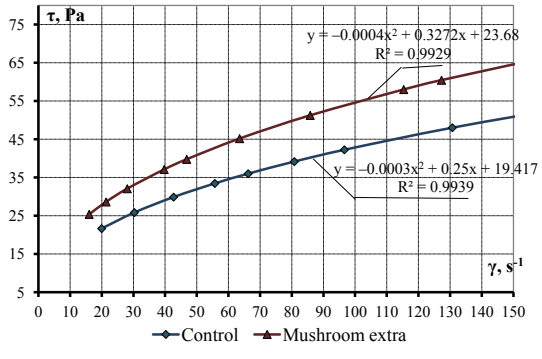

Fig. 3. Dependence of shear stress on shear rate of mushroom sauces. («Control» – mushroom sauce according to the traditional recipe, «Mushroom extra» – sauce with mushroom powders)

The value of the coefficient of determination of the polynomial regression = 0.99, according to the data of the dependence it follows that 99 % of the variations in the values of the shear stress of the mushroom sauces are explained by the magnitude of the shear rate, and the remaining 1 % is due to the influence of extraneous factors.

Analyzing the data of the dependence of the shear stress on the shear rate of the mushroom sauces, it can be concluded that when the shear rate increases, the shear stress increases moderately. In order to break down the structure of the prototypes, a small shear stress is required: at a shear rate of 100 s^{-1} $\tau = 42$ Pa for a mushroom sauce prepared according to traditional technology, and for a «Mushroom extra» sauce, $\tau = 55$ Pa. This allows to conclude that the rheological properties of the mushroom sauce with mushroom powders are similar to the control sample. However, the sauce has better viscosity and strength of the structure, and therefore it is recommended in the production technology of sauce products for restaurants. The dynamic viscosity and shear stress of the «Mushroom Extra» mushroom sauce are optimal for sauces from the thickener, and consequently – a product with predicted consumer characteristics and increased nutritional value was obtained.

In the future it is planned to investigate the amino acid composition of the «Mushroom Extra» sauce, as well as the biocompatibility of proteins and amino acids, which are contained in this sauce with the aim of further popularizing the sauce products with mushroom powders in the technology of the restaurant facilities.

7. SWOT analysis of research results

Strengths. Among the strengths of this research, it is possible to distinguish that the formulation of the mushroom sauce with the mushroom powders of champignons (Agaricus campestris), reishi (Ganoderma lucidum) and shiitake (Lentinula edodes) has been optimized. The dynamic viscosity of a mushroom sauce with mushroom powders and comparatively their control sample (mushroom sauce prepared according to a traditional recipe) is studied. The resulting innovative sauce using substandard mushroom raw materials in the form of a mushroom powder in the technology of catering products is economically beneficial and resource-saving. The obtained research results allow solving technological issues of production of mushroom sauces with desired consumer characteristics and high quality indicators.

Weaknesses. The weaknesses of this research are related to the fact that the application of these technological developments will be successful only if the mushroom powders of champignons, reishi and shiitake are prepared using the proposed technology with the proposed particle size of the mushroom. Changes in the size of fungal particles significantly affect the final result of the production of mushroom sauces – the larger the size of the fungal particles, the greater the laying of mushroom powders should be done according to the recipe. This technology is recommended for obtaining sauces with a thickener, for which high-grade wheat flour is used as the thickener. The manufacturer may seek to replace the flour with another thickener, for example starch, but this may adversely affect the rheological performance of the finished product. To prevent the occurrence of the above situation, further research should be done on the effect of the thickener type on the structural and mechanical properties of sauces with mushroom powders.

Opportunities. Additional possibilities of the proposed technological solution consist in expanding the assortment of sauces on plant raw materials with increased biological value. It is possible to model the formulation of mushroom sauces by using substandard mushroom raw materials in the form of mushroom powders. The resulting new product has better structural and mechanical properties than the mushroom sauce prepared according to the traditional recipe. Therefore, the production of mushroom sauces with mushroom powders according to the proposed technology is promising, convenient and beneficial for restaurants, strive to release high-quality products, observe the trends of healthy eating.

Threats. The difficulties in implementing the research results are related to the following factors:

– a complex and unstable position of modern restaurants, the dominance of Ukrainian consumers' demand for fast food products, which are characterized by a narrow range of own production of sauce;
– risks associated with unstable supplies of cheap off-grade mushroom raw materials from champignons, reishi and shiitake Ukrainian agricultural enterprises that specialize in the cultivation of these mushrooms;
– financial costs associated with the production of semi-finished products for sauces with mushroom powders, that is, the costs of obtaining mushroom powders.

These factors can influence the intensity of the process of introducing an innovative sauce product with increased biological value in Ukrainian restaurants.

8. Conclusions

1. Optimization of the sauce formulation with mushroom powders was carried out on the basis of studying the structural and mechanical properties of the inves-

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tigated product. Optimal quantities of the formulation components of the innovative product are determined, namely the ratio of the fungal powders in the formulation composition as 1:1:2 (shiitake:reishi:champignons). The ratio of thickeners is proposed as 1:1 (wheat flour and whey protein concentrate).

2. The technology of production of sauce with mushroom powders, which have high biological value and high consumer properties and is resource-saving, has been developed and justified. So, the cooking time of the innovative sauce is 20–25 minutes.

3. The structural and mechanical properties of the sauce with mushroom powders have been analyzed according to the developed technology in comparison with the control sample – a mushroom sauce prepared according to the traditional technology, according to the recipe No. 868 of the Recipe of Foods and Culinary Products. Based on the analysis, it is established that the structural and mechanical properties of the new sauce product are close to the control sample. However, the viscosity and shear stresses are higher. Thus, at a shear rate of 200 s^{-1}, the viscosity of the developed sauce is 0.38 Pa·s, while the viscosity of the mushroom sauce prepared according to conventional technology is 0.3 Pa·s. This is optimal from the point of view of the organoleptic evaluation of the quality and the possibility of effective introduction of this product into the technology of the products of modern restaurants.

The results of the conducted researches allow to draw the following conclusions:

– production of mushroom sauces with specified consumer characteristics technologically possible and economically profitable;

– obtained data positively correlate with the organoleptic evaluation of the quality of the mushroom sauce «Mushroom Extra».

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