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Qualitative characteristics of the fungus *Cyclocybe aegerita* strains 2229, 2230, 2231 IBK under industrial cultivation conditions

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Abstract. Poplar mushroom is characterised by attractive fruiting bodies in terms of appearance and taste. *Cyclocybe aegerita* mushrooms are also known to contain unique substances, including proteins, polysaccharides, and aromatic substances with proven nutritional value and medicinal effects. However, the lack of a sound cultivation technology using available plant material limits the saturation of the domestic market with mushrooms of this species. Three strains of *C. aegerita* from the IBK National Collection of Agaricale Cultures of the Institute of Ecology and Natural Resources were studied for their potential introduction into commercial culture. It was determined that strains 2230 and 2231 have a vegetation cycle of 42 days compared to 46-64 days for the previously studied strains. The highest yield in the experiment was obtained for strain 2231, which ranged from 217 to 220 g per kilogram of a substrate over three cultivation cycles. The biological efficiency of the strains according to the results of the first wave of fruiting ranged from 20.2 (2229) to 60.4% (2231), which is consistent with the published data of other researchers. The appearance and parameters of the fruiting bodies of the strains, which differed in both the colour of the pileus and the size, were described in detail. Under microclimatic conditions of the experiment, strains 2230 and 2231 had a rich brown colour of pilei, while the formed fruit bodies of strain 2229 were distinguished by a pleasant milky cream colour. The largest fruiting bodies in terms of weight were obtained by cultivation of strain 2229 (7.5 ± 0.4 g), which is on average 2 g higher than the weight of mushrooms of other studied strains. The highest fruiting bodies were discovered in strain 2230 having a height of 91.0 ± 1.8 mm, which also had the widest pilei with a diameter of 29.5 ± 0.9 mm. The largest stem diameter, which reached an average of 10.8 ± 0.3 mm, was detected in the fruiting bodies of strain 2229. This study investigated the variability of morphological traits and identified trends in the number of fruiting bodies of a certain size in the total volume of collected mushrooms, which facilitates the design of packaging and marketing campaigns

Keywords: poplar mushroom, vegetation cycle, yield, biological efficiency, morphological characteristics, artificial cultivation

RELEVANCE

Cyclocybe aegerita (V.Brig.) Vizzini (synonyms *Agrocybe aegerita*, *C. cylindracea*), is commonly known as “black poplar”, “pioppino mushroom”, or “poplar mushroom”. Although this mushroom is quite rare on the Ukrainian market, it is widely cultivated worldwide on substrates made from crop waste and processing of industrial crops as an edible and bioactive substance producer (Chang & Wasser, 2017; Diyalanage *et al.*, 2008; Huaqi *et al.*, 2004; Muthu *et al.*, 2014). Ordinary consumers value it for its distinctive rich flavour attributed to the presence of 11 aromatic compounds (Surup *et al.*, 2019). The medicinal

properties of this variety attract the attention of healthy food connoisseurs and professional manufacturers of bioactive supplements (Diyalanage *et al.*, 2008; Jing *et al.*, 2018; Landi *et al.*, 2017; Stránský *et al.*, 2010; Zhao *et al.*, 2003). This may be the reason why the current price of poplar mushrooms is 2-6 times higher than the price of champignons, which makes it an attractive crop for mushroom producers (Mulderij, 2016). The species has a high edible and medicinal value, so growing this crop in industrial volumes with a satisfactory quality of fruit bodies will make it possible to replenish the modern market

of functional products with an important source of unique compounds that have a natural antibiotic, Gerontological and antioxidant effect (Jing et al., 2018; Landi et al., 2017; Lo & Cheung, 2005; Stránský et al., 2010).

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The poplar mushroom is a widespread species, which has been recorded on all continents, although it is less common in northern latitudes. It grows on living trees or dead trunks of deciduous trees of the genera *Populus*, *Salix*, *Quercus*, *Ulmus*, *Acer* and *Robinia* (Frings et al., 2020; Uhart et al., 2008). The international scientific literature contains sufficient evidence on the technical characteristics and morphological features of natural and commercial strains of this species, but data on Ukrainian research on the cultivation of *C. aegerita* is extremely limited. The natural diversity of poplar mushroom ecotypes causes heated discussions about the identification characteristics of this species and introduces significant inconveniences for its introduction into commercial culture. The results of studies on *Cyclocybe aegerita* and *Agrocybe aegerita* have already been unified in scientific databases, as these names are used synonymously. However, after analysing the genetic DNA domains of the fruiting bodies of the genus *Cyclocybe*, scientists combine this species into one group with *C. cylindracea* and argue that their genomes are homogeneous, and therefore that certain phenotypic traits are similar. (Frings et al., 2020; Niveiro et al., 2020; Vizzini et al., 2014.)

Currently, the catalogue of the IBK National Collection of Cultures of Agaricales of the M.G. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine, latest edition (2016), contains 14 strains of *C. aegerita* and 1 strain of *C. cylindracea* (DC.) Vizzini & Angelini, none of which have been used in domestic

industrial cultivation, although the results of a study on the biology and physiology of this culture have been published (Bisko et al., 2012; Buhalo et al., 2011; Bisko et al., 2016).

Based on the analysis of recent studies and publications, certain features of the practice of artificial cultivation of *C. aegerita* have been identified:

1) Substrate formulas are based on sawdust, straw, corn cobs, cotton ginning waste, etc.; enriched with bran, phosphorus fertilisers, and gypsum or chalk as a source of calcium (Cheong et al., 2010; Huaqi et al., 2004; Jun-long, 2006; Siwulski et al., 2019);

2) incubation is carried out at the optimum temperature for physiological growth of 25-27°C; according to published data, an increase in temperature to 26°C during the last half of the incubation period increases the yield by 25% (Cheong et al., 2010; Landingin et al., 2020; Xing et al., 2004);

3) the optimal temperature for initiating the formation of fruit bodies is 11-16°C, but for some strains this process occurs at temperatures above 16, sometimes even over 26°C (Fujisawa, 2002; Xing et al., 2004);

4) the yield and quality characteristics of fruit bodies are influenced by the composition of the substrate composition, growing temperature, light intensity, etc., so the advancement of artificial cultivation technology of this species is to identify new, promising strains with high biological efficiency of disposal of available plant residues for industrial cultivation and to determine the optimal microclimate conditions that provide the highest productivity (Bandura et al., 2020; Heo et al., 2019; Isikhuemhen et al., 2009; Uhart et al., 2008).

Purpose of the study. From the findings of modern scientific research, it becomes clear that the search for new strains that are promising for commercialisation and biotechnological

use is an urgent issue for practical mushroom growing around the world. Therefore, the purpose of the present study was to determine the qualitative characteristics of three strains grown on substrates from local plant residues at existing farms in Ukraine. The possibility of introducing the strains into industrial production was substantiated based on the results of the analysis of technical characteristics: length of the vegetation cycle, yield, and biological efficiency. Morphological characteristics of fruiting bodies were studied: weight, size, external features of the strains to form characteristics of their quality indicators.

MATERIALS AND METHODS

Cultures of three strains of *C. aegerita* 2229, 2230 and 2231 IBK were obtained from the National Collection of Agaricale Cultures of the M.G. Kholodny Institute of Botany and maintained on a nutrient medium of the following composition: agar-agar – 20 g, malt dextrose – 30 g, fermented dry peptone or dry yeast extract – 2 g; water – up to 1 litre; pH was adjusted to 6.7 ± 0.2 by adding 0.1N KOH solution dropwise. The nutrient medium was sterilised for 35 minutes at a temperature of 121°C (Dudka *et al.*, 1982).

The substrates were sterilised in an industrial autoclave at a temperature of $124 \pm 1^\circ\text{C}$ (pressure – 1.4-1.5 atm) in polypropylene bags with four air filters. The bags were filled with a substrate weighing 3120 ± 150 g and wrapped so that during sterilisation steam would enter the substrate. Rapeseed was added to the substrate composition from a mixture of plant residues (barley straw and sunflower husk). The efficiency of this composition for *C. aegerita* 2230 culture was identified in previous studies (Bandura *et al.*, 2018; Bandura *et al.*, 2020; Bandura *et al.*, 2021).

Inoculation of the substrate with 1% (by weight) of grain mycelium and incubation was carried out under aseptic conditions of the

controlled microclimate of the laboratory for the production of sowing grain mycelium of LLC SPE “Gribnyi Likar” (Sadove, Melitopol district, Zaporizhzhia o blast). The incubation temperature was $24 \pm 1^\circ\text{C}$; the air humidity in the room was maintained at $67 \pm 2\%$; the CO_2 content was 1200 ± 150 ppm.

The effectiveness of strains and features of cultivation were studied at the facilities of three enterprises: LLC SPE “Gribnyi Likar”, LLC “ES-MASH-3” and LLC “Fungoterra” (Kyiv) during three growing cycles from February to May 2020 using the same batches of plant material from the 2019 harvest. After incubation for 25 days (first cycle), 28 days (second cycle), and 32 days (third cycle), the packages of 50 pieces of each strain were delivered to the cultivation chambers of the enterprises in closed form and placed on the shelves randomly. An incision was made along the top of the bag and the polypropylene film was turned sideways, forming a narrow hole 10-25 mm wide at a distance of 100-150 mm above the surface of the substrate (Bandura *et al.*, 2021). The microclimate conditions were maintained in accordance with the optimums determined by previous studies: air temperature $16-18^\circ\text{C}$, humidity 90-93%, carbon dioxide content up to 1300 ppm; lighting at 500-600 lux (Stamets, 2000).

The duration of the vegetation cycle was determined by the number of days from inoculation to the date of harvesting the fruiting bodies.

The yield was calculated by the weight of fresh fruit bodies of the first fruiting wave relative to the initial weight of the substrate (before incubation) for each package.

The biological efficiency of the strains was determined as a percentage by the ratio of the mass of fresh fruit bodies of the first wave to the mass of dry matter in the substrate multiplied by 100.

The morphological parameters of fruiting bodies (FB) were evaluated by determining the

colour and structure of the pilei and stem, the diameters of the pileus and stem, the height of the pedicel and the fruiting body as a whole, and the weight of the fruiting bodies. The variability of traits was determined from samples with at least 40 fruit bodies for each growing cycle with a sample (p) for general statistical analysis of at least 100 fruit bodies.

Statistical analysis was performed using Microsoft Office Excel 2016 and the built-in QI Macros 2020 programme. The strains were compared based on the results of descriptive statistics, two-factor and one-factor ANOVA using Tukey and Scheffe tests: α – the highest index in the experiment; the same letters indicate no significant difference; different letters indicate

significant differences. The smallest significant difference was found using the significance level of $\alpha = 0,05$.

RESULTS

Technical indicators. Incubation requires maintaining optimal microclimatic conditions for a certain period of time, so any delay in this process increases energy and labour costs. According to the results of statistical analysis of the date of obtaining fruiting bodies after three cycles of cultivation, no significant effect of prolonging the incubation time on the technical parameters of one strain was found, but significant differences between the strains were determined ($p < 0.0001$) (Table 1).

Table 1. Technical indicators for three cycles of cultivation of *C. aegerita* strains 2229, 2230, and 2231 of the IBK (mean \pm s.e.)

Strain	Cycle number (incubation duration, day)	Date of receiving the FB, day	Yield, g/kg of substrate	Biological efficiency, %
2231	1(25)	42.6 \pm 0.6 ^{bc}	219.5 \pm 11.3 ^a	59.32 \pm 3.04 ^a
	2(28)	42.9 \pm 0.4 ^{bc}	216.8 \pm 15.1 ^a	58.54 \pm 2.85 ^a
	3(32)	43.3 \pm 0.3 ^b	220.1 \pm 9.7 ^a	60.42 \pm 3.31 ^a
2230	1(25)	41.1 \pm 0.3 ^c	215.5 \pm 9.5 ^a	57.89 \pm 2.37 ^a
	2(28)	42.2 \pm 0.5 ^{bc}	218.1 \pm 10.1 ^a	58.89 \pm 3.14 ^a
	3(32)	42.7 \pm 0.4 ^{bc}	214.4 \pm 9.8 ^a	57.63 \pm 1.97 ^a
2229	1(25)	48.7 \pm 1.2 ^a	73.2 \pm 12.5 ^b	19.87 \pm 3.37 ^b
	2(28)	49.2 \pm 1.3 ^a	75.1 \pm 10.2 ^b	20.2 \pm 4.06 ^b
	3(32)	48.8 \pm 0.8 ^a	72.8 \pm 14.1 ^b	19.78 \pm 3.88 ^b
LSD ₀₅		2.07	28.7	7.54
<i>p-value</i>		< 0.0001	< 0.0001	< 0.0001

Strain 2229 was characterised by a longer growing cycle, which on average ended 6 days later than in 2231 and 2230. Strain 2230 had the shortest vegetation in the experiment, the fruit bodies of which began to be harvested after 41.1 ± 0.3 days. According to the analysis of the duration of the three cultivation cycles, there was no significant difference between strains 2230 and 2231, and the average result was that the fruiting bodies of these strains were obtained after 42 days from the moment of inoculation. These indicators are significantly lower than the results of Heo *et al.* (2019), who obtained fruiting bodies of the Cham and JBAC15-1 strains at 64 days at a growth temperature of 18°C. However, the indicators of vegetation duration of the studied strains are similar to the results of screening 4 industrial and 8 natural strains of *C. aegerita*, in which the researchers obtained fruit bodies on days 46-64, depending on the nutritional value of the substrates (Heo *et al.*, 2019; Uhart *et al.*, 2008).

Thus, the studied strains are characterised by a short vegetative cycle, and it is not advisable to delay incubation beyond 25 days. However, due to technological needs, such as logistical delays or additional operations to sanitise the growing chambers, incubation can be extended to 8 days without significantly affecting the yield and biological efficiency of the strains.

No differences were found between strains 2230 and 2031 in terms of yield and biological efficiency, while strain 2229 differed significantly ($p < 0.0001$).

The highest yield of 220.1 ± 9.7 g/kg of the substrate in the experiment was found for strain 2231, the lowest at 72.8 ± 14.1 g/kg – for strain 2229. Accordingly, the biological efficacy rates also differed: the highest of $60.42 \pm 3.31\%$ was estimated in strain 2231, and the lowest of $9.78 \pm 3.88\%$ in strain 2229. The yield of the tested

strains is consistent with previously published data. In particular, Li *et al.* (1998) noted that, depending on the nutritional content of the substrates, the yield ranged from 96 g (on plant residues after extraction of medicinal substances) to 113 g of fresh fruiting bodies per kilogram of the substrate when enriched with sawdust with pea waste (10%) (Lee *et al.*, 1998). Isikyumen *et al.* (2009) obtained from 95 to 643 g of fresh fruiting bodies when straw was enriched with grain waste from poultry production, and Yasinska *et al.* cultivating poplar mushroom on sawdust of hardwood trees, obtained from 87 to 395 g/kg (Isikhuemhen *et al.*, 2009; Jasińska *et al.*, 2011). Uhart *et al.* (2008) determined that the biological efficiency of *C. aegerita* is a characteristic feature of the strains and ranges from 21% (strain 313/00) to 70% (621/04) on a wheat straw substrate, which is consistent with results obtained in the present study. However, researchers claim that this figure can rise significantly due to an increase in the nutritional value of the substrate. For example, the biological efficiency of strain 621/04 increased to 140% when 20% soy flour was added to the straw (Uhart *et al.*, 2008).

Thus, strains 2230 and 2231 are promising for introduction into commercial cultivation, but the possibility of improving yields and biological efficiency by optimising the substrate formula and growing conditions requires further study.

Morphological indicators. A prerequisite for the effective introduction of the strain into commercial culture is the study of the morphological characteristics of the shoots or fruit bodies, which is necessary for planning and organising post-harvest activities for the sale or storage of raw materials with appropriate quality. The studied strains exhibited several phenotypic features that allowed them to be distinguished visually (Fig. 1).



Figure 1. Visual appearance of fruiting body growths of the first wave of fruiting of *C. aegerita* strains

In particular, the strains differed in the colour saturation of the pilei, and the surface texture of the pilei and stems, and had some distinctive features of the veil (Table 2).

Table 2. Morphological features of fruiting bodies of *C. aegerita* strains 2231, 2230, 2229 IBK

Features	2231	2230	2229
Pileus shape	Convex, round, becomes flat over time, but the edge is rounded to the stem	Convex, round, becomes flat over time, the edge is thinned, often cracks	Cone-shaped at an early stage, becomes round-convex by the time of technical ripeness, the edge is bent to the stem
Pileus colour	Bright brown, white at the edge, the pileus brightens over time, but with no significant distribution of shades	Dark brown, not divided into shades at the beginning of development, with age from rich dark brown at the apex to almost white along the edge of the pileus	The colour is spread in a ring from dark brown at the top to a bright white skirt at the beginning of development. Changes to the colour of baked milk over time
Texture	Velvety	Velvety	First velvety, then smooth
Stem colour	Milky, with a beige tint over time	Beige	Milky white
Hymenium colour	Beige, darkens to brown over time	Beige, becomes more saturated with age	Milky white, turns beige with age
The presence of a veil	Present, leaves a ring on the stem, often dark in colour	Present, leaves a ring on the stem, which disappears over time	Present, in young fruiting bodies at the edge of the pileus has a skirt like ring of aerial mycelium
Characteristics of scales	There are small scales (less than 1 mm) over the entire surface of the fruiting body	Scales up to 2 mm, in the upper and middle part of the stem, at the base of the stem are practically absent	The scales are small, almost invisible, but create a velvety texture

The shape of the fruit bodies, characteristic features of the pileus attachment to the stem, hymenium location, development and attachment of the veil, and the presence of a ring on the stem after reaching biological

maturity did not differ in the studied strains. However, according to the results of statistical analysis, significant differences were found between the weight and size of fruiting bodies (Table 3, Fig. 2).

Table 3. Morphological parameters of fruiting bodies of the first wave of fruiting of *C. aegerita* strains 2229, 2230, 2231 IBK

Strain	FB height, mm	S length, mm	S diameter, mm	P diameter, mm	FB weight, g
2231	78.2 ± 2.3 ^b	68.6 ± 2.1 ^b	8.3 ± 0.3 ^b	28.6 ± 1.2 ^a	5.5 ± 0.6 ^b
2230	91.0 ± 1.8 ^a	81.1 ± 1.7 ^a	7.8 ± 0.2 ^b	29.5 ± 0.9 ^a	4.9 ± 0.3 ^b
2229	74.7 ± 1.5 ^b	64.2 ± 1.4 ^b	10.8 ± 0.3 ^a	25.4 ± 0.7 ^b	7.5 ± 0.4 ^a
LSD ₀₅	5.25	4.92	0.77	2.62	1.25
<i>p</i> -value	<0.0001	<0.0001	<0.0001	0.007	<0.0001

Notes: FB – fruit body, S – stem, P – pileus



Figure 2. Fruiting bodies of *C. aegerita* strains 2231, 2230, 2229 IBK of the first wave of fruiting

The highest height was determined in the fruiting bodies of strain 2230, which differed significantly from other strains in the experiment

($p < 0.0001$). Moreover, the variability of this trait in strain 2230 was the lowest: fruiting bodies ranged in height from 57 mm to 138 mm (Fig. 3).

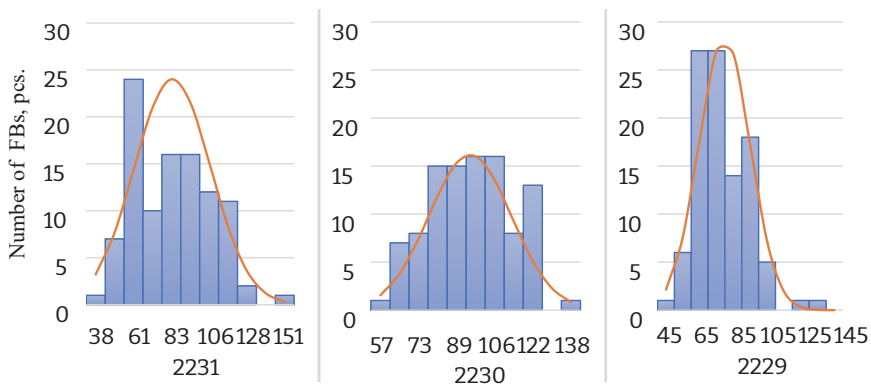


Figure 3. Variation of fruiting body height (mm) of strains in $p = 100$

The coefficient of skewness (C_{sk}) of the sample was -0.006 , which indicates a highly symmetrical distribution graph, but the negative sign determines a slight deviation to higher values of the parameter.

The lowest height in the experiment was observed in the fruiting bodies of strain 2229 (74.7 ± 1.5 mm), which did not statistically differ from this characteristic of strain 2231 (78.2 ± 2.3 mm), with the corresponding values of the coefficients: C_{sk} 2229 = 0.97 and C_{sk} 2231 = 0.2 with a tendency to lower values. With a similar pileus thickness, which was 10 ± 1 mm

in all strains, the stem length was determinative in the total height of the fruit bodies of the strains, respectively, the largest in strain 2230 (81.1 ± 1.7 mm) and the smallest in strain 2229 (64.2 ± 1.4 mm), and the distributions of samples were similar to the values of FB height.

The results of the analysis revealed that the largest stem diameter of 10.8 ± 0.3 mm was found in the fruiting bodies of strain 2229 (from 6 to 18 mm) with a significant difference from other strains in the experiment. C_{sk} of 2229 was 0.21, whereas C_{sk} 2231 and C_{sk} 2230 had values of 1.51 and 1.12, respectively (Fig. 4).

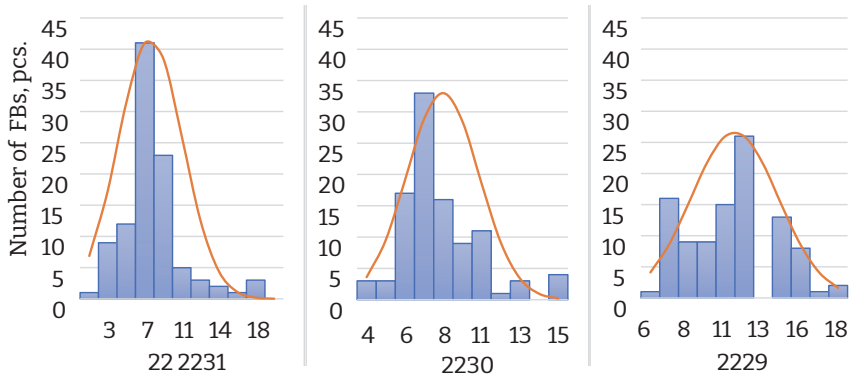


Figure 4. Variability of the stem diameter (mm) of strains by $p = 100$

Strains 2231 and 2230 had a significantly wider pileus, although the variability of this indicator was higher when compared with strain 2229 (Fig. 5). Strain 2230 had the largest pileus

diameter in the experiment (29.47 ± 0.86 mm), strain 2231 did not differ (28.59 ± 1.17), and pileus of strain 2229 was on average 4-5 mm narrower (25.43 ± 0.73).

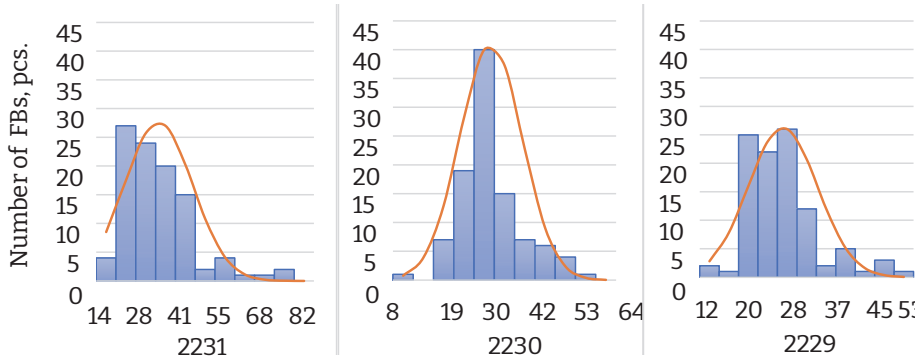


Figure 5. Variability of the pileus diameter (mm) of strains by $p = 100$

The highest average weight of mushrooms was found for strain 2229 (7.46 ± 0.42 g), while the fruiting bodies of strains 2231 and 2230 weighed on average 2 g less (5.53 ± 0.59 and 4.91 ± 0.27 , respectively). The variability of this indicator in the experiment was quite high, but

for all strains, the asymmetry coefficients were higher than unity ($C_{sk} 2231 = 3.34$; $C_{sk} 2230 = 1.60$; $C_{sk} 2229 = 1.28$) (Fig. 6).

This fact indicates a general tendency of the samples to low fetal body weights, which in the experiment ranged from 1 to 43 g.

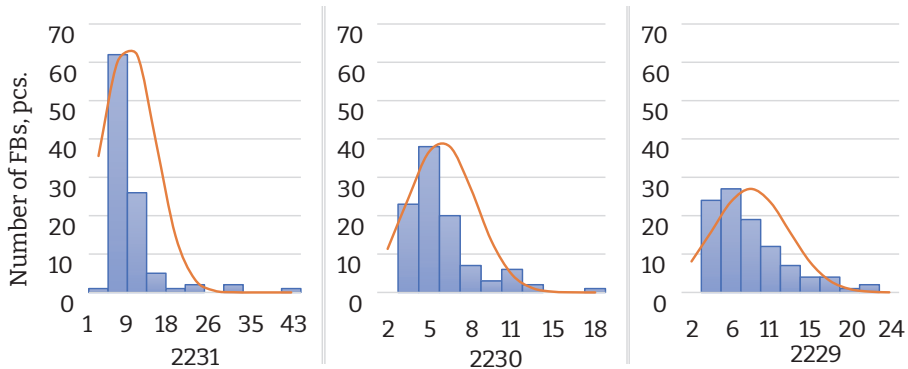


Figure 6. Variation of fruiting body weight (mm) of strains by $p = 100$

The study of trends in the variability of fruiting body weight (mm) of strains by $p = 100$ of morphological traits of strains allows for assessing their stability and, accordingly, makes it possible to predict the total number of fruiting bodies of a certain size in the total volume of the crop, which is important for product packaging and marketing operations.

The parameters of the fruiting bodies of the studied strains by weight and size coincided with the results of a morphological assessment of strains of other researchers under similar cultivation conditions. In particular, scientists from South Korea received fruiting bodies of *A. cylindracea* strains JBAC15-1 and Cham strains weighing from 3.0 to 5.5 g, respectively. However, they emphasise the dependence of morphological traits on fruiting temperature regimes: an increase in the diameter of the pileus of strain JBAC15-1 from 32.2 ± 0.7 mm when grown at 18°C to 43.0 ± 2.3 mm at 25°C and the height of the stem from 70.1 ± 1.8 (18°C) to 85.1 ± 1.9 (25°C) (Heo *et al.*, 2019).

The determined values of pileus diameters were also similar to the results of the analysis of

three strains of *C. aegerita* studied by Argentinian scientists, yielding pileus diameters ranging from the smallest of 26 ± 5 mm (strain 9/98) to the maximum size of 42 ± 8 mm (strain 621/04) (Uhart *et al.*, 2008).

However, the determined average weight and height of the stems of experimental strains were significantly higher than the results of Yasynska *et al.* (2012), who obtained fruiting bodies weighing 3.7 g on a substrate of birch sawdust and 2 g on a substrate of beech sawdust. According to their data, the fruiting bodies reached a maximum height of 48 mm on a substrate made of a mixture of beech and alder sawdust. However, the diameter of the pileus of *A. aegerita* ranged from 27 mm (beech) to 31 mm (birch), which is consistent with the findings of the present study (Jasińska *et al.*, 2012). It is evident that the manifestations of phenotypic parameters are not only related to the unique properties of the strains. The morphological characteristics of fruiting bodies are influenced by the technological features of cultivation: the use of substrates of different composition, differences in

microclimatic environment, etc. This conclusion is supported by the findings of Heo *et al.* who emphasise that conditions affect not only the size of the fruit bodies but also the colour of the pileus. Thus, the strain “Cham” at 18°C had a rich dark pileus colour, and at 25°C it was light with a white edge (Heo *et al.*, 2019). Thus, the study of morphological parameters is an important component of the optimisation of cultivation technology and establishment of consumer quality of *C. aegerita* fruiting bodies and requires more thorough research.

CONCLUSIONS

Analysis of technical indicators of cultivation efficiency and morphological features of three strains of *C. aegerita* substantiates the possibility of their introduction into industrial culture. Fungi of strains 2230 and 2231 IBK were obtained on 42 ± 1 day with a yield of 214 to 220 g/kg of substrate on the first wave of fruiting, which is consistent with the results of other

researchers. Strain 2229 had a low yield and a prolonged vegetation cycle compared to strains 2230 and 2231 but was distinguished by interesting morphological features: a milky cream colour of the pileus, the highest weight of fruit bodies (7.5 ± 0.4 g) and the thickest stem in the experiment (10.8 ± 0.3). Thus, its appeal makes it possible to increase the selling price, thereby compensating for the reduced efficiency of its cultivation. The variability of the morphological traits of the strains was analysed and the coefficients of sample asymmetry were calculated, which allows predicting the production of fruiting bodies of a certain size. The studied strains have been proven to have stable morphological characteristics, and therefore can be recommended for distribution. However, high results of growing *C. aegerita* strains of foreign origin on substrates with optimised formulas encourage further scientific research to improve the cultivation techniques of this valuable edible and medicinal species.

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Якісна характеристика гриба *Cyclocybe aegerita* штамів 2229, 2230, 2231 ІВК в умовах промислового культивування

Анотація. Тополевий гриб характеризується привабливими плодовими тілами з точки зору зовнішнього вигляду та смакових якостей. Гриби *Cyclocybe aegerita* також відомі тим, що містять унікальні речовини, зокрема білки, полісахариди та ароматичні речовини з доведеною харчовою цінністю та лікувальною дією. Однак відсутність обґрунтованої технології вирощування з використанням доступного рослинного матеріалу обмежує насичення вітчизняного ринку грибами цього виду. Три штами *C. aegerita* з Національної

колекції культур агарицевих грибів Інституту екології та природних ресурсів (ІБК) вивчали на предмет їх потенційного введення в промислову культуру. Встановлено, що штами 2230 і 2231 мають вегетаційний цикл 42 дні порівняно з 46-64 днями у раніше досліджених штамів. Найвищу врожайність в експерименті було отримано для штаму 2231, яка становила від 217 до 220 г на кілограм субстрату протягом трьох циклів культивування. Біологічна ефективність штамів за результатами першої хвилі плодоношення становила від 20,2 (2229) до 60,4% (2231), що узгоджується з опублікованими даними інших дослідників. Детально описано зовнішній вигляд і параметри плодових тіл штамів, які відрізнялися як за кольором ворсинок, так і за розмірами. За мікрокліматичних умов експерименту штами 2230 і 2231 мали насичений коричневий колір піле, тоді як сформовані плодові тіла штаму 2229 вирізнялися приємним молочно-кремовим кольором. Найбільші за масою плодові тіла отримано при культивуванні штаму 2229 ($7,5 \pm 0,4$ г), що в середньому на 2 г перевищує масу грибів інших досліджуваних штамів. Найвищі плодові тіла виявлено у штаму 2230 висотою $91,0 \pm 1,8$ мм, який також мав найширші пілеї діаметром $29,5 \pm 0,9$ мм. Найбільший діаметр ніжки, який сягав у середньому $10,8 \pm 0,3$ мм, було виявлено у плодових тілах штаму 2229. У роботі досліджено мінливість морфологічних ознак та виявлено тенденції щодо кількості плодових тіл певного розміру в загальному обсязі зібраних грибів, що сприяє розробці дизайну пакування та маркетингових кампаній

Ключові слова: тополиний гриб, вегетаційний цикл, урожайність, біологічна ефективність, морфологічні ознаки, штучне культивування