



Fresh and processed wild *Cantharellus cibarius* L. growing in West Siberia: food value

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Abstract:

Introduction. *Cantharellus cibarius* L. is a wild mushroom that has been part of human diet for many centuries. However, there is little reliable information about its nutritional value, storage conditions, shelf life, and processing. The research objective was to study the nutritional value of *C. cibarius* growing in West Siberia, as well as to define its storage and processing conditions.

Study objects and methods. The research featured fresh and processed (boiled and salted) wild chanterelles (*C. cibarius*) obtained from the forests of the Novosibirsk region. The mushrooms were tested for amino acids, fatty acids, nutrients, reducing sugars, trehalose, mannitol, glycogen, fiber, mucus, squalene, ash, minerals, vitamins, trypsin inhibitor, chlorides, mesophilic and facultative anaerobes, etc. The samples also underwent sensory evaluation.

Results and discussion. The samples of *C. cibarius* proved to have a high nutritional value. The samples contained 3.6% proteins, including essential amino acids; 3.9% carbohydrates, including sugars and dietary fiber; and 0.7% lipids, including saturated, monounsaturated, and polyunsaturated acids. In addition, *C. cibarius* appeared to be rich in biologically active substances. It contained trypsin inhibitors that reduce the absorption of protein compounds. Purchasing centers can be recommended to use 70–80% relative air humidity. At 0–2°C, the storage time was five days; at 5–10°C – three days; at 15–20°C – two days; at 20–30°C – one day. Before processing, the mushrooms were washed twice in non-flowing water. *C. cibarius* also proved to be a valuable raw material for boiled and salted semi-finished products. The optimal boiling time was 5–10 min. Lightly-, medium-, and strong-salted semi-finished mushrooms were ready for consumption after the fermentation was complete, i.e. after day 15, 10, and 3, respectively.

Conclusion. Boiled and salted semi-finished products from Siberian *C. cibarius* demonstrated excellent sensory qualities and can become part of various popular dishes.

Keywords: Edible mushrooms, *Cantharellus cibarius*, nutrients, sensory properties, microbiological safety

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INTRODUCTION

Mushrooms have typical taste and aroma, high nutritional value, and relatively low calorie content. As a result, they have always been an integral part of human diet. However, the advantageous properties of mushrooms depend on their chemical composition, processing method, etc. Mushrooms owe their antibacterial, anti-inflammatory, wound healing, tonic, immunomodulating, and other therapeutic properties due to various biologically active substances in their composition [1–4]. The chemical composition of mushrooms depends on the season, area, ecology, size, and age [5]. Their chemical composition includes 50–65% carbohydrates, 19–35% proteins, 2–6% fats. They are rich in palmitic, oleic, and linoleic acids, with unsaturated fatty acids prevailing over saturated acids.

In addition, mushrooms contain a lot of vitamins, especially fat-soluble, e.g. ergosterol [3, 5, 6].

Food scientists are busy developing new processing technologies to optimize mushroom production, improve the quality of mushroom products, and increase demand [7–10].

For instance, Taiwan experts studied the taste profile of canned *Agaricus bisporus*, *Volvariella volvacea*, and *Flammulina velutipes*. The content of soluble sugars and polyols was 22.9–30.9 µg/g in the fruiting body and 5.6–14.2 µg/g in the canning brine. Canned samples of *F. velutipes* appeared to have the largest amount of total free amino acids, i.e. 247 µg/g in the fruiting body and 146 µg/g in the brine, closely followed by *A. bisporus* (42.8 and 33.3 µg/g). *V. volvacea* had the lowest content of soluble sugars and polyols, i.e. 27.2 and 12.4 µg/g [11].

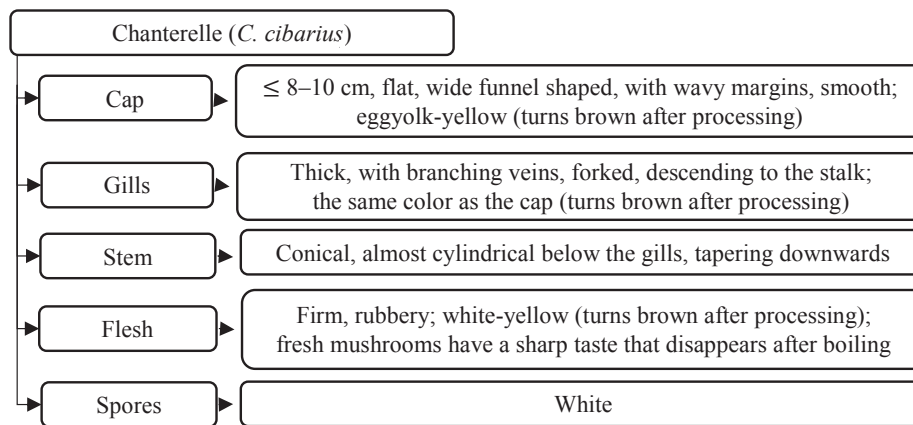


Figure 1 Identification criteria for raw and processed chanterelle (*Cantharellus cibarius*)

Some studies featured the effect of freezing and such pretreatments as blanching, soaking in water / solutions of sodium metabisulfite and/or citric acid and/or low-methylated pectin, etc. [12]. Polish scientists proved the effect of freezing and thermal treatment on the amino acid content of *A. bisporus*, *Boletus edulis*, and *Pleurotus ostreatus*. Processed samples of *B. edulis* contained more amino acids than *A. bisporus* and *P. ostreatus*. The content of alanine, arginine, proline, cysteine, methionine, and tyrosine depended on the processing method. Limiting amino acids were detected in *B. edulis*, both frozen (leucine) and canned (lysine) [13].

Chinese and American scientists found that frozen, canned, and salted *A. bisporus* are a good source of vegetable protein (16.54–24.35 g/100 g). The content of free amino acids dropped during six months of storage, especially that of tyrosine, alanine, glutamine, and cysteine. Salting and thermal treatment led to a decrease in 5'-nucleotides [14].

Increasing the shelf life of fresh mushrooms is one of the most popular tasks of food research. Spanish scientists investigated the effect of various active substances on the shelf life of mushrooms, their color, and consumer appeal. Sodium metabisulfite in combination with citric acid and green tea extract increased the shelf life, while cinnamon essential oil and purple carrot extracts did not have enough antioxidant properties to inhibit spoilage and/or prolong the shelf life of the mushrooms [15]. Portuguese researchers proved that gamma-, electron beam, and UV irradiations increase the shelf life of fresh *A. bisporus*, *Lentinus edodes*, and *P. ostreatus* [16].

Scientists have always been concerned about the safety of mushroom products [17, 18]. American and British researchers proposed to assess the safety of mushrooms by DNA methods, which is a promising alternative to traditional toxicological tests on animals [19].

A recent research featured five macro- and microelements in 14 species of mushrooms cultivated in China and Poland (*A. bisporus*, *Amauroderma rude*, *Auricularia auricula-judae*, *Auricularia nigricans*, *Ganoderma lucidum*, *Lentinula edodes*, *Lignosus P. ostreatus*, *Sparassis crispa*, *Tremella fuciformis*, *Wolfiporia cocos*, and *V. volvacea*). The samples demonstrated a high content of such toxic elements as aluminum, arsenic, and platinum. In fact, the content of platinum, nickel, erbium, and neodymium exceeded all previously published data. The quantity of the chemical elements did not make the samples toxic, but scientists will have to find a way to reduce the nickel content [20].

As a highly demanded product with high safety and quality standards, mushrooms are bound to be subject to geographical tracking by all international market members, e.g. by using the method of stable isotopes, bar coding, etc. [21, 22].

Chanterelle (*Cantharellus cibarius* L.) is a mycorrhizal symbiotroph of birch, spruce, pine, fir, and oak. This wide-spread mushroom grows alone or in rings all over Russian mixed forests. It can be found in Europe, America, Africa, China, Japan, and Australia [5]. Consumers like *C. cibarius* for its good transportability, storage capacity, and processing options [5, 23]. *C. cibarius* is less prone to damage from larvae, slugs, and other pests [5, 24]. The average weight of one mushroom is 7 g [24]. *C. cibarius* is wild and edible. Its fruiting bodies appear in summer and autumn, and their structure and hymenophore location make them lamellar (Fig. 1) [5]. In Russia, *C. cibarius* belongs to the third category of nutritional value, as stated in Sanitary Regulations SP 2.3.4.009-93 "Sanitary Rules for the Procurement, Processing, and Sale of Mushrooms", approved by the State Committee for Sanitary and Epidemiological Supervision of the Russian Federation No. 10 on August 20, 1993.

The chemical composition of *C. cibarius* is diverse. It includes proteins (eight amino acids), carbohydrates

(monosaccharides, trehalose, mannitol, glycogen, fiber, etc.), lipids (phospholipids, monoglycerides, sterols, free fatty acids, triglycerides, waxes, etc.), organic acids (malic, succinic, etc.), and biologically active substances (ascorbic acid, thiamine, riboflavin, niacin, beta-carotene, potassium, sodium, calcium, magnesium, phosphorus, sulfur, etc.) [5, 24, 25]. The list of medicinal substances that can be isolated from mushrooms includes quinomannose, ergosterol, and trametonolinic acid. These substances are used in medicines that treat helminthic infestations, liver diseases, viral hepatitis, etc. [24, 26]. Fruiting bodies contain polyozellin that possesses antitumor properties as it inhibits the activity of prolyl endopeptidase, an enzyme involved in protein metabolism of the precursor of β -amyloid [24]. Chinese scientists used *C. cibarius* to isolate a new linear 3-O-methylated galactan (WCCP-Nb), which enhances macrophage phagocytosis, NO release, and secretion of TNF- α , IL-6, and IL-1 β . In addition, it activates macrophages through Akt/NF- κ B and mitogen-activated protein kinase through TLR2 [27].

Polish scientists studied the health-improving properties of polysaccharides in *C. cibarius*. Mushroom poly-saccharides consist of one monosaccharide in a repeating unit $\rightarrow 6$ - α -D-Manp-(1 \rightarrow ; they inhibit COX-1 and COX-2, decrease the proliferation of colon cancer cells, and stimulate the growth of *Lactobacillus* [28]. Blanching appeared to decrease antioxidant activity and the content of polyphenols. When *Lactobacillus plantarum* was used for lactic acid fermentation of fruiting bodies, it decreased the pH value and the formation of highly concentrated single phenolic acids, e.g. gallic, homogenous, and ferulic [29]. The Polish team also studied the mineral composition of *C. cibarius*, which included silver, aluminum, barium, calcium, cadmium, cobalt, chromium, copper, iron, mercury, potassium, magnesium, manganese, sodium, nickel, lead, phosphorus, rubium, strontium, and zinc. The mineral profile of *C. cibarius* depended on the area where the mushroom was harvested [30]. A Polish-Chinese research revealed that some elements depend not only on the geographical location, but also on anthropogenic factors. For example, the Chernobyl disaster increased the cesium content in *C. cibarius* growing in Poland, compared to samples from Yunnan [31].

Blanching and pickling led to a 77–91% decrease in cadmium content in *C. cibarius*. Blanching of fresh mushrooms decreased cadmium content by 11–36%, while in frozen mushrooms it fell by about 40%. A similar rate of cadmium reduction was observed after blanching with drinking or deionized water for 5–15 min. After pickling the blanched mushrooms in diluted vinegar marinade, cadmium dropped by 37–71% [32]. Convective or freeze drying also affected the aromatic composition and sensory qualities of *C. cibarius*. Fresh and dried mushrooms contained 39 volatile compounds in various concentrations, the largest being 1-hexanol, 1-octene-3-ol, and 2-octene-1-ol [33, 34].

Russian scientists proved that 20 min of thermal treatment detoxifies heavy metals in mushrooms [35].

American scientists found out that *C. cibarius* and *Morchella esculenta* have the lowest folate content ($\leq 6 \mu\text{g}/100 \text{ g}$), compared to *P. ostreatus* (44.2 $\mu\text{g}/100 \text{ g}$), *B. edulis*, *L. edodes*, *Grifola frondosa*, *F. velutipes*, *A. bisporus* (cream strain), *A. bisporus* “Portobello”, and UV-treated samples of *A. bisporus* [36].

German scientists identified several taste-affecting C18-acetylenic acids in *C. cibarius*: (9Z,15E)-14,17,18-trihydroxy-9,15-octadecadien-12-ynoic acid, (9Z,15E)-14-oxo-9,15-octadecadien-12-ynoic acid, (10E,15E)-9-hydroxy-14-oxo-10,15-octadecadien-12-ynoic acid, (10E,15E)-9-hydroperoxy-14-oxo-10,15-octadecadien-12-ynoic acid, (10E,15E)-9,14-dioxo-10,15-octadecadien-12-ynoic acid, (9Z,15E)-14-oxo-9,15-octadecadien-12-ynoic acid methyl ester, (9Z,15E)-17(18)-epoxy-14-oxo-9,15-octadecadien-12-ynoic acid methyl ester, (10E,14Z)-9-hydroperoxy-10,14-octadecadien-12-ynoic acid [37].

German and Swedish scientists studied the content of sterols and vitamin D₂ in wild and cultivated *Cantharellus tubaeformis*. Cultivated samples had a greater content of provitamin D₂ (ergosterol) (4.0–5.0 mg/g) than wild mushrooms (1.7–3.5 mg/g). *C. tubaeformis* also contained ergosta-7,22-dienol, ergosta-5,7-dienol, and ergosta-7-enol. Wild *C. tubaeformis* proved to be a better source of vitamin D₂ (0.7–2.2 $\mu\text{g}/\text{g}$) than cultivated mushrooms ($< 0.1 \mu\text{g}/\text{g}$). UV irradiation of sublimated *C. tubaeformis* led to a slight decrease in the content of ergosterol, while the content of vitamin D₂ increased by nine times [38].

Portuguese scientists discovered that *C. cibarius*, *L. edodes*, *P. ostreatus*, *Craterellus cornucopioides*, and *Lepista nuda* contain insignificant amounts of selenium, compared to *Boletus aestivalis*, *Boletus pinophilus*, *B. edulis*, *Boletus aereus*, *Boletus fragans*, *Boletus spretus*, *Marasmius oreades*, *A. bisporus* “Portobello”, *A. bisporus*, and *Russula cyanoxantha* [39].

Available sources reveal no information on the nutritional value of wild Russian *C. cibarius*, while its nutritional value is known to depend on a great number of factors, e.g. climatic zones, environmental impact, etc.

The present research objective was to study the nutritional value of wild *C. cibarius* growing in West Siberia, as well as the qualitative characteristics of semi-finished products from *C. cibarius*.

STUDY OBJECTS AND METHODS

The research featured wild chanterelles (*Cantharellus cibarius* L.): fresh samples ($\leq 4 \text{ h}$ after mycelium separation) and processed samples (boiled and salted).

The mushrooms were young, mature, and of medium maturity. The age was defined according to the diameter and shape of the cap, the state and color of the hymenophore, and the size and condition of the stem. The mushrooms were harvested in different districts of the Novosibirsk region in 1986–2018. The batch volumes were determined according to standard procedures [5].

The species was established organoleptically [5]: the characteristics of the specimen had to meet the requirements specified in Fig. 1. The mushrooms also met the safety standards in terms of toxicity, pesticides, and radionuclides, namely the mushrooms complied with the Technical Regulation of Customs Union TR CU 021/2011 “On food safety”.

The samples of *C. cibarius* were tested for:

- total protein content using dye amide black 10B [40]; amino acid composition of proteins using an AAA-339M amino acid analyzer; total tryptophan content – by spectrophotometric method developed at the Bakh Institute of Biochemistry; qualitative analysis of proteins – by calculating the coefficient of digestibility and comparable redundancy [41];
- content of reducing sugars and trehalose was defined by the semi-micro Bertrand method [42]; mannitol – by the iodine-metric method [43]; glycogen – after extraction with trichloroacetic acid; hydrolysis – by the semi-micro Bertrand method [42]; cellulose – by the Pochinok method [44]; mucus – by the gravimetric method [45];
- lipid content was defined according to the Bligh and Dyer method [46]; fatty acid composition – using a Hewlett Packard gas chromatograph HP 6890 (USA); squalene – by high-performance gas-liquid chromatography in a liquid microcolumn chromatograph Milichrom A-02 (Russia);
- ash content was measured by ashing the sample at $525 \pm 25^\circ\text{C}$; ash weight was defined according to State Standard 25555.4-91 “Fruit and vegetable products. Methods for determination of ash and alkalinity of total ash and water-soluble ash”;
- ascorbic acid was measured by the titrimetric method according to State Standard 24556-89 “Products of fruits and vegetables processing. Methods for determination of vitamin C”; thiamine, riboflavin, and niacin – by highly efficient gas-liquid chromatography in a Milichrom A-02 chromatograph according to State Standards 25999-83 “Products of fruits and vegetables processing. Methods of determination of vitamins B₁ and B₂” and State Standards R 50479-93 “Fruit and vegetable products. Method for determination of vitamin PP (niacin) content”;
- content of minerals (potassium, sodium, calcium, magnesium, phosphorus, sulfur, iron, manganese, cobalt, zinc, copper, and nickel) was described by atomic absorption in an air-acetylene flame using QUANT AFA equipment;
- content of trypsin inhibitor – by the method developed by Gofman and Vaisblai [47];
- sensory properties were described according to a 100-point scale. The weighting factors for the indicators were as follows: appearance – 4; color – 3; consistency – 7; aroma – 6. Quality categories: excellent (90–100 points), very good (80–89 points), good (60–79 points), fair (40–59 points), and poor (≤ 39 points);
- count of mesophilic aerobes and facultative anaerobes was measured by cultivation on nutrient media with agar according to State Standard 10444.15-94 “Food

products. Methods for determination of quantity of mesophilic aerobes and facultative anaerobes”;
– chloride content was determined by the argentometric method according to State Standard 26186-84 “Fruit and vegetable products, meat and meat-vegetable cans. Methods for determination of chloride content”.

RESULTS AND DISCUSSION

A long-term research revealed that the chemical composition, and, consequently, the nutritional value of chanterelles (*Cantharellus cibarius* L.) growing in the Novosibirsk region was not affected by the climatic conditions over a number of years: the mass fraction of proteins was 3.6%; digestible carbohydrates – 1.8%; mass fraction of dietary fiber – 2.1%; mass fraction of lipids – 0.7%; mass fraction of ash – 1.2% [5].

An adult needs eight amino acids: valine, isoleucine, leucine, lysine, methionine, threonine, tryptophan, and phenylalanine. Figure 2 shows that tryptophan proved to be the limiting amino acid, while methionine + cystine appeared to be predominant.

The amino acid score can be ranked as follows: methionine + cystine (147%) > phenylalanine + tyrosine (128%) > valine (120%) > threonine (119%) > lysine (109%) > isoleucine + leucine (107%). Human body can digest 60% of the amino acids in *C. cibarius* due to the coefficient of digestibility and comparable redundancy. The coefficient of digestibility of the amino acid composition of the protein (0.607 CU) reflects the balance of essential amino acids in relation to the standard [41]. The indicator of comparable redundancy (22.2%) describes the total amount of unused amino acids in an amount equivalent to their potentially digestible content in 100 g of the reference protein [41]. Therefore, *C. cibarius* is a potential source of methionine, phenylalanine, valine, and threonine. The amino acids are responsible for the specific aroma and taste: methionine, phenylalanine, tyrosine, valine, isoleucine, and leucine add bitterness while threonine adds sweetness [48].

The qualitative composition of carbohydrates in *C. cibarius* is highly variable [49]. The carbohydrate composition of *C. cibarius* is represented by 1.5% mono- (glucose) and oligosaccharides (trehalose),

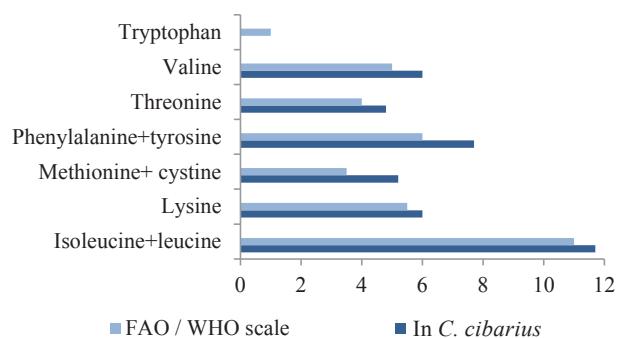


Figure 2 Content of essential amino acids in *Cantharellus cibarius*, g/100 g of protein

0.3% polyols (mannit), 0.1% glycogen, 2% fiber, and 0.8% mucus. Mono- and oligosaccharides, as well as polyols, are responsible for the typical taste of *C. cibarius*. This mushroom owes its physiological value due to trehalose. It consists of two molecules of D-glucose, mannit, glycogen, insoluble fiber, and soluble mucus. Trehalose and mannitol perform mainly a protective function in stress-induced situations. Glycogen performs the accumulative function; for example, it stores energy, which, if necessary, replenishes the lack of glucose. Insoluble fiber and branched sulfated arabinoxylans perform the protective function as they bind and remove toxic and radioactive elements.

The research revealed that 100 g of *C. cibarius* contained about 3.6 g of lipids. Lipids define sensory properties of fresh and processed products and also determine their stability during storage. Figure 3 demonstrates that the lipids of *C. cibarius* include fatty acids with 14–24 carbon atoms in the carbon chain.

The fatty acid composition of fresh *C. cibarius* is represented by the following fatty acids: linoleic (C18:2) – 62.2% of the total fatty acids; palmitic (C16:0) – 16.9%; oleic (C18:1) – 15.2%; stearic (C18:0) – 4.4%; palmitoleic (C16:1) – 0.7%; pentadecanoic acid (C15:0) – 0.3%; and heptadecanoic (C17:0) – 0.2%. The samples revealed no myristic, arachidic, behenic, lignoceric, and eicosadienic fatty acids. The samples also demonstrated high biological effectiveness, since the amount of polyunsaturated acids was 62.2%; monounsaturated – 15.9%; saturated – 21.8%; the ratio of polyunsaturated acids to saturated ones was 2.9%. The obtained results were consistent with the data published by Bengu, who conducted comparative studies of cultivated and wild mushrooms in Turkey [50]. However, the content of unsaturated fatty acids in *C. cibarius* should be taken into account during processing since mushrooms are prone to oxidation. The lipids of *C. cibarius* contained squalene (C₃₀H₅₀), a hydrocarbon that is not only a mother substance in sterol synthesis, but also possesses a high physiological

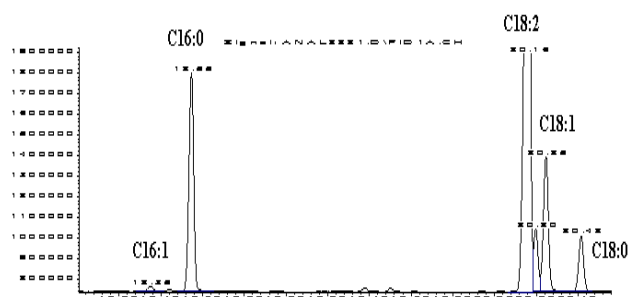


Figure 3 Chromatogram of fatty acid composition of *Cantharellus cibarius*

activity as it normalizes blood cholesterol, has antioxidant properties, etc.

The fresh samples contained a significant amount of vital biologically active substances, such as vitamins, macro- and microelements, etc. [51].

The fresh samples of *C. cibarius* were rich in ascorbic acid (15.05–34.92 mg/100 g), thiamine (0.01–0.03 mg), riboflavin (0.09–0.37 mg) (Fig. 4), and niacin (13.0 mg). Niacin consisted of nicotinic acid and nicotinamide (Fig. 5), the amount of which was 9.94 and 3.10 mg/100 g, respectively.

Micro- and macroelement analysis of the samples showed a significant amount of potassium (450.0–622.2 mg/100 g), sodium (0.0–33.4 mg), calcium (4.0–8.9 mg), magnesium (7.0–7.8 mg), phosphorus (44.0–48.9 mg), sulfur (44.4 mg), iron (0.7–8.6 mg), manganese (0.31–0.55 mg), cobalt (0.03–0.08 mg), zinc (0.34–0.64 mg), copper (0.51 mg), and nickel (0.06 mg).

The samples also demonstrated a trypsin inhibitor in the amount of 0.44–0.67 mg/g, which blocks the activity of enzymes in the digestive tract and also reduces the absorption of protein compounds.

Fresh mushrooms are conditionally-live products because of the ongoing irreversible biological and biochemical processes as they consist mainly of water

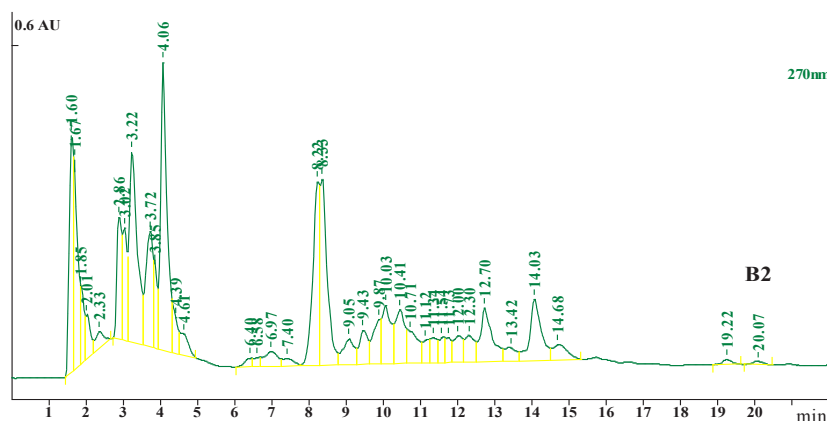


Figure 4 Chromatogram of the riboflavin release area in *Cantharellus cibarius*

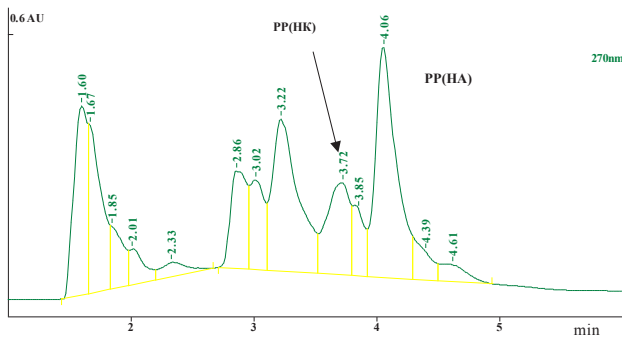


Figure 5 Chromatogram of the niacin release area in *Cantharellus cibarius*

(about 89.1%), proteins, and carbohydrates. High temperature, relative humidity, and long-term storage spoil the sensory properties of mushrooms, release cell juice, etc. As a result, scientists have to define shelf life for each type of mushroom, before processing under controlled and unregulated conditions. Table 1 shows the results of sensory evaluation of *C. cibarius* after 72 h of storage under different conditions.

When harvested, the mushrooms were fresh, undamaged, with well-developed hymenophores, uniform in size, and the number of stems matched the number of caps. After a while, some specimen became slightly wilted and/or crushed. After longer storage, the wilting increased, as did the number of crashed specimen. Eventually, all the mushrooms become wilted and slimy and demonstrated signs of tissue maceration.

The uniform yellow color of the fresh mushrooms gradually became heterogeneous and then browned slightly. The browning became more and more pronounced over time. The initial consistency was firm but gradually turned semi-firm and soft. The smell of the fresh mushrooms was typical for *C. cibarius* and pronounced; over time, the smell began to disappear and became weakly expressed, insignificant, musty, and even putrid.

The optimal storage time for fresh *C. cibarius* was 25 days at 0–2°C; ≤ 3 days at 5–10°C; ≤ 2 days at 15–20°C; and ≤ 1 day at 25–30°C.

Table 2 Effect of washing on the total microbial count of *Cantharellus cibarius*

Washing conditions	QMAFAnM, CFU/g	Effectiveness, %
Before washing	$(1.5 \pm 1.1) \times 10^6$	–
After double washing in non-flowing water	$(2.1 \pm 1.1) \times 10^5$	86.0
After washing in flowing water	$(9.6 \pm 2.8) \times 10^4$	93.6

Fresh mushrooms are hardly ever consumed raw. As a rule, they are served only after processing. Washing is the first procedure to prepare raw materials for processing. It removes impurities and microorganisms. Double washing in non-flowing water proved optimal for *C. cibarius* (Table 2).

Boiling in salt water is one of the processing methods for *C. cibarius*. The concentration of food salt in the finished product was 2.0–3.0%. After 5–10 min of boiling, the mushrooms maintained their typical color and aroma but did not retain the required tough-elastic consistency (Table 3). When the boiling time exceeded 15 min, the mushrooms developed atypical rubbery consistency, smell, and browning.

During boiling, *C. cibarius* underwent some chemical changes. After 10 min of boiling, water-soluble carbohydrates dropped by 50%, proteins – by 4%, ash – by 38%, riboflavin and nicotinic acid – by 34%. However, the content of fiber, glycogen, and nicotinamide increased by 1.5, 6.5, and 32.3%, respectively. Boiling triggered the extraction of free amino acids, especially phenylalanine (63.9%) and aspartic acid (45.7%) (Table 4).

Table 5 shows that boiling affected the content of palmitic, stearic, and oleic acids: their losses were 18.8, 9.1, and 1.3%, respectively. The content of polyunsaturated fatty acids increased by 7.4%, following the increase in linoleic acid.

Boiled mushrooms were used to prepare semi-finished products with different salt content: lightly-salted – 3.5–6.0%, medium-salted – 7.0–1.0%, and strong-salted – 25.0–30.0%. The salt penetration rate

Table 1 Sensory properties of *Cantharellus cibarius* after 72 h of storage, depending on weighting factors (n = 5)

Indicator	Storage temperature, °C			
	0 ^a	10 ^a	20 ^b	30 ^b
Appearance	18.4 ± 2.0	16.8 ± 1.6	11.2 ± 1.6	5.6 ± 2.0
Color	13.2 ± 1.5	12.6 ± 1.2	6.6 ± 1.2	3.6 ± 1.2
Consistency	33.6 ± 2.8	30.8 ± 3.4	15.4 ± 2.8	8.4 ± 2.8
Aroma	26.4 ± 3.0	25.2 ± 2.4	12.0 ± 0.0	9.6 ± 2.9
Total score	91.6 ± 4.7	85.2 ± 4.6	45.2 ± 3.4	27.2 ± 4.7
Quality category	excellent	very good	fair	poor

^a – relative humidity 80–90 %

^b – relative humidity 70–80 %

Table 3 Sensory properties of *Cantharellus cibarius* after boiling, depending on weighting factors (n = 5)

Indicator	Boiling time, min			
	5	10	15	20
Appearance	15.2 ± 1.6	13.6 ± 2.0	12.8 ± 1.6	10.4 ± 2.0
Color	12.0 ± 0.0	11.4 ± 1.2	10.2 ± 1.5	6.6 ± 1.2
Consistency	26.6 ± 2.8	23.8 ± 3.4	19.6 ± 2.8	14.0 ± 0.0
Aroma	24.0 ± 0.0	20.4 ± 2.9	18.0 ± 0.0	14.4 ± 2.9
Total score	77.8 ± 3.2	69.2 ± 5.1	60.6 ± 3.5	45.4 ± 3.7
Quality category	good	good	good	fair

from the brine at $10 \pm 5^\circ\text{C}$ made it possible to obtain ready-to-use lightly-salted or medium-salted products after 10–15 days. Strong-salted mushrooms needed 3–4 days at $25 \pm 5^\circ\text{C}$ with two or three replacements of brine. As a result of diffusion processes, the semi-finished products lost some amount of water-soluble substances (Fig. 6).

The concentration of sodium chloride affected the amount of free amino acids, saturated and monounsaturated fatty acids, riboflavin, nicotinic acid, and nicotinamide, which dropped to 25.0, 18.5, 50.8, 37.5, 3.7 and 19.8%, respectively. The proportion of polyunsaturated fatty acids reached 20.3%.

Lightly- and medium-salted semi-finished products retained their quality characteristics for six months of storage at $\leq 25^\circ\text{C}$ and a relative humidity of $\leq 75\%$ in the dark in hermetically sealed glass jars. Strong-salted mushrooms retained their quality for 12 months under the same conditions.

At the beginning of storage, the salted semi-finished products had microbial count of 2.6×10^3 to 4.5×10^3 , e.g. micrococci, spore bacteria and bacteria without spores,

and yeast. The number of microorganisms gradually increased, especially that of yeasts and molds, which caused a sour and/or musty odor, softening, whitish or green coating, etc. The number of thermophilic bacteria with spores of the *Clostridium butyricum* kind, which caused a putrid odor and gas release.

During storage, the protein content in the salted semi-finished products decreased gradually under the effect of hay bacillus, mold, and butyric acid bacteria. The hydrolytic breakdown of protein increased the amount of free amino acids by 25–30% of the initial content.

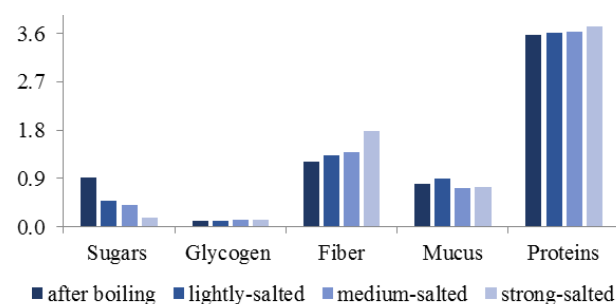
The content of saturated and monounsaturated fatty acids increased by an average of 21 and 142%,

Table 5 Content of fatty acids in *Cantharellus cibarius* after 10 min of boiling

Fatty acid	Content, % total	
	Fresh	Boiled
Pentadecanoic	0.3	0.3
Palmitic	16.9	13.0
Heptadecanoic	0.2	0.2
Stearic	4.4	4.0
Palmitoleic	0.7	0.7
Oleic	15.2	15.0
Linoleic	62.2	66.8
Total saturated fatty acids	21.8	17.5
Sum of monounsaturated fatty acids	15.9	15.7
Sum of polyunsaturated fatty acids	62.2	66.8

Table 4 Content of amino acids in *Cantharellus cibarius* after 10 min of boiling

Amino acid	Content, $\mu\text{g/g}$	
	fresh	boiled
Aspartic Acid	138.4 ± 10.2	75.1 ± 5.8
Threonine	112.9 ± 9.5	78.0 ± 6.3
Serine	83.0 ± 6.6	61.2 ± 4.9
Glutamic Acid	127.3 ± 11.3	98.5 ± 7.6
Proline	549.1 ± 38.6	421.2 ± 36.5
Glycine	87.5 ± 6.1	83.6 ± 6.9
Alanine	99.6 ± 8.9	103.5 ± 9.1
Valine	121.8 ± 10.5	96.1 ± 8.2
Methionine	8.9 ± 0.6	7.1 ± 0.5
Isoleucine	73.1 ± 5.9	63.9 ± 5.7
Isoleucine	127.3 ± 11.1	112.0 ± 10.9
Tyrosine	77.5 ± 6.5	76.0 ± 5.7
Phenylalanine	155.0 ± 13.9	55.9 ± 4.3
Histidine	66.4 ± 5.5	40.6 ± 3.8
Lysine	60.9 ± 5.9	63.6 ± 5.2
Arginine	135.1 ± 10.8	93.1 ± 8.9
Total	2023.8	1529.4

**Figure 6** Basic nutrients in the semi-finished product from *Cantharellus cibarius*, depending on the sodium chloride content, %

respectively, while the amount of polyunsaturated acids decreased by 34%. These changes resulted from oxidative and hydrolytic processes, e.g. under the effect of mold and butyric acid bacteria, which were responsible for the typical mushroom smell.

By the end of the shelf life, the salted semi-finished products had almost no riboflavin left, and the amount of niacin dropped by 50%. No trypsin-inhibiting activity was detected in the canned samples.

CONCLUSION

In the Novosibirsk Region of West Siberia, chanterelles (*Cantharellus cibarius* L.) are still harvested in the wild, and no efforts are being made for their industrial cultivation. *C. cibarius* proved to be a good source of such nutrients as proteins, carbohydrates, lipids, vitamins, macro- and microelements, etc. The mushrooms contained a significant amount of amino acids, e.g. methionine, phenylalanine, valine, threonine, etc., squalene, trypsin inhibitors, and other bioactive substances.

The sensory evaluation revealed the optimal storage time for *C. cibarius* in marketing centers, depending on the temperature. The microbiological tests showed that *C. cibarius* has to be double-washed in non-flowing water before processing. The sensory evaluation showed that boiled lightly-, medium-, and strong-salted semi-finished products from *C. cibarius* should be consumed within 15, 10, and 3 days after the end of fermentation, respectively. Further research into the nutritional value of fresh and processed *C. cibarius* can improve the quality of mushroom products.

CONTRIBUTION

V.I. Bakaytis supervised the research. O.V. Golub and Yu.Yu. Miller performed the experiments, processed the data, and wrote the manuscript.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

REFERENCES


1. Ma G, Yang W, Zhao L, Pei F, Fang D, Hu Q. A critical review on the health promoting effects of mushrooms nutraceuticals. *Food Science and Human Wellness*. 2018;7(2):125–133. <https://doi.org/10.1016/j.fshw.2018.05.002>.
2. Niksic M, Klaus A, Argyropoulos D. Safety of foods based on mushrooms. In: Prakash V, Martin-Belloso O, Keener L, Astley SB, Braun S, McMahon H, et al. editors. *Regulating safety of traditional and ethnic foods*. Academic Press; 2016. pp. 421–439. <https://doi.org/10.1016/B978-0-12-800605-4.00022-0>.
3. Rathore H, Prasad S, Sharma S. Mushroom nutraceuticals for improved nutrition and better human health: A review. *PharmaNutrition*. 2017;5(2):35–46. <https://doi.org/10.1016/j.phanu.2017.02.001>.
4. Valverde ME, Hernández-Pérez T, Paredes-López O. Edible mushrooms: Improving human health and promoting quality life. *International Journal of Microbiology*. 2015; 2015. <https://doi.org/10.1155/2015/376387>.
5. Kutaf'eva NP, Bakaytis VI, Tsapalova IEH, Poznyakovskiy VM. Ehkspertiza gribov. *Kachestvo i bezopasnost' [Expertise of mushrooms. Quality and safety]*. Novosibirsk: Sibirskoe universitetskoe izdatel'stvo; 2007. 288 p. (In Russ.).
6. Aisala H, Sola J, Hopia A, Linderborg KM, Sandell M. Odor-contributing volatile compounds of wild edible Nordic mushrooms analyzed with HS–SPME–GC–MS and HS–SPME–GC–O/FID. *Food Chemistry*. 2019;283:566–578. <https://doi.org/10.1016/j.foodchem.2019.01.053>.
7. Aisala H, Laaksonen O, Manninen H, Raittola A, Hopia A, Sandell M. Sensory properties of Nordic edible mushrooms. *Food Research International*. 2018;109:526–536. <https://doi.org/10.1016/j.foodres.2018.04.059>.
8. Aisala H, Manninen H, Laaksonen T, Linderborg KM, Myoda T, Hopia A, et al. Linking volatile and non-volatile compounds to sensory profiles and consumer liking of wild edible Nordic mushrooms. *Food Chemistry*. 2020;304. <https://doi.org/10.1016/j.foodchem.2019.125403>.
9. Paudel E, van der Sman RGM, Westerik N, Ashutosh A, Dewi BPC, Boom RM. More efficient mushroom canning through pinch and exergy analysis. *Journal of Food Engineering*. 2017;195:105–113. <https://doi.org/10.1016/j.jfoodeng.2016.09.021>.
10. Kozhedub TI. Wild macromycetes as a source of phosphorus in the diet of the population of Belarus. *Health and Ecology Issues*. 2016;48(2):86–89. (In Russ.).
11. Chiang P-D, Yen C-T, May J-L. Non-volatile taste components of canned mushrooms. *Food Chemistry*. 2006;97(3):431–437. <https://doi.org/10.1016/j.foodchem.2005.05.021>.
12. Jaworska G, Bernaś E, Mickowska B. Effect of production process on the amino acid content of frozen and canned *Pleurotus ostreatus* mushrooms. *Food Chemistry*. 2011;125(3):936–943. <https://doi.org/10.1016/j.foodchem.2010.09.084>.
13. Bernaś E, Jaworska G. Effect of preservation method on amino acid content in selected species of edible mushroom. *LWT – Food Science and Technology*. 2012;48(2):242–247. <https://doi.org/10.1016/j.lwt.2012.03.020>.


14. Liu Y, Huang F, Yang H, Ibrahim SA, Wang Y-F, Huang W. Effects of preservation methods on amino acids and 5'-nucleotides of *Agaricus bisporus* mushrooms. *Food Chemistry*. 2014;149:221–225. <https://doi.org/10.1016/j.foodchem.2013.10.142>.
15. Wrona M, Bentayeb K, Nerin C. A novel active packaging for extending the shelf-life of fresh mushrooms (*Agaricus bisporus*). *Food Control*. 2015;54:200–207. <https://doi.org/10.1016/j.foodcont.2015.02.008>.
16. Fernandes Â, Antonio AL, Oliveira MBPP, Martins A, Ferreira ICFR. Effect of gamma and electron beam irradiation on the physico-chemical and nutritional properties of mushrooms: A review. *Food Chemistry*. 2012;135(2):641–650. <https://doi.org/10.1016/j.foodchem.2012.04.136>.
17. Chiaravalle AE, Mangiacotti M, Marchesani G, Bortone N, Tomaiuolo M, Trotta G. A ten-year survey of radiocontamination of edible Balkan mushrooms: Cs-137 activity levels and assessed dose to the population. *Food Control*. 2018;94:263–267. <https://doi.org/10.1016/j.foodcont.2018.05.045>.
18. Zou H, Zhou C, Li Y, Yang X, Wen J, Hu X, et al. Occurrence, toxicity, and speciation analysis of arsenic in edible mushrooms. *Food Chemistry*. 2019;281:269–284. <https://doi.org/10.1016/j.foodchem.2018.12.103>.
19. VanderMolen KM, Little JG, Sica VP, El-Elimat T, Raja HA, Oberlies NH, et al. Safety assessment of mushrooms in dietary supplements by combining analytical data with in silico toxicology evaluation. *Food and Chemical Toxicology*. 2017;103:133–147. <https://doi.org/10.1016/j.fct.2017.03.005>.
20. Mleczek M, Rzymiski P, Budka A, Siwulski M, Jasińska A, Kalač P, et al. Elemental characteristics of mushroom species cultivated in China and Poland. *Journal of Food Composition and Analysis*. 2018;66:168–178. <https://doi.org/10.1016/j.jfca.2017.12.018>.
21. Chung I-M, Han J-G, Kong W-S, Kim J-K, An M-J, Lee J-H, et al. Regional discrimination of *Agaricus bisporus* mushroom using the natural stable isotope ratios. *Food Chemistry*. 2018;264:92–100. <https://doi.org/10.1016/j.foodchem.2018.04.138>.
22. El Sheikha AF, Hu D-M. How to trace the geographic origin of mushrooms? *Trends in Food Science and Technology*. 2018;78:292–303. <https://doi.org/10.1016/j.tifs.2018.06.008>.
23. Vlasova MV, Akhmedova TP. Influence of products of processing of mushrooms on baking properties of wheat flour. *OrelSIET Bulletin*. 2017;40(2):79–84. (In Russ.).
24. Galushchak IP. Lesnye griby: do evrostandartov eshche daleko [Forest mushrooms: a long way from European standards]. *Standards and Quality*. 2012;(9):58–60. (In Russ.).
25. Nyman AAT, Achmann FL, Rise F, Ballance S, Samuelsen ABC. Structural characterization of a branched (1→6)- α -mannan and β -glucans isolated from the fruiting bodies of *Cantharellus cibarius*. *Carbohydrate Polymers*. 2016;146:197–207. <https://doi.org/10.1016/j.carbpol.2016.03.052>.
26. Gerasimenko AN. Grib lisichka v protivopukholevykh i protivoparazitarnykh kompozitsiyakh “Blastaps” i “Vermostoping” [Chanterelle mushroom in antitumor and antiparasitic compositions “Blastaps” and “Vermostoping”]. *Prakticheskaya fitoterapiya* [Practical Phytotherapy]. 2013;(4):9–15. (In Russ.).
27. Yang G, Qu Y, Meng Y, Wang Y, Song C, Cheng H, et al. A novel linear 3-O-methylated galactan isolated from *Cantharellus cibarius* activates macrophages. *Carbohydrate Polymers*. 2019;214:33–43. <https://doi.org/10.1016/j.carbpol.2019.03.002>.
28. Nowacka-Jechalke N, Nowak R, Juda M, Malm A, Lemieszek M, Rzeski W, et al. New biological activity of the polysaccharide fraction from *Cantharellus cibarius* and its structural characterization. *Food Chemistry*. 2018;268:355–361. <https://doi.org/10.1016/j.foodchem.2018.06.106>.
29. Jablonska-Rys E, Sławińska A, Sz wajgier D. Effect of lactic acid fermentation on antioxidant properties and phenolic acid contents of oyster (*Pleurotus ostreatus*) and chanterelle (*Cantharellus cibarius*) mushrooms. *Food Science and Biotechnology*. 2016;25(2):439–444. <https://doi.org/10.1007/s10068-016-0060-4>.
30. Drewnowska M, Falandysz J. Investigation on mineral composition and accumulation by popular edible mushroom common chanterelle (*Cantharellus cibarius*). *Ecotoxicology and Environmental Safety*. 2015;113:9–17. <https://doi.org/10.1016/j.ecoenv.2014.11.028>.
31. Falandysz J, Chudzińska M, Barańkiewicz D, Drewnowska M, Hanć A. Toxic elements and bio-metals in *Cantharellus* mushrooms from Poland and China. *Environmental Science and Pollution Research*. 2017;24(12):11472–11482. <https://doi.org/10.1007/s11356-017-8554-z>.
32. Drewnowska M, Hanć A, Barańkiewicz D, Falandysz J. Pickling of chanterelle *Cantharellus cibarius* mushrooms highly reduce cadmium contamination. *Environmental Science and Pollution Research*. 2017;24(27):21733–21738. <https://doi.org/10.1007/s11356-017-9819-2>.
33. Falandysz J, Widzicka E, Kojta AK, Jarzyńska G, Drewnowska M, Dryałowska A, et al. Mercury in common Chanterelles mushrooms: *Cantharellus* spp. update. *Food Chemistry*. 2012;133(3):842–850. <https://doi.org/10.1016/j.foodchem.2012.01.102>.

34. Politowicz J, Lech K, Sánchez-Rodríguez L, Szumny A, Carbonell-Barrachina ÁA. Volatile composition and sensory profile of *Cantharellus cibarius* Fr. as affected by drying method. *Journal of the Science of Food and Agriculture*. 2017;97(15):5223–5232. <https://doi.org/10.1002/jsfa.8406>.
35. Che SN, Bakaytis VI, Tsapalova IE. Influence of heat treatment on macromycete physical characteristics and the content of heavy metals in them. *Food Processing: Techniques and Technology*. 2015;37(2):138–143. (In Russ.).
36. Phillips KM, Ruggio DM, Haytowitz DB. Folate composition of 10 types of mushrooms determined by liquid chromatography – mass spectrometry. *Food Chemistry*. 2011;129(2):630–636. <https://doi.org/10.1016/j.foodchem.2011.04.087>.
37. Mittermeier VK, Dunkel A, Hofmann T. Discovery of taste modulating octadecadien-12-ynoic acids in golden chanterelles (*Cantharellus cibarius*). *Food Chemistry*. 2018;269:53–62. <https://doi.org/10.1016/j.foodchem.2018.06.123>.
38. Teichmann A, Dutta PC, Staffas A, Jägerstad M. Sterol and vitamin D₂ concentrations in cultivated and wild grown mushrooms: Effects of UV irradiation. *LWT – Food Science and Technology*. 2007;40(5):815–822. <https://doi.org/10.1016/j.lwt.2006.04.003>.
39. Costa-Silva F, Marques G, Matos CC, Barros AIRNA, Nunes FM. Selenium contents of Portuguese commercial and wild edible mushrooms. *Food Chemistry*. 2011;126(1):91–96. <https://doi.org/10.1016/j.foodchem.2010.10.082>.
40. Buzun GA, Dzhemukhadze KM, Meleshko LF. Opredelenie belka v rasteniyakh s pomoshch'yu amido-chernogo [Determination of protein in plants using dye amide black]. *Fiziologiya Rastenij*. 1982;29(1):198–204. (In Russ.).
41. Lipatov NN. Nekotorye aspekty modelirovaniya aminokislотноy sbalansirovannosti pishchevykh produktov [Some aspects of modeling amino acid balance of food products]. *Pishchevaya i pererabatyvayushchaya promyshlennost'* [Food and Processing Industry]. 1986;(4):48–52.
42. Lisitsyn DI. Polumikrometod dlya opredeleniya sakharov v rasteniyakh [Semi-micromethod for the determination of sugars in plants]. *Biokhimiya* [Biochemistry]. 1950;15(2):165–167. (In Russ.).
43. Opredelenie mannita (mannitola) v biologicheskikh lekarstvennykh preparatakh [Determination of mannitol in biological medicinal products] [Internet]. [cited 2020 Feb 25]. Available from: <http://docs.cntd.ru/document/554199329>.
44. Pochinok KhN. Metody biokhimicheskogo analiza rasteniy [Methods of biochemical analysis of plants]. Kiev: Naukova dumka; 1976. 334 s. (In Russ.).
45. Ermakov AI. Metody biokhimicheskogo issledovaniya rasteniy [Biochemical research methods of plants]. Leningrad: Agropromizdat; 1987. 429 p. (In Russ.).
46. Keyts M. Tekhnika lipidologii. Vydelenie, analiz i identifikatsiya lipidov [Technique of lipidology. Isolation, analysis, and identification of lipids]. Moscow: Mir; 1975. 322 p. (In Russ.).
47. Gofman YuYa, Vaysblay IM. Opredelenie inhibitorov tripsina v semenakh gorokha [Determination of trypsin inhibitors in pea seeds]. *Applied Biochemistry and Microbiology*. 1975;11(5):777–783. (In Russ.).
48. Manninen H, Rotola-Pukkila M, Aisala H, Hopia A, Laaksonen T. Free amino acids and 5'-nucleotides in Finnish forest mushrooms. *Food Chemistry*. 2018;247:23–28. <https://doi.org/10.1016/j.foodchem.2017.12.014>.
49. Li X, Guo Y, Zhuang Y, Qin Y, Sun L. Nonvolatile taste components, nutritional values, bioactive compounds and antioxidant activities of three wild *Chanterelle* mushrooms. *International Journal of Food Science and Technology*. 2018;53(8):1855–1864. <https://doi.org/10.1111/ijfs.13769>.
50. Bengu AS. The fatty acid composition in some economic and wild edible mushrooms in Turkey. *Progress in Nutrition*. 2020;22(1):185–192. <https://doi.org/10.23751/pn.v22i1.7909>.
51. Muszynska B, Grzywacz-Kisielewska A, Kala K, Gdula-Argasinska J, et al. Anti-inflammatory properties of edible mushrooms: A review. *Food Chemistry*. 2018;243:373–381. <https://doi.org/10.1016/j.foodchem.2017.09.149>.

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