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COMPARATIVE CHARACTERISTICS OF AROMA PROFILE OF WILD AND CULTURED EDIBLE MUSHROOMS

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Abstract. The increased consumption of edible mushrooms is not only due to their nutritional value, but also to their unique taste and specific flavor. The aroma of cultivated mushrooms is different from wild ones, it is often less pronounced. The aim of the study was to determine the characteristics of the aroma of wild and cultivated edible mushrooms using the methods of sensory profile analysis and ultraviolet spectrophotometry. Sensory profile analysis showed that aroma profiles of mushroom samples differed in intensity depending on a kind of a mushroom. It was found that *Boletus sp.* had the highest intensity of the mushroom component of flavor among wild mushrooms. The intensity of woody flavor components was higher in *B. subtomentosus*, *L. aurantiacum* and *P. ostreatus* IBK-1535. More pronounced herbaceous notes were observed for a wild *P. ostreatus* and A. *silvaticus*, sweet – for *S. luteus*, and floral – for *P. djamor*. Among the cultivated fungi, the most pronounced mushroom notes are observed for *A. bisporus*. The lowest intensity of aroma had such wild mushrooms as *P. ostreatus* and *S. luteus*. Also, the least pronounced flavor was noted for the cultivated *P. djamor*. The flavor of this mushroom is characterized by fishy notes. The obtained UV-spectra of different mushroom species varied in the intensity of the light absorption maxima. The highest intensity in the entire wavelength range had the extract of *B. edulis* fruit bodies. Among the cultivated fungi, *A. bisporus* was characterized by the highest optical density of hexane extract at 207 nm, and *A. bisporus* and *P. ostreatus* strains IBK-551 and IBK-1535 absorbed light the most intense in the region of 260–290 nm. The results of determining the organoleptic profile and spectrophotometric analysis of mushroom extracts indicate that the industrial cultivation of edible mushrooms disrupts or inhibits the formation of aroma substances by fruiting bodies, which leads to a decrease in their consumer quality. Therefore, in order to increase the demand for cultivated edible mushrooms, the flavor of which is one of the determining factors of their attractiveness, it is necessary to conduct a comprehensive study of the dependence of the aroma substances formation on the growing process parameters.

Keywords: edible mushrooms, aroma, sensory profile analysis, UV-spectrophotometry.

Introduction. Formulation of the problem

Today, about 2,000 species of mushrooms are considered edible [1]. Most of them are widely available or used commercially in food. Mushrooms can be found in many recipes and have been used as food or food ingredients for millennia [2].

Considerable attention to edible mushrooms as food products is related to the content of proteins, polysaccharides, dietary fibers, vitamins, and minerals in fruit bodies [3]. Also, mushrooms are rich in various biologically active substances such as antioxidants, phenolic compounds, terpenoids, antibiotics, and lectins. Therefore, most edible mushrooms, in addition to high nutritional value, are also characterized by medicinal properties [4].

The increased consumption of edible mushrooms is not only due to their nutritional value, but also to their unique taste and specific flavor [5]. In addition to the volatile eight-carbon compounds such as 1-octen-3-ol and 1-octen-3-one, the typical mushroom flavor consists of water-soluble components including free amino acids and 5′-nucleotides [6].

Due to the large number of volatile components, the aroma profile is the so-called "business card" of the product, which can be used to determine its organoleptic quality and authenticity [7]. Edible mushrooms are no exception [8].

Despite such significant consumer appeal, the consumption of edible mushrooms in many countries of the world, including Ukraine, is at a very low level. One of the reasons for this situation can be considered insufficiently expressed organoleptic properties of cultivated mushrooms compared to wild ones.

A comprehensive and extended characterization of the mushroom aroma profile will make it possible to determine exactly those flavor substances, the formation of which changes in a certain way during the industrial production of mushrooms compared to natural conditions. Such results will open the possibility to obtain fruiting bodies of the highest quality under conditions of solid-phase cultivation.

Analysis of recent research and publications

More than 100 volatile compounds determine the specific aroma of mushrooms. These are substances of different chemical nature that are formed in the mushroom cells through a number of biochemical reactions. Among them are C8 compounds, alcohols, aldehydes, ketones, fatty acid methyl esters, sulfur compounds and many others [9,10].

The aroma of mushrooms varies in a very wide range. From the very typical mushroom, characteristic of *Boletus edulis* Bull., to fruit, characteristic of the fungus *Inocybe erubescens* A. Blytt, *Russula emetica* (Schaeff.) Pers., *Lactarius deliciosus* (L.) Gray, *Leucoagaricus leucothites* (Vittad.) Wasser, almond-anise, characteristic of *Hygrophorus agathosmus* (Fr.) Fr., *Agaricus arvensis* Schaeff., *A. bitorquis* (Quél.) Sacc., *A. sylvicola* (Vittad.) Peck, *Gloeophyllum odoratum* (Wulfen) Imazeki, *Trametes suaveolens* (L.) Fr., and *Clitocybe gibba* (Pers.) P. Kumm. [11].

Flavor properties of mushroom depends on the geographical conditions of existence, changes under the influence of external environmental factors, in the process of cooking, storage, age of fruit bodies, flush of yielding and carpophores size [11, 12].

Researchers also believe that the synthesis of aroma substances by mushrooms depends on the substrate composition, development conditions, growth stage and genetic characteristics of the strains [13].

In recent years, there has been increased attention to the volatile aromatic substances of mushrooms, both wild and cultivated [14].

The purpose of this study was to determine the characteristics of the aroma of wild and cultivated edible mushrooms using the methods of sensory profile analysis and ultraviolet spectrophotometry. For this purpose, the following **objectives** were achieved:

– collection of wild edible mushrooms in the territory of the Dnipropetrovsk region;

– obtaining of fruiting bodies of various species and strains of edible mushrooms by the method of solid-phase cultivation;

– carrying out a sensory profile analysis of dried fruiting bodies of mushrooms;

– extraction of flavor compounds and ultraviolet spectrophotometry of the obtained extracts;

– comparison of aroma profiles of wild and cultivated mushrooms.

Research materials and methods

Mushroom strains. The objects of research were:

1) fruiting bodies of wild edible mushrooms *B. edulis*, *B. subtomentosus* L., *Suillus luteus* (L.) Roussel, *Leccinum aurantiacum* (Bull.) Gray, *Kuehneromyces mutabilis* (Schaeff.) Singer & A.H. Sm., *A. arvensis*, *A. silvaticus* Schaeff., *Pleurotus ostreatus* (Jacq.) P. Kumm., collected in the Dnipropetrovsk region during 2021;

2) industrial strains of *P. ostreatus* (IBK-549, IBK-551, and IBK-1535) were obtained from the IBK Mushroom Culture Collection of the M. G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine [15];

3) fruiting bodies of white and brown varieties of cultivated mushroom *A. bisporus*, purchased in the trade network;

4) dried fruit bodies of *P. djamor* (Rumph. ex Fr.) Boedijn, obtained during research work at the Department of Biotechnology of Ukrainian State University of Chemical Technology, Dnipro, Ukraine.

Spawn, Substrate Preparation and Fruiting of Cultivated Mushrooms. Grain spawn was prepared on barley grains. The sunflower husk was the substrate for the production of fruiting bodies.

Mushrooms were grown in three replicates for every strains. The first and second flushes were harvested.

Drying of mushrooms. Cultivated and collected wild mushrooms were dried at 40–45°C in a dehydrator up to 8–10 % humidity.

Sensory Profile Analysis. The sensory profile of the aroma of dried mushroom samples was studied according to ISO 13299:2016. The panel consisted of five experts trained for organoleptic analysis. First, the characteristic attributes of the aroma were determined, and then the intensity of each of them on a 5-point scale. The studied samples were evaluated three times. Microsoft Office Excel 2007 software was used to construct the aroma profiles of dried mushroom samples.

Spectrophotometric analysis. For a spectrophotometric study, extraction of dried crushed mushroom fruit bodies was performed according to [16]. The absorption spectra were recorded in the wavelength range of 200–400 nm.

Statistical Analysis. The obtained data were processed statistically using one-way analysis of variance (ANOVA). All samples were carried out in triplicate. Differences at $P \leq 0.05$ were considered to be significant.

Results of the research and their discussion

Profile analysis of the mushroom aroma

During the sensory analysis by the panel, the following attributes of the aroma of dried mushroom samples were determined: mushroom, sweet, woody, herbaceous, sour, fish, meat, earthy, floral, and putrescent.

The results of sensory analysis of dried wild mushroom samples are presented in circle plots in Figures 1 and 2, as well as samples of dried cultivated mushrooms – in Figure 3.

From the provided diagrams it is evident that aroma profiles of mushroom samples differed in intensity (the area of an internal surface of the diagram) depending on a kind of a mushroom.

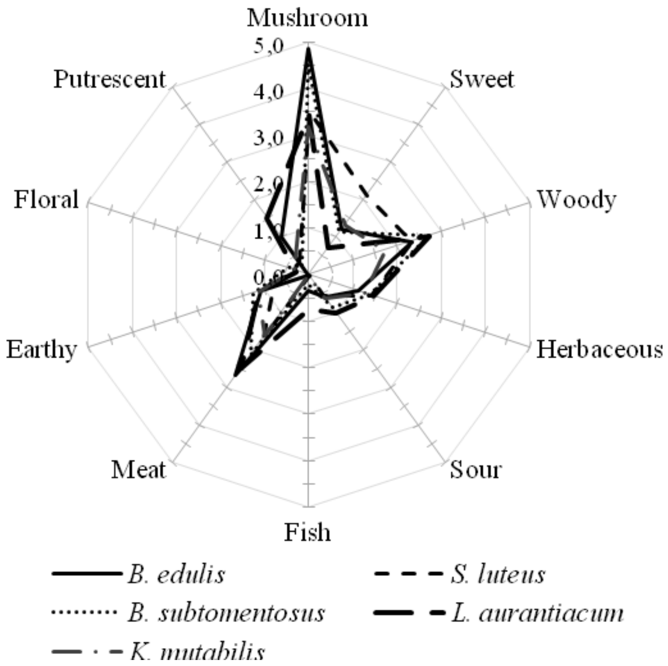

Fig. 1. Sensory profiles of aroma of dried wild mushrooms (part 1)

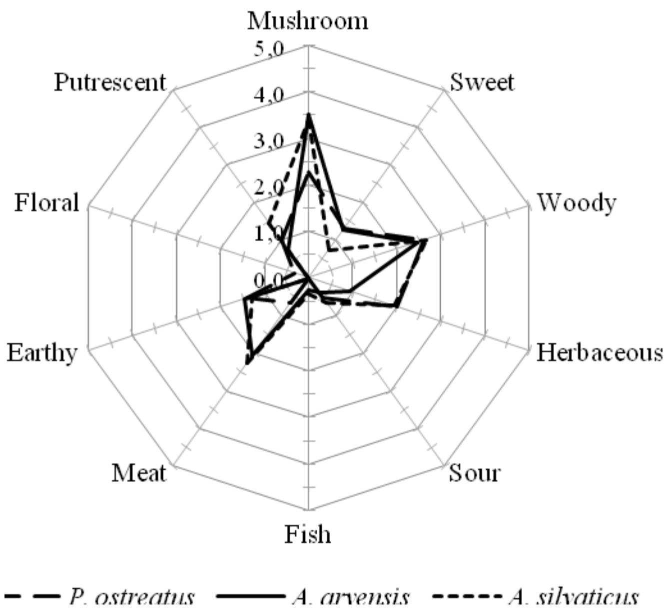

Fig. 2. Sensory profiles of aroma of dried wild mushrooms (part 2)

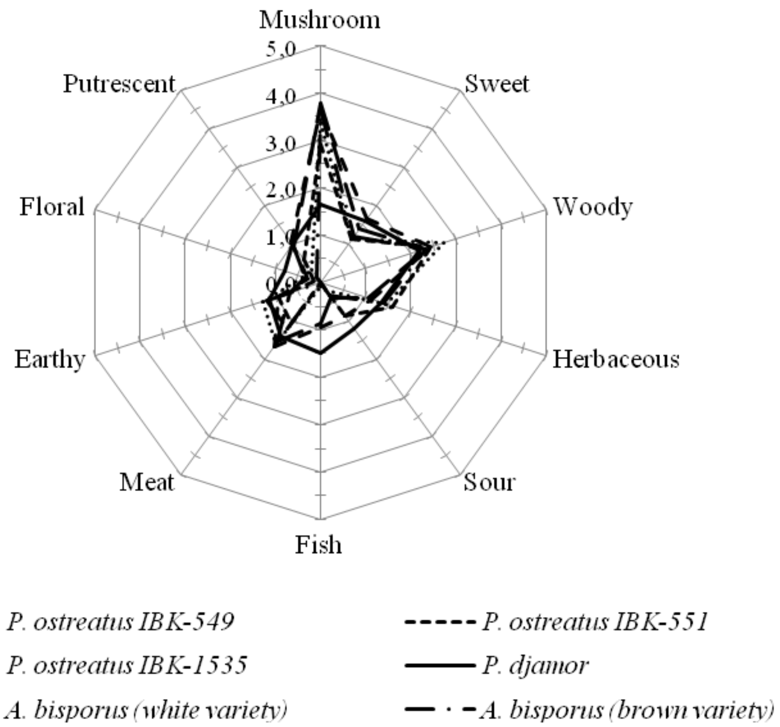

Fig. 3. Sensory profiles of aroma of dried cultivated mushrooms

Representatives of the genus Boletus (*B. edulis* end *B. subtomentosus*) had the highest intensity of the mushroom component of flavor among all the studied samples of dried mushrooms. The lowest value of this attribute compared to other mushrooms was recorded for *P. djamor*. Among the cultivated mushrooms, the most pronounced mushroom notes are observed for *A. bisporus*.

The intensity of woody notes in 1.2–1.6 times higher was observed for *B. subtomentosus*, *L. aurantiacum* and *P. ostreatus* IBK-1535, and herbaceous – for a wild *P. ostreatus* and A. *silvaticus* (1.3–2.2 times).

Meat notes were more pronounced in *B. edulis* and *L. aurantiacum* samples, and least in the wild sample of *P. ostreatus* and its cultivated strain IBK-551.

As for the sweet attribute of flavor, its highest intensity is noted for *S. luteus*, and floral – for *P. djamor*.

The fish notes are most pronounced in *L. aurantiacum* and *P. djamor*.

Some of the samples, both wild (*L. aurantiacum*, *A. silvaticus*) and cultivated (*P. djamor*, *P. ostreatus* IBK-549) mushrooms, showed the presence of slightly pronounced sour and putrescent notes of aroma.

According to the results of the scoring of the intensity of the aroma attributes, the standard deviation did not exceed ± 1 point (on a 5-point scale), which indicates the homogeneity of the experts' assessments.

Ultraviolet spectroscopy. The registered UV absorption spectra of hexane wild mushroom extracts are presented in Figures 4 and 5, cultivated mushroom extracts – in Figure 6.

On the UV spectra of hexane extracts of the studied species of fungi, light absorption maxima were observed at 205–207 nm and in the region of 250–290 nm. Such spectral properties are characteristic of solutions of unsaturated compounds having unbound double bonds, saturated and unsaturated aldehydes and ketones. Also in the study [17] it was found that the absorption spectrum of 1-octen-3-ol, which is considered to be the main flavor compound responsible for the characteristic mushroom aroma, has a light absorption maximum at 207 nm.

The obtained spectra of different species of mushrooms differed in the intensity of the light absorption maxima. Thus, the spectrum of porcini (*B. edulis*) extract had the highest intensity in the entire wavelength range. At 207–210 nm, its optical density was 1.8–2.9 times higher, and in the range of 250–290 nm – 1.3–2.0 times higher than in other species of wild edible mushrooms. The spectrum of hexane extract of wild oyster mushroom (*P. ostreatus*) had the lowest optical density.

Among the cultivated fungi, *A. bisporus* was characterized by the highest optical density of hexane extract at 207 nm, and *A. bisporus* and *P. ostreatus* strains IBK-551 and IBK-1535 absorbed light the most intense in the region of 260–290 nm. The lowest intensity of light absorption in the whole studied range of wavelengths is marked by pink oyster mushroom (*P. djamor*).

Thus, the studied wild basidiomycetes had a more pronounced mushroom aroma, which is confirmed by the peaks of the spectra in the range of 207–210 nm, which has 1-octen-3-ol – the substance corresponding to the mushroom flavor. And cultivated mushrooms have more pronounced herbaceous and floral notes of aroma, due to the intense synthesis of aldehydes (increased peaks in the range of 260–290 nm).

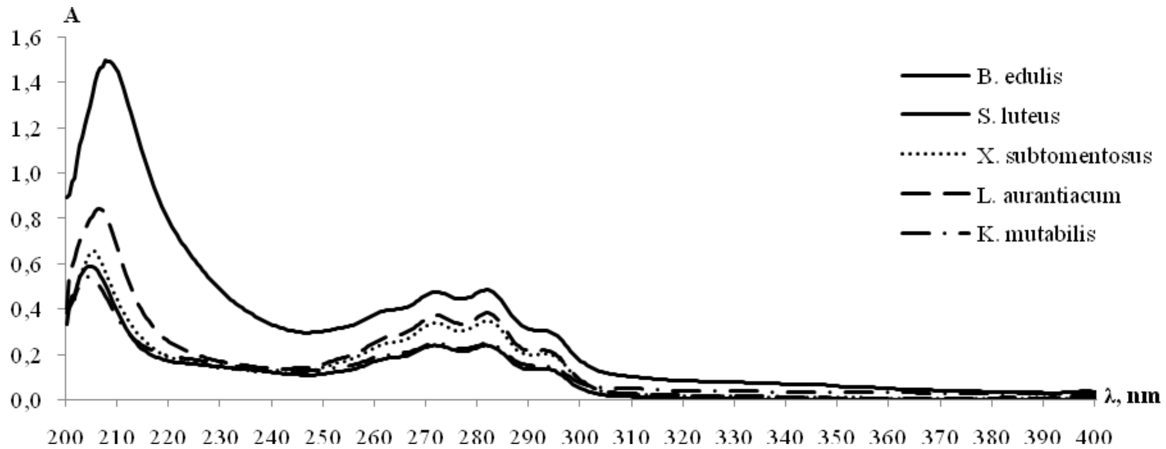

Fig. 4. UV spectra of hexane extracts of dried wild mushrooms samples (part 1)

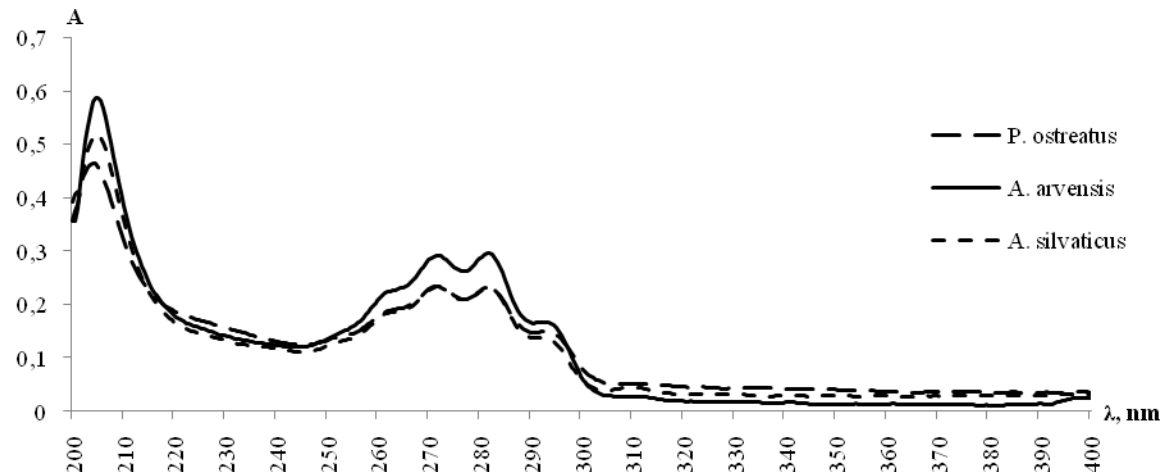

Fig. 5. UV spectra of hexane extracts of dried wild mushrooms samples (part 2)

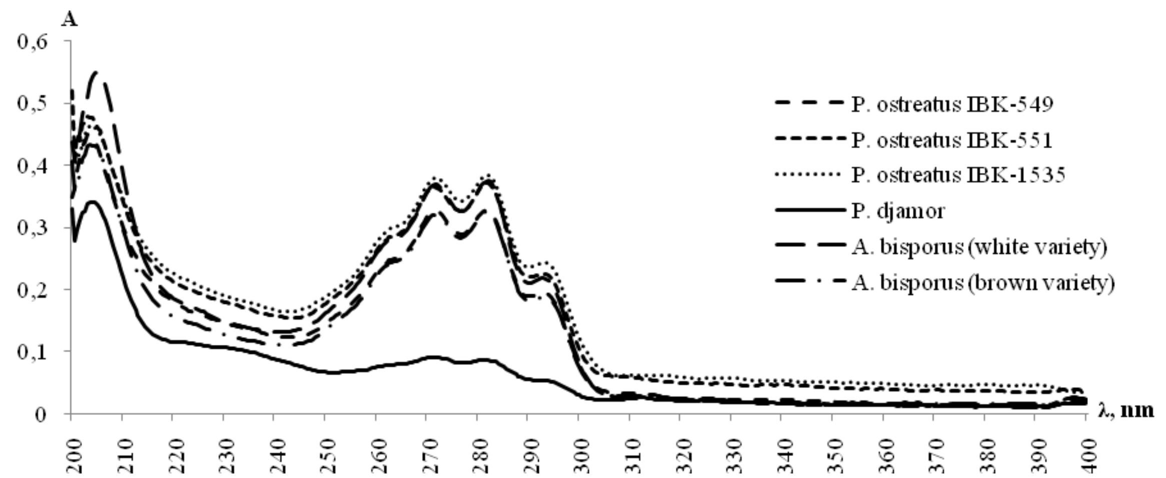

Fig. 6. UV spectra of hexane extracts of dried cultivated mushrooms samples

The conducted studies, as well as the analysis of literature data, indicate that each type of mushroom has its own unique aroma profile.

According to the results of the sensory profile analysis, it can be concluded that the analyzed mushrooms have differences in the ratio of various aroma notes. *B. edulis* is characterized by a high intensity of mushroom notes. The intensity of woody flavor components was higher in *B. subtomentosus*, *L. aurantiacum* and *P. ostreatus* IBK-1535. More pronounced herbaceous notes were observed for a wild *P. ostreatus* and A. *silvaticus*, sweet – for *S. luteus*, and floral – for *P. djamor*.

A variety of mushroom flavors is shown in the works of other researchers. Characteristics of aroma substances of four wild mushroom species (*Boletus edulis*, *Lactarius camphoratus*, *Cantharellus cibarius* and *Craterellus tubaeformis*) with trained assessors using gas chromatography-olfactometry as well as gas chromatography-mass spectrometry demonstrated the overall volatile profile differences. Each mushroom had several unique volatile compounds that were not present in other mushrooms [14].

The studied eleven wild edible mushrooms were separated in three groups. One of them is rich in C8-compounds, such as 3-octanol, 1-octen-3-ol, *trans*-2-octen-1-ol, 3-octanone, and 1-octen-3-one; another one is rich in terpenic volatile compounds; and the last one is rich in methional. Mushrooms of each group had significant differences in aroma [18].

In general, it should be noted that the highest total intensity of all the marked components of the aroma were characterized by representatives of the genus *Boletus*. This is clearly confirmed by the graphical representation of their profiles in Figure 1 (largest area of profiles). Its aroma is characterized as a typical mushroom.

By using aroma extract dilution analysis (AEDA) combined with gas chromatography-mass spectrometry (GC–MS) was employed to identify the odorants of *B. edulis*. Among the 12 main components, 1-octen-3-ol was contained in the largest amount in the fruiting bodies. Another compounds such as 3-methylbutanal, (*E*,*E*)-2,4-decadienal and (*E*,*E*)-2,4-nonadienal were also responsible for the unique aroma profile [1]. A high content of C8 volatiles has been identified in porcini mushrooms collected in Turkey. It is these compounds that determined the presence of a distinct mushroom flavor [19].

Among the samples of wild mushrooms, the lowest intensity of aroma had *P. ostreatus* and *S. luteus*.

For the mushrooms of the genus *Agaricus* recorded the highest intensity of flavor among all samples of cultivated fungi.

Another study characterized flavor of three raw *A. bisporus* mushrooms (white, crimini, and portobello) using quantitative descriptive analysis. High aroma intensity was observed for these mushrooms. The attributes perceived to be present at the highest intensities were mushroom, earthy, hay, soybean, and woody notes [20].

It should be noted that *P. djamor* had the least pronounced aroma among all studied cultivated mushrooms. The flavor of this mushroom is characterized by fishy notes.

In the study of this fungus using gas chromatography, a high content of 2-pentylfuran was found in the fruiting bodies. At the same time, it was established the very high optical purity of the main odorant 1-octen-3-ol in *P. djamor*, even higher than in *P. ostreatus* [21]. This once again confirms the significant variation in the synthesis of volatile aromatic substances by mushrooms depending on many environmental factors.

Conclusion

Edible cultivated mushrooms are attracting increasing attention from consumers around the world. And since one of the most important characteristics of this product is aroma, the study of the ways of synthesis of flavor substances by mushrooms cannot be ignored by scientists. As the study showed, cultivated mushrooms have a less pronounced aroma than wild mushrooms. A detailed study of the conditions influencing the formation of volatiles by fruiting bodies will make it possible to obtain mushrooms with a characteristic aroma that are in no way inferior to wild ones.

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ПОРІВНЯЛЬНА ХАРАКТЕРИСТИКА АРОМАТИЧНОГО ПРОФІЛЮ ДИКИХ ТА КУЛЬТИВОВАНИХ ЇСТІВНИХ ГРИБІВ

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Анотація. Зростання споживання їстівних грибів пояснюється не тільки їх харчовою цінністю, але й унікальним смаком і специфічним ароматом. Аромат культивованих грибів відрізняється від дикорослих, часто менш виражений. Метою дослідження було визначення особливостей аромату дикорослих та культивованих їстівних грибів за допомогою методів сенсорного профільного аналізу та ультрафіолетової спектрофотометрії. Сенсорний аналіз показав, що профілі аромату зразків грибів відрізнялися за інтенсивністю залежно від виду гриба. Було встановлено, що *Boletus sp*. мали найвищу інтенсивність грибної складової запаху серед дикорослих грибів. Інтенсивність деревного компоненту запаху була вищою у *B. subtomentosus*, *L. aurantiacum* та *P. ostreatus* IBK-1535. Більш виражені трав'янисті ноти спостерігалися у дикого *P. ostreatus* та *A. silvaticus*, солодкі – у *S. luteus*, квіткові – у *P. djamor*. Серед культивованих грибів найбільш виражені грибні ноти відзначені для *A. bisporus*. Найнижчу інтенсивність аромату мали такі дикорослі гриби, як *P. ostreatus* та *S. luteus*. Також найменш виражений запах відзначений у культивованого *P. djamor*. Аромат цього гриба охарактеризований рибними нотами. Отримані УФ-спектри різних видів грибів відрізнялися за інтенсивністю максимумів поглинання світла. Найбільшу інтенсивність у всьому діапазоні довжин хвиль мав екстракт плодових тіл *B. edulis*. Серед культивованих грибів *A. bisporus* характеризувався найвищою оптичною густиною гексанового екстракту при 207 нм, а *A. bisporus* та штами *P. ostreatus* ІБК-551 та ІБК-1535 найінтенсивніше поглинали світло на ділянці 260–290 нм. Результати визначення органолептичного профілю та спектрофотометричного аналізу екстрактів грибів свідчать про те, що при промисловому культивуванні їстівних грибів порушується або гальмується утворення запашних речовин плодовими тілами, що призводить до зниження їх споживчої якості. Тому для підвищення попиту на культивовані їстівні гриби, аромат яких є одним з визначальних факторів їх привабливості, необхідно проводити всебічне дослідження залежності утворення запашних речовин від параметрів процесу вирощування.

Ключові слова: їстівні гриби, аромат, сенсорний профільний аналіз, УФ-спектрофотометрія.