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NUTRITIONAL AND BIOLOGICAL VALUE OF MUSHROOM SNACKS

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Abstract: *The paper presents the results of research and scientific substantiation of nutritional and biological value of developed new mushroom chips and snacks.*
Taking into account the high popularity of snacks, the prospects for the use of artificially cultivated mushrooms due to the valuable chemical composition and useful properties, the global volume of their cultivation, such research is appropriate and relevant.
To achieve this goal, the task was to investigate experimentally the chemical and amino acid composition, digestion of protein substances of developed chips and snacks based on edible mushrooms. The research was conducted using modern methods.
On the basis of experimental researches, the increased consumer and biological value of the developed mushroom products, and also their low caloric content was proved. It was found that mushroom products increased the enzymatic hydrolysis of protein substances compared to fresh mushrooms at both pepsin and trypsin stage of their hydrolytic cleavage, which contributed to their increase digestibility.
The conducted research and developed technologies of mushroom chips and snacks can be used both in the food concentrate branch and in other branches of the food industry.

Key words: *oyster mushrooms, champignon mushrooms, mushroom products, chemical composition, amino acid composition, digestion.*

1. Introduction

The rapid growth of modern living standards and at the same time the deterioration of the ecological situation in the world encouraged the development of food products of new generation using both traditional and non-traditional raw materials, which in addition to high quality and nutritional value will have protective properties.
Snacks are very popular all over the world. The biggest supporters of snack products are the generation of millennials. In order to meet this demand, opportune adaptation and an innovative approach by snack producers is needed.
Unfortunately, most of the raw materials used in the production of snacks are characterized by the high content of easily digestible carbohydrates, which leads to low biological value and high caloric content of products. An alternative to the most popular types of snacks, namely potato chips, are chips from other vegetable crops or fruit chips which are high-quality natural food products with high taste properties [1, 2].
A possible promising way to solve this problem is also the use of artificially cultivated edible mushrooms as the main raw material in the production of snack products. This choice of raw materials was due to the fact that mushrooms have a

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valuable chemical composition and high protein content [3–10].

In recent years, there was an intensive development of industrial production of artificially cultivated mushrooms. Today, world production of edible mushrooms is about 5 million tons per year. Mushroom production increased annually by 13 - 18% in the last 20 years. Champignon mushrooms and oyster mushrooms are the most popular among the population [11, 12]. However, only 20% of the total mushrooms grown is processed. The reasons that constrain their widespread use in production and promotion at the consumer market are the short shelf life and insufficient processing technologies.

The analysis of scientific literature data showed that in case of the market economy to ensure consumer demand and constant sales, it was necessary to develop new technologies for processing mushrooms and expand the range of low-calorie snack products with high nutritional and biological value.

Taking into account the above-mentioned arguments, the development of snack products based on edible champignon mushrooms and oyster mushrooms and the study of their nutritional and biological value was appropriate and relevant.

The purpose of this work was the research and scientific substantiation of nutritional and biological value of mushroom chips and snacks.

To achieve this goal, the following tasks were formulated:

- to investigate experimentally the chemical and amino acid composition, digestion of protein substances of developed chips and snacks of high nutritional and biological value based on edible mushrooms;
- to determine the nutritional and biological value of mushroom chips and snacks.

2. Materials and methods

In laboratory studies, cultivated mushrooms of the oyster mushrooms (*Pleurotus ostreatus*) and champignon mushrooms (*Agaricus bisporus*), salt, citric acid monohydrate, sunflower oil, wheat flour of second grade and water were used. The objects of research were also finished products from these raw materials.

Developed technologies of mushroom chips and snacks involved obtaining products from whole mushrooms.

In the production of chips, oyster mushrooms were the main raw material, and salt, citric acid, water, and refined sunflower oil were additional materials. The production of mushroom chips could be divided into the following main stages: preparation of raw materials for production, preparation of mushroom semi-finished products, cooling, mixing mushroom semi-finished products with oil, frying, cooling products, packaging.

To prepare the mushroom semi-finished product, mushrooms were loaded into the cooking boiler and an acid-salt solution with a mass fraction of salt of 1% and citric acid of 0.02% was added. Hydrothermal treatment of mushrooms was carried out at a temperature of 95 ± 5 °C, the duration of the process was 5 minutes. Frying of the semi-finished product was carried out in a frying machine for 15 minutes at a temperature of 195 °C.

In the production of snacks, the mushroom semi-finished product was additionally mixed with a breading mixture consisting of wheat flour of the second grade and salt. Frying of the semi-finished product was carried out for 10 minutes at a temperature of 195 °C.

Oyster mushrooms or champignon mushrooms were used as the main raw materials for the production of mushroom appetizers. The technology of appetizers differed from the above technology of chips as instead of the frying process, the

drying process was carried out, and the use of oil was excluded. The obtained mushroom semi-finished product was dried at a temperature of 55 ± 3 °C.

Analytical, chemical, biochemical, experimental-statistical research methods were conducted with the use of modern devices and information technologies. The experimental part was performed in the laboratory of the University of Rzeszow (Poland), the National University of Food Technologies (Ukraine) and in the O.A. Palladin Institute of Biochemistry of the National Academy of Sciences of Ukraine.

The total nitrogen content was determined by the Kjeldahl method [13]. A conversion factor of 6.25 was used to convert the total nitrogen content to protein.

The amino acid composition of proteins was determined by ion-exchange liquid column chromatography using amino acid analyzer T339 (Czech Republic) [14] after preliminary acid hydrolysis of a portion of concentrated HCl for 24 hours at 106 °C. Alkaline hydrolysis was performed to determine tryptophan in the samples, which was made with 5 mol/dm^3 NaOH solution at 60 °C for 2 hours in sealed ampoules.

The fiber content was determined by the Kurschner-Hanakmethod with the modification by Kogan; the content of dextrins was determined by the photoelectro coloremetric method; the content of reducing substances was determined by the iodometric method; the content of glycogen was determined by the Preobrazhenskaya method and the content of starch was determined by the Ewers polarimetric method [15]. The total carbohydrate content was determined as the sum of individually identified carbohydrates.

Nutritional and biological value was determined by calculation method. Digestibility of protein substances of products was evaluated by the intensity of their hydrolysis by pepsin and trypsin in the *in vitro* system.

3. Results and discussion

The results of our previous comprehensive studies of chemical composition, quality indicators and technological properties of oyster mushrooms and champignon mushrooms, as well as the impact of technological processing on changes in their components showed the effectiveness and feasibility of using these raw materials to create new types of food concentrates [16, 17]. On the basis of the obtained results the technologies of appetizers «Oyster mushroom» and «Champignon mushroom», chips and snacks were developed.

Recipes, technological instructions, technical conditions for new types of food concentrates were developed and approved, the conclusion of the state sanitary-epidemiological examination was obtained. According to the results of this work, a patent of Ukraine for a utility model was obtained.

Chemical composition and nutritional value of new mushroom products. Food products should contain all the nutrients necessary for the normal functioning of the human body, and it was desirable that their ratio met the requirements of nutrition. In connection with the above, new mushroom products were created, namely: chips, snacks, appetizer "Oyster mushroom", appetizer "Champignon mushroom". They were evaluated for both nutritional and biological value.

Nutritional value reflected a set of properties of the food product that met the physiological needs of the human body in essential nutrients and energy. Determination of the chemical composition and energy value of mushroom products was performed by calculation using the obtained experimental data. An integrated score of products was additionally found,

and expressed the level of satisfaction of the human body's needs in essential nutrients. When calculating the nutritional value the norms of physiological needs of the population in basic nutrients and energy for men aged 18 - 29 years and group I of labor intensity were used. Estimated data are given in Table 1.

It was established that the created mushroom food concentrates were characterized by the increased content of mass fraction of protein, which played an important role in human nutrition as it performed important functions in the human body and was a major component of cells of all organs and tissues.

Table 1

Chemical composition and nutritional value of new mushroom products

Nutrient, energy value	Daily requirement	Chips		Snacks		Appetizer "Oyster mushroom"		Appetizer "Champignon mushroom"	
		content in 100 g	integrated score, %	content in 100 g	integrated score, %	content in 100 g	integrated score, %	content in 100 g	integrated score, %
Proteins, g	67	18.2	27.2	17.7	26.4	21.0	31.4	18.3	27.3
Fats, g	68	7.7	11.3	9.8	14.4	2.8	4.1	1.8	2.7
Carbohydrates, g including fibers	392	45.0 8.6	11.5	50.9 8.3	13.0	44.4 9.5	11.3	34.2 7.1	8.7
Energy value, kcal	2450	215	8.8	261	10.7	162	6.6	116	4.7

Due to the use of 100 g of products, 26.4 - 31.4% of the body's daily protein needs were covered.

Mushroom products were also rich in fiber, which affected the regulation of physiological and biochemical processes in the digestive system, intensity and metabolism of proteins, fats and carbohydrates. The developed food concentrates were low in calories (115 - 261 kcal/100 g) compared to other products of the snack group [1].

Studies identified 19 amino acids in the developed mushroom products. The amino acid composition of mushroom chips and snacks is presented in Table 2.

It was established that in the amino acid composition of the developed mushroom products included aspartic and glutamic acids, leucine, alanine, serine, proline prevailed. It contained less cystine, tryptophan and methionine.

The biological value of the product reflected the degree of compliance of the amino acid composition of the protein to the needs of the human body in amino acids for its synthesis.

Table 2

Amino acid content of food mushroom products

Amino acids	Amino acid content,% of DM			
	chips	snacks	Appetizer "Oyster mushroom"	Appetizer "Champignon mushroom"
Alanine	0.79	0.56	1.70	2.57
Arginine	0.69	0.49	1.05	0.83
Aspartic acid	1.00	0.78	1.96	1.98
Valine	0.64	0.49	0.82	0.95
Gamma-aminobutyric acid (GABA)	0.02	0.01	1.11	0.83
Histidine	0.26	0.19	0.43	0.46
Glycine	0.56	0.42	1.04	1.05
Glutamic acid	1.69	2.18	6.12	2.88
Isoleucine	0.39	0.31	0.73	0.82
Leucine	0.99	0.71	1.39	1.67
Lysine	0.64	0.53	1.05	1.31
Methionine	0.21	0.16	0.40	0.46
Proline	0.62	0.74	1.00	0.92
Serine	0.76	0.57	1.26	1.45
Tyrosine	0.38	0.24	0.66	0.58
Threonine	0.64	0.38	1.09	1.35
Tryptophan	0.14	0.13	0.24	0.23

Phenylalanine	0.54	0.41	0.81	1.02
Cystine	0.11	0.09	0.18	0.18

It was known that the most complete idea of the biological value of a protein was given by the method of comparing the composition of essential amino acids of this protein with the corresponding amino acid composition of the "ideal protein" by calculating the amino acid score.

In Table 3 it is shown the amino acid rate of the products.

Table 3

Amino acid score of mushroom products

Name of amino acids	The content in the ideal protein, mg/g	Chips		Snacks		Appetizer "Oyster mushroom"		Appetizer "Champignon mushroom"	
		amino acid content, mg/1g of protein	amino acid score, %	amino acid content, mg/1g of protein	amino acid score, %	amino acid content, mg/1g of protein	amino acid score,%	amino acid content, mg/1g of protein	amino acid score, %
Valine	50	58.0	116.1	52.1	104.3	38.7	77.4	44.1	88.2
Isoleucine	40	35.0	87.5	33.0	82.5	31.4	78.4	38.1	95.2
Leucine	70	89.8	128.4	75.4	107.6	71.8	102.5	77.5	110.8
Lysine	55	57.4	104.4	56.4	102.6	56.3	102.4	60.8	110.6
Methionine + cystine	35	28.9	82.6	26.6	76.0	25.8	73.7	29.7	84.9
Threonine	40	57.6	143.9	40.9	102.2	46.8	117.1	62.7	156.7
Tryptophan	10	12.7	126.5	11.8	117.5	10.3	103.1	10.7	106.8
Phenylalanine + tyrosine	60	82.9	138.1	69.2	115.3	60.2	100.3	74.3	123.8

The calculations showed that chips and snacks were low the following amino acids: isoleucine, methionine and cystine. Amino acids valine, isoleucine, methionine and cystine were determined in lower quantities in appetizers. The first limiting amino acid of the products was the sum of sulfur-containing acids methionine and cystine. At the same time, the products were rich in tryptophan and lysine, the deficiency of which was acutely felt in many plant proteins. Mushroom products had a high biological value of proteins, which indicated the prospects for the use of new food products. The biological value of chips was 82.6%, snacks - 76.0%, appetizer "Oyster mushroom" - 73.7%, appetizer "Champignon mushroom" - 84.9%.

Thus, the obtained new mushroom food concentrates were characterized by high content of important nutrients and high biological value, which indicated the feasibility of using these food products.

Digestibility of mushrooms and food concentrates obtained on their basis. The biological value of proteins was determined not only by their amino acid composition, but also the degree of digestibility. The intensity of the process of protein breakdown in the human digestive tract depended on the activity of proteolytic enzymes and the susceptibility of food proteins to their action.

During the research, the rate of digestion of protein substances of fresh oyster mushrooms and champignons was determined, as well as products based on them - chips, snacks, appetizers "Oyster mushroom" and "Champignon mushroom". The degree of digestibility of protein substances of raw materials and products was evaluated by the intensity of their hydrolysis by the enzymes pepsin and trypsin *in vitro*. The intensity of

digestibility was evaluated by the increase of the number of final products of enzymatic hydrolysis of protein substances - free amino acids in the model medium.

Analysis of the kinetics of the process of enzymatic hydrolysis of raw materials and products (Figure 1) showed that in contrast to fresh mushrooms, for which the hydrolysis process was almost constant, mushroom products were characterized by a higher digestion rate at the pepsin stage.

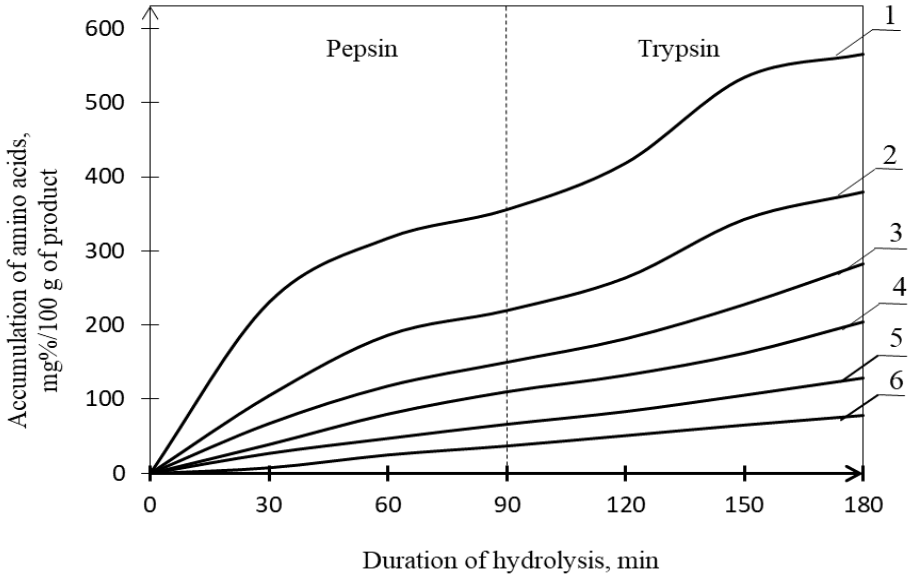

Fig. 1. Accumulation of free amino acids during hydrolysis of proteins of mushroom and their products *in vitro*: 1 – appetizer "Oyster mushroom"; 2 – appetizer "Champignon mushroom"; 3 – chips; 4 – snacks; 5 – fresh oyster mushroom; 6 – fresh champignon mushroom

During the pepsin stage, 51.6% and 47.4% of free amino acids from their total amount were accumulated in fresh oyster mushrooms and champignons, respectively, and in chips and snacks this amount was 53.1% and 53.9%, respectively, in appetizers "Oyster mushroom" and "Champignon mushroom" - 57.9% and 62.9%, respectively. It was found that the total amount of accumulated free amino acids in oyster products was much higher than in fresh mushrooms – for appetizer "Oyster mushroom" this index was 3 times higher, for chips – 2.2 times higher, and for snacks - 1.6 times higher. Appetizer "Champignon mushroom" had the best ability to the digestion, which accumulated 7 times more free amino acids compared to fresh mushrooms.

Digestion of proteins of fresh mushrooms was slightly slower compared to food products due to the higher resistance of native proteins to enzymes. In the process of production of mushroom products, protein substances underwent changes that affected their assimilation [18].

At insignificant denaturation of proteins, their attack by proteolytic enzymes amplified. Heat treatment using harsh temperatures led to a certain decrease in protein absorption due to excessive compaction of protein molecules, which reduced the availability of peptide bonds of proteins to digestive enzymes. This explained the better ability to digest mushroom appetizers compared to chips and snacks. The accumulation of protein fractions of albumin and globulin in mushroom products caused an increase in their degree of assimilation.

The process of assimilation was also influenced by the amino acid composition of products and the presence of other nutrients. Fiber promoted faster passage of

food by increasing intestinal peristalsis and some proteins did not have time to be hydrolyzed, in addition, it adsorbed proteinases and binded some amino acids, removing them from the body. When obtaining mushroom products there was a decrease in the degree of polymerization of fiber, which contributed to better digestibility of products.

4. Conclusion

In this study mushroom chips and snacks on the basis of Pleurotus Ostreatus and Agaricus bisporus were developed and their composition and nutritional and biological values were determined.

It was established that the obtained new mushroom products were characterized by high content of important nutrients and high biological value. The biological value of proteins of chips was 83.6%, of snacks - 76.0%, of appetizer "Oyster mushroom" - 73.7%, of appetizer "Champignon mushroom" - 84.9%.

It was found that mushroom products increased the enzymatic hydrolysis of protein substances compared to fresh mushrooms at both pepsin and trypsin stage of their hydrolytic cleavage, which contributed to their increased digestibility. The total amount of accumulated free amino acids in appetizer "Oyster mushroom" was 3 times more than in fresh mushrooms, in appetizer "Champignon mushroom" - 7 times more, in chips - 2.2 times more, in snacks - 1.6 times more.

The conducted research and developed technologies of mushroom chips and snacks can be used both in the food concentrate branch and in other branches of the food industry. In addition, such new types of mushroom products created opportunities for expanding the market for both artificially grown mushrooms and snack producers.

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