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, mannit, 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].
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 symbiobiont 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, mannit, 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 trametolonic acid. These substances are used in medicines that treat helminthic infestations, liver diseases, viral hepatitis, etc. [24, 26]. Fruiting bodies contain polyzellerin that possesses antitumor properties as it inhibits the activity of prollyl 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-1β. In addition, it activates macrophages through Akt/NF-κB and mitogen-activated protein kinase through TLR2 [27].

Polish scientists studied the health-improving properties of polysaccharides in C. cibarius. Mushroom polysaccharides consist of one monosaccharide in a repeating unit →(→6)-α-D-Manp-(1→; 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, stronitium, 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 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 Russian C. cibarius, while its nutritional value is known to depend on a great number of factors, e.g. climatic zones, environmental impact, etc.

**STUDY OBJECTS AND METHODS**

The research featured wild chanterelles (Cantharellus cibarius L.): fresh samples (≤ 4 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]; mannan – 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 ± 25°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),...
This mushroom owes its physiological value due to trehalose. It consists of two molecules of D-glucose, mannot, glycogen, insoluble fiber, and soluble mucus. Trehalose and mannot 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 arabinogalactans 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 eicosadecane 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 fresh samples of C. cibarius contained a significant amount of 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 niacinamide (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.

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, mannot, glycogen, insoluble fiber, and soluble mucus. Trehalose and mannot 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 arabinogalactans perform the protective function as they bind and remove toxic and radioactive elements.

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Fresh mushrooms are conditionally-live products because of the ongoing irreversible biological and biochemical processes as they consist mainly of water.
(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 hymnephors, 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 crushed 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 1 Sensory properties of *Cantharellus cibarius* after 72 h of storage, depending on weighting factors (n = 5)

| Indicator          | Storage temperature, °C | 0°       | 10°      | 20°      | 30°      |
|--------------------|-------------------------|----------|----------|----------|----------|
| 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               | 18.4 ± 2.0 | 16.8 ± 1.6 | 11.2 ± 1.6 | 5.6 ± 2.0 |
|                    | very good               | 13.2 ± 1.5 | 12.6 ± 1.2 | 6.6 ± 1.2  | 3.6 ± 1.2 |
|                    | fair                    | 33.6 ± 2.8 | 30.8 ± 3.4 | 15.4 ± 2.8 | 8.4 ± 2.8 |
|                    | poor                    | 26.4 ± 3.0 | 25.2 ± 2.4 | 12.0 ± 0.0 | 9.6 ± 2.9 |

Small differences were observed in the weight of the fungi, but 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 crushed specimen. Eventually, all the mushrooms become wilted and slimy and demonstrated signs of tissue maceration.

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

| Washing conditions | QMAFAnM, CFU/g | Effectiveness, % |
|--------------------|----------------|------------------|
| Before washing     | (1.5 ± 1.1)×10⁶ | –                |
| After double washing in non-flowing water | (2.1 ± 1.1)×10⁶ | 86.0 |
| After washing in flowing water | (9.6 ± 2.8)×10⁴ | 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 phenyalanine (63.9%) and aspartic acid (45.7%) (Table 4).

Table 3 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

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

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

| Amino acid      | Content, μg/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        |

from the brine at 10 ± 5°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 ± 5°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 ≤ 25°C and a relative humidity of ≤ 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 2.6×10³ to 4.5×10³, 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 |

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. Kutafʹeva NP, Bakaytis VI, Tsapalova IEh, Poznyakovskiy VM. Ehkspertiza gribov. Kachestvo i bezopasnostʹ [Expertise of mushrooms. Quality and safety]. Novosibirsk: Sibirskoe universitetskoe izdatelʹstvo; 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 macrofungi 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 Á, 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. Chiaramelli AE, Mangiacotti M, Marchesani G, Bortone N, Tomaiuolo M, Trota 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, Rzymski 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 grify: do evrostandartov eshe daleko [Forest mushrooms: a long way from European standards]. Standards and Quality. 2012;9(9):58–60. (In Russ.).

25. Nyman AAT, Aachmann 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 protivoopukholevykh 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, 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, Szwajgier 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/s10068-016-0606-4.

30. Drewnowska M, Falandysz J. Investigation on mineral composition and accumulation by popular edible mushroom 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, Baralkiewicz D, Drewnowska M, Hanč T. 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, Hanč A, Baralkiewicz 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, Koja 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-Rodriguez 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/10.1010/j.foodchem.2018.06.123.

38. Teichmann A, Dutta PC, Staffas A, Jägerstad M. Sterol and vitamin D 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/10.1010/j.foodchem.2010.10.082.

40. Buzn GA, Dzhemukhadze KM, Meleshko LF. Oпределение белка в растениях с помощью аммиаклональной реакции (Ин Рус.).

41. Lipatov NN. Некоторые аспекты моделирования аминокислотного баланса [Some aspects of modeling amino acid balance of food products]. Fishcheyvaya i pererabatyvayushchaya promyshlennost’ [Fish and Processing Industry]. 1986;(4):48–52.

42. Lisitsyn DJ. Polumikrometod diya opredeleniya sakharov v rasteniakh [Semi-micromethod for the determination of sugars in plants]. Biokhimiya [Biochemistry]. 1950;15(2):165–167. (In Russ.).

43. Manninen H, Rotola-Pukkilä 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.

44. 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.

45. 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.

46. 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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