FOOD TECHNOLOGY PROGRESSIVE SOLUTIONS

Collective monograph

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Olesia Priss

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AUTHORS

Chapter 1

Olesia Priss
Doctor of Technical Sciences, Professor
Department of Food Technology and Hotel
and Restaurant Business
Dmytro Motornyi Tavria State Agrotechnological
University
ORCID: https://orcid.org/0000-0002-6395-4202

Szymon Glowacki
Doctor of Technical Sciences, Professor
Department of Fundamentals of Engineering
and Power Engineering
Institute of Mechanical Engineering
Warsaw University of Life Sciences (SGGW)
ORCID: https://orcid.org/0000-0002-0373-6633

Chapter 2

Liudmyla Kiurcheva
PhD, Associate Professor
Department of Food Technology and Hotel
and Restaurant Business
Dmytro Motornyi Tavria State Agrotechnological
University
ORCID: https://orcid.org/0000-0002-8225-3399

Serhii Holiachuk
PhD, Associate Professor
Department of Technologies and Processing
Enterprises Equipment
Lutsk National Technical University
ORCID: https://orcid.org/0000-0002-4835-8154

Chapter 3

Kyrylo Samoichuk
Doctor of Technical Sciences, Professor,
Head of Department
Professor Fedir Yalpachyk Department
of Processing and Food Production Equipment
Dmytro Motornyi Tavria State Agrotechnological
University
ORCID: https://orcid.org/0000-0002-3423-3510

Valentyna Verkholantseva
PhD, Associate Professor
Professor Fedir Yalpachyk Department
of Processing and Food Production Equipment
Dmytro Motornyi Tavria State Agrotechnological
University
ORCID: https://orcid.org/0000-0003-1961-2149

Nadiia Palianychka
PhD, Associate Professor
Professor Fedir Yalpachyk Department
of Processing and Food Production Equipment
Dmytro Motornyi Tavria State Agrotechnological
University
ORCID: https://orcid.org/0000-0001-8510-7146

Alexandr Kovalyov
PhD, Senior Lecturer
Professor Fedir Yalpachyk Department
of Processing and Food Production Equipment
Dmytro Motornyi Tavria State Agrotechnological
University
ORCID: https://orcid.org/0000-0002-4974-5201

Dmytro Dmytrevskyi
PhD, Associate Professor
Department of Equipment and Engineering
of Processing and Food Industries
State Biotechnology University
ORCID: http://orcid.org/0000-0003-1330-7514

Dmytro Horielkov
PhD, Associate Professor
Department of International E-commerce
and Hotel and Restaurant Business
V. N. Karazin Kharkiv National University
ORCID: http://orcid.org/0000-0002-9315-9322

Vitalii Chervonyi
PhD, Associate Professor
Department of International E-commerce
and Hotel and Restaurant Business
V. N. Karazin Kharkiv National University
ORCID: http://orcid.org/0000-0002-9085-2260

Volodymyr Voitsekhivskyi
PhD, Associate Professor
Professor B. V. Lesik Department of Storage, Processing and Standardization of Plant Products
National University of Life and Environmental Sciences of Ukraine
ORCID: https://orcid.org/0000-0003-3568-0985

Chapter 4

Iryna Bandura
Doctor of Agriculture Science, Associate Professor
Department of Food Technology and Hotel and Restaurant Business
Dmytro Motornyi Tavria State Agrotechnological University
ORCID: https://orcid.org/0000-0001-7835-3293

Tetiana Krupodorova
PhD, Senior Researcher
Department of Plant Food Products and Biofortification
Institute of Food Biotechnology and Genomics
National Academy of Sciences of Ukraine
ORCID: https://orcid.org/0000-0002-4665-9893

Chapter 5

Igor Dudarev
Doctor of Technical Sciences, Professor
Professor Fedir Yalpachyk Department of Processing and Food Production Equipment
Lutsk National Technical University
ORCID: https://orcid.org/0000-0002-2016-5342

Svitlana Panasyuk
PhD, Associate Professor
Professor Fedir Yalpachyk Department of Processing and Food Production Equipment
Lutsk National Technical University
ORCID: https://orcid.org/0000-0001-9734-3998

Iryna Taraymovich
PhD, Associate Professor
Professor Fedir Yalpachyk Department of Processing and Food Production Equipment
Lutsk National Technical University
ORCID: https://orcid.org/0000-0003-4129-2671

Volodymyr Say
PhD, Associate Professor
Professor Fedir Yalpachyk Department of Processing and Food Production Equipment
Lutsk National Technical University
ORCID: https://orcid.org/0000-0002-6187-6175

Nadiia Zahorko
PhD, Associate Professor
Department of Food Technology and Hotel and Restaurant Business
Dmytro Motornyi Tavria State Agrotechnological University
ORCID: https://orcid.org/0000-0003-4828-5343

Chapter 6

Yuliia Honchar
PhD, Associate Professor
Department of Food Technology and Hotel and Restaurant Business
Dmytro Motornyi Tavria State Agrotechnological University
ORCID: https://orcid.org/0000-0002-8087-0641

Victoriya Gnitsevych
Doctor of Technical Sciences, Professor
Department of Restaurant and Craft Technologies
State University of Trade and Economics
ORCID: https://orcid.org/0000-0002-6089-1082

Chapter 7

Tetiana Kolisnychenko
PhD, Associate Professor
Department of Food Technology and Hotel and Restaurant Business
Dmytro Motornyi Tavria State Agrotechnological University
ORCID: https://orcid.org/0000-0003-0560-9520

Kateryna Sefikhanova
PhD, Associate Professor, Dean
Autonomous subdivision "Dnipro Faculty of Management and Business of Kyiv University of Culture"
ORCID: https://orcid.org/0000-0002-7921-6108

Chapter 8

Olena Danchenko
Doctor of Agricultural Sciences
Department of Food Technology and Hotel and Restaurant Business
Dmytro Motornyi Tavria State Agrotechnological University
ORCID: https://orcid.org/0000-0001-5049-3446

Daniil Maiboroda
PhD student
Department of Food Technology and Hotel and Restaurant Business
Dmytro Motornyi Tavria State Agrotechnological University
ORCID: https://orcid.org/0000-0003-4649-992X

Viktoriya Gryshchenko
Doctor of Veterinary Sciences
Department of Biochemistry and Physiology of Animals named after Academician M. F. Gulyi
National University of Life and Environmental Sciences of Ukraine
ORCID: https://orcid.org/0000-0001-6601-1392

Mykola Danchenko
PhD
Department of Higher Mathematics and Physics
Dmytro Motornyi Tavria State Agrotechnological University
ORCID: https://orcid.org/0000-0001-7555-6511

Chapter 9

Olha Sumska
PhD, Associate Professor
Department of Food Technologies
Kherson State Agrarian and Economic University
ORCID: https://orcid.org/0000-0003-1606-6103

Nataliia Panchenko
PhD
Department of Food Technologies
Kherson State Agrarian and Economic University
ORCID: https://orcid.org/0009-0004-3306-7161

Olena Ishchenko
Doctor of Technical Sciences, Associate Professor
Department of Chemical Technologies and Resource Saving
Kyiv National University of Technologies and Design
ORCID: https://orcid.org/0000-0002-9510-6005

CHAPTER 4

Qualimetric assessment and features of quality formation for cultivated mushrooms in accordance with the methods of further processing

Iryna Bandura
Tetiana Krupodorova

Abstract

Recently mushrooms, due to their special functional properties, are confidently included in the daily diet of people who consider the possibilities of nutrition to improve their health. Therefore, the production and consumption of mushrooms, as well as products of their processing, is growing rapidly, and the range of species available on the market is actively expanding. In this study, the topical issues of expanding the assortment and quality of cultivated mushrooms are highlighted, the main principles of ensuring the quality of the mushroom harvest are considered. The possibility of preserving the value of the harvest by expanding the options for processing mushrooms is also examined. The difficulties and visible prospects of expanding the range of products are considered. The monograph discusses the factors that determine the quality of the harvest of cultivated fungi of the genera *Calocybe*, *Cyclocybe*, *Pleurotus*, and the features of the qualitative assessment of mushroom raw materials in accordance with the directions of its processing. The parameters for a comprehensive assessment of qualitative indicators of fruiting bodies of *Calocybe indica*, *Cyclocybe aegerita*, *Pleurotus citrinopileatus*, *P. pulmonarius* have been established, and the coefficients of the values of individual and group indicators of crop quality have been determined. An experimental evaluation of changes in morphological parameters in the technical and biological maturity of the fruit bodies of mushrooms was carried out, and their nutritional value has been investigated. Modern methods of optimizing post-harvest procedures and storage of mushrooms determined their critical storage terms according to directions of processing. The proposed seasonal approach to the cultivation of the studied strains indicates the possibility of reducing the cost of the mushroom crop. The qualimetric assessment of the post-harvest characteristics of strains from the domestic collection makes suggests high prospects for use the studied mushrooms for visual attraction customers to expand the range of mushroom products

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on supermarket shelves. A comprehensive analysis of the proposed qualimetric assessment and the quality features of the cultivated mushrooms studied, depending on the methods of further processing, indicates the prospects of this area of research and the feasibility of bringing other species of exotic cultivated mushrooms to the market.

Keywords

Calocybe, *Cyclocybe*, *Pleurotus*, pioppino, gold oyster mushroom, lung oyster mushroom, milky mushroom, storage, processing, quality, cultivation, market.

4.1 Introduction

Mushroom consumption properties are heavily influenced by cultural and traditional habits, and even some myths. One of the scares is the fear of toxic compounds in mushrooms with bright color caps. Another myth with deep roots is the difficulty in converting mushrooms by the digestive system of young or old organisms. Furthermore, common cuisines in some European countries have a very limited number of recipes that include mushroom ingredients. At the same time, the rapidly developing cultivation of mushrooms makes it possible to expand the range of species with proven health properties and saturate the market with a variety of mushroom flavors and textures. Therefore, the organization of an open and understandable quality management system to produce fresh mushrooms and their processed products is a topical topic. Let's believe that only the continuous improvement of this system at each stage of the production cycle and the demonstration of the results obtained to the modern consumer will help to get rid of the existing prejudices regarding the introduction of mushrooms into the daily diet of people of any age.

4.2 Actual issues of expanding the assortment and forming quality of the cultivated mushrooms

On the global mushroom market, a significant increase in demand for mushrooms is observed every year. In 2022, mushroom production was ranked sixth in the list of the total value of vegetable production. According to the Global Market forecast: "Revenue in the Root Vegetables & Mushrooms market will reach 118.10 billion USD in 2024. The average volume per person in the root vegetables and mushrooms sector is expected to reach 8.9 kg market in 2024" [1].

The observed progress is due to the unique functional properties of mushrooms, which include a high protein and dietary fiber content, as well as a low-fat content.

Such a nutrient balance fully corresponds to modern trends in healthy eating and cannot but attract representatives of the food industry. In addition, the physiological features of mushroom nutrition make it possible to regulate the nutrient composition of the crop and contribute to the accumulation of essential elements in the fruiting bodies by modelling the composition of substrates and aqueous solutions used for moistening plant raw materials and technological irrigation. It should be noted that the mushroom industry is quickly responds to market needs. Ten years ago, no more than 4 types of mushrooms could be found on the shelves of vegetable stores in European countries and North America: bottom mushroom, shiitake, oyster mushroom and eryngii. Nowadays, the range offered has expanded significantly, mainly thanks to the technical solutions of Chinese researchers who have introduced, according to various sources, from 20 to 60 species of mushrooms into commercial cultivation over the past decade [2]. If desired, a modern European consumer can diversify their daily diet with fresh exotic fungi: enoki (winter mushroom), pioppino (poplar mushroom), shimeji (beech mushroom), oyster mushrooms (lung, golden, pink) and many other species. However, the high price of fresh mushrooms and short shelf life limit the use of their health-promoting potential in the daily diet of the average consumer. Modern research in practical mycology is still focused on finding ways to expand the range of edible fungi with proven biological value and the possibility of reducing harvesting costs.

4.2.1 The basic principles of ensuring the quality of mushroom crop

The expansion of the range of artificially grown mushrooms on the world market creates additional questions regarding the determination of the quality indicators of the obtained harvest. The main indicator of quality is the food safety of mushroom products, which is clearly regulated by the requirements of Codex Alimentarius. There are three standards that control the safety of fungi and their products: CXS 38-1981 – Standard for Edible Fungi and Fungus Products; CXS 39-1981 – Standard for Dried Edible Fungi and Separate Regional Standard for Wild Chanterelles; CXS 40R-1981 – Regional Standard for Chanterelles [3]. Due to the rapid expansion of the market range, the general standardization system cannot manage all requirements to quality of edible mushrooms. To develop a quality management system for the cultivation and processing of edible and medicinal mushrooms, it is significant important to identify safety issues. The analysis of published scientific data and practical studies made it possible to the develop a program that outlines the basic principles of mushroom harvest quality (**Fig. 4.1**).

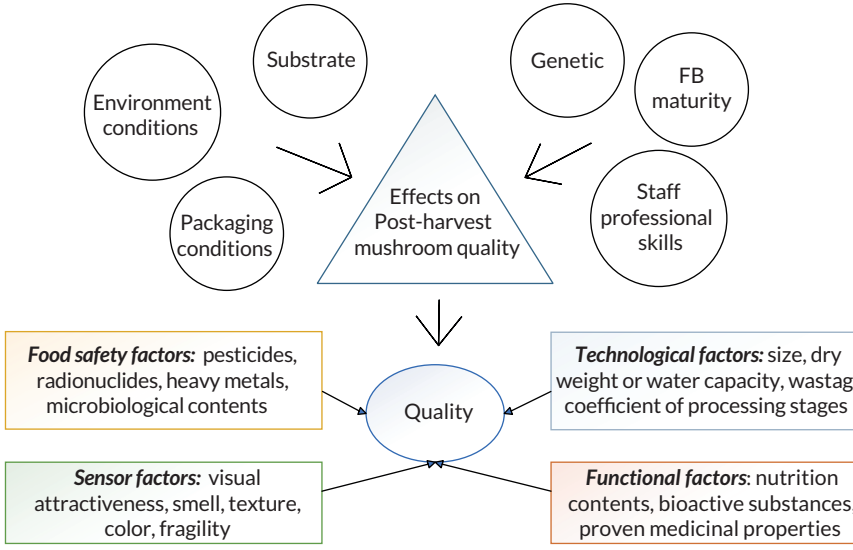


Fig. 4.1 Program of mushroom crop quality formation

According to most operators of the mushroom business, the quality of the substrates used is one of the main factors affecting the crop quality. The formula's balance of organic and mineral components, microbiological electivity, purity, and availability of raw materials are the most common factors that influence it [4, 5]. The conditions for growing mushrooms are equally important. The optimal environmental parameters for each culture are different, including temperature, humidity, lighting, and air composition [6]. The technical regulation of microclimatic conditions at each stage of mushroom culture development, considering their specific needs, is constantly being studied and improved. The shelf life of harvested mushrooms is limited. The loss of crop weight in the first hours after harvest is caused by the peculiarities of physiological processes (intensive respiration) and high enzymatic activity in fungal cells, regardless of temperature. In addition, scientists have emphasized that fruiting bodies undergo rapid changes in chemical composition and physical and microbiological deterioration during stored [7]. Clearly organization of post-harvest procedures is no less important for preserving the quality of the harvest. The organoleptic, technical, and functional properties of mushroom yield directly depend on the genetic characteristics of the cultivated species and strain. It is necessary to determine the specific time of harvesting when the appearance and biochemical composition of the fruiting bodies will meet the requirements of

the buyer or processor as much as possible. Only highly qualified personnel can implement this approach. The organization of timely analyses can be simplified through close cooperation between manufacturing companies, research centers, universities, or private laboratories.

The complexity of the qualitative assessment of the harvest lies in the need to determine the main quality indicators of mushroom products, which, first of all, must meet the requirements of the average consumer. In most cases, organoleptic characteristics are the most important elements of the evaluation. However, the formation of the pricing policy, and, consequently, the availability of mushrooms for buyers, depends primarily on the technical features of growing a particular species. As a result of the analysis of production processes at domestic and foreign enterprises for the cultivation and processing of mushrooms, ways to managing the quality of the harvest of new introduced species have been determined. Thus, following the general principle of forming complex indicators of product quality, the relative quality coefficient of a new type of crop can be determined by the formula:

$$Q_i = \frac{P_i}{P_{iSt}} (i = 1...n),$$

where P_i – value of the i-th indicator of mushroom crop; P_{iSt} – value of the i-th indicator of control (base) cultivar, for example: *A. bisporus*; n – number of indicators. It can be: P_1 – morphology or other organoleptic indicators; P_2 – dry matter (or water content); P_3 – biomass texture (dense, fibrous, delicate); P_4 – quantity of bioactive substances; P_5 – biological efficacy; P_6 – duration of the technological cycle; P_7 – terms of shelf life; P_8 – weight loss coefficients in post-harvest procedures; P_9 – market pricing policy; $P_{10...n}$ – other individual parameters.

The calculated coefficient determines the advantages (more than 1) or disadvantages (less than 1) of the implemented technology in comparison with the one already used at the enterprise. It makes it possible to consider the market reaction to a new species of mushroom, as well as the increase or decrease in production costs. The proposed formula makes it possible to analyze the features of the formation of crop quality at individual enterprises, namely:

– reasonable selection of species and strains that are of interest to the local market;

– improvement of technological solutions for the organization of microclimatic conditions;

– determination of the timing of harvesting and ways of selling the obtained mushrooms.

Local markets have specific requirements for the quality of mushrooms, which are determined by the country's consumer culture and purchasing power levels.

An individual approach is also applied to the search for technological solutions in the creation of a microclimate in the premises where mushrooms are cultivated. However, maintaining the crop quality by optimizing post-harvest procedures and processing methods are quite general that it is possible to consider in more detail.

4.2.2 Expansion of processing areas as a tool to preserve the crop value

One of the main problems of the mushroom industry is the preservation of the quality of the harvested crop, so the fruiting bodies have a short shelf life in fresh form from 2–3 days (*Hericium erinaceus* (Bull.) Pers) to a month (*Lentinula edodes* (Berk.) Pegler) [8]. Therefore, the possibilities of preserving the nutritional and biological value of mushroom crops are actively being studied. Scientists are testing improvements in post-harvest procedures post-harvesting procedures: UF lightening, modified packaging, spraying with antibacterial solution etc. One of the main ways is rapid processing into a variety of food products available to a wide range of consumers. A wide range of mushroom products, from bakery products to beverages, are already available on store shelves. Based on the results of the analysis of scientific publications containing information on the use of mushrooms in the food industry, a scheme of existing and possible processing options was drawn up (**Fig. 4.2**).

Researchers offer several options for the temperature effect on raw materials:

1) high-temperature – frying, boiling, drying;
2) low-temperature – freezing.

Baking mushrooms involves the additional use of fats, which contradicts to the general concept of a healthy eating. But today, it is a widely used approach to quick cooking of both main dishes and side dishes, as well as salads, sauces, pates. The method of frying and stewing is more often used for processing mushrooms at home and in public catering establishments: restaurants, cafes, common culinary. A separate direction of frying is the production of mushroom chips. Modern vacuum deep-frying technology can significantly reduce the fat content of such a product, making it very popular among consumers of all ages. Proponents of this processing direction are considering the possibility of balancing the nutrient composition of mushroom raw materials by introducing a fat component and making it a full-fledged component of the daily diet. The researchers emphasize the possibility of a significant reduction in microbiological objects on the surface of chips, which contributes to an increase in shelf life [9, 10]. The growing popularity of Asian cuisine has contributed to the active study of the most common method of heat treatment of mushrooms: boiling in water and steaming.

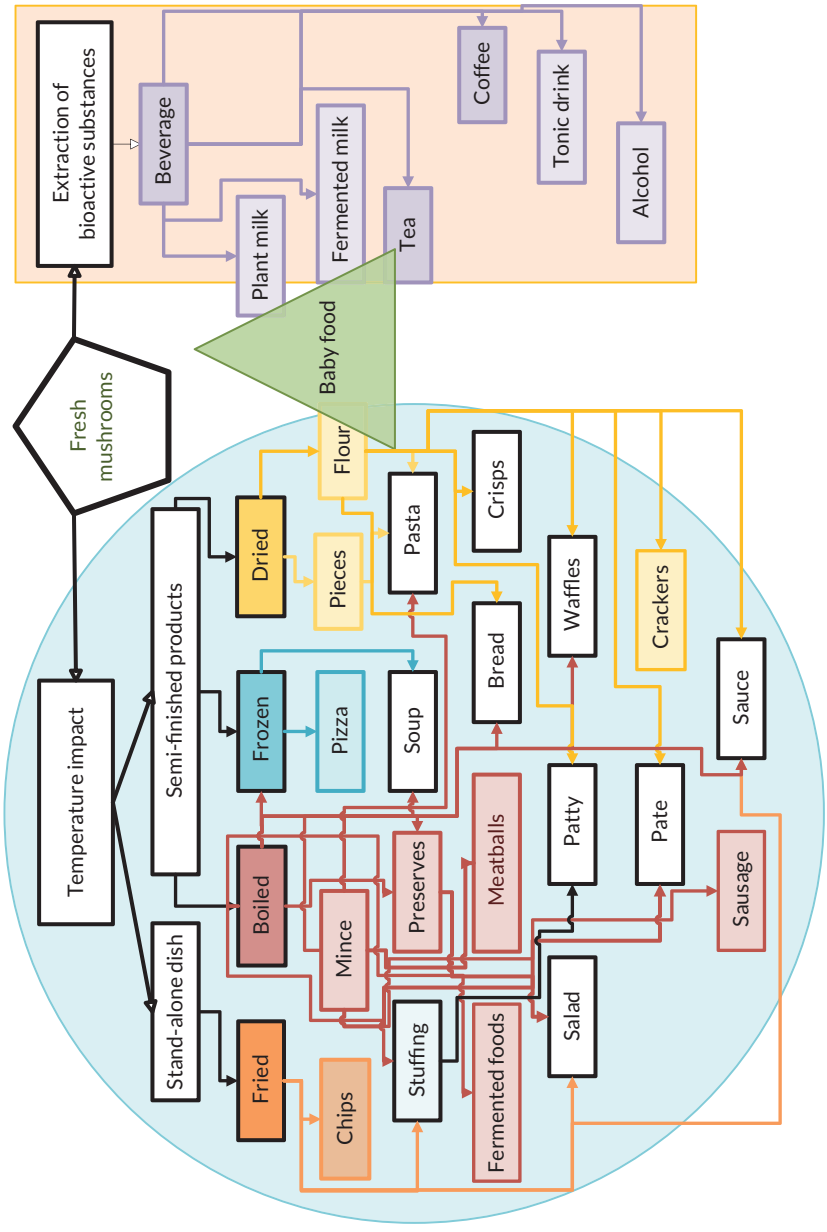


Fig. 4.2 Ways of fresh mushroom processing

Emphasizing the need to find individual solutions, the scientists argue that in order to preserve antioxidant properties, the preferred steam treatment time for *F. velutipes* was 1.5 minutes, while for *P. ostreatus* and *L. edodes* (4.5 minutes). For *A. bisporus* using a microwave oven for 1.5 minutes turned out to be the most optimal. The antioxidant value of *the P. eryngii* culture was highest in the experiment when using pressure-cooked in 100 mL of distilled water at 121 °C under 2 MPa for 15 min [11]. Blanching or short-term boiling is considered a prerequisite to produce semi-finished products, fermented mushroom products and marinades (pickles). Biological preservation of mushroom fruiting bodies using lactic acid fermentation is currently not applicable on an industrial scale; nonetheless, in the middle of the last century this method was very popular. Current research from Poland has shown the fungal raw material can be successfully preserved via lactic acid fermentation and the finished product can be an alternative to salted, marinated, or sterilized mushrooms [12]. Such products can be both independent dishes and semi-finished products, which are used in the preparation of minced meat for meat products and vegetable mixtures, fillings for pies, pate, soups, bakery products, salads, etc. Boiled or steamed mushrooms can be left whole or crushed for subsequent freezing, which allows to increase the shelf life up to 6 months [7].

Scientists do not recommend freezing mushrooms without pre-blanching or short-term boiling. Ice crystals destroy the delicate cells of the fungal tissue, which leads to a significant loss of mass and functional substances after defrosting. The deactivation of enzymes during heat treatment helps to preserve the biological value of mushrooms even during long-term storage of frozen semi-finished products (up to 12 months) [13]. For short-term storage, it is proposed to wash chopped fresh mushrooms in water containing sodium metabisulfite (5 g/l), which prevents browning of the fruiting bodies [14]. Blanched, sterilized mushrooms successfully replace frozen ones in further culinary use (soups, vegetable mixes, pies).

Drying mushrooms is considered to be the cheapest way to preserve their nutritional and biological value. Many drying methods have been studied, but the most popular is convection at temperatures up to 50 °C, as it reduces the browning of fruiting bodies and preserves their structure [15]. The proposed modern approach, which combines microwave and vacuum effects, is more expensive, but, according to the developers, makes it possible to improve the technical characteristics of the resulting semi-finished product for further use. Microwave vacuum drying made it possible to preserve a greater amount of flavor-active amino acids, as well as improve nutrient retention and color characteristics. In addition, the uniform honeycomb mesh created by microwave vacuum drying as well as the less coagulated structure of dried samples can be used to explain the observed the high rehydration factor

observed during drying [16]. The use of dried mushrooms and mushroom powders attracts the greatest attention of researchers, since the terms and conditions of storage of such semi-finished products are the most interesting for further processing. The concentration of bioactive components in dried mushrooms is much higher and is constant for a long time, which increases the possibility of regulated fortification of products for daily consumption: bakery, pasta and meat products, sauces and many other products [17, 18]. But scientists are especially attracted by the possibility of using mushroom powders to increase the health functions of baby food [19]. It has long been known about the immune-regulating and restorative effect of mushroom consumption, which is especially important in childhood and adolescence [20]. But it is also known about the low digestibility and difficulty of digestion of mushrooms in the human body. Therefore, there is a strong opinion that mushrooms and mushroom products are not recommended for those who have digestive problems and children under 12 years of age [21]. Research results confirm the safety and expediency of introducing mushroom components with a high degree of grinding or decoctions (extracts) into children's diets [22–25].

The use of aqueous and chemical extraction is one of the most used methods for obtaining bioactive ingredients of mushroom raw materials for the food industry and medicine [26, 27]. Besides conventional extraction methods, a wide range of advanced extraction technologies is available nowadays for the recovery of these bioactive ingredients from mushrooms, such as ultrasonic-assisted extraction, microwave-assisted extraction, enzyme-assisted extraction, ultrasonic-microwave synergistic extraction, subcritical water extraction, pulsed electric field-assisted extraction, aqueous two-phase extraction, integrated extraction techniques, and other novel extraction technologies [28]. Extracted fractions of mono-, oligo- and polysaccharides of mushrooms and other biologically valuable products: unique organic acids, enzymes and vitamins are successfully used in the production of various beverages [29, 30]. Unlike solid semi-finished products obtained from mushroom raw materials, extracts are easily absorbed by the human body and can be used in diets for consumers of all ages. Extracts from fruiting bodies, spore material and mycelium biomass are successfully used in the food industry.

4.2.3 Difficulties and prospects of expanding the assortment of mushroom products

Growing a variety of mushrooms is a challenging task for a farmer. As already mentioned, each species has its own characteristics that must be taken into account

when planning technological operations aimed at achieving high-quality harvest. The specific characteristics of the carpophores, which are manifested in the variety of shapes and colors of fruiting bodies, form the buyer's interest in the first place. But no less important factor for making a purchase is the affordability of mushrooms. Therefore, it is not enough to improve the visual representation of the crop on store shelves; for its successful sale, it is necessary to minimize production costs. Let's believe that one of the ways to solve such a complex issue is to cultivation of seasonal species and strains, for which the creation of optimal temperature conditions for fruiting will be the least expensive. In previous studies, 2 groups of oyster mushroom strains and pulmonary oyster mushrooms were studied, the seasonal cultivation of which made it possible to reduce the duration of technological cycles with the achievement of high biological efficiency [31]. This study examines the technological features of growing and processing four varieties of edible mushrooms in order to improve the color presentation of mushroom products on store shelves: *Calocybe indica* 2598, *Cyclocybe aegerita* 2231, *Pleurotus citrinopileatus* 2161, *P. pulmonarius* 2314. Technological regimes of growing of these strains and their impact on the biological efficiency of crops have been studied in previous studies (**Table 4.1**).

Table 4.1 Technical cultivation parameters (minimum and maximum index) according to publication data and different treatment in our previous research

Species	Days of incubation term	Days to mushroom flush	Biological efficiency, %	Fruiting temperature, °C	References
Agaricus bisporus (J.E. Lange) Imbach	13…20	18…21	49…81	14…19	[32]
Calocybe indica Purkay. & A. Chandra	19…25	4…8	90…180	25…35	[33]
Cyclocybe aegerita (V. Brig.) Vizzini	25…32	4…10	10…25	12…18	[34]
Pleurotus citrinopileatus Singer	18…30	5…8	53…85	14…28	[35]
Pleurotus ostreatus (Jacq.) P. Kumm	12…25	4…8	30…97	8…28	[36]
Pleurotus pulmonarius (Fr.) Quél	11…15	2…5	52…96	16…28	[37]

In comparison with the main cultivars of the European region: bottom and oyster mushroom (*A. bisporus* and *P. ostreatus*), it was found that the qualimetric assessment of habit and texture of fruiting bodies in the studied strains was higher. The duration of the vegetative growing period in the presented species did not exceed, and for *P. pulmonarius* 2314 it was significantly shorter than the average indicators of other species. The highest biological efficacy was recorded in the case of *C. indica* 2598

cultivation, the lowest for *C. aegerita* 2231, although in data published by other researchers these indices are higher or at the level of the main cultivars (**Table 4.1**). A significant advantage of the studied strains is the reduction of costs for maintaining the microclimate. The bright fruiting bodies of *C. aegerita* and *P. citrinopileatus* can be obtained at a temperature of 12...16 °C, and in the hot summertime produce *P. pulmonarius* and tropical mushroom *C. indica*, capable of bearing fruit at a temperature of 28 °C. It is logical that the introduction of new, species unfamiliar to the buyer will require initial marketing efforts, and the volume of their sales in fresh form is likely to be significantly lower than those of bottom or oyster mushrooms. Accordingly, the problem of maintaining the quality of the crop and finding ways to process new cultivars in a timely manner is quite acute. Therefore, the purpose of the experimental study was to conduct a qualimetric assessment of the post-harvest indicators of edible mushrooms *C. indica* 2598, *C. aegerita* 2231, *P. citrinopileatus* 2161, and *P. pulmonarius* 2314.

4.3 Experimental evaluation of crop quality preservation features of *C. indica* 2598, *C. aegerita* 2231, *P. citrinopileatus* 2161, and *P. pulmonarius* 2314

4.3.1 Materials and methods

4.3.1.1 Spawn

Pure cultures of mushrooms were obtained by cutting pieces of trama from the inner parts of the carpophores and transferring them to agar medium with malt extract and incubated for 14 days at 25 °C. Pure cultures were deposited at the IBK Mushroom Culture Collection of the M. G. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine, which is officially recognized as the national heritage of the country. They were maintained on 3 % malt extract agar medium and stored at 4±1 °C (*C. aegerita* 2231, *P. citrinopileatus* 2161, *P. pulmonarius* 2314), at 16±2 °C for *C. indica* 2598, because it is not thermoresistant strain. Some cultures days (*P. citrinopileatus* 2161, *P. pulmonarius* 2314) were incubated 7 at 24 °C, and at 30 °C for culture *C. indica* 2598. Only *C. aegerita* 2231 required 10 days under 24 °C for fulling Petry dish surface. Actively growing mycelia was used for mycelia spawn preparation, which contained barley, wheat, rape, flax, and chalk ($CaCO_3$) combined in the ratio 60:30:8:1:1 [38]. Pre-cooked barley and wheat, pre-soaked rapeseeds, flaxseeds, and chalk were properly mixed before loading (6 kg) into polypropylene

bags of size (570×470 mm), PP75/BEU6/X47-57 (Sac02, Belgium). The bags were sterilized at 128 °C, 1.8 atm for 3 h. Upon cooling, the sterile grain mixture was inoculated with mother spawn (0.5 % w/w), sealed, and incubated at 22 °C (*C. aegerita* 2231, *P. citrinopileatus* 2161, *P. pulmonarius* 2314) and 30±1 °C (*C. indica* 2598) for six or seven days, followed by shaking and thorough mixing to achieve uniform mycelia colonization throughout the bag. After 8±1 days for *P. citrinopileatus* 2161 and *P. pulmonarius* 2314, and 10±1 days for *C. indica* 2598 and *C. aegerita* 2231, the resulting spawn and was ready. Spawn of *C. aegerita* 2231, *P. citrinopileatus* 2161 and *P. pulmonarius* 2314 was cooling to 10±1 °C and after that placing in refrigerator and storing at 2±1 °C until use. Grain mycelium of *C. indica* 2598 stored at 15±1 °C.

4.3.1.2 Substrate

The substrate was made from barley straw, sunflower husk, sunflower husk pellets, rapeseeds, corn flour, and chalk combined in the ratio 30:40:70:20:17:1 and water content adjusted to 68±1 %. The substrate was packed into 580×480 mm polypropylene bags with four 20×480 mm filter strips located 150 mm apart on one side of the bag. The substrate was sterilized for 2 h at 125±1 °C, cooled under aseptic conditions to 28±1 °C, and inoculated with spawn (5 % w/w). The bags were sealed, and the spawn was carefully mixed in by shaking to achieve even distribution throughout the substrate. The average weight of each substrate bag inoculated with spawn was 3330±123 g. 30 bags with substate used for each treatment.

4.3.1.3 Incubation

The substrates with mushroom cultures were incubated under 24±2 °C and 65 % air relative humidity (RH) during different time for each cultivar *C. aegerita* 2231 at 28±3 days, *P. citrinopileatus* 2161 – 18±2 days, *P. pulmonarius* 2314 – 12±1 days to start of pinning. Illumination was not applicable. The substrates with *C. indica* 2598 were incubated at 28±2 °C, and the average temperature inside the substrate bags was to 34±1 °C. On the 19th day, the bags were transferred to the fruiting chamber, opened, leaving a 6–7 cm high rim and applicated 30 mm casing from peat moss, which was soaking to 75 % water content. The casing layer was moistened with water at the rate of 100 ml per 0.047 m^2 every 48 hours. After casing, the following microclimate parameters were maintained in the fruiting room: temperature 29±3 °C, RH=91±4 %, CO_2 content 1520±310 ppm, and illumination 150±30 lux.

4.3.1.4 Fruiting

The environment conditions for fruiting formation supported under optimal parameters for each cultivar. It was for *C. aegerita* 2231 and *P. citrinopileatus* 2161 at 16±2 °C, RH – 96±2 %. CO_2 – 1150±150 ppm (0.11 %), illumination was 150–200 lux during no less 8 hours per day. Fruiting of *P. pulmonarius* 2314 started without temperature changing at 24±2 °C, RH – 90±2 % CO_2 – 900±150 ppm. For *C. indica* 2598 fruiting the microclimate did not change after casing. In previous studies, a significant influence of the harvest time of 2 groups of *P. ostreatus* and *P. pulmonarius* strains on their technical, chemical and organoleptic indicators was revealed [31]. Therefore, for the studied cultivars, first of all, the possibility of harvesting at different stages of maturity was determined. The *P. pulmonarius* 2314 strain, which has been studied in previous experiments, has been designated as the baseline. Fruit bodies cropped in two maturates stage: before sporulation (technical) and when sporulation had started (biological). The total weight of the fruiting bodies obtained from each bag. The weight, the diameter (for *C. aegerita* 2231 and *C. indica* 2598, *P. citrinopileatus* 2161) and thickness of the caps, the height and width of caps for *P. pulmonarius* 2314 (because cap has oyster shape); the diameter and height of the stipe were measured for 100 fruiting bodies randomly. The biological efficiency (BE) was calculated for each flush as the total weight of fruiting body yield per flush divided by the dry weight of starting substrate (SW) multiplied by 100 % [39].

4.3.1.5 Storage and processing

The freshly harvested fruiting bodies were quickly cooled with active ventilation in a refrigerator with a temperature of 2±1 °C. Stored for no more than a day before processing: boiling or drying. After 12 hours of such storage, the fruiting bodies of *C. indica* 2598 were damaged, began to drain, lose elasticity, and the surface darkened (**Fig. 4.3, *f***). Therefore, in further studies, fresh *C. indica* fruiting bodies were used for processing, which were stored at a temperature of 14±1 °C for no more than a day. Boiled mushrooms (300 g) in boiling water for 5 minutes, cooled and let the water drain on a sieve, after 10 minutes the resulting sample was weighed. Drying was carried out by convection method at a temperature of 60±5 °C for 6 to 12 hours to a constant weight. Dried samples were ground to particles less than 1 mm and used for further analyses. It was stored for no more than 2 weeks at a temperature of 4±1 °C in a hermetically sealed container. The repetition of each experiment is threefold.

4.3.1.6 Nutritional and chemical analysis

Fresh fruiting bodies were dried at 45–50 °C until constant weight, followed by grinding to particles less than 1 mm in diameter. The resulting powder was further dried in an oven at 92 ± 2 °C to obtain absolute dry weight. The percentage moisture content in fruiting bodies was calculated as the difference in weight between fresh and absolute dry weight of fresh mushrooms multiplied by 100 %. The ash content was determined by weighing 3 g of absolute dry fruiting body powder into ceramic crucibles of known weight, burn in the oven (550 ± 10 °C) for three hours, and cooled in a desiccator. The difference in weight between the leftover and starting dry fruiting body material in the crucible is the ash content expressed in percentage. Total nitrogen was determined by Kjeldahl method multiplied by a factor of 4.38. The lipids content was determined by extraction from the mushroom sample (absolute dry) with petroleum ether as a solvent, using a Soxhlet apparatus (AOAC, 1995). The carbohydrate content was determined according to the formula: 100 – (percentage proteins, lipids, and ash combined).

4.3.1.7 Statistical data analysis

Statistical data analysis was performed using Microsoft Office Excel 2016 MSO (16.0.4266.1001). The ANOVA Single Factor was used for comparing variable data. Differences were considered significant at $p < 0.05$. The repetition of each experiment is threefold.

4.3.2 Morphological changes during technical and biological maturity

The external characteristics of the fruiting bodies changed significantly during the onset of sporulation (**Table 4.2**).

In all cultivars, the edge of the cap was thinned, but the pigmentation of its surface decreased to varying degrees, and the lamellae of the hymenal layer darkened. The flesh of the cap became looser with the onset of biological maturity. Common to all strains were changes in the structure of the legs: they became more rigid and fibrous.

The appearance of the baseline (control) *C. indica* 2598 and *P. pulmonarius* 2314 changed slightly with age (**Fig. 4.3**). It should be noted that due to the decrease in turgor in the pulp cells, the fruiting bodies *of C. indica* 2598 became less elastic, and when mechanically pressed during harvesting, slightly visible watery spots were

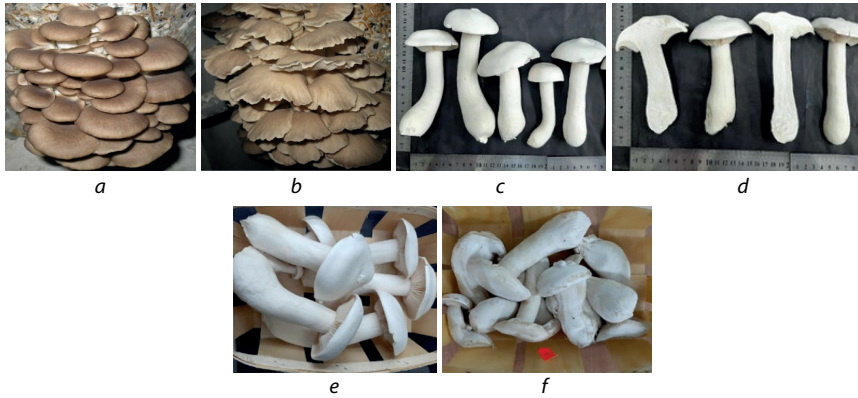
formed on the stems. In general, the qualitative characteristics of the fruiting bodies of these two strains in of varying degrees of maturity remained satisfactory.

Table 4.2 Morphological descriptions of mushroom crop with different maturities

Parameter	Maturity	Species and strains			
		Calocybe indica 2598	*Cyclocybe aegerita* 2231	*Pleurotus citrinopileatus* 2161	*Pleurotus pulmonarius* 2314
1	2	3	4	5	6
Cap shape	Technical	Round, convex, symmetrical, sometimes having a slight elevation in the center, and its edge is smooth and dense	Round, convex, with downturned edges, connected by a vail to the stipe	Rounded, with clear edges, and deepening in the center	Rounded, rarely slightly oystered, the width is always almost equal to the height, with even, firm edges
	Biological	Round, flattened, the edge is thin, sometimes with small cracks up to 1–3 mm deep	Round, flat or slightly convex, edges smooth, sometimes with remnants of a pieces of vail on the edges	Rounded, sometimes with a slightly offset center and wavy, brittle edges	Oyster, wider than height, edges loose, slightly wavy, sometimes curved upwards
Cap color	Technical	The color is milky white, matte, and free of any blemishes or tints	The color ranges from dark brown to bright brown, sometimes with a lighter edge and velvety	The color is yellow, but the center is more intense	The surface is uniformly gray-brown, with a slight lighter color at the stipe attachment point
	Biological	Milky with a slight yellowness, less saturated at the edge of the cap	Light brown – darker in the center and almost white on the edge	Light yellow at the edge, more intense in the center, sometimes with dark watery spots	Lighter shade compared to biological maturity, noticeable ripples in the form of darker and more loopy areas, especially along the edge of the cap
Hymenium color	Technical	Milky white, matte. The gills are translucent in the light	Pinkish-white, gills are translucent	Transparent white, with a slight boogie tint	White, with a slight beige tint
	Biological	Pinkish with a beige tint, intense	Brown, rich, velvety	Light beige, with a slightly pinkish tint	Beige, "dirty" due to slight unevenness

Continuation of Table 4.2

1	2	3	4	5	6
Stipe properties	Technical	Long, dense, elastic, but not fibrous, with no visible differences in density around the perimeter	Dense, elastic, does not break well, tightly connected to the cap	Dense but not rigid, with centric or slightly asymmetrical attachment to the cap	Short, fibrous, but not rigid, asymmetrical attachment to the cap, hymenium smoothly transitions to the stem
	Biological	The enlarged lower part is slightly compacted, at the point of attachment to the substrate	Fibrous, easily detached from the cap, covered with scales up to 1 mm	The loose tissue of the stipe becomes denser, especially around the perimeter	With age, it does not increase or thicken, does not become stiffer



a *b* *c* *d* *e* *f*

Fig. 4.3 Changes in mushrooms with age: *P. pulmonarius* 2314 fruiting clusters in the technical (*a*) and biological (*b*) maturity; *C. indica* 2598 whole (*c*) and cutting fruiting bodies (*d*); carpophores after day storage at 14±1 °C (*e*) and at 2±1 °C (*f*)

The fruiting bodies of *P. citrinopileatus* 2161 became brittle and crumbled at the base of the stalk. In the fruiting bodies of *C. aegerita* 2231, with the onset of biological maturity, the cover was torn, and the cap was easily separated from the stem during harvesting. The shedding of dark spores caused the surface to turn brown, which spoiled the appearance of the crop. Therefore, the cultivars *C. aegerita* 2231 and *P. citrinopileatus* 2161 should only be harvested at the stage of technological maturity. Increased temperatures during the fruiting period contribute to the acceleration of physiological processes in the fruiting bodies of fungi, which, accordingly, leads to

rapid ripening. Therefore, in order to preserve the quality of the crop, *P. pulmonarius* 2314 is harvested 2–3 times a day. It is possible to recommend the same approach when growing *C. indica* 2598.

The morphological features of the fruiting bodies were analyzed, the variability of which in the samples did not exceed 20 %, which indicates the satisfactory constancy of this indicator of the quality of the harvest for all studied varieties (**Table 4.3**).

Table 4.3 Morphological characteristics of fruiting bodies (technical maturity)

Species, strain	FB weight, g	FB height, mm	Stipe length, mm	Stipe diameter, mm	Cap diameter, mm
C. indica 2598	84.7±4.8	130.1±5.9	100.7±1.31	34.2±1.1	80.6±1.9
C. aegerita 2231	5.5±0.6	78.2±2.3	68.6±2.1	8.3±0.3	28.6±1.2
P. citrinopileatus 2161	10.5±0.9	74.6±1.7	45.5±2.1	12.2±0.7	51.2±2.3
P. pulmonarius 2314	3.5±0.2	38.5±1.0	18.6±0.8	5.6±0.2	41.1±1.4

The fruiting bodies of *C. indica* 2598 had the highest weight, which ranged from 20 to 380 g in isolated cases, while more than 80 % of the crop consisted of fruiting bodies weighing from 55 to 127 g. Let's assume that such differences will make it possible to influence the visual perception of the assortment of mushrooms on supermarket shelves and, thus, attract the attention of customers.

4.3.3 Nutritional value of fruiting bodies

Cultivars recommended for summer cultivation significantly ($p<0.05$) differed in a higher content of dry substances in fruiting bodies in comparison with the conditional "winter" group of studied strains (**Table 4.4**).

Table 4.4 Chemical composition of cultivars

Species, strain	Dry matter, %	Contents, % (DW)			
		Crude proteins	Lipids	Carbohydrates	Ash
C. indica 2598	11.02±0.51	12.31±0.37	5.27±0.66	74.75±0.83	7.63±0.21
C. aegerita 2231	8.49±0.49	19.36±0.17	2.59±0.08	70.73±0.04	7.33±0.25
P. citrinopileatus 2161	8.54±0.05	21.46±0.51	1.56±0.23	68.33±0.31	8.64±0.08
P. pulmonarius 2314	11.17±0.22	18.75±0.63	1.12±0.13	72.81±0.27	7.11±0.03

At the same time, there were practically no differences in this indicator within these conditional groups. The fruiting bodies of *P. citrinopileatus* 2161 (21.46±0.51 %) had the highest protein content, while *C. indica* 2598 had the lowest protein content in the experiment (12.31±0.37 %). *C. indica* 2598 had the highest fat content (5.27±0.66 %), which is 4.7 times higher than that of *P. pulmonarius* 2314, which had the lowest score (1.12±0.13 %), and 2 times *C. aegerita* 2231. The total carbohydrate content ranged from 74.75±0.83 % (*C. indica* 2598) to 68.33±0.31 % (*P. citrinopileatus* 2161), however, no significant differences were found between other strains. The highest ash content among the studied cultivars was found in the fruiting bodies of *P. citrinopileatus* 2161 (8.64±0.08 %), while the lowest in *P. pulmonarius* 2314 (7.11±0.03). The ratio protein/fat/carbohydrate nutrients were different for the studied strains 2:1:14 (*C. indica* 2598), 7.5:1:27 (*C. aegerita* 2231); 14:1:44 (*P. citrinopileatus* 2161); 17:1:65 (*P. pulmonarius* 2314) and but all had in common a low-fat content. It should also be taken into account that the amount of easily digestible carbohydrates in mushrooms does not exceed 0.1 % [40]. Such a balance makes it possible to use mushrooms and products of their processing in low-calorie diets that meet the general trends in the development of the modern food industry.

4.3.4 Determination of the yield coefficient of semi-finished products in different processing options

To establish an integral quality indicator that incorporates the costs of obtaining the final product, it is necessary to have a precise forecast of losses at every stage of raw material processing. For the studied strains, the greatest losses at the purification stage were found during the processing of the *C. indica* 2598 crop – 7.3 % and *P. citrinopileatus* 2161 – 7 %, while during the cleaning of the clusters *P. pulmonarius* 2314 lost no more than 1 % of the weight of the collected mushrooms (**Table 4.5**).

Table 4.5 Yield coefficients of semi-finished mushroom products processing stages

Species, strain	Cleansing	Boiling	Drying
C. indica 2598	0.927±0.021	0.798±0.009	0.088±0.007
C. aegerita 2231	0.956±0.004	0.803±0.006	0.092±0.005
P. citrinopileatus 2161	0.930±0.011	0.853±0.019	0.098±0.006
P. pulmonarius 2314	0.991±0.017	1.095±0.028	0.090±0.003

Let's attribute this to the lack of a cluster base in this strain, which makes it possible to easily separate the fruiting bodies from each other for pickling or drying. The increased weight loss of *C. indica* 2598 during cleaning depends on the need to remove the remaining casing soil from the base of the stem. Short-term boiling of *P. pulmonarius* 2314 mushrooms was accompanied by a slight increase (up to 1 %) in the mass of processed raw materials due to moisture retention by loose tissues of fruiting bodies. Perhaps this is due to the high content of water-soluble components, the need to determine which is dictated by the possibility of using mushroom decoctions to make broths or obtain extracts. The highest loss rate is typical for the processes of obtaining dry semi-finished mushroom products. Thus, the drying of *C. indica* 2598 led to a decrease in the weight of the crop by 91.2 % (the maximum indicator in the experiment), and the smallest losses were recorded when the fruiting bodies of *P. citrinopileatus* 2161 (90. 2 %) were dried. In general, the highest losses of raw materials were identified in the processing of the *C. indica* 2598 crop, and the lowest in the case of the control strain.

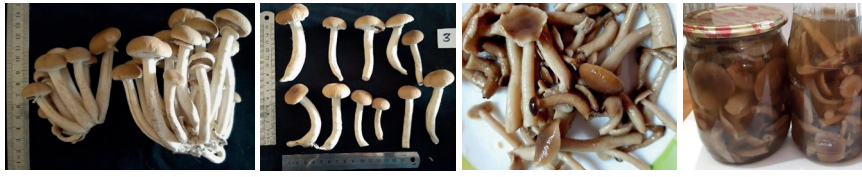
It is necessary to note the change in the organoleptic characteristics of the studied strains after boiling. For example, the fruiting bodies of *P. citrinopileatus* 2161 changed their bright yellow color to beige (**Fig. 4.4**), which indicates that it is inexpedient to use this cultivar for the preparation of marinades in transparent glass containers. However, the boiled fruiting bodies of this strain acquired a pleasant aroma of seafood, and the broth turned a pleasant yellow color. Such changes, in our opinion, restaurateurs will be interested in making main dishes: soups, side dishes, as well as minced meat, fillings, pâtés. The powder obtained from the dried mushrooms of this strain had pleasant yellow hue and aroma, which makes it possible to use it as a natural coloring and flavoring agent in the creation of sauces, pasta and bakery products.

The fruiting bodies of *C. aegerita* 2231 did not lose their color and elasticity after boiling. "Crispy", with a rich mushroom aroma – they were most suitable for pickling (**Fig. 4.5**). At the same time, minced meat from this raw material was tender and elastic but had a dark brownish tint. Dried mushrooms were easily crushed, the powder had a brownish hue, a pleasant mushroom aroma. Semi-finished products obtained from the crop *P. pulmonarius* 2314 had similar organoleptic characteristics. After boiling, the fruiting bodies did not lose pigmentation on the surface of the cap, remaining elastic, and were easily chewed. The consistency of the minced meat was homogeneous, like minced meat from *C. aegerita* 2231. The aroma was neutral, unsaturated, which, in our opinion, makes it possible to use such raw materials as a filler and a partial replacement of the meat component in cutlets, sausages and pâtés. It should be noted the high moisture-holding capacity of such a semi-finished product. Powder from *P. pulmonarius* 2314 had a light gray hue and a faint, barely perceptible aroma. Therefore, the harvest of these mushrooms is most suitable

for pickling, the manufacture of meat and vegetable semi-finished products and finished products, but to a lesser extent for sauces and fillings.

a *b* *c* *d*

Fig. 4.4 *Pleurotus citrinopileatus* 2161 clusters (*a*) and carpophores (*b*) and changing of carpophore color after of 3 minutes (*c*) and 10 minutes (*d*) boiling



a *b* *c* *d*

Fig. 4.5 *Cyclocybe aegerita* 2031 clusters (*a*) and carpophores (*b*) and carpophores after of 10 minutes boiling (*c*) and as pickles with 2 % acetic acid (*d*)

The large fruiting bodies of *C. indica* 2598 must be crushed before processing, which negatively affects the visual perception of marinades. It is also necessary to consider that heat treatment for more than 5 minutes makes the flesh of these mushrooms tough. The minced meat was coarse-grained, dense, and difficult to mix with other ingredients. The most successful method was the quick blanching of slices or bars with a thickness of no more than 5 mm, instant salads, sauces and first courses. The powder from the dried fruiting bodies did not have a pronounced mushroom aroma, it was fine-grained, almost airy. Thus, the processing of the crop of this cultivar can be more successful in the direction of the production of blanched semi-finished products for restaurants and cafes, as well as powders used in the future to produce sauces, pasta and bakery products.

Conclusions

In recent decades, mushrooms, due to their special functional properties, are confidently included in the daily diet of people who consider the possibilities of

nutrition to improve their health. Therefore, the production and consumption of mushrooms, as well as products of their processing, is growing rapidly, and the range of species available on the market is actively expanding. The organization of a system for assessing the quality of the mushroom harvest and products made from it is a complex process, since, in addition to food safety, it must consider the peculiarities of the morphology and physiology of the cultivars, individual changes during storage and heat treatment process, and, in addition, constantly changing market preferences. Main indicators for a complex estimate of mushroom crop quality for future processing procedures include safety characteristics, organoleptic indicators, dry matter (or water content), and biomass texture (dense, fibrous, delicate). One way to solve the problem of preserving the quality of mushroom crop, which has a limited shelf life, is to expand the ways of its processing. This investigation presents the results of the study of morphological, technical, and chemical indicators of the harvest and processed products of edible fungi *Calocybe indica* (milky mushroom), *Cyclocybe aegerita* (pioppino), *Pleurotus citrinopileatus* (golden oyster mushroom), and *Pleurotus pulmonarius* (lung oyster mushroom). The qualimetric assessment of the post-harvest characteristics of strains from the domestic collection makes suggests high prospects for use the studied mushrooms for visual attraction customers to expand the range of mushroom products on supermarket shelves. The proposed seasonal approach to the cultivation of the studied strains considers the possibility of reducing the cost of the mushroom crop. A comprehensive analysis of the proposed qualimetric assessment and the quality features of the cultivated mushrooms studied, depending on the methods of further processing, indicates the prospects of this area of research and the feasibility of bringing other species of exotic cultivated mushrooms to the market.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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