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СЕНСАЦІЙНІ ФАКТИ ТА ВІДКРИТТЯ ПРИХОВАНИХ ФОРМ БІЛКА В ГРИБАХ ШАМПІНЬЙОНАХ ПІД ЧАС ОТРИМАННЯ НАНОПРОДУКТІВ У ЛЕГКОЗАСВОЮВАНІЙ ФОРМІ

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Розроблено унікальний метод виготовлення нанопродуктів із грибів шампіньйонів із використанням нового покоління обладнання, яке застосовується на підприємствах ресторанного бізнесу та дозволяє вилучити із сировини важкозасвоюваний білок із зв'язаної, прихованої форми в нанокомплексах з іншими біополімерами у вільну форму (в 1,7–1,8 разу більше, ніж у вихідній сировині) та трансформувати його в легкозасвоювані амінокислоти (на 65–70%). Авторами вперше в міжнародній практиці зроблено відкриття та виявлено прихований білок у свіжих грибах. Показано, що в пюре, отриманому з грибів, у 2 рази більше білка, який знаходиться в розчинній формі, ніж у свіжій сировині.

Ключові слова: *гриби шампіньйони, важкозасвоювані білки, термодеструкція, механоліз, оздоровчі нанопродукти, інактивація ферментів.*

СЕНСАЦИОННЫЕ ФАКТЫ И ОТКРЫТИЕ СКРЫТЫХ ФОРМ БЕЛКА В ГРИБАХ ШАМПИНЬОНАХ ПРИ ПОЛУЧЕНИИ НАНОПРОДУКТОВ В ЛЕГКОУСВОЯЕМОЙ ФОРМЕ

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Разработан уникальный метод изготовления нанопродуктов из грибов шампиньонов с использованием нового поколения оборудования, которое применяется на предприятиях ресторанного бизнеса и позволяет извлечь из сырья трудноусвояемый белок из связанной, скрытой формы в нанокомплексах с другими биополимерами в свободную форму (в 1,7–1,8 раз больше, чем в исходном сырье) и трансформировать его в легкоусвояемые аминокислоты (на 65–70%). Авторами впервые в международной практике сделано открытие и выявлен скрытый белок в свежих грибах. Показано, что в пюре, полученном из грибов, в 2 раза больше белка в растворимой форме по сравнению со свежим сырьем.

Ключевые слова: *грибы шампиньоны, трудноусвояемые белки, термодеструкция, механолиз, оздоровительные нанопродукты, инактивация ферментов.*

SENSATIONAL FACTS AND THE DISCOVERY OF HIDDEN FORMS OF PROTEIN IN MUSHROOMS DURING THE OBTAINING OF NANOPRODUCTS IN AN EASILY DIGESTIBLE FORM

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The unique method of obtaining of nanoproducts from champignons with the use of new generation of equipment is developed. This equipment is used at the restaurant business enterprises and allows extracting the hardly digestible protein of raw materials from the hidden, bound with the other biopolymers form in nanocomplexes to a free condition (1,7–1,8 times more than in the start raw materials) and transform it into the digestible aminoacids (65–70 %). The authors of the article for the first time in the international practice made a revelation and discovered the hidden protein in fresh mushrooms. It is shown that the content of protein in puree from champignons is 2 times higher than in the start raw materials and it is in a soluble form.

It is found that, the enzymatic processes (particularly their activation) during the processing in a steam convection oven occur with a lower intensity than during the using traditional method of heat treatment of champignons (particularly boiling). Thus, the activation of oxidative enzymes (peroxidase and polyphenol oxidase) after 10 minutes of boiling in a traditional apparatus increases 3–3,5 times, in a steam convection oven – 2–2,1 times. Primarily it can be explained by the different temperatures during the steam-thermal treatment and by the different amounts of kinetic heat energy that participates in these processes. It is shown that during the steam-thermal treatment of champignons in a steam convection oven, the loss of aromatic and other BAS is 1,8–2 times less than in the traditional cooking.

It is shown that the extraction of hidden forms of aromatic substances and L-ascorbic acid from the raw materials occurs more completely after the steam-thermal processing and fine-dispersed grinding during the obtaining of mushroom puree in the nanoform. The mass fraction of the 70–75% of substances is in a nanoscale and easily-digestible form due to the fine-dispersed grinding of mushrooms obtained by traditional cooking.

It is determined that the complex use of steam-thermal treatment (in the steam-convection oven) and fine-dispersed grinding of champignons allows obtaining the nanopuree and pates on their basis with the high quality, which exceeds the known analogues several times (particularly the content of free α-amino acids and aromatic substances in pates is 2 times higher than in the raw materials).

Keywords: *champignons, hardly digestible proteins, thermal destruction, mechanolysis, healthful nanoproducts, inactivation of enzymes.*

Statement of the problem. Today, the global problem in the international practice in many countries of the world is a deficit of vitamins, proteins, minerals, carotene and other biologically active substances (BAS) in daily diets [1; 2]. The requirement of them is satisfied by only 50%

among Ukrainians [3]. There is also an imbalance of products that promote good health, in food rations in Ukraine: a shortage of milk, fish, meat, fruits and berries. It is also known that 50% of the Earth's population is starving [1; 3; 4]. In this regard, there are many programs around the world, aimed to the industrial production of such synthetic food products as milk, meat, vegetables, flour, cereals, etc. These products are almost the same in appearance and taste as natural products, but they are harmful to the human body. They are practically not absorbed and difficult to remove. That's why these substances are accumulated in the form of allergens, that lead to various diseases. In addition, there is a deterioration of the ecological situation and a decrease of immunity in the population all over the world [1–4]. In this regard, functional healthful products (especially vegetables and fruits), which are aimed at health promotion, are very popular in many countries [4; 5]. This is one of the most important and relevant scientific areas, which is intensively developing in international practice.

Review of the latest researches and publications. The mushrooms, particularly champignons, have a special place among the herbal raw materials. It is known that they are a traditional source of herbal complete proteins, essential amino acids, heteropolysaccharides (cellulose, starch, pectins, etc.). These substances are in the form of highly soluble nanoassociates and nanocomplexes in herbal raw materials. That's why they are weakly digestible by the human body (just on 30–50 %) [6; 7]. These substances are the type of prebiotics, non-digestible food ingredients that stimulate the development, the metabolic and biological activity of one or more groups of own bacteria in the human body that compose the intestinal microflora and have a positive effect on the microbiocenosis, so they support the intestine in a healthy state. It is known that the state of the immune system of a person depends on the state of intestine by 80% [8; 9].

It is known that proteins of mushrooms are not inferior to animal by their biological value. However, today they have not found a proper application in the food industry of Ukraine. The assortment of products from mushrooms is limited and presented by several types of products. The innovative technologies of obtaining of fine-dispersed additives from mushrooms in the form of puree and nanopowders were investigated by the authors previously [10; 11]. Therefore the development of nanostructured additives, healthful products from mushrooms and their introduction into production are actual today.

Today, one of the advanced methods of processing of herbal raw materials is cryogenic grinding, which needs special equipment. Recently, information appeared that steam-thermal treatment with the use of modern equipment (steam-convection ovens) and fine-dispersed grinding without

the use of cold are rated as progressive methods [12–14]. As for the processing of mushrooms, practically none of these methods was used, the processes of mechanical degradation, mechanical activation were not studied, except of the authors of the article [15]. For today, the perspective ways of fine-dispersed grinding are already widely used in the chemical, aviation, textile and construction industries in different countries of the world. However, in the food industry, these processes are studied poorly [16; 17].

In this regard, the task of the research work was to search and develop an alternative (to cryogenic treatment) method of deep processing of raw materials without the use of low temperatures. This would allow preserving and using the biological potential of raw materials maximally. As an alternative to cryogenic method of deep processing, it was proposed to use a complex effect of steam-thermal treatment and fine-dispersed grinding on the raw materials with the use of new generation of modern, highly effective equipment – steam convection oven (Italy) and activator-chopper-curter (France). This equipment is widely used in international practice and has already found application in Ukraine: in elite restaurants, culinary shops of supermarkets, dining rooms of sanatoriums – dispensaries, food factories, etc. [2; 11; 13]. However, there is no data in the scientific literature about the impact of technological processing with the use of the above-mentioned types of modern equipment on the quality of champignons (on the content of BAS, on the activity and removal of protein) during the processing and obtaining of high quality products. In this regard, it is actual to develop the new nanostructured additives from mushrooms (in the form of puree), obtained with the use of modern equipment, and the manufacture of a wide range of healthful products from them in easily digestible form (for example: pates, snacks, phalafels, spreads, etc.).

The objective of the article. The purpose of research is to study the impact of deep processing of mushrooms with the use of steam-thermal treatment and fine-dispersed grinding on the preservation and removal of aromatic substances and protein from the bound with the nanocomplexes state into an easily digestible form with the use of new equipment generation, that allow obtaining the healthful products in nanoform.

To achieve the purpose, the following tasks have been solved:

– to study the impact of steam-thermal treatment and non-enzymatic catalysis – mechanolysis on the transformation of mushroom's protein from the hidden (or bound with heteropolysaccharides in nanocomplexes) form into a free state; to study their amino acid composition;

– to study the impact of steam-thermal treatment and fine-dispersed grinding on the quality of mushroom puree in a nanosized form (by the content of BAS);

– to study the quality and the content of essential amino acids of nanopuree from champignons and to develop the new nanoproducts in the form of pastes based on the mushroom's fine-dispersed puree and to study their quality and amino acid score in comparison with their analogues.

Presentation of the research. *Materials and equipment used in experimental research*. The research was conducted at Kharkov State University of Food Technology and Trade (Kharkov, Ukraine) at the Department of Technologies of the Processing of Fruits, Vegetables and Milk in the Laboratory "Innovative Cryo- and Nanotechnologies of Herbal Additives and Healthful Products" with the participation of specialists of Academy of Hotel and Restaurant Management in Poznan (Poland) and Kharkov Trade and Economic Institute of Kyiv National University of Trade and Economics (Ukraine).

For the experimental part of the research work and for the obtaining of a new product, it was used such equipment as: steam-convection oven UNOC SPA XVC-series (Italy), which has 70 programs that differ between each other in their treatment regimes (it allow the preservation of useful substances in the product); activator-chopper-cutter (France) was used for fine-dispersed grinding, that allows obtaining the product with the particles, which size is tens of times smaller than the size of particles in the products received by traditional grinding.

The authors of article used the following research objects: the fresh champignons, champignons after traditional cooking, champignons after a steam convection oven, the nanostructured mushroom puree, a finished product in the form of mushroom paste, obtained by nanotechnology and analogues.

Methods of determining the parameters of the studied samples. As the criteria for quality control of champignons (start raw materials), steam-treated mushrooms and the finished product, it was determined the following parameters: protein (by total nitrogen), free and bound amino acids, fat, dry substances, moisture, aromatic substances, L-ascorbic acid, phenolic compounds (by chlorogenic acid) and the enzymatic activity of oxidative enzymes (peroxidase and polyphenol oxidase). Details of the methods of determining the parameters of the studied samples can be found in the literary source [18].

Development of a new generation of healthful products from champignons for food industries and enterprises of restaurant business and trade. A unique technology of deep processing of champignons has been proposed and developed in Kharkov State University of Food Technology and Trade (Kharkov, Ukraine) in cooperation with Academy of Hotel and Restaurant Management (Poznan, Poland) and Kharkov Trade and

Economic Institute of Kiev National University of Trade and Economics (Kharkov, Ukraine), and. The technology allows obtaining healthful products in easily digestible nanoform with fundamentally new consumer properties in comparison with products, which were obtained with the use of traditional methods of steam-thermal treatment (blanching, boiling) and fine-dispersed grinding. In particular, they have a high content of BAS (1,5–2,0 times more than the same parameter in the raw materials). In addition, due to the use of proposed technology it is possible to extract the protein from mushrooms completely. It was not possible till now because the protein is in the hidden (bound with other biopolymers) state in the form of insoluble nanocomplexes with other high-molecular biopolymers (cellulose, pectin substances, chitin, etc.), which are not absorbed by the human body. The research also allows transforming (destruction) of protein due to the steam-thermal treatment and non-enzymatic biocatalysis – mechanolysis with the use of fine-dispersed grinding till the individual α-amino acids (by 65–70%) in the easily digestible form. The authors managed to discover and give an impetus to a new direction for the processing of mushrooms.

It is known that the inactivation of oxidative enzymes is one of the main factors in the processing of mushrooms (including the steam-thermal treatment), which affects the degree of preservation of vitamins, aromatic and other biologically active substances. To inactivate enzymes the authors of the article have used such approaches as steam-thermal treatment with different temperatures and different amount of steam in a steam convection oven.

It is known, that according to the theory of famous scientist biochemist A.I. Oparin, initially the enzymatic activity occurs in the product during the steam-thermal treatment of herbal raw materials. It happens as a result of heating the product due to the activation of enzyme molecules by increasing of kinetic energy. It is determined that the processes of steam-thermal treatment of champignons with the use of steam convection oven and traditional cooking in standard apparatus in the boiling water occur in different ways (table 1).

It is found that the fermentative processes occur with the less intensity during the processing of champignons in the steam convection oven comparing with the traditional method by heat treatment (boiling). As it should be expected, the research allowed revealing, that initially the activation of oxidative enzymes occurs.

Table 1

The impact of steam-thermal treatment on the activity of oxidative enzymes of champignons after the steam-convection oven and after the cooking (boiling) in traditional conditions

Product	Oxidative enzymes			
	Peroxidase		Polyphenol oxidase	
	ml 0,01 n. I per DS	% per the start raw materials	ml 0,01 n. I per DS	% per the start raw materials
Fresh mushrooms	695,0	100,0	155,0	100,0
Mushrooms after boiling (τ=5 min)	1390,2	200,0	320,2	201,0
Mushrooms after boiling (τ=10 min)	2432,5	350,1	465,0	301,0
Mushrooms after boiling (τ=20 min)	1737,5	250,2	341,2	210,2
Mushrooms after boiling (τ=30 min)	277,5	39,9	43,4	28,0
Mushrooms after boiling (τ=40 min)	0	0	0	0
Mushrooms after steam-thermal treatment in the steam convection oven (τ=5 min)	1042,0	150,0	235,6	152,4
Mushrooms after steam-thermal treatment in the steam convection oven (τ=10 min)	1181,5	170,0	310,0	200,2
Mushrooms after steam-thermal treatment in the steam convection oven (τ=20 min)	451,8	65,0	116,6	75,2
Mushrooms after steam-thermal treatment in the steam convection oven (τ=30 min)	0	0	0	0

For example, the activation of oxidative enzymes of champignons (peroxidase and polyphenol oxidase) in boiling water after 10 minutes increases 3–3,5 times more than the activity in the raw materials). At the same time the activation of enzymes in the steam convection oven is 1,7–2,0 times higher. It is shown that the heating of the product contributes to the activity of oxidative enzymes, and even it's much more in traditional devices. The maximum activity of enzymes occurs within 10 minutes and then inactivation of enzymes follows. It is shown that complete inactivation of oxidative

enzymes in mushrooms occurs in the steam convection oven much earlier (30% faster) than during the cooking in traditional devices). Therefore, it could be assumed, that the destruction of BAS during the heat treatment of mushrooms in the steam-convection oven would be lower comparing with the traditional cooking (boiling).

It is determined, that the losses of vitamin C during the steam-thermal treatment in a steam convection oven are significantly lower (almost 2 times) than during the cooking (boiling) using traditional equipment (fig.).

So, the mass fraction of L-ascorbic acid in mushrooms after 30 minutes of their steam-thermal treatment in a steam convection oven is stored at 75–80%. The mass fraction of aromatic substances in this way of cooking is stored at 70–75%. In the same time during the boiling of champignons in the traditional equipment (blanchers, cooking pans) the mass fraction of L-ascorbic acid is stored at 40–45% and the mass fraction of aromatic substances at 35–40%. Thus, it is found that during the heat treatment of mushrooms in the steam convection oven the oxidation (destruction) of L-ascorbic acid and aromatic substances is less intensive (2 times less) than during the boiling and using traditional equipment.

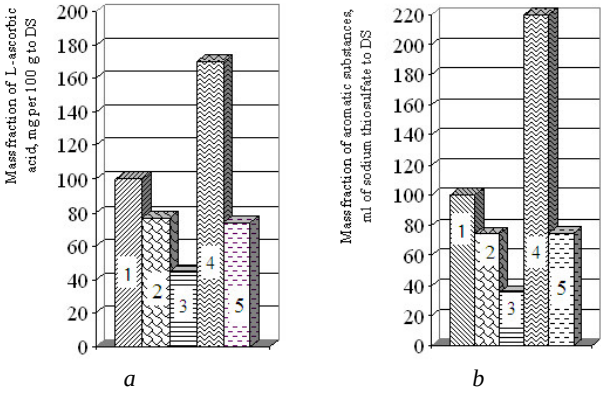

Fig. The impact of steam-thermal treatment and fine-dispersed grinding of mushrooms on the content of aromatic additives (a) and L-ascorbic acid (b) in comparison with fresh raw materials, where: 1 – fresh champignons; 2 – mushrooms after steam-thermal treatment (bowling during 30 minutes); 3 – mushrooms after cooking in the traditional conditions; 4 – fine-dispersed puree of mushrooms after the treatment in the steam convection oven; 5 – fine-dispersed mushrooms after the boiling in the traditional conditions

It is also determined that extraction of BAS from the steam-treated mushrooms is more complete during the fine-dispersed grinding in both cases: after cooking in traditional equipment and in a steam convection oven. Thus, during the fine-dispersed grinding the extraction of aromatic substances from the champignons treated in a steam-convection oven is 2,2 times higher than after traditional cooking (boiling). It means that aromatic substances and L-ascorbic acid of mushrooms are almost stored completely (70% of the raw materials) after the traditional cooking and fine-dispersed grinding. After the treatment of mushrooms in the steam convection oven during 30 minutes and further grinding, not only all the BAS are completely stored, but their hidden forms are also extracted. Particularly, the mass fraction of aromatic substances is 2,2 times more than in the raw materials, and the mass fraction of L-ascorbic acid is 1,7 times more (fig.).

The main thing during the developing of nanotechnology of puree from mushrooms with the use of deep processing of raw materials (in particular steam-thermal treatment and fine-dispersed grinding) is not only to prevent darkening of the product due to the action of enzymatic oxidation, but also to preserve the aromatic and other biologically active substances maximally. In addition, it is important to increase extraction of hidden bound forms, valuable high-molecular proteins, which are connected in nanocomplexes with food fibers, chitosans, minerals and other BAS to a free condition – into easily digestible nanoform. For this purpose, the steam-thermal treatment in the steam-convection oven and the fine-dispersed grinding (without the use of cold) are used.

It is determined that the destruction of protein-chitin nanocomplexes occurs during the steam-thermal treatment and the fine-dispersed grinding of mushrooms. The liberation of protein from the bound state is 65–73% higher than its amount in the raw materials. The destruction of protein to the individual α-amino acids is 65–70% (table 2).

It is shown that the total amount of protein in fresh champignons is 2,66 g in 100 g. The mass fraction of amino acids in the bound state from this amount is 2,028 g in 100 g and 0,632 g in 100 g in the free state (table 4). The total protein content is 5,42 g in 100 g of nanostructured fine-dispersed puree from mushrooms. The mass fraction of amino acids in the bound state is 3,19 g in 100 g and 2,23 g in 100 g in the free state. It is explained by the fact that the protein-chitin nanocomplexes are destroyed during the steam-thermal treatment and fine-dispersed grinding and 65,0–73,0% of bound amino acids are liberated from them additionally. For example, the mass fraction of bound amino acids in the fresh mushrooms is 2,028 g in 100 g, and after the fine-dispersed grinding is 3,192 g in 100 g.

Table 2

The impact of steam-thermal treatment in the steam-convection oven and fine-dispersed grinding of mushrooms on destruction of protein-chitin complex and mechanolysis of protein to free amino acids during the obtaining of puree from mushrooms

Amino acid	Total amount of amino acids in the raw mushrooms, g in 100 g	Amino acids of mushrooms (in the bound condition)			Amino acids of mushrooms (in the free condition)		
		in the raw materials, g in the 100 g	the fine-dispersed puree from shampignons, g in 100 g	the increase of free amino acids to the start raw materials, times	in the raw materials, g in the 100 g	the fine-dispersed puree from shampignons, g in 100 g	the increase of (to the start raw materials) (to the start raw materials) amino acids in the free condition after the fine-dispersed grinding, times
Lysine	0,360	0,248	0,304	1,23	0,112	0,166	1,48
Tryptophan	0,078	0,050	0,110	2,20	0,028	0,108	3,86
Methionine	0,078	0,064	0,192	3,0	0,014	0,132	9,43
Isoleucine	0,106	0,094	0,160	1,70	0,012	0,172	14,33
Leicine	0,198	0,144	0,266	1,85	0,054	0,174	3,22
Phenylalanin	0,092	0,084	0,142	1,69	0,008	0,076	9,50
Histidine	0,152	0,066	0,208	3,15	0,086	0,148	1,72
Threonine	0,108	0,096	0,108	1,13	0,012	0,072	6,0
Serine	0,114	0,104	0,146	1,40	0,010	0,090	9,0
Aspartic	0,272	0,228	0,322	1,41	0,044	0,152	3,45
Glutamic	0,380	0,268	0,372	1,39	0,112	0,372	3,32
Proline	0,150	0,084	0,116	1,38	0,066	0,136	2,06
Glycine	0,122	0,114	0,148	1,30	0,008	0,050	6,25
Alanine	0,114	0,104	0,140	1,35	0,010	0,110	11,0
Cysteine	0,024	0,012	0,016	1,33	0,012	0,018	1,50
Valine	0,118	0,108	0,136	1,26	0,010	0,102	10,20
Tyrosine	0,114	0,096	0,124	1,29	0,018	0,048	2,67
Arginine	0,080	0,064	0,182	2,84	0,016	0,106	6,63
Total	2,66	2,028	3,192	–	0,632	2,232	–

It is also found that amount of individual amino acids increased 1,3–3,2 times in comparison with this amount in fresh mushrooms. In the opinion of authors of the article, the mechanism of this process can be explained by the fact that protein substances in the raw materials

(mushrooms) are in the highly soluble and hardly digestible nanocomplexes with chitin and polysaccharides, as well as salts (often salts of silicium, calcium, magnesium, etc.). The fine-dispersed grinding destroys these nanocomplexes, liberates the proteins from the bound state and promotes its mechano-destruction due to the non-enzymatic catalysis-mechanolysis. It is determined that during the fine-dispersed grinding there is not only disaggregation and destruction (non-enzymatic catalysis) of hardly soluble protein-chitin-mineral complexes, but also the mechanical destruction (mechanical cracking) of proteins to the free amino acids (65,0–70,0%).

It is known that the molecule size of the monomer of protein-amino acids is about one nanometer. Data analysis (table 2) showed that mechanoactivation results to significant changes in structure of the protein globule and protein chitin complexes due to mechanical degradation. It also leads to loss of the natural primary structure and the transformation of proteins into the individual free amino acids. As a consequence, the solubility in the water increases and the high digestibility by the living organisms is provided [11; 19; 20].

The obtained data on the content of amino acids in the mushroom protein are compared with the hypothetical "ideal protein" (table 3). The standard scale of amino acids is proposed by FAO/WHO. It allows comparing the protein composition of the studied product with the "ideal protein".

Table 3

Amino acid composition of mushrooms (champignons) and amino acid score in comparison with the FAO/WHO scale

Amino acid composition	The FAO/WHO scale, mg in 1 g of protein	The content of amino acids, mg in 100 g (protein content is 2,66%)	The content of amino acids, mg in 1 g of protein	Score, %
Essential amino acids				
Tryptophan	10	78	29,32	293,2
Lysine	55	360	135,34	246,1
Threonine	40	108	40,60	101,5
Valine	50	118	44,36	88,7
Methionine+Cystine	35	102	38,35	109,6
Isoleucine	40	106	39,85	99,6
Leicine	70	198	74,44	106,3
Fenilalanine+tyrosine	60	206	77,44	129,1
Total	–	1276	479,7	–

The calculation of the amino acid score has showed that the protein of the champignons is approaching the "ideal protein" by its amino acid composition, but is limited to such an amino acid as valine. Besides that, the protein of the mushrooms exceeds the "ideal protein" by tryptophan and lysine 2,6–3 times, and by the total amount of phenylalanine and tyrosine – 1,3 times (table 3).

The obtained scientific results are used during the development of nanotechnology of fine-dispersed puree from champignons with the use of the steam-thermal treatment and fine-dispersed grinding as innovation. These processes allowed the extraction of hidden forms of BAS and biopolymers in herbal raw materials, the destruction of the protein into the individual amino acids and the use of biological potential of herbal raw materials more completely.

Two recipes of new types of pates ("Mushroom pate" and "Mushroom pate with ham") are developed on the base of the research results. The nanostructured fine-dispersed puree from champignons is used as the main ingredient in amount of 55–60%. As additional ingredients are used the fried carrots, fried onions, vegetable oil, dry milk, salt, sugar, a mixture of spices, phytoextracts from natural spices (black pepper, cloves) (a mixture 1:1 with a content of dry substances 3,5–3,8%), ham and broth or water according to recipe.

It is determined that the new pates have a pleasant taste and smell by the sensory parameters due to the use of nanostructured fine-dispersed puree from mushrooms and the mentioned components. The finished product has a steady color and an elastic, homogeneous consistency, which is usual for this type of canned food. In addition, such product is in the easily digestible nanoform.

The obtained results of the research of amino acid composition and physical and chemical parameters of developed pates with the use of nano-structured puree from mushrooms are presented in the table 4.

It is shown that the mass fraction of protein in new pates exceeds its mass fraction in the fresh mushrooms 2 times. Particularly, it is 5,4% in pates with the use of nanostructured fine-dispersed puree from the mushrooms and 2,7% – in the fresh mushrooms. Moreover, it should be noticed that its amino acid composition is complete.

It is shown that the pates are characterized by a high content of essential amino acids, aromatic and low-molecular phenol compounds. They have immunomodulating and detoxifying properties (table 4) according to the chemical composition and exceed the world-known analogues significantly.

Table 4

Amino acid composition and physical and chemical parameters of the quality of "Mushroom pate" and "Mushroom pate with ham" with the use of nanostructured puree from mushrooms

Parameter	"Mushroom pate"	"Mushroom pate with ham"	Analogue "Mushroom pate" (Poland)
Mass fraction of dry substances, %	43,91	42,36	43,22
Mass fraction of protein, %	5,4	5,0	2,7
Essential amino acids (mg in 100 g of protein)			
Threonine	0,200	0,250	0,95
Valine	0,250	0,300	0,108
Methionine	320	340	100,0
Isoleucine	210	205	94,0
Leucine	450	420	144
Fenilalanine	210	205	84
Lysine	66	300	100
Tryptophan	250	218	50
Mass fraction of fat, %	11,2	12,8	13,0
Mass fraction of phenols (by the chlorogenic acid), mg in 100 g	685,2	716,0	72,0
Mass fraction of aromatic substances (by the number of flavor), ml of thiosulphate Na in 100 g	97,1	89,6	28,4
pH	6,2	6,1	6,3

All of these results suggest the high efficiency of the use of a new generation of steam treatment equipment and fine-dispersed grinding of mushrooms. The approbation of experimental parties of nanoproducts (nanopuree, nanopates, snacks "Cheese-Ball", etc.) in the production conditions, in particular in the scientific research firm "KRYAS PLUS" (Kharkov, Ukraine), NPF "KHPP" (Kharkov, Ukraine), KPK "KDK" (Kharkov, Ukraine) confirms the expediency of using a new generation of equipment and obtaining nanoproducts for both: the restaurant industry and large food companies.

The results obtained during the research the impact of deep processing of champignons with the use of steam-thermal treatment and fine-dispersed grinding and their discussion

The authors hope that the results presented in this article will have a significant practical value for Ukrainian and international community, as there is a shortage of natural products in the world.

Despite the useful properties of raw materials, today the biological potential (based on the content of vitamins, other BAS, biopolymers), which is incorporated to the raw materials, is used only in part the world. Significant amount of BAS (20–80%) is lost using the traditional methods of processing of herbal raw materials, as well as during the consumption of fresh and finished raw materials. Most of the healing substances of the raw materials is digested on 30–50% in the human body. It means that significant losses of biological potential of valuable herbal raw materials occur during their processing and consumption. So within the limits of our planet, it can be consist hundreds of billions of tons. One of the main world-used ways to preserve all the valuable substances in the herbal raw materials (including the mushrooms) is the introduction of resource-saving and non-waste production technologies. However, none of the world scientific community (except the authors of this work) has never raised the question that there are a large number of hidden (bound) forms of low-molecular BAS and biopolymers in the herbal and mushroom raw materials, the mass fraction of which is 2–5 times more than it is well-known in the world and fixed by traditional chemical research methods. The authors of the article found that there are significant hidden reserves in the fresh herbal and mushroom raw materials, such as low-molecular food compounds, biologically active substances and biopolymers.

So, the offered methods of deep treatment of raw materials and the technological processes with developed technologies allow extract the biological potential of the raw materials as much as possible. The use of the biological potential can be compared with the increase the yield of herbal and mushroom raw materials several times.

Using the obtained results allows providing theoretical and practical bases which give the possibility of purposeful obtaining of herbal heterogeneous disperse systems in the food industry in the nanoscale diapason with the use of mechanical destruction, cryogenic mechanical destruction and non-enzymatic catalysis. These processes allow using the biological (including the hidden) potential of herbal raw materials more completely and obtaining the products and additives with fundamentally new consumer properties, which can not be achieved with the use of traditional technologies, which are characterized by significant losses of BAS in the raw materials.

Conclusions. It is determined that the new method of steam-thermal treatment (in the steam-convection oven) and fine-dispersed grinding of champignons during the obtaining of nanopuree allows extraction of hard-soluble

protein from the raw materials from the bound form in nanocomplexes with other biopolymers into the free form 1,7–1,8 times more than in the raw materials and transformation (destruction) of the protein into the easily digestible nanoform to the individual α-amino acids (65–70%) due to the non-enzymatic catalysis. The authors of the article for the first time in the international practice made a revelation and discovered the hidden protein in fresh mushrooms.

It is shown that the extraction of hidden forms of aromatic substances (2,2 times) and L-ascorbic acid (1,7 times) from the raw materials occurs more completely after the steam-thermal processing and fine-dispersed grinding during the obtaining of mushroom puree in the nanoform. The mass fraction of the 70–75% of substances is in a nanoscale and easily-digestible form due to the fine-dispersed grinding of mushrooms obtained by traditional cooking.

It is found that, the enzymatic processes (in particular, their activation) during the processing in a steam convection oven occur with a lower intensity than during the using traditional method of heat treatment of champignons (particularly, boiling). Thus, the activation of oxidative enzymes (peroxidase and polyphenol oxidase) after 10 minutes of cooking (boiling) in a traditional apparatus increases 3–3,5 times, in a steam convection oven – 2–2,1 times. Primarily it can be explained by the different temperatures during the steam-thermal treatment and by the different amounts of kinetic heat energy that participates in these processes. It is shown that during the steam-thermal treatment of mushrooms (champignons) in a steam convection oven, the loss of aromatic and other BAS is 1,8–2 times less than in the traditional cooking.

It is determined that the complex use of the steam-thermal treatment (in the steam-convection oven) and the fine-dispersed grinding of champignons allows obtaining the nanopuree and pates on their basis with the high quality, which exceeds the known analogues several times (in particular, the content of free α-amino acids and aromatic substances in pates is 2 times higher than in the raw materials).

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