Development of sauce production technology based on cultivated oyster mushrooms (*Pleurotus ostreatus* (Jacq.) P. Kumm)

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Abstract. Cultivated oyster mushrooms (*Pleurotus ostreatus* (Jacq.) P. Kumm) are common for many countries of the world mainly because of their high yield. Their growing doesn’t require special conditions. The mushrooms contain useful nutritional substances and have high sensory characteristics, so they can be suitable for developing of new types of culinary production. In the paper, the technology of sauce production using paste-like semi-finished products from oyster mushrooms is described. While obtaining the semi-finished products, it is advisable to use chopping of raw mushrooms before their heat treatment in combi oven by 100 °C during 30 min. The hot and cold sauce production samples based on the semi-finished products have got mainly high points for their sensory evaluation. The estimated nutritional value of sauces shows that they appear to be low-calorie products containing vitamins and mineral substances. Thus, the developed sauce production based on cultivated oyster mushrooms can be recommended for further researches and practical implementation at public catering enterprises.

1. Introduction

Oyster mushroom (*Pleurotus ostreatus* (Jacq.) P. Kumm) is one of the most common cultivated edible mushrooms in the world. It belongs to *Pleurotus* species, which represent a well-defined group of Basidiomyceteous fungi of the *Agaricales* order and *Tricholomataceae* family. The mushrooms are characterized by the production of fruiting bodies with an eccentric stalk and a wide cap shaped like an oyster shell, with the widest portion of the cap being away from the stalk. They grow over a wide range of temperatures and can colonize wide spectrum of unfermented, natural, lignin-cellulosic wastes. Because of fast mycelium growth rate, they colonize substrates rapidly; the yield of fruiting bodies is also high. The bifactorial inheritance, observed in many of the species, suggests the likelihood of a high degree of genetic variability, and, hence, considerable breeding potential. Oyster mushrooms can be grown on a commercial scale, without the need for composting and artificial conditioning of the ambient temperature [1]. The further processing of cultivated mushrooms can be carried out by their pickling, salting, drying, obtaining of fried and frozen semi-finished products, etc. [2]. They can also be sold in retail in fresh state.

At the same time, among existing technologies of oyster mushrooms processing there is no technology, which can be used at public catering enterprises for preparing culinary production. This technology proposes decreasing the amount of technological operations during preparation. Thus, the process can be faster and more effective.
Puree soups and sauces from cultivated edible mushrooms are common dishes in many countries. However, the heat treatment and grinding of mushrooms can take a lot of time and effort. For the optimization of these operations we suggest sauce production technology based on paste-like semi-finished products from oyster mushrooms, which is described in the paper.

2. Theoretical researches
The study of cultivated oyster mushrooms chemical composition is carried out widely enough. The information on their chemical composition and nutritional value varies significantly. According to the information from different authors, oyster mushrooms contain proteins ranging from 15 to 34%, lipids from 1.5 to 8.7%, carbohydrates from 19.5 to 52%, ash from 5 to 11.4% and moisture from 85 to 90% [1, 3–8].

It is well known, that oyster mushrooms have a complete set of essential amino acids such as tryptophan, cystine, aspartic acid, lysine, alanine [3, 5], as well as vitamins B1 (0.35–0.92 mg/100g), B2 (1.17–1.74 mg/100g), B6 (1.72–2.75 mg/100g), B12 (6.85–8.0 mg/100g), C (3.27–3.65 mg/100g), D (3.8–4.22 mg/100g), etc. [4].

Macro- and microelements are presented by nitrogen (4.5 mg/100g), phosphorus (0.81 mg/100g), potassium (1.3 mg/100g), calcium (32.25 mg/100g), magnesium (10.62 mg/100g), iron (46.8 mg/100g), copper (3.5 mg/100g), manganese (2.43 mg/100g) and zinc (12.88 mg/100g) [6].

Fatty acids in oyster mushrooms are mainly presented by monounsaturated oleic acid (C18:1) and polyunsaturated linoleic acid (C18:2n-6). These fatty acids provide normal tissue growth and prevent the cholesterol level increase [4].

The high content of pure protein in oyster mushrooms fruiting bodies helps to prevent and treat hepatitis, stomach ulcers, reduces the amount of cholesterol in the blood, helps to normalize blood pressure during both hyper- and hypotension, has antitumor effect and boosts the body's immune resistance. The bactericidal characteristics of oyster mushrooms give them anti-radiation and radio-protective properties. Isolated extracts obtained from oyster mushrooms are used to prevent cardiovascular diseases [4, 9–11]. Carbohydrates contained in mushrooms are used to produce several substances: melanin, beta-glucans, that are used as anti-cancer biologically active supplements and drugs [12].

The taste and smell of mushrooms are composed from volatile metabolic products compounds of the group of aliphatic aldehydes, ketones, alcohols (among which octane derivatives are most often identified) and the group of nitrogen-containing compounds, including simple amines, amides, amino acids, derivatives of glutamic acid, etc. These substances create specific taste and smell of heat-treated oyster mushrooms, which can be attractive for consumers [13].

All these beneficial features of oyster mushrooms allow to increase their cultivation in many countries using various substrates [4–6, 14–17]. The world leader in cultivated edible mushroom production (mainly two-sided champignons, oyster mushrooms and shiitake) is China, where there are more than 30 billion kg of edible mushrooms (almost 87% of global production) are produced every year [14]. At the same time, the edible mushroom cultivation is increasing in Russia mainly because of food embargo on products imported from USA, Europe and other countries. Thus, oyster mushrooms can be available for Russian consumers both in fresh and processed forms because of their high yield and low cost [15–17], and it is necessary to develop various approaches to their integrated processing technology.

Processed oyster mushrooms can be quite interesting for public catering enterprises. One of the main tasks for public catering is to gain the increase through improving consumer demands. This can be reached by using semi-finished products obtained from oyster mushrooms in culinary production formulations. These semi-finished products allow to reduce preparation time of culinary production and expand its range. They may have different forms (dried, salted, pickled, etc.) and can be used in soups, main course dishes, pastry and bakery production [2]. Among that, the processed oyster mushrooms can be used in a paste-like form in sauce production formulations, which we have developed in our researches.
3. Experimental researches
Mushroom sauces are suitable for many kinds of food production: such as meat, fish and vegetable dishes, as well as pasta or cereals. They are used both in hot and cold state.

It is known that traditional mushroom sauces formulations are based on mushroom broth or extract. In the developed formulations, paste-like semi-finished products from oyster mushrooms were used as base ingredients. The oyster mushroom fruiting bodies parts were ground and heat-treated. Further, the starch-containing thickening agents (potato puree, rice puree or heat-treated wheat flour) were added and the mixtures were homogenized. Herewith, the quality of used thickening agents can be evaluated only after the sauce is ready. The evaluation was carried out by sensory method during acceptable shelf life and realization of sauce production for 3 hours. The main criterium for choosing of thickening agent was sauce consistency (stability of sauce emulsion).

The formulations and technology of developed sauces are based on semi-finished products from oyster mushrooms with further addition of ingredients used in existing sauce formulations. For obtaining of hot sauces the semi-finished products were mixed with milk, cream, butter, species, mushroom salts, etc. and heated up. For obtaining of cold sauces the semi-finished products were mixed with dairy products, vegetable oil, green vegetables, beets, etc.

The general model of obtaining semi-finished products from oyster mushrooms is shown on Figure 1.

![Figure 1. Obtaining of semi-finished products from oyster mushrooms general model.](image)

In the first step of obtaining semi-finished products the caps were cut from druses. It is recommended to use oyster mushroom fruiting bodies without a cap, since:

- such processing methods as pickling, frying, stuffing preparing, etc. are more applicable for caps; they can be sold fresh too;
- sensory characteristics of paste-like semi-finished products from caps have low values (dark color, liquid consistency, strong smell, etc.);
- oyster mushroom stalks contain more vitamins, macro- and micro elements and amino acids;
- losses during heat treatment are greater for caps than for stalks, because dry substances content in caps (including cellulose) is 1.4–1.5 times less [7].

The flow chart of semi-finished products from obtaining oyster mushrooms based on formulation models and technological properties of mushrooms was developed (Figure 2).

The technological properties of oyster mushrooms substantially depend on proteins, fibers and water content [13]. This causes a different behavior of mushroom parts during their heat treatment. It is possible to predict large losses during heat treatment and its shorter duration for caps than for stalks. This also indicates that caps and stalks of oyster mushrooms should not be used simultaneously for the same methods of heat treatment – such as steam cooking in a combo oven. This method was chosen because most food substances are preserved in the product, and they are not extracted into the broth.
The obtaining of paste-like semi-finished products from oyster mushrooms was carried out in two following ways:

*Technology № 1. Stages:*
- Heat treatment of raw oyster mushrooms;
- Grinding of heat-treated mushrooms;
- Homogenization with thickening agent.

*Technology № 2. Stages:*
- Chopping raw oyster mushrooms;
- Heat treatment;
- Homogenization with thickening agent.

The weight losses, which were evaluated visually, were less while using technology № 2. This can be explained due to increasing of the heated surface area of mushrooms and decreasing of heat treatment duration. Thus, the technology № 2 is preferable, because it saves more nutritional substances contained in mushrooms together with the chosen heat treatment method.

While the technology of obtaining semi-finished product from oyster mushrooms was developed, their technological properties were considered through the different heat treatment duration for caps and
stalks. The weight losses of the oyster mushroom fruiting bodies parts after heat treatment are given in the Table 1. The dynamics of the change in the weight of oyster mushrooms parts depending on heat treatment duration and temperature are shown in the Figure 3.

**Table 1. Changes of the oyster mushroom parts weights after heat treatment (HT).**

| Mushroom part | HT by 100 °C, 30 min | HT by 100 °C, 60 min | HT by 130 °C, 60 min |
|---------------|----------------------|----------------------|----------------------|
|               | Weight before HT, g  | Weight after HT, g   | Weight before HT, g  | Weight after HT, g   | Weight before HT, g  | Weight after HT, g   | Losses, %  | Losses, %  | Losses, %  |
| Caps          | 3010 ± 5.0           | 2220 ± 7.0           | 278 ± 1.06           | 186 ± 2.0            | 33.09 ± 4.0         | 295 ± 0.39         | 26.24      | 33.09      | 50.51      |
|               |                      | 32.18                |                      |                      | 49.22               |                      |
| Stalks        | 2490 ± 8.0           | 2290 ± 6.0           | 261 ± 0.37           | 177 ± 0.72           | 32.18 ± 0.72        | 258 ± 3.0          | 8.03       | 3.0        | 0.98       |

**Figure 3.** The magnitude of weight losses of caps and stalks of oyster mushrooms after heat treatment.

The results from Table and Figure show that the highest losses were for both caps (50.51%) and stalks (49.22%) heat-treated by 130 °C during 60 min. A better result was for both caps (33.09%) and stalks (32.18%) heat-treated by 100 °C during 60 min. Thus, the temperature lowering caused decrease for weight losses of heat-treated mushrooms. The least weight losses were found out for stalks (8.03%) heat-treated by 100 °C during 30 min. They are less approximately on 18%, than for caps (26.24%). Thus, 30 min for heat treatment duration of stalks is enough to obtain the product for further grinding and homogenization together with the thickening agent.

The obtained semi-finished products were the base ingredients for 6 developed sauce production formulations. The basis for determining the optimal ratio of the original sauce ingredients in formulations was sensory characteristics of the sauce production samples.

For imparting the aroma of forest mushrooms to developed production, white mushrooms and chanterelles were introduced into the samples in the form of mushroom salts (fine-ground dried white mushrooms or chanterelles).

For sensory evaluation, the sauce production samples were divided into two groups – hot and cold sauces. It was carried out by 5 semi-trained panelists. As a result, the total scores for each sensory characteristic (appearance, consistency, smell, taste and color) were obtained.

In the first group there were white mushroom sauce (sample № 1), chanterelle sauce (sample № 2), cheese sauce (sample № 3); in the second group (cold sauces) were tartar (sample № 4) and pesto sauces with olive oil (sample № 5) and sour cream with beets puree (sample № 6).
The Table 2 presents the developed requirements for sensory evaluation of new sauce production.

Table 2. Requirements for sensory evaluation of sauce production.

| Quality indicators            | Characteristics                                                                 |
|-------------------------------|--------------------------------------------------------------------------------|
| **Appearance and consistency** | Homogeneous, viscous, non-stratified wiped mass, without extraneous inclusions,  |
|                               | without films on the surface, with evenly distributed ingredients.              |
| **Smell**                     | Pleasant, pronounced, specific for incoming ingredients, without extraneous      |
|                               | smells.                                                                        |
| **Taste**                     | Pleasant, pronounced, specific for incoming ingredients, slightly salted,        |
|                               | moderately sour (for sauces with dairy products), without bitterness or        |
|                               | extraneous unspecific taste.                                                   |
| **Color**                     | Pronounced, uniform, from beige to light gray, red purple (for sauces with      |
|                               | beets), appropriate to the color of the incoming ingredients and additives.     |

The results of sensory evaluation of samples № 1, № 2 and № 3 are presented in Figure 4, the results of sensory evaluation of samples № 4, № 5 and № 6 – in Figure 5.

Figure 4. Results of sensory evaluations for the first group of sauces.

Figure 5. Results of sensory evaluations for the second group of sauces.
All samples from the first group received high points for sensory evaluation. The best one was the sample № 1. The samples № 2 and № 3, according to panelists’ opinion, are characterized by a less distinguishable taste.

In the second group, each sample received lower points for sensory characteristics compared to the first group, due to their specific smell and taste of dill and parsley.

The results of the evaluation show that sensory characteristics of developed sauces are high. Therefore, the formulations of the samples from the second group may be improved through correcting the ratios of the used sauce ingredients.

The Table 3 shows the nutritional value of developed mushroom sauces, which was calculated based on theoretical data from “Chemical Compositions of Russian Food Products Manual” (2002).

| Sauces samples | Proteins, g | Fats, g | Carbohydrates, g | Calorie, kcal | Ash, g | K, mg |
|----------------|-------------|---------|------------------|---------------|--------|-------|
| Sample № 1    | 5.4         | 4.0     | 13.5             | 111           | 1.72   | 1.85  |
| Sample № 2    | 6.6         | 4.4     | 15.3             | 127           | 1.86   | 1.79  |
| Sample № 3    | 7.7         | 7.6     | 13.1             | 152           | 1.0    | 0.43  |
| Sample № 4    | 4.3         | 3.1     | 7.2              | 74            | 1.49   | 0.12  |
| Sample № 5    | 4.5         | 4.9     | 7.6              | 92            | 1.66   | 0.6   |
| Sample № 6    | 4.8         | 2.6     | 8.0              | 75            | 1.48   | 0.12  |

| Sauces samples | Carotene, mg | B₁, mg | B₂, mg | PP, mg | B₅, mg |
|----------------|--------------|--------|--------|--------|--------|
| Sample № 1    | 1.75         | 390.2  | 297.89 | 1376.12| 41.41  |
| Sample № 2    | 1.69         | 422.74 | 276.74 | 1403.39| 41.41  |
| Sample № 3    | 0.03         | 0.11   | 0.29   | 4.04   | 0.86   |
| Sample № 4    | 4.36         | 186.27 | 399.3  | 890.77 | 178.48 |
| Sample № 5    | 0.04         | 0.14   | 0.39   | 5.09   | 1.29   |
| Sample № 6    | 5.01         | 193.48 | 402.54 | 880.5  | 192.65 |

As shown in the Table, all sauce samples are appeared to be low-calorie products. The highest protein, fats and carbohydrates content has sample № 3 because of cheese ingredient, the lowest substance content have samples № 4 and № 6. All samples also contain different amounts of such substances as potassium, carotene vitamins B₁, B₂, PP, B₅. The obtained results of calculation correspond to results of other authors [1, 3–8]. For their further confirmation, the practical researches of sauce production nutritional value must be carried out.

4. Conclusion

The results of carried out researches have shown that paste-like semi-finished products from cultivated oyster mushrooms are perspective ingredients for new low-calorie sauce production with high sensory characteristics.

The researches have also shown that the most useful parts of mushrooms for paste-like semi-finished products and sauce production are mushrooms stalks. The production samples from them had high sensory characteristics and food substances content because of less weight loss in stalks during heat treatment.

Thus, the developed sauce production line can expand the mushroom sauces range and improve sensory characteristics of various culinary production, which will be carried out in further researches.

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