Current Research in Environmental & Applied Mycology (Journal of Fungal Biology)
X(X): X–X (2021) ISSN 2229-2225
www.creamjournal.org **Article**
Doi 10.5943/cream/X/X/X

Review of the basic cultivation conditions influence on the growth of basidiomycetes

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Krupodorova TA, Barshteyn VYu, Sekan AS 2021 – Review of the basic cultivation conditions influence on the growth of basidiomycetes. Current Research in Environmental & Applied Mycology (Journal of Fungal Biology) 11(1), 494–531, Doi 10.5943/cream/11/1/34

Abstract

Recently, the significant economic and therapeutic potential of different fungi causes the intense cultivation of the prospective species. This review presents the analysis of the basic physicochemical conditions for fungi cultivation that have an influence on basidiomycetes' mycelia or biomass growth options (maximal mycelial dry weight, maximal mycelial growth, maximal mycelial growth rate, mycelial density, colony diameter, etc.). Not only different species, but different strains of the same fungus require different cultivation conditions, the variability of nutrition media, temperature, pH, carbon and nitrogen sources. Several parameters optimal cultivation can be explained by the geographical and climatic factors. Analysis of literature data and the resulting conclusions will help a deeper understanding of the biological characteristics of fungi, their nutritional needs, optimal temperature and pH, and optimization of the production of fungal biomass. Comparison of the collected information on various fungal strains growth aimed to facilitate the further development and optimization in existing cultivation protocols. According to this, the maximum growth for biotechnological and industrial application is expected to be obtained. Also, the prolongation in safekeeping of viable fungal forms and the preservation of the fungi biodiversity for their re-introduction in nature is expected as one of the benefits after protocol optimization.

Keywords – Basidiomycota – cultivation parameters – growth – mycelial production

Introduction

One of the main aims of Food and Agriculture Organization of the United Nations (FAO) is the promotion and development of non-wood forest products (NWFP) with the view of improving (providing a rapidly growing world population with food) and contributing toward the wise management of worldwide forests with the conservation of their biodiversity. One of the significant NWFP groups are fungi as a part of natural ecosystems equilibrium. However, their growth is extremely slow in the wild (e.g., due to a galloping climate change) and restricted by growing area, seasonality that influences sizes and yields in general. Surely, wildlife resources can be used to a certain extent without compromising their conservation or preservation. Artificial cultivation of fungi contributes to problem of the natural mushroom flora protection and improving food security. However, there are some limitations of fungal cultivation. For instance, the raising of a fruiting body under solid culture conditions is quite a labor and energy-consuming process. Nowadays, more perspective and appropriate way is in obtaining valuable cellular or extracellular substances

Submitted 25 July 2020, Accepted 16 September 2021, Published 16 December 2021
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from a submerged mycelial culture applied in the formulation of nutraceuticals and functional foods (Shih et al. 2007, Barshteyn & Krupodorova 2016). The interest in different fungi species is strongly increasing worldwide because of their nutritional, nutraceutical, and medicinal values. Strengthen interest in the valuable basidiomycete species in industrial applications implies the establishment of simple techniques for the optimisation of the conditions of cultive resource utilization, intensification of seed mycelium production, augmentation of the biomass yield along biosynthesis of therapeutically interesting substances.

A sufficient number of studies are devoted to the introduction of basidiomycetes into the culture with an attempt to optimize the cultivation protocols. It means the investigation of the influencing physicochemical parameters of cultivation (culture media, temperature, pH, the optimum carbon and nitrogen sources and C/N ratio, etc.). On the other hand, it is necessary to point out that a bunch of the research is dedicated to the effect of cultivation conditions on fungi growth. Nevertheless, there are very few reviews devoted to the study of this topic regarding species of fungi from certain genera, in particular of genus *Pleurotus* (Gregori et al. 2007), and *Coriolus* (Antonenko & Klechak 2011).

Recently, the interest in the products containing fungi species for medicinal purposes has resurged (Elisashvili 2012, Lin et al. 2019, Hyde et al. 2019, Frljak et al. 2021). However, a much smaller number of publications is devoted to the impact of the cultivation parameters on the synthesis of metabolites, and, therefore, the therapeutic properties of fungi. Meanwhile, very often the maximum growth of mycelium and the highest therapeutic activity are achieved using different cultivation conditions (Kim 2003, Krupodorova 2011, Krupodorova et al. 2019, Bisko et al. 2020).

Thus, basic physical requirements and nutritional preferences demand the best basidiomycetes growth towards the relevant bioactive compound's biosynthesis. However, as far as we know, only the work by Elisashvili (2012) described the different factors in detail of submerged cultivation of medicinal mushrooms for the production of mycelium and bioactive metabolites. Hence, we focused our literature analysis on the basic optimal parameters conducive to fungal growth with the aim to fill in the missing information. The main goal of the presented work is to investigate the literature data on the effect of the basic parameters of the fungi cultivation for determination the most optimal criteria of their growth (the colony diameter or growth rate of the mycelium, or biomass production, etc.). The presented paper is developed with the aim to elucidate the current knowledge on basidiomycetes cultivation with subsequent growth optimization both in industrial and health care areas. In order to do that, the presented article is developed to elucidate current knowledge and further identify research applications. According to our observations, such an exploratory comparison of the cultivation parameters on different species and strains of fungi is carried out for the first time.

Materials & Methods

Therefore, we have selected reports describing the main physical and chemical parameters among the many other influencing factors forming the life cycle and development of fungi. Hence, the following keywords were employed for the data searching: temperature, nitrogen and carbon content of the medium, pH, and suitable nutrition media. Current literature data were retrieved from peer-reviewed journals placed on electronic databases such as NCBI, Springer, Google Scholar, ScienceDirect, ResearchGate, and subject-specific professional websites. Further categorization of the report's relevance and journal impact factor was applied with the aim to compare the content from different scientific sources. Also, we focused on cultivation parameters for various strains from mutual genus during the literature analysis that helps to fulfill the statistical assessment of published data. The assessment of obtained parameters elucidated from reports was applied for the conducting of bibliometric maps described below in tables.

Results & Discussion

Influence of culture media on the mycelial growth

Culture media are the important factor in mushroom cultivation as they supply the required nutrients for mycelium growth. Suitable nutritional media is also a way of storing a fungus biologically viables. Different types of media are used for cultivation and determination of fungi growth. Depending on the composition and the purpose the media are divided by consistency: solid agar medium, semi solid media and liquid media. Agar is the most common of medium compactors. In terms of structure and nutritional composition, media can be simple or complex. Simple media have accurate chemical compositions that support the growth of non-fastidious fungi, for example "hungry" agar (GA). Complex media have unknown chemical composition, for example blood agar. Originally, the media basis is conditionally divided into natural, synthetic and semi-synthetic. Natural media are composed of organic substances and include the plant stock (different plant or wood extracts, beer wort, coconut water, etc.) or animal by-products (milk serum, cheese whey, blood, etc.). The composition of these components is unknown entirely or has a range of variability for individual parts. In contrast, in synthetic media like Czapek Dox medium, Sabouraud dextrose agar, all organic and inorganic media components are exactly known (including additives, in particular – growth factors), without yeast, animal, or plant tissue additives. As a rule, synthetic media for mushroom cultivation contain minimal ingredients required for the growth: sources of carbon, nitrogen, less commonly vitamins, mineral salts and amino acids. Onwards, semi-synthetic media along with a synthetic base additionally contain a small amount of acidic, tryptic, yeast, fungal, casein hydrolyzate, albumin, or native blood serum. The example of a well-known semi-synthetic medium is malt extract agar (MEA). The qualitative and quantitative composition of media are studied in order to understand the nutritional demands of fungi and the physiology of their growth. The type of medium that supports the growth of fungi can vary not only from species to species but also from strains to strains of the same species. Because the morpho-genetic characteristics of different strains are varying, the development of one universal medium suitable for the related species growth even within the same genus is doubtful. Bisko et al. (2012) investigated the effect of the growing of 50 fungus species on four different media and also studied their strains (all together – 131 cultures). The influence of media on the growth rate of 78% of the studied cultures has been established. The tested media can be placed in the following row (by the degree of favorableness of used media for basidiomycetes growth): wheat agar > potato glucose agar > oat meal agar > wort agar. The current knowledge of different solid media influence on the growth of analyzed fungi mycelium is summarized in table 1. However, the number of media tested for fungi growth in different studies varies from 1 to 12. The vast majority of these studies were carried out in synthetic media and in semi-synthetic media; more seldom in media based on agricultural raw materials and waste. In general, researchers have chosen to use a variety of commercial dehydrated culture media like potato dextrose agar (PDA), MEA, Czapek dox agar (CDA), yeast malt extract agar (YMEA), corn meal agar (CMA), Sabouraud dextrose agar (SDA), malt yeast extract (MYE) that are easy to prepare. It should be noted some popularity of usage of enriched potato culture media like potato malt agar (PMA), potato carrot agar (PCA), potato sucrose gelatin (PSG), potato malt peptone (PM), yeast potato dextrose agar (YPDA), potato dextrose yeast agar (PDYA), potato glucose agar (PGA). According to the analysis of the influence of the media on fungal growth, PDA and MEA media provide the maximum effect due to their rich complex composition for the appropriate fungal growth. Media, tested by the investigators for fungi growth, differ by the composition of organic and inorganic compounds, and have been differently enriched with nutrients, such as carbohydrates, nitrogen sources, micro- and macroelements, amino acids and vitamins. Glucose as a carbon source used in most commonly known media like yeast extract agar, glucose peptone agar (GPA), MYE, Leonian, Hennerberg, Hoppkins, mushroom complete medium. Another monosaccharide dextrose is also basic component is different media: PDA, CMA, SDA, yeast malt Czapek Dox, yeast malt agar (YMA), wheat dextrose agar, oat extract agar, YPDA.

Table 1 Influence of different media on the growth of fungi mycelium

Fungal species and strains	Used media	Preferred media	Reference
Agaricus bisporus (J.E. Lange) Imbach (strains: IE-623, IE-746, IE-273, IE-751, IE-752, IE-754, IE-755, IE-610)	YMEA, yeast extract and indulin AT (YMEA-indulin AT), compost extract (CMEA)	CMEA	Salmones et al. (2018)
A. bitorquis (Quél.) Sacc. (strain DSM 4135)	PDA, WDA, malt soy peptone agar	WDA	Furlan et al. (1997)
Agrocybe aegerita mushroom (Current Name: ***Cyclocybe aegerita*** (V. Brig.) Vizzini)	SDA, MEA, PDA, GPA, YMA	MEA	Muthu & Shanmugasundaram (2015)
Auricularia auricula-judae (Bull.) Quél. (strain ASI 6033)	CDA, GPA, PDA, MEA, YMA, MCM, MYE, Hennerberg, Lilly, Hoppkins, Leonian, YEA	MCM	Jo et al. (2014)
Calocybe indica Purkay & A. Chandra	PDA, MEA	PDA	Sardar et al. (2020)
Chlorophyllum molybdites (G. Mey.) Massee	agar media including safflower decoction, mung bean decoction, yellow corn grit decoction, feed conditioner decoction, sorghum decoction, taro decoction, potato dextrose decoction, snap bean decoction, rice bran decoction, coconut water	potato dextrose decoction agar	Garcia et al. (2020)
Coriolus versicolor (Current name: ***Trametes versicolor*** (L.) Lloyd) (strains ASI 16003, ASI 16006, ASI 16008, GBCV-01)	CDA, GPA, MYE, Hennerberg, Lilly, Hoppkins, Leonian, PDA, MEA, YEA, YMA, MCM	MYE, PDA, MCM, YEA	Jo et al. (2010)
Cyclocybe cylindracea (DC.) Vizzini & Angelini	PDA, MEA, SDA, mycological agar (MA), coconut (*Cocos nucifera*) water agar (CWA), potato (*Solanum tuberosum*) decoction sucrose agar (PSA), corn (*Zea mays*) grit decoction agar, rice (*Oryza sativa*) bran decoction agar (RBDA)	PSA, RBDA, MEA	Landingin et al. (2020)
Flammulina velutipes (Curtis) Singer (strain DSM 1658)	PDA, WDA, malt soy peptone agar	WDA	Furlan et al. (1997)
Floccularia luteovirens (Alb. & Schwein.) Pouzar (strain IE 5034)	PDA, MEA, CMA, coconut water agar (CWA), water agar (WA)	MEA, WA, CWA	Arana-Gabriel et al. (2020)
Ganoderma applanatum (Pers.) Pat. (7 strains)	CDA, GPA, MYE, Hennerberg, Lilly, Hoppkins, Leonian, PDA, MEA, YEA, YMA, MCM	PDA, YMA, and MCM	Jo et al. (2009)
G. lucidum (Curtis) P. Karst	CDA, PDA, YMA, Hamada, Hennerberg, Hoppkins, GPA, Glucose Tryptone, Lilly, MCM	GPA, YMA, MCM, Lilly	Jayasinghe et al. (2008)
G. lucidum (strain GA3)	Raper, potato glucose agar (PGA), PGA + rice bran extract, PGA + fresh oyster mushroom extract	PGA + rice bran extract	Nguyen et al. (2019)
Grifola frondosa (Dicks.) Gray	PDA, MEA, YEA, malt extract yeast agar (MEYA), potato dextrose yeast agar (PDYA), wheat extract agar (WEA), wheat extract yeast agar (WEYA), cane juice agar (CJA), cane juice yeast agar (CJYA), sawdust extract agar (SEA), corn extract agar (COEA), potato dextrose yeast agar (PDYA)	PDA	Khandakar et al. (2009)
Hypsizygus ulmarius (Bull.) Redhead	PDA, MEA, CMA, CDA, OMA	OMA, PDA, MEA	Emayavarman & Singh (2021)

Table 1 Continued.

Fungal species and strains	Used media	Preferred media	Reference
Kuehneromyces mutabilis (Schaeff.) Singer & A.H. Sm. (strain DSM 1684)	PDA, WDA, malt soy peptone agar	WDA	Furlan et al. (1997)
Lentinula edodes (Berk.) Pegler (strain DSM 1899)	PDA, WDA, malt soy peptone agar	WDA	Furlan et al. (1997)
L. edodes	MEA, PDA, potato malt agar (PMA), potato carrot agar (PCA), OMA, Raper's complete medium	MEA	Reddy et al. (2017)
Lentinus connatus Berk.	agar with: *Phaseolus vulgaris* (red bean, black bean), *Phaseolus aureus* (mung bean), *Glycine max* (L.) (soybean), *Sorghum bicolor* (L.) Moench (sorghum)	black bean agar	Klomklung et al. (2014)
L. roseus Karun., K.D. Hyde & Zhu L. Yang	agar with: *Phaseolus vulgaris* (red bean, black bean), *Phaseolus aureus* (mung bean), *Glycine max* (soybean), *Sorghum bicolor* (L.) Moench (sorghum)	read bean agar	Klomklung et al. (2014)
L. squarrosulus Mont. (strain ZB12MF02)	potato sucrose gelatin (PSG), rice bran decoction gelatin (RBDG), crack corn decoction gelatin (CCDG), coconut water gelatin (CWG)	PSG	De Leon et al. (2017)
L. subnudus (Current name: ***Lentinus squarrosulus*** Mont.)	MEA, PDA, CMA, YEA, agar media with food matrix: yellow and white corn, wheat, rice, Ife brown beans, sorghum and Irish potato, soybeans, cassava and yam tubers	PDA, MEA	Gbolagade et al. (2006)
L. swartzii Berk. (strain BIL4618)	PDA, MEA, SDA, mycological agar (MA), agar rice bran sucrose (broth from 5% D1 rice bran + 1% sucrose) gulaman (local crude agar), corn grit sucrose (broth from 5% local yellow cracked corn + 1% sucrose) gulaman, coconut water gulaman (CWG), potato sucrose (25% potato cubes + 1% sucrose) gulaman (PSG)	CWG, PSG, PDA	Dulay et al. (2021)
Macrolepiota detersa Z.W. Ge, Zhu L. Yang & Vellinga (strains: MFLUCC 13-0901, SIMA 13266)	CMA, OMA, PDA, MEA, SDA, YMEA, glucose peptone yeast extract agar (GYPA), malt extract agar-sucrose (MEA-S), malt and yeast extracts agar	MEA	Rizal et al. (2014)
M. dolichaula (Current name: ***Macrolepiota clelandii*** Grgur.)	PDA, MEA, CMA, OMA, SDA, rice bran extract agar (RBEA), compost extract agar (CEA), rice straw extract agar (RSEA), coconut extract agar (COEA)	MEA	Rizal et al. (2016)
Phellinus spp.	CDA, Hamada, Hennerberg, GPA, Lilly, MCM, PDA, YMA, Glucose Tryptone	PDA, GPA, Hamada, YMA	Hur et al. (2008)
Pleurotus cystidiosus O.K. Mill. (strain AG 2041)	PDA, MEA, sweet potato dextrose agar (SPDA), yam dextrose agar (YDA)	PDA, YDA, SPDA, MEA	Hoa & Wang (2015)
P. djamor (Rumph. ex Fr.) Boedijn	PDA, chickpea extract agar, black gram extract agar, pigeon pea extract agar, oat extract agar, Barley extract	oat extract agar	Singh & Singh (2018)
P. eryngii (DC.) Quel. (14 strains)	CDA, Hamada, Hennerberg, Hoppkins, GPA, MCM, PDA, glucose tryptone, Lilly, yeast malt extract agar	MCM, yeast malt extract agar	Alam et al. (2009)

Table 1 Continued.

Fungal species and strains	Used media	Preferred media	Reference
P. eryngii	MEA, PDA, Rose Bengal, CMA, CDA, Waksman's glucose agar	MEA	Abdel Aziz et al. (2018)
P. eryngii (strain 2015)	CDA, MEA, PDA, glucose peptone yeast extract agar	CDA	Krupodorova & Barshteyn (2020)
P. giganteus (Berk.) Karun. & K.D. Hyde	CMA, CDA, glucose yeast extract agar, MEA, OMA, PDA, soybean meal agar, V8 medium, wheat agar	PDA	Kumla et al. (2013)
P. giganteus	agar with *Phaseolus vulgaris* (red bean, black bean), *Phaseolus aureus* (mung bean), *Glycine max*) L. (soybean), *Sorghum bicolor* (L.) Moench (sorghum)	sorghum agar, soy bean agar	Klomklung et al. (2014)
P. ostreatus (Jacq.) P. Kumm. (strain DSM 1833)	PDA, WDA, and malt soy peptone agar (MPA)	WDA	Furlan et al. (1997)
P. ostreatus (strain AG 2042)	PDA, MEA, sweet potato dextrose agar (SPDA), yam dextrose agar (YDA)	PDA, YDA	Hoa & Wang (2015)
P. ostreatus	MEA, PDA, Rose Bengal, CMA, CDA, Waksman's glucose agar	MEA	Abdel Aziz et al. (2018)
P. ostreatus	PDA, SDA	PDA	Fletcher et al. (2019)
P. ostreatus	PDA, OMA, MEA, CMA, wheat extract agar	PDA	Pant et al. (2020)
P. ostreatus (11 isolates)	PDA, MEA, Richard's Agar	MEA	Phadke et al. (2020)
P. ostreatus f. ***florida*** (Current name: ***Pleurotus ostreatus*** (Jacq.) P. Kumm.)	malt extract yeast agar (OMYA), corn meal yeast agar (CMYA), potato dextrose yeast agar (PDYA)	OMYA, CMYA	Okwulehie & Okwujiako (2009)
P. ostreatus f. ***florida***	MEA, PDA, Rose Bengal, CMA, CDA, Waksman's glucose agar	MEA	Abdel Aziz et al. (2018)
P. sajor-caju (Current name: ***Lentinus sajor-caju*** (Fr.) Fr.)	PMP, MCM, YMA	YMA	Kim et al. (2002)
P. salmoneostramineus **(**Current name: ***P. djamor***)	PGA, MCM, Glucose Yeast Peptone (GYP)	GYP	Abd El-Zaher et al. (2015)
Poria cocos (Current name: ***Wolfiporia cocos*** (Schwein.) Ryvarden & Gilb.)	CDA, GPA, MYE, Hennerberg, Lilly, Hoppkins, Leonian, PDA, MEA, YEA, YMA, MCM	MEA	Jo et al. (2016)
Pycnoporus cinnabarinus (Current name: ***Trametes coccinea*** (Fr.) Hai J. Li & S.H. He) (strain M 20)	PDA, CDA, MEA, yeast powder starch soluble agar	PDA	Sharma & Jaitly (2017)
P. sanguineus (Current name: ***Trametes coccinea*** (Fr.) Hai J. Li & S.H. He) (strain M22)	PDA, CDA, MEA, yeast powder starch soluble agar	PDA	Sharma & Jaitly (2017)
Sarcodon aspratus (Current name: ***Sarcodon imbricatus*** (L.) P. Karst.)	potato malt peptone (PMP), MCM, YMA	MCM	Kim et al. (2002)
Schizophyllum commune Fr.	MEA, PDA, PMA, potato carrot agar (PCA), OMA and Rapper's complete medium	PDA	Reddy et al. (2017)
S. commune	PDA, MEA, OMA, SDA, potato carrot agar (PCA), MEA + yeast extract + glucose (MYGPA), V8 Agar	MYGPA	Rosnan et al. (2019)
S. commune	PDA and MEA	MEA	Aminah et al. (2020)

Table 1 Continued.

Fungal species and strains	Used media	Preferred media	Reference
Stropharia rugosoannulata Farl. ex Murrill (strain DSM 1655)	PDA, WDA, malt soy peptone agar	WDA	Furlan et al. (1997)
Trametes versicolor (L.) Lloyd	Raulin's, Richard's, Dox's, Coon's, Brown's I, Brown's II, GPA, Glucose-nitrate, Czapek's I, Czapek's II, Asthana&Hawker's and Elliot's	Brown's-II, GPA	Chauhan (2016)
Tricholoma terreum (Schaeff.) P. Kumm.	PDA, biotin aneurin folic acid agar (BAF), MEA, modified mediums: Melin-Norkrans agar and M40	all media	Kibar & Peksen (2011)
Volvariella volvacea (Bull.) Singer. (strain DSM 3279)	PDA, WDA, MPA	WDA	Furlan et al. (1997)
V. volvacea	SDA, PDA, and MEA	SDA	Abon et al. (2020)

Note: PDA – potato dextrose agar, WDA – wheat dextrose agar, SDA – Saboraud's dextrose agar, MEA – malt extract agar, GPA – glucose peptone agar, YMA – yeast malt extract agar, MYE – malt yeast extract, MCM – mushroom complete medium, YEA – yeast extract agar, CMA – corn meal agar, OMA – oat meal agar, PMA – potato malt agar, PMP – potato malt peptone, YMEA – malt extract with yeast extract

Disaccharide sucrose is well used in such media as CDA, PSG, malt extract agar-sucrose (MEA-S). In view of the possible conversion of dextrose and sucrose to glucose, the last one can be considered as the main sugar source for the preparation of media. Mostly used nitrogen sources as media constituents were malt or yeast extracts, peptone or their combination; less commonly – amino acids, nitrates and ammonium salts. Meeting the needs of mushrooms in macro- (C, O, H, N, S, P, K, Ca, Mg, and Fe) and microelements (Mn, Zn, Co, Mo, Ni and Cu) is reflected in the media in the form of the presence of various salts: K_2HPO_4, KH_2PO_4, KCl, $CaCl_2x2H_2O$, $MgSO_4x7H_2O$, $FeSO_4x7H_2O$, $ZnSO_4x7H_2O$ and $MnSO_4x7H_2O$.

Studies with comparative analysis of the effects of commercial culture media and natural media from the local wastes on fungal growth deserve the special attention (Rizal et al. 2016, Reddy et al. 2017, Landingin et al. 2020, Arana-Gabriel et al. 2020, Dulay et al. 2021). Because it is not always possible to find the proper composition in synthetic and semi-synthetic media that would provide better growth than naturally originated nutrient medium (Rizal et al. 2016, Reddy et al. 2017). Thus, the results become more obvious after comparison of mycelium growth activity obtained with engaging of differently originated nutrition media. Numerous reports describe the fungal growth on natural media based on local raw materials and found that the yield is higher or comparable to those obtained on commercial media. Investigations of medium content impact on the growth of such fungal species as *Pleurotus cystidiosus* and *P. ostreatus* (Hoa & Wang 2015), *Cyclocybe cylindracea* (Landingin et al. 2020), *Floccularia luteovirens* (Arana-Gabriel et al. 2020), *Lentinus swartzii* (Dulay et al. 2021) are as an example. Thereby, the efficiency of natural media application contributes to a significant reduction in the cost of the final product and is also focused on a waste-free production cycle that leads to the bioremediation effect.

Natural media contain a sufficient amount of biologically active substances that are vital to fungal growth, and they can be used as mono-substrates. With this purpose, the natural media that is based on locally sourced predominantly plant-based or agricultural residues waste is a high-desirable and easy of approach. Various perennial and annual herbaceous plants have been tested as ingredients for the natural media (Table 1). Also, plants with a high potato-like starch content are promising candidates as a substrate for mushroom growth and include examples of *Solanum tuberosum* (L.) (Mshandete & Mgonja 2009, Hoa & Wang 2015, Landingin et al. 2020), sweet potato (*Ipomoea batatas* (L.) Lam.), yam (*Dioscorea* spp.) (Mshandete & Mgonja 2009, Hoa & Wang 2015), etc. *Poaceae* family species such as *Triticum* L., *Oryza* L. (Okwulehie & Okwujiako 2009, Klomklung et al.

2014, Garcia et al. 2020, Landingin et al. 2020), *Zea mays* L. (L) (Landingin et al. 2020), *Sorghum* spp. (Klomklung et al. 2014, Garcia et al. 2020), and also *Fabaceae* family representatives like *Phaseolus vulgaris* L., *P. aureus* L., *Glycine max* (L.) Merr (Klomklung et al. 2014) are rich in protein and carbohydrate (starch), and can be a valorized as potential basis raw material for nutrient media. Coconut water from *Cocos nucifera* L. contains a growth factor that supports growth of different fungal species like *Schizophyllum commune* (Reyes et al. 2009), *Lentinus squarrosulus* (De Leon et al. 2017), *Pleurotus ostreatus* (Rachmawati et al. 2020), *Floccularia luteovirens* (Arana-Gabriel et al. 2020), *Chlorophyllum molybtides* (Garcia et al. 2020), *Lentinus swartzii* (Dulay et al. 2021).

One may note that natural media based on plant components (ingredients) are used in the form of decoctions such as safflower decoction, mung bean or snap bean decoction, yellow corn grit decoction, sorghum or taro decoction, rice bran or coconut water decoction (Garcia et al. 2020, Landingin et al. 2020) or extracts like citrus peel extracts from lemon, orange, grapefruit (Yang et al. 2012), with rice bran or rice straw extracts (Rizal et al. 2016, Nguyen et al. 2019), chickpea or pigeon pea extract, barley or oat extract (Singh & Singh 2018). Cotton waste is also suitable as a good cellulose source for the formulation of natural media in supporting fungal growth that was described on *V. volvacea* cultivation (Akinyele & Adetuyi 2005).

Today, various by-products as food waste can be an excellent platform for bio-utilization by mushrooms. Thus, *Phlellinus linteus* was successfully cultivated in cheese-processing wastewater (Lee et al. 2011). Milk serum found suitable for biomass production of *Ganoderma applanatum* and *G. lucidum* (Krupodorova 2011). Flour milling waste products like grits and broken vermicelli was reported as the encouraging alternative component for the cultivation of 17 fungi species (Krupodorova & Barshteyn 2012). Perspective medium for fungal biomass production can be developed on press cakes from the oil-fat industry. Among 12 tested press cakes of rosehip fruit, linseed (flaxseed), pumpkin seed, milk thistle seed, wheat germ, oat seed, walnut, soybean, camelina seed, rapeseed (canola seed), mustard seed and sunflower seed suitable media were found for 27 basidiomycetes species from different ecological and systematic groups (Krupodorova & Barshteyn 2015). A similar stimulatory effect of press cakes was described for *Inonotus obliquus*, where sea buckthorn press cakes were taken as a basis for nutrition medium (Beltrame et al. 2021). Waste from vegetables, winemaking, and fruit also can be considered as optimal carbohydrates sources for the obtaining of mycelium biomass. Such constituents of media like onion and cumin powders are also found as the excellent growth supplies for the cultivation of *Pleurotus eryngii* and *P. ostreatus* (Chechan et al. 2017). Apple pomace as natural medium for the submerged cultivation was effective conversed into mycelia of *Agrocybe aegerita*, *Pleurotus sapidus*, *P. sajor-caju*, *P. salmoneostramineus*, *Lentinus edodes*, *Stropharia rugosoannulata*, *Wolfiporia cocos* (Ahlborn et al. 2019).

The waste quality may be related to the habitat area of the plants as the refuse precursors. The waste obtaining process also counts the geographical proximity to the source of available waste. In turn, this naturally reflects the possibility to utilize the certain basis with the aim to create a natural media that can stimulate the fungi growth. Some basis for nutrient media formulations like *Triticum* spp., *Zea mays*, *Glycine max*, *Solanum tuberosum*, *Gossypium hirsutum* L. are typical for the majority of the countries of the world, some of them such as citrus species, sweet potato, yam are representative only for tropical and subtropical regions. Moreover, the availability of natural wastes for media formulations throughout the year or only their seasonal availability determines the rate and dynamics of the possible consumption of the raw materials. However, the complex nature of the media applied for growing fungi and based on natural raw materials makes it difficult to determine some physiological characteristics such as the rate of substrate uptake. Therefore, the real mycelia demands become much more difficult in analysis (Fraatz et al. 2014). Despite some limitations on the use of agro-industrial side streams, the effective bioconversion of waste by basidiomycetes clearly indicates the relevance and prospects of this modern direction.

The correct choice of an optimal culture media to successful fungal growth is one of the initial points to guarantee their future productive fermentation process. It should be noted, that the

application of various media is inextricably linked with some other parameters of cultivation: the temperature, pH of medium and the aeration. The results of studying the influence of the culture media revealed the mycelium of various fungal species grow with different intensity on a wide range of media: synthetic, semi-synthetic and media based on agricultural raw materials as well as food waste. Despite the numerous studies there is no single commonly accepted standard media for the optimal fungal growth. Effect on the mycelial growth can vary depending on fungi species and their strains. Media such as PDA and PGA, followed by MEA and MCM were found as the best for the growth of many basidiomycetes. However, the agricultural and food wastes contain a sufficient amount of biologically active substances that can provide better growth of fungi than synthetic and semi-synthetic media. In addition, the problem of recycling numerous agricultural wastes can be solved. Also, the utilization of wastes by fungi can be viewed as eco-friendly practices in the biotechnological industry.

Influence of temperature on mycelium growth

Temperature is one of the key factors in the growth and development of the fungal mycelium. In general, this abiotic factor directly influences many integrated metabolic activities in live organisms. In fungi the temperature factor can be related to the process of assimilation and translocation of sugar and nitrogen, respiration, and biosynthesis. An abundance of information describes the temperature influence on the growth *in vitro* of different fungal species. Also, it is well-known that many fungi species are potent to grow in a broad range of temperatures. Generally, researchers focus on studies of such cardinal growth temperatures as minimum (the beginning of growth), optimum (the best growth) and maximum (growth cessation). The experimental work may be carried out for one, several species or for different strains of one fungus. Moreover, in the prominent report from Gastillo et al. (2004) is described the growth response of the 66 tropical fungal species, collected before in Papua New Guinea, *in vitro* to a temperature change. Particular interest is also attracted to the article by Imtiaj et al. (2009) which shows the effect of the temperature impact on the mycelial growth of 371 strains belonging to 9 species of the most edible mushrooms. Establishing the optimal growth temperature is an important starting point for fungal cultivation *in vitro*. Therefore, the mushrooms are found as producents of versatile compounds with imposing therapeutic effects. The current knowledge about the temperature influence on fungi growth is represented in table 2. Many experiments were conducted in the temperature range of 10–40°C at intervals 5 or 10°C, seldom 3ºC. Optimal temperature for the cultivation of fungal species and even strains are wide in variability (Table 2). Most of the analyzed fungal species and their strains were characterized by a preference for a definite temperature regime with subsequent growth enhancement. On the other hand, some of them had the same level of mycelial growth at different temperatures. The variation in growth in the response to the optimal temperature condition is probably genetically determined by the climatic and geographical characteristics of the place from which the mushroom was collected. Gastillo et al. (2004) reported that *Ganoderma chalceum* (Cooke) Steyaert, strains PDG 45 (from a trunk), PDG 77 (found in relatively open forest of the slopes of the Manam volcano) showed an optimum growth at 30ºC, while strain PDG 123, which was collected in a habitat with more vegetation cover – at 25ºC.

However, the factor of optimal temperatures may be combined with the nutrient medium content. Thus, the maximal level of linear growth rates of *A. aegerita*, *A. auricula-judae*, *P. ostreatus*, *P. pulmonarius*, *P. eryngii*, *L. edodes*, *V. volvaceae* at different temperatures (15−40ºC) varied up in the presence of potato dextrose agar and cellulose medium (Zervakis et al. 2001). The best incubation temperature in the study with *Grifola sordulenta* (Mont.) Singer and *G. gargal* Singer has also been changed with tested media (Postemsky et al. 2006). Similar tendency is also demonstrable from the results with 27 strains of *P. eryngii* cultivated on solid media (PDA and MCM) as well as different broth media (PDB broth, MCM and YMG broth) represented by Ryu et al. (2007). However, Phutela & Phutela (2012) established a lack of correlation between the effect of temperature (at 30°C) and culture medium (potato dextrose broth and on maltova broth) in cultivation of *Calocybe indica*.

Another important cultivation parameter like pH also can influence the suitable temperature for the fungal growth. The best mycelial growth of *Hydnum repandum* L. at temperatures 15, 20 and 25°C changed depending on the pH levels 4.0-6.5 (Peksen et al. 2013).

Numerous reports are dedicated to the influence of the temperature condition on mycelium growth velocity of such edible mushrooms as *Agaricus* spp., *Pleurotus* spp., *Lentinus* spp., *F. velutipes* and such mushrooms with strong therapeutic properties as *Ganoderma* spp., *Phellinus* spp., *Trametes* spp., etc. The majority of described basidiomycetes is cultivated at optimal temperature range between 20ºC and 30ºC, although some species prefer to grow at higher ranges 35ºC–37ºC. In general, the tendency to establish the optimal high temperature (≥30.0ºC) can be assumed owing to the origin of the fungal species. Particularly, it is considerable about the endemic fungi found in tropical countries, such as *Agaricus bitorquis*, *A. brasiliensis*, *Lentinus* spp., *V. volvacea.* Establishment of fungal species tolerant to the high temperature over 30°C contribute to the expansion of the species diversity of cultivated fungi in tropical and subtropical areas.

The largest worldwide group of cultivated mushrooms is *Pleurotus* spp. They were found widely in temperate, subtropical and tropical regions of the world, so the mycelia were able to grow at a wide range of temperatures. The lowest temperature optimum for *Pleurotus* spp. isolates growth was found at 20ºC and the highest −at 30ºC (Phadke et al. 2020). Some species can well grow in quite broad of temperature intervals: 24ºC–32ºC in case of *P. cystidiosus* cultivation, strain AG 2041 (Hoa &Wang 2015); 20ºC–35ºC in case of *P. sapidus* grown, strain FW-133 (Sardar et al. 2015).

Table 2 Influence of different temperature on the growth of fungi mycelium

Fungal species and strains	Used temperature (ºC)	Preferred temperature (ºC)	Reference
Agaricus bisporus	16, 20, 24, 28, 32, 36	22~24ºC	Ma et al. (2014)
A. bisporus (strain AS-51)	20, 25, 30	25ºC	Ali et al. (2015)
A. bisporus (strains: 1946, 1947, 1948, 1955, 1956, 2029, 2097, 2102, 2107, 2177, 2178)	15, 20, 25, 30, 35	22ºC (strains: 1946, 1947, 1948, 1955, 1956, 2029, 2097, 2107, 2177, 2178), 25ºC (strain 2102)	Ismail et al. (2016)
A. bisporus (strains: IE-273, IE-746, IE-751, IE-752, IE-754, IE-755, IE-610)	22, 25, 28	22ºC and 25ºC (strain IE-623), 25ºC and 28ºC (strains: IE-755, IE-610), 28ºC (strains: IE-273, IE-746, IE-751, IE-752, IE-754)	Salmones et al. (2018)
A. bisporus (strains: S-79, A-15, Delta)	15, 20, 25, 30	25ºC	Yadav & Chandra (2014)
A. bitorquis (strains: AS-64, W20)	25, 30, 35	30ºC	Hussain et al. (2004)
A. bitorquis (strains: AS60, AS61, AS65, W20, W2-F, K26, K32)	20, 25, 30	30ºC	Ali et al. (2015)
A. blazei Murill	10, 15, 20, 25 30	25ºC	Rozsa et al. (2016)
A. brasiliensis Wasser, M. Didukh, Amazonas & Stamets (strains: 97/11, 99/25, 99/26, 99/28, 99/29)	22, 25, 28, 31, 34	25ºC ~ 28ºC	Colauto et al. (2008)
Agrocybe aegerita (Current name: ***Cyclocybe aegerita*** (V. Brig.) Vizzini) (strain SIEF 0834)	15, 20, 25, 30, 35, 40	25ºC	Zervakis et al. (2001)
Antrodia cinnamomea (Current name: ***Taiwanofungus camphoratus***	20~32	25ºC	Lin & Sung (2006)

Table 2 Continued.

Fungal species and strains	Used temperature (ºC)	Preferred temperature (ºC)	Reference
(M. Zang & C.H. Su) Sheng H. Wu, Z.H. Yu, Y.C. Dai & C.H. Su) (strain BCRC 35396)			
Armillaria luteovirens (Current name: ***Floccularia luteovirens*** (Alb. & Schwein.) Pouzar)	23, 25, 28	23ºC	Xu et al. (2011)
Auricularia auricula-judae	15, 20, 25, 30, 35, 40	25°C	Zervakis et al. (2001)
A. auricula-judae (strains: GBAA-01, GBAA-02, GBAA-03, ASI 6009, ASI 6033)	10~35	25°C, 30°C	Jo et al. (2014)
A. delicata (Mont. ex Fr.) Henn. (strain YD99)	15, 20, 25, 30, 35	25°C	Jacob et al. (2020)
A. polytricha (Current name: ***Auricularia nigricans*** (Sw.) Birkebak, Looney & Sánchez-García	15, 20, 25, 30, 35	20ºC	Yang et al. (2003)
A. polytricha	5, 10, 15, 20, 25, 30, 35, 40, 45, 50	25°C	Jonathan et al. (2009)
A. polytricha (strain ASI 6009)	10~35	30°C	Jo et al. (2014)
Calocybe indica	25, 30, 35, 40, 45	30°C	Phutela & Phutela (2012)
C. indica	15, 18, 20, 23, 25, 28, 30, 32, 35	30°C ~ 32°C	Min et al. (2020)
C. indica	25, 30, 35	30°C	Sardar et al. (2020)
Cantharellus cibarius Fr.	15~30	22.5°C	Deshaware et al. (2021)
Chlorophyllum molybdites	3.4, 18~19, 24~28	24°C ~ 28°C	Garcia et al. (2020)
Coprinus comatus (O.F. Müll.) Pers. (strains: GMCC 54001, GMCC 67001, GMCC 67002, MCC 67003, GMCC 67004)	17, 20, 23, 26, 29, 32	23ºC ~ 26ºC	Jang et al. (2009)
Coriolus brevis (Current name: ***Cerrena zonata*** (Berk.) H.S. Yuan) (strain ASI 16007)	10, 15, 20, 25, 30, 35	30°C	Jo et al. (2010)
C. hirsutus (Current name: ***Trametes hirsuta*** (Wulfen) Lloyd)	26, 28, 30, 32, 34, 36	30°C ~ 36°C	Emelyanova (2005)
C. hirsutus (strain IBK 5137)	18, 28, 30, 34, 37	30°C	Antonenko et al. (2011)
C. pubescens **(**Current name: ***Trametes pubescens*** (Schumach.) Pilát) (strain ASI 16002)	10, 15, 20, 25, 30, 35	30°C	Jo et al. (2010)
C. versicolor (strains: ASI 16003, ASI 16006, ASI 16008, GBCV-01)	10, 15, 20, 25, 30, 35	25°C (strain ASI 16008), 30°C (strains: ASI 16003, ASI 16006, GBCV-01)	Jo et al. (2010)
C. versicolor (strain IBK 353)	18, 28, 30, 34, 37	30°C	Antonenko et al. (2011)
C. villosus (***Trametes villosa*** (Sw.) Kreisel (strain 1009)	18, 28, 30, 34, 37	28°C	Antonenko et al. (2011)
C. zonatus (Current name: ***Trametes ochracea*** (Pers.) Gilb. & Ryvarden) (strain IBK 5302)	18, 28, 30, 34, 37	30°C	Antonenko et al. (2011)
Cyclocybe cylindracea	9, 23~25, 28~33	23°C ~ 25°C, 28°C ~ 33°C	Landingin et al. (2020)
Flammulina velutipes (strain DSM 1658)	20, 25, 30, 35, 40	25°C	Furlan et al. (1997)
Fomes fomentarius (L.) Fr. (strains: IB20130011,	10, 20, 25, 30, 32, 37	25°C (strains: IB20130011,	Dresch et al. (2015)

Table 2 Continued.

Fungal species and strains	Used temperature (ºC)	Preferred temperature (ºC)	Reference
IB 20130016, IB 20130019, IB 20130022, IB 20130033, IB P74908)		IB 20130016, IB 20130019, IB 20130022, IB P74908), 32°C (IB 20130033)	
Fomitopsis betulina (Bull.) B.K. Cui, M.L. Han & Y.C. Dai (strain IBK 327)	24, 26, 28, 30	26ºC ~ 28ºC	Krupodorova et al. (2019)
F. pinicola (Sw.) P. Karst. (14 strains)	10, 20, 25, 30, 32, 37	25ºC (8 strains), 30ºC (2 strains)	Dresch et al. (2015)
Ganoderma adspersum (Schulzer) Donk (strains: Ga-1, Ga-3, Ga-2-1, Ga-3-3, Ga-9, Gad-6, Ga-2-2, Gad-03, Gad-VII, 1016)	25, 30, 35, 38	25°C (strains: Ga-1, Ga-3), 26ºC ~ 28ºC (strains: Ga-2-1, Ga-3-3, Ga-9, Gad-6), 25°C (strains: Ga-2-2, Gad-03, Gad-VII, 1016)	Badalyan et al. (2019)
G. applanatum (strains: IBK 1530, IBK 1896, IBK 1897, IBK 1898, IBK 1899, IBK 920, IBK 1552, IBK 1553, IBK 1701, IBK 1672, IBK 1572, IBK 1593, IBK 1895)	15, 20, 25, 28, 30	28ºC (strains: IBK 1530, IBK 1896, IBK 1897, IBK 1898, IBK 1899), 32ºC (strains: IBK 920, IBK 1552, IBK 1553), 20ºC, 28ºC (strain IBK 1895), 28ºC, 32ºC (IBK 1701, IBK 1672, IBK 1572, IBK 1593)	Bisko et al. (2012)
G. australe (Fr.) Pat. (strain MFLUCC 12-0527)	20, 25, 30, 35	30°C	Luangharn et al. (2017)
G. lucidum (strain CCRC 36123)	20, 25, 30, 35, 40	30ºC ~ 35ºC	Yang & Liau (1998)
G. lucidum (strains: IUM 0037, IUM 0047, IUM 0637, IUM 0751, IUM 0757, IUM 0805, IUM 0938, IUM 1027)	15, 20, 25, 30, 35	25ºC (strains: IUM 0805, IUM 0938), 30ºC (strains: IUM 0037, IUM 0047, IUM 0637, IUM 0751, IUM 0757), 25ºC, 30ºC (strain IUM 1027)	Jayasinghe et al. (2008)
G. lucidum (strains: IBK 922, IBK 1888, IBK 1621, IBK 1907, IBK 1908, IBK 1911, IBK 1788, IBK 921)	15, 20, 25, 28, 30, 35	20ºC ~ 28ºC (strain IBK 1788), 28ºC ~ 32ºC (strains: IBK 922, IBK 1888, IBK 1621, IBK 1907, IBK 1908, IBK 1911), 20ºC, 28ºC, 32ºC (strain IBK 921)	Bisko et al. (2012)
G. lucidum (strains: OE-52, OE-53, PLP-2)	5, 10, 15, 20, 25, 30, 35	30ºC (strains: PLP-2, OE-53), 35ºC (strain OE-52)	Kapoor & Sharma (2014)
G. lucidum	22, 30, 37	22ºC	Fletcher et al. (2019)
G. lucidum (strain GA3)	20, 25, 30, 35	30ºC	Nguyen et al. (2019)
Grifola frondosa (strain KACC51146)	15, 20, 25, 30, 35	20ºC	Kim (2003)
G. frondosa	Bellow 8, 10-13, 17-23, 24-27, 28-31, 35	24ºC ~ 27ºC	Khandakar et al. (2009)
G. gargal Singer	18, 20, 24	20ºC	Postemsky et al. (2006)
G. sordulenta (Mont.) Singer	18, 20, 24	20ºC	Postemsky et al. (2006)
Hericium erinaceus (Bull.) Pers. (strains: (IUM0217, IUM1128, IUM2876, IUM 3271)	15, 20, 25, 30, 35	20ºC and 25ºC (strain IUM1128), 25ºC (strains: IUM0217, IUM2876, IUM 3271)	Imtiaj et al. (2008a)
Hydnum repandum L.	15, 20, 25, 30	20ºC and 25°C	Peksen et al. (2013)
Hypsizygus ulmarius	15, 20, 25, 30	25ºC	Sharma et al. (2018)

Table 2 Continued.

Fungal species and strains	Used temperature (ºC)	Preferred temperature (ºC)	Reference
H. ulmarius	21, 22, 23, 24, 25	24°C	Emayavarman & Singh (2021)
Inonotus obliquus (Fr.) Pilát (strains: B-26, B-7)	18, 24, 28	24ºC	Bisko et al. (2012)
Lentinula edodes	15, 20, 25, 30, 35, 40	30ºC	Zervakis et al. (2001)
L. edodes (strain KCTC 6735)	20, 23.6, 25, 30	23.6ºC	Inglet et al. (2006)
L. edodes	10, 15, 20, 25, 30, 35, 40	25ºC	Reddy et al. (2017)
L. edodes (strain Le-17-04)	22, 24, 26, 28, 30	24ºC	Kumar et al. (2019)
L. edodes (strain IBK 502)	24, 26, 28, 30	26°C ~ 28°C	Krupodorova & Barshteyn (2020)
Lentinus conatus (strain MFLU 08-1389)	20, 25, 30, 35	30ºC	Klomklung et al. (2014)
L. crinitus (L.) Fr. (strains: U9-1, U15-9)	22~37	25ºC ~ 28°C (strain U9-1), 28ºC ~ 37°C (strain U15-9)	Marim et al. (2018)
L. crinitus (strain U9-1)	19, 22, 25, 28, 31, 34, 37, 40	31ºC ~ 34°C	Colla et al. (2020)
L. roseus (strain MFLU 08-1376)	20, 25, 30, 35	30ºC	Klomklung et al. (2014)
L. squarrosulus (strain ZB12MF02)	15, 32, 40	32ºC	De Leon et al. (2017)
L. strigosus (Current name: ***Panus neostrigosus*** Drechsler-Santos & Wartchow)	25, 30, 35, 40, 45	35ºC	Vargas-Isla & Ishikawa (2008)
L. subnudus	10, 15, 20, 25, 30, 35, 40, 45	30ºC	Gbolagade et al. (2006)
L. swartzii	10, 20, 30	30ºC	Dulay et al. (2021)
Leucocalocybe mongolica (S. Imai) X.D. Yu & Y.J. Yao	13, 15, 20, 25, 27	25°C	Lu et al. (2017)
Macrolepiota detersa (strains: MFLUCC 13-0901, SIMA 13266)	16, 18, 25, 30	30°C	Rizal et al. (2014)
M. dolichaula (strains: MFLUCC 13-0579, MFLUCC 14-0742)	16, 18, 20, 25, 30	30°C	Rizal et al. (2016)
M. procera (Scop.) Singer	10, 15, 20, 25, 30, 35	30°C	Shim et al. (2005)
M. procera	15, 20, 25, 30	20°C, 25°C	Pekşen & Kibar (2020)
Mycena leptocephala (Pers.) Gillet	20, 25, 30, 37	25ºC	Vahidi et al. (2004)
Oudemansiella radicata (Current name: ***Hymenopellis colensoi*** (Dörfelt) R.H. Petersen) (strain UM00779)	15, 20, 25, 30, 35	25ºC	Kim et al. (2005)
Phellinus alni (Current name: ***Phellinus igniarius*** (L.) Quél.) (strain IUM3151)	15, 20, 25, 30, 35	25ºC	Hur et al. (2008)
P. baumi (Current name: ***Sanghuangporus baumii*** (Pilát) L.W. Zhou & Y.C. Dai) (strain IUM3169)	15, 20, 25, 30, 35	20ºC	Hur et al. (2008)
P. cavicola (Current name: ***Fomitiporella cavicola*** (Kotl. & Pouzar) T. Wagner & M. Fisch.) (IUM3164)	15, 20, 25, 30, 35	25ºC	Hur et al. (2008)
P. chrysoloma (Fr.) Donk (strain IUM3149)	15, 20, 25, 30, 35	25ºC	

Table 2 Continued.

Fungal species and strains	Used temperature (ºC)	Preferred temperature (ºC)	Reference
P. conchatus (Current name: ***Phellinopsis conchata*** (Pers.) Y.C. Dai) (strain IUM3150)	15, 20, 25, 30, 35	25ºC	Hur et al. (2008)
P. linteus (Current name: ***Tropicoporus linteus*** (Berk. & M.A. Curtis) L.W. Zhou & Y.C. Dai)	20, 25, 30, 35	25ºC	Kim et al. (2001)
P. linteus (strains: IUM 3159, IUM 3161)	15, 20, 25, 30, 35	25ºC (strain IUM 3161), 30ºC (strain IUM 3159	Hur et al. (2008)
P. linteus (strain KCTC 6719)	20, 25, 30	26.2ºC	Lee et al. (2011)
P. lundellii Niemelä (strain IUM3153)	15, 20, 25, 30, 35	25ºC	Hur et al. (2008)
P. pomaceus (Pers.) Maire (strain IUM3156)	15, 20, 25, 30, 35	25ºC	Hur et al. (2008)
P. populicola Niemelä (strain IUM3155)	15, 20, 25, 30, 35	20 ºC	Hur et al. (2008)
P. robustus (Current Name: ***Fomitiporia robusta*** (P. Karst.) Fiasson & Niemelä) (strains: M 10, IBK-1551, IBK-1695, IBK-1730)	18, 24, 28	24ºC (strain M 10), 28ºC (strains: IBK-1551, IBK-1695, IBK-1730)	Bisko et al. (2012)
P. toruluosus (Current name: ***Fuscoporia torulosa*** (Pers.) T. Wagner & M. Fisch.) (strain IUM3158)	15, 20, 25, 30, 35	25ºC	Hur et al. (2008)
P. vorax Harkn. ex Černý (strain IUM3163)	15, 20, 25, 30, 35	25ºC	Hur et al. (2008)
***Pleurotus* spp.** (11 isolates)	20, 22, 24, 26, 28, 30	20ºC,22ºC, 24ºC, 26ºC, 28ºC, 30ºC	Phadke et al. (2020)
Pleurotus colimbinus Quél.	15, 20, 25, 30, 35	25ºC	Sardar et al. (2015)
P. cornucopiae* var *citrinopileatus (Current name: ***Pleurotus citrinopileatus*** Singer)	25, 30, 35	25ºC	Zharare et al. (2010)
***P. cystidiosus* (**strain AG 2041)	16, 20, 24, 28, 32, 36	24ºC, 28ºC, 32ºC	Hoa & Wang (2015)
***P. cystidiosus* (**strain 1726)	16, 20, 24, 28, 32, 36	28ºC	Pereima & Ivanova (2017)
P. cystidiosus (strains: B1 and B122)	15, 20, 25, 30	25ºC	Dawidowicz et al. (2018)
P. djamor	23, 24, 25, 26, 27, 28	28ºC	Singh & Singh (2018)
P. eryngii	15, 20, 25, 30, 35, 40	25ºC	Zervakis et al. (2001)
P. eryngii	0, 5, 10, 15, 20, 25, 30, 35, 40	20ºC	Alavi et al. (2004)
P. eryngii	20, 25, 30	25ºC	Choi et al. (2005)
P. eryngii (27 strains)	10, 15, 20, 25, 30	20ºC, 25ºC, 30ºC	Ryu et al. (2007)
P. eryngii	25, 30, 35	30ºC	Zharare et al. (2010)
P. eryngii	15, 20, 25, 30, 35	25ºC	Sardar et al. (2015)
P. eryngii	15, 20, 25, 30	25ºC	Soylu et al. (2016)
P. eryngii	20, 25, 30, 35	25ºC	Chechan et al. (2017)
P. eryngii	15, 20, 25, 30, 35	25ºC	Abdel Aziz et al. (2018)
P. eryngii	20, 24, 26, 28, 30	20ºC	Krupodorova & Barshteyn (2020)
P. florida	20, 25, 28, 32	25ºC	Gorai & Sharma (2018)
P. florida	15, 20, 25, 30, 35	25ºC	Abdel Aziz et al. (2018)
P. giganteus	15, 20, 25, 30, 35, 40, 45	25ºC	Kumla et al. (2013)
P. giganteus (strain MFLU 10-0154)	20, 25, 30, 35	25ºC	Klomklung et al. (2014)

Table 2 Continued.

Fungal species and strains	Used temperature (ºC)	Preferred temperature (ºC)	Reference
P. ostreatus* var. *columbinus (Current name: ***Pleurotus columbinus*** Quél.)	25, 30, 35	25ºC	Zharare et al. (2010)
P. ostreatus* f. *florida	10, 15, 20, 25, 30, 35,40, 45	25ºC	Okwulehie & Okwujiako (2008)
P. ostreatus	15, 20, 25, 30, 35, 40	30ºC	Zervakis et al. (2001)
P. ostreatus	18-47	28ºC	Nwokoye et al. (2010)
P. ostreatus (strains: 1, 2)	25, 30, 35	25ºC	Zharare et al. (2010)
P. ostreatus	15, 25, 35, 45	25ºC	Adebayo-Tayo et al. (2011)
P. ostreatus	21, 23, 25, 27, 29, 31, 33, 35	25ºC	Akinyele et al. (2012)
P. ostreatus	15, 20, 25, 30, 35	25ºC	Sardar et al. (2015)
P. ostreatus (strain AG 2042)	16, 20, 24, 28, 32, 36	28ºC	Hoa & Wang (2015)
P. ostreatus (strain: HK-35)	16, 20, 24, 28, 32, 36	28ºC	Pereima & Ivanova (2017)
P. ostreatus	20, 25, 30, 35	25ºC	Chechan et al. (2017)
P. ostreatus	-	22ºC	Lee et al. (2018)
P. ostreatus	20, 25, 28, 32	25ºC	Gorai & Sharma (2018)
P. ostreatus	15, 20, 25, 30, 35	25ºC	Abdel Aziz et al. (2018)
P. ostreatus	22, 30, 37	22ºC	Fletcher et al. (2019)
P. ostreatus	20, 25, 30, 35	25ºC	Pant et al. (2020)
P. pulmonarius	15, 20, 25, 30, 35, 40	30ºC	Zervakis et al. (2001)
P. sajor-caju (strains: 1, 2)	25, 30, 35	25ºC (strain 2), 30ºC (strain 1)	Zharare et al. (2010)
P. sajor-caju	15, 20, 25, 30, 35	25ºC	Sardar et al. (2015)
P. sajor-caju	20, 25, 28, 32	25ºC	Gorai & Sharma (2018)
P. salmoneostramineus	25, 30, 35	25ºC	Zharare et al. (2010)
P. salmoneostramineus	20, 25, 30, 35	25ºC	Abd El-Zaher et al. (2015)
P. sapidus (Current name: ***Pleurotus cornucopiae*** (Paulet) Rolland) (strain FW-133)	15, 20, 25, 30, 35	35ºC	Sardar et al. (2015)
P. tuber-regium (Fr.) Singer	20, 25, 30, 35, 40, 45	30ºC	Moyib et al. (2019)
Poria cocos (strains: Andong 01, Andong 02, Andong 03, KFRI 1103, KRFI 1104, KFRI 1107, ASI 13007, KFRI 1105, KFRI 1106, KRFI 1108)	10, 15, 20, 25, 30, 35	30ºC (strains: Andong 02, Andong 03, KFRI 1103, KRFI 1104, KFRI 1107, ASI 13007), 35ºC (strains: KFRI 1105, KFRI 1106, KRFI 1108), 30ºC and 35ºC (strain Andong 01)	Jo et al. (2016)
Pycnoporus cinnabarinus (strain M20)	20, 25, 30, 35	25°C	Sharma & Jaitly (2017)
P. sanguineus (strain M22)	20, 25, 30, 35	25°C	Sharma & Jaitly (2017)
Schizophyllum commune (strains: IUM 0207, IUM 0395, IUM 0669, IUM 1020, IUM 1097, IUM 1114, IUM 1452, IUM 1649, IUM 1690, IUM 1726)	15, 20, 25, 30, 35	25°C and 30°C (strain IUM 1452), 30°C, 35°C (strains: IUM 0207, IUM 0395, IUM 0669, IUM 1097, IUM 1114, IUM 1649, IUM 1690), 25°C, 30°C, 35°C (IUM 1726)	Imtiaj et al. (2008b)
S. commune (strains: (IUM 1763, IUM 1768, IUM 0137, IUM 0157, IUM 0202, IUM 0395, IUM 0548, IUM 2324, IUM 2650, IUM 2659, IUM 3353, IUM 3566)	15, 20, 25, 30, 35	25°C, 30°C (strains: IUM 0202, IUM 1768, IUM 2324), 30°C, 35°C (strains: IUM 0137, IUM 0157, IUM 0395, IUM 0548, IUM 2650, IUM 2659, IUM 3353, IUM 3566), 25°C, 30°C, 35°C (strain	Alam et al. (2010)

Table 2 Continued.

Fungal species and strains	Used temperature (ºC)	Preferred temperature (ºC)	Reference
		IUM 1763)	
S. commune	10, 15, 20, 25, 30, 35, 40	30°C	Reddy et al. (2017)
S. commune	25, 30, 40, 50, 60	30°C	Teoh & Don (2016)
S. commune	16, 24, 28, 32, 36	28°C, 32°C	Rosnan et al. 2019
Sclerotium rolfsii	15, 20, 25, 30, 35	25°C, 30°C	Sravani & Chandra (2020)
Trametes elegans (Spreng.) Fr.	15, 20, 25, 30, 35, 40	30°C	Sagar et al. (2020)
T. versicolor	16, 20, 24, 28	24°C	Chauhan (2016)
T. versicolor	15, 20, 25, 30, 35, 40	30°C	Sagar et al. (2020)
Tricholoma terreum	15, 20, 25, 30	25°C	Kibar & Peksen (2011)
Volvariella volvacea	20, 25, 30, 35, 40	35ºC	Fasidi (1996)
V. volvacea	15, 20, 25, 30, 35, 40	35ºC	Zervakis et al. (2001)
V. volvacea	10, 15, 20, 25, 30, 35, 40, 45, 50	30ºC	Akinyele & Adetuyi (2005)
V. volvacea	15, 20, 25, 30, 35, 40	30ºC ~ 35ºC	Kumar et al. (2016)
V. volvacea	9, 26–28, 32	26°C – 28°C, 32°C	Abon et al. (2020)

Every fungus as well as strain has an optimal temperature for the growth and it is necessary to take into account, that the optimum for the cultivation of different fungal cultures belonged to the same genus can vary depending on the particularities of the strains, cultivation medium, its pH, and method of cultivation.

Influence of pH on mycelium growth

One of the most important chemical factors for the cultivation of fungi is the pH of the medium. The pH has a remarkable impact on mycelial growth and morphological changes through the differentiation of cell membrane function, as well as influence on the synthesis of metabolites. Also, it effects the solubility of salts, and uptake of necessary nutrients from the medium (Gbolagade et al. 2006, Jonathan et al. 2009, Adebayo-Tayo et al. 2011, Elisashvili 2012). Fungi are usually limited to grow in a narrow pH range close to neutrality, although some can tolerate extreme pH (Deacon 2006). On the other hand, the secretion of compounds, such as organic acids allow fungi to change the pH around them (Cervantes-Chavez et al. 2010). The value of pH change depends also on the nutrient suitability, and on the ability of the fungus to disposal ammonium ions from ammonium sulfate salt or to excrete H^+-ions as a byproduct of NH_4^+ assimilation (Prusky et al. 2001, Bi et al. 2016). Adaptation to different pH requires an internal pH homeostatic system and a specific regulatory system, which assures, that molecules exposed to the environment, be secreted only under favorable conditions (Penalva et al. 2008).

It is known that fungi can grow and development over a wide pH ranges. One of the important parts of a comprehensive study of fungi in culture is determination of the optimum pH level as the most favorable pH for their growth. The current data about the characterization of the pH effect on the fungal growth is represented in Table 3. The statistically significant effect of pH of the initial medium on mycelium growth has been demonstrated for different analyzed basidiomycetes. It was found the pH influence on these fungal species had extended meaning. The most used pH range of values was 1.0 or 0.5 units, seldom 0.2 or 0.3 units. Studies were conducted in broad (up 2–3 to 10–12) as well as in quite narrow (up 4.0 to 6.5–7.0) tested pH ranges. From the analyzed data it can be noted that the pH range between 4.0−9.0 was the most used to study the effect of pH on fungal growth. A preference for one certain pH, which provides maximum growth, was characterized for the most of the analyzed fungal species as well as strains. Some of them were noted by a speedy growth (at the same level) in a certain pH range. In contrast, pH 5.0−7.0 are more appropriate for the growth of the most of characterized fungi. The results of pH influence on the growth of analyzed fungal species showed, that optimal pH occurred between 3.0 to 9.0. These results reflected the ability of fungi to be acidophilic (pH from 0 to 5.5), neutrophilic (pH from 5.5 to 8.0) and alkaliphilic (above 8.0) since basidiomycetes comprise the quite unique

ecophysiological group of macrofungi that can be found in virtually all terrestrial ecosystems. The ability of fungi to perceive and adapt to relevant pH changes in their environment is very important for their survival. This vital trait is especially important for fungal species ecologically and trophically associated with host organisms like pathogens, parasites, and symbionts. The majority of analyzed in current study fungal species are saprotrophs, playing an important role in soil, litter and wood decay, others are symbionts, particularly mycorrhizal fungi. The best suitable pH for plant pathogen on tomatoes like *Sclerotium rolfsii* growth was found to be 6.0. The maximal growth of *Pleurotus eryngii*, which naturally grow on the roots of *Apiaceae* plants like *Eryngium* spp. and *Ferula* spp., was recorded at pH 6.0-7.0. Ectomycorrisal fungi such as *Cantharellus cibarius*, *Hydnum repandum*, *Lactarius deliciosus*, *Russula sanguinaria*, *Suillus collinitus*, *S. granulatus*, *Tricholoma batschii*, *T. imbricatum*, *T. terreum* preferred quite narrow range of pH between 4.0 and 6.5. Ecologically, the rest analyzed basidiomycetes can be divided into those inhabiting wood and those which growing on the ground (soil): in humus-rich soil of different edaphic types and/or leaf-litter environment, on road sides, in grass. The best growth of saprotrophic which growing on the ground (*Agaricus* spp., *Chlorophyllum molybdites*, *Coprinus comatus*, *Floccularia luteoviens*, *Leucocalocybe mongolica*, *Lyophyllum decastes*, *Macrolepiota* spp., *Mycena leptocephali*, *Stropharia rugosoannulata*, *Volvariella volvacea*) was established on soil from strongly acid to strongly alkaline with optimum pH levels between 5.5 – 9.0. Majority of soils have pH values between 3.5 and 10 depending to multiple parameters in soil biogeochemical processes (Neina 2019). The broad optimal pH occurred for wood inhabiting fungi from extremely acid (pH 3.0) to strongly alkaline (pH 9.0) levels. The pH magnitude of wood species also varies greatly from strongly acidic to strongly alkaline depends tree species, habitat features such as wet, temperature level, and etc. (Geffert et al. 2019). However, generally the most favorable for plant growth pH levels up 4.5 to 7.5 due to the easily available for the most plant nutrients in this range (Neina 2019).

Table 3 Influence of different pH on the growth of fungi mycelium

Fungal species and strains	Used pH	Preferred pH	Reference
Agaricus bisporus (strains: S-79, A-15, Delta)	6.0~9.0	9.0	Yadav & Chandra (2014)
A. bisporus	5.5~8.0	7.0~7.5	Ma et al. (2014)
A. bisporus (strains: 1946, 1947, 1948, 1955, 1956, 2029, 2097, 2102, 2107, 2177, 2178)	4.0~9.0	6.0	Ismail et al. (2016)
A. bitorquis (strain DSM 4135)	4.0~6.4	6.4	Furlan et al. (1997)
A. blazei	4.0~8.0	6.0	Rozsa et al. (2016)
A. brasiliensis (strains from L1 to L5)	3.0~8.0	5.56	Colauto et al. (2008)
Antrodia camphorata (Current name: ***Taiwanofungus camphoratus*** (M. Zang & C.H. Su) Sheng H. Wu, Z.H. Yu, Y.C. Dai & C.H. Su)	3.0~6.0	4.0	Shu & Lung (2004)
A. cinnamomea (strain BCRC 35396)	4.0~6.0	5.5	Lin & Sung (2006)
Armillaria luteovirens	4.0~7.0	5.0	Xu et al. (2011)
Auricularia auricula-judae	4.0~8.0	5.0~6.0	Yu et al. (2013)
A. auricula-judae (strains: GBAA-01, GBAA-02, GBAA-03, ASI 6009, ASI 6033)	4.0~9.0	4.0~9.0	Jo et al. (2014)
A. delicata	5.0~7.0	6.0	Jacob et al. (2020)
A. polytricha	3.0~10.0	4.0	Yang et al. (2002)
A. polytricha	4.0~9.5	6.5	Jonathan et al. (2009)
Calocybe indica	2.0~7.0	6.0	Phutela & Phutela (2012)
C. indica	3.0~11.0	6.0	Min et al. (2020)
C. indica	6.0~8.0	7.0	Sardar et al. (2020)

Table 3 Continued.

Fungal species and strains	Used pH	Preferred pH	Reference
Cantharellus cibarius	5.0~8.0	6.0	Deshaware et al. (2021)
Chlorophyllum molybdites	4.0~9.0	5.0–5.5	Garcia et al. (2020)
Coprinus comatus (strains: GMCC 54001, GMCC 67001, GMCC 67002, GMCC 67003, GMCC 67004)	4.0~8.0	7.0	Jang et al. (2009)
Coriolus hirsutus	3.0~8.0	5.6~5.8	Emelyanova (2005)
C. hirsutus (strain IBK 5137)	-	4.0~4.5	Antonenko et al. (2011)
C. pubescens	4.0~9.0	4.0	Jo et al. (2010)
C. versicolor	4.0~9.0	6.0~9.0 (ASI 16003), 4.0~5.0 (ASI 16006; GBCV-01), 4.0 (ASI 16008)	Jo et al. (2010)
C. versicolor (strain IBK 353)	-	5.0~5.5	Antonenko et al. (2011)
C. villosus (strain IBK 1009)	-	4.5~5.0	Antonenko et al. (2011)
C. zonatus (strain IBK 5302)	-	5.5~6.0	Antonenko et al. (2011)
Cyclocybe cylindracea	6.0~8.0	6.0	Landingin et al. (2020)
Flammulina velutipes (strain DSM 1658)	4.0~6.4	6.4	Furlan et al. (1997)
Floccularia luteovirens (strain IE 5034)	4.0~6.0	4.0, 5.0, 6.0 (different media)	Arana-Gabriel et al. (2020)
Fomitopsis betulina	3.5~6.5	3.5~4.0	Krupodorova et al. (2019)
Ganoderma applanatum (strains: ASI 50167, ASI 52821, ASI 52822, ASI 52823, ASI 53399, GBGA-01, GBGA-02)	4.0~9.0	6.0~9.0	Jo et al. (2009)
G. applanatum	3.0~8.0	3.0	Jeong et al. (2009)
G. applanatum (13 strains)	4.0~6.5	5.0~5.5	Bisko et al. (2012)
G. australe (strain MFLUCC 12-0527)	5.0~8.0	7.0~8.0	Luangharn et al. (2017)
G. lucidum	3.5~8.5	6.5	Fang & Zhong (2002)
G. lucidum	4.0~6.5	5.5	Simonić et al. (2008)
G. lucidum (8 strains)	5.0~9.0	5.0~9.0	Jayasinghe et al. (2008)
G. lucidum (27 strains)	4.0~6.5	5.0~5.5	Bisko et al. (2012)
G. lucidum (8 strains)	2.0~12.0	5.0	Kapoor & Sharma (2014)
G. lucidum (strain GA3)	3.0~12.0	9.0~12.0	Nguyen et al. (2019)
Grifola frondosa	3.0~12.0	5.0	Kim (2003)
G. frondosa	3.0~9.0	5.0	Khandakar et al. (2009)
G. frondosa (strains: IBK 332, IBK 962, IBK 1790, IBK 1794)	4.6~8.1	5.4–6.0 (IBK 332, IBK 962, IBK 1794), 6.8 (IBK 1790)	Linovyts'ka et al. (2011)
G. gargal (strain CIEFAP 191)	4.0~7.0	4.0	Postemsky et al. (2006)
G. sordulenta (strain CIEFAP 154)	4.0~7.0	4.0	Postemsky et al. (2006)
G. umbellate (Current name: ***Polyporus umbellatus*** (Pers.) Fr.)	3.0~8.0	6.0	Huang & Liu (2008)
Hericium erinaceus (strains: (IUM0217, IUM1128, IUM2876, IUM 3271)	5.0~9.0	6.0	Imtiaj et al. (2008a)
Hydnum repandum	4.0~6.5	5.5	Peksen et al. (2013)
Hypsizygus ulmarius	5.0~8.0	7.0	Sharma et al. (2018)
Hypsizygus ulmarius	4.0~8.0	6.0, 8.0	Emayavarman & Singh (2021)
Kuehneromyces mutabilis (strain DSM 1684)	4.0~6.4	6.4	Furlan et al. (1997)
Lactarius deliciosus (L.) Gray	4.0~7.5	5.8~6.5	Lazarević et al. (2016)
Laetiporus sulphureus (Bull.) Murrill (strain 205)	3.0~5.6	3.0-3.5	Bisko et al. (2012)
Lentinula edodes (strain DSM 1899)	4.0~6.4	6.4	Furlan et al. (1997)
L. edodes	4.0~6.0	5.0	Inglet et al. (2006)

Table 3 Continued.

Fungal species and strains	Used pH	Preferred pH	Reference
L. edodes	3.5~9.0	4.5~6.5	Reddy et al. (2017)
L. edodes (strain Le-17-04)	4.0~8.0	5.0~6.0	Kumar et al. (2019)
L. edodes	4.0~6.5	3.5	Krupodorova et al. (2019)
Lentinus connatus	5.0~8.0	5.5	Klomklung et al. (2014)
L. crinitus (strains U9-1 and U15-9)	5.0~7.0	5.0~7.0	Marim et al. (2018)
L. crinitus	2.0~11.0	6.1	Colla et al. (2020)
L. roseus	5.0~8.0	5.5~7.5	Klomklung et al. (2014)
L. squarrosulus	5.0~8.0	6.5~7.0	De Leon et al. (2017)
L. strigosus	4.0~9.0	6.0	Vargas-Isla & Ishikawa (2008)
L. subnudus	4.0~7.0	5.0~7.0	Gbolagade et al. (2006)
L. swartzii	4.0~9.0	5.5	Dulay et al. (2021)
Leucocalocybe mongolica	4.0~7.0; 6.0~8.0	6.5	Lu et al. (2017)
Lyophyllum decastes (Fr.) Singer.	4.0~9.0	8.0	Pokhrel & Ohga (2007)
Macrolepiota detersa (strains: MFLUCC 13-0901, SIMA 13266)	4.0~9.0	7.0~8.0	Rizal et al. (2014)
M. dolichaula	4.0~9.0	7.0	Rizal et al. (2016)
M. procera	4.0~7.0	6.0	Pekşen & Kibar (2020)
Mycena leptocephala	3.5~7.5	5.5	Vahidi et al. (2014)
Oudemansiella radicata (Current name: ***Hymenopellis radicata*** (Relhan) R.H. Petersen)	4.0~9.0	6.0	Kim et al. (2005)
Phellinus alni (strain IUM 3151)	4.0~9.0	5.0	Hur et al. (2008)
P. baumi (strain IUM 3169)	4.0~9.0	5.0	Hur et al. (2008)
P. cavicola (strain IUM 3164)	4.0~9.0	6.0	Hur et al. (2008)
P. chrysoona (strain IUM 3149)	4.0~9.0	6.0	Hur et al. (2008)
P. conchaatus (strain IUM 3150)	4.0~9.0	6.0	Hur et al. (2008)
P. linteus	4.0~8.0	7.0	Kim et al. (2001)
P. linteus (strains IUM 3159, IUM 3161)	4.0~9.0	7.0, 6.0	Hur et al. (2008)
P. linteus	4.0~6.0	5.0	Lee et al. (2011)
P. linteus	5.5~7.5	5.5	Liang et al. (2020)
P. lundellii (strain IUM 3153)	4.0~9.0	7.0	Hur et al. (2008)
P. popaceus (strain IUM 3156)	4.0~9.0	7.0	Hur et al. (2008)
P. populicola (strain IUM 3155)	4.0~9.0	7.0	Hur et al. (2008)
P. robustus (strain M-10)	2.0~10.0	6.0~9.0	Bisko et al. (2012)
P. toruluae (strain IUM 3158)	4.0~9.0	4.0	Hur et al. (2008)
P. trenulae (strain IUM 3157)	4.0~9.0	7.0	Hur et al. (2008)
P. vorax (strain IUM 3163)	4.0~9.0	7.0	Hur et al. (2008)
Pleurotus spp. (11 isolates)	5.0~9.0	6.0	Phadke et al. (2020)
P. citrinopileatus Singer	4.0~7.0	6.0	Wu et al. (2008)
P. djamor	6.9, 7.1, 7.3, 7.5, 7.7, 7.9, 8.1	7.5	Singh & Singh (2018)
P. eryngii	4.0~9.0	6.0	Alam et al. (2009)
P. eryngii	5.5~7.0	6.5	Chechan et al. (2017)
P. eryngii	5.0~7.0	7.0	Abdel Aziz et al. (2018)
P. ferulae (Current name: ***Pleurotus eryngii*** (DC.) Quél.)	3.5~8.0	6.5	Choi et al. (2005)
P. florida	5.0~7.0	6.0~6.5	Abdel Aziz et al. (2018)
P. florida	4.5~8.5	6.5~7.5	Gorai & Sharma (2018)
P. giganteus	2.0~9.0	7.0	Kumla et al. (2013)
P. giganteus	4.0~9.0	5.0~6.5	Klomklung et al. (2014)
Pleurotus ostreatus (strain DSM 1833)	5.0~9.0	5.0~6.4	Furlan et al. (1997)
P. ostreatus	4.0~6.4	6.5	Salem et al. (2014)
P. ostreatus	3.0~8.0	8.0	Adebayo-Tayo et al. (2014)
P. ostreatus	6.0~10.0	5.5	Horincar et al. (2014)
P. ostreatus	5.0~6.0	5.0~6.0	Lee et al. (2018)

Table 3 Continued.

Fungal species and strains	Used pH	Preferred pH	Reference
P. ostreatus	4.0~8.0	6.5~7.5	Gorai & Sharma (2018)
P. ostreatus	4.5~8.5	7.0	Pant et al. (2020)
P. ostreatus	5.0~9.0	7.0	Abdel Aziz et al. (2018)
P. ostreatus* f. *florida	5.0~7.0	6.4~7.0	Okwulehie & Okwujiako (2009)
P. sajor-caju	3.0~8.0	6.5~7.5	Gorai & Sharma (2018)
P. salmoneostramineus	4.5~8.5	6.0	Abd El-Zaher et al. (2015)
Poria cocos (10 strains)	4.5~8.0	4.0~6.0	Jo et al. (2016)
Russula sanguinaria (Schumach.) Rauschert	4.0~7.5	5.8~6.5	Lazarević et al. (2016)
Schizophyllum commune	3.0~9.0	5.0~8.0	Reddy et al. (2017)
S. commune	4.0~8.0	4.0	Rosnan et al. (2019)
S. commune	5~10	5.0, 6.0	Aminah et al. (2020)
Sclerotium rolfsii	4.0~9.0	6.0	Sravani & Chandra (2020)
Stropharia rugosoannulata (strain DSM 1655)	4.0~6.4	5.0~6.4	Furlan et al. (1997)
Suillus collinitus (Fr) Kuntze	4.0~7.5	4.0~5.2	Lazarević et al. (2016)
S. granulatus (L.) Rousell	4.0~7.5	4.0~5.2	Lazarević et al. (2016)
Trametes elegans	4.0~9.0	7.0	Sagar et al. (2020)
T. versicolor	3.0~8.0	6.0	Chauhan (2016)
T. versicolor	4.0~9.0	7.0	Sagar et al. (2020)
Tremella mesenterica Retz.	5.0~7.0	6.0	Wasser et al. (2003)
Tricholoma batschii Gulden ex Mort. Chr. & Noordel.)	4.0~7.5	5.8~6.5	Lazarević et al. (2016)
T. imbricatum (Fr.) P. Kumm	4.0~7.5	4.0~5.2	Lazarević et al. (2016)
T. terreum (Schaeff.) P. Kumm.	4.0~6.0	5.0~5.5	Kibar & Peksen (2011)
Volvariella volvacea (strain VDSM 3279)	4.0~6.4	6.4	Furlan et al. (1997)
V. volvacea	2.0~9.0	6.5	Akinyele & Adetuyi (2005)
V. volvacea	5.0~10.0	6.0~8.0	Kumar et al. (2016)
V. volvacea (strains: La Clementina, Vinces, Montalvo)	5.5~8.0	6.5~7.5	Abon et al. (2020)

It will be noted that growth conditions can affect on establishment of the optimal pH. Growth rate of *Floccularia luteovirens* at optimal pH 4.0, 5.0, 6.0 changed depending on the applied solid media like malt extract agar; corn meal agar; coconut water agar (Arana-Gabriel et al. 2020).

The results of pH influence on mycelium accumulation showed, that the various fungal species as well as their strains, could grow in a wide range of pH levels. Optimal initial pH is from 3.0 to 9.0 for mycelial growth depends on the fungal species, strains of the same fungus, and also include some other cultivation conditions like culture medium. It might be also attributed to genetic differences of fungi species, as well as strains and their adaptation properties to the individual growth conditions. In general, it can be concluded, that slight acidic and neutral pH are more appropriate for the growth of the most investigated fungi.

Influence of carbon and nitrogen sources on mycelium growth

Characterization of the nutritional needs of fungi allows us to establish their physiological features. Carbon-containing substrates, such as sugars and their derivatives (oligo- and polysaccharides), carry out the energy sources for cells and more or less replicate the nutrition substrates from natural habitation. Fungi as chemoorganotrophs depend on the fixed forms of organic compounds for their carbon and energy supply. Basidiomycetes is divided into very diverse ecological groups with different strategies targeted on obtaining organic compounds. Their capability produces a broad range of hydrolytic and oxidative enzymes allows them to have unique abilities to utilize various carbon sources.

One of the significant key points of the study in trophic characteristics of fungi in culture is the establishment of suitable carbon sources for the growth. The current knowledge on preferred C-

source(s) for the growth of analyzed fungi is summarized in table 4. Overviewed basidiomycetes in this table utilize a wide variety of carbon sources such as monosaccharides, disaccharides, polysaccharides, sugar alcohols, different natural origin sources like molasses, black sugar, rye flour. A preference for one certain carbon source, which provided the best growth, was typical for the most of the analyzed fungal species and their strains. The efficiency degree for the utilization of monosaccharides by fungi can be represented schematically as follow: glucose > fructose > xylose = mannose > dextrose > galactose > arabinose. Among disaccharides, sucrose was suitable for the most species, half as much – maltose, and very rarely – lactose. Among polysaccharides, dextrin was described as the most desirable carbon source and starch was on the next place, unlike the cellulose substrate. Also, a satisfied growth of some fungal species was detected on the media with two carbon sources. Dextrin along with other sugars performed as an appropriate substrate for fungal biomass growth. Its nutritional favorability can be considered on the same level with such C-sources as disaccharides like sucrose, maltose, lactose; monosaccharides such as glucose, xylose, mannose; and also, with sugar alcohols: sorbitol, mannitol, glycerol. Less variation was appropriated with starch, in particular with glucose, mannose and sucrose. Single variations also took place in utilization of dextrose and mannitol, mannitol and sorbitol, xylose and fructose, as well as xylose and galactose. Less commonly, three saccharides have promoted the growth of fungi at the same level. In this context, polysaccharides dextrin and starch were often used with different other carbon sources: dextrin, lactose, mannitol; dextrin, mannose, fructose; dextrin, maltose, sucrose; dextrin, glucose, arabinose; starch, cellobiose, maltose; starch, sucrose, maltose; starch, maltose, glucose; starch, sucrose, glucose. Also, single variations took place in utilization of sucrose, molasses, glucose; sucrose, glucose, arabinose; sucrose, dextrose, glucose. Otherwise, wood decay fungi are able to consume with equal efficiency a wide range of different carbon sources: galactose, dextrose, mannose, maltose in case of *Ganoderma lucidum* strain IUM 0751 (Jayasinghe et al. 2008), mannose, maltose, sucrose, dextrin for *Schizophyllum commune* strain IUM 0207 and sorbitol, fructose, mannose, maltose, dextrin in case of *Schizophyllum commune* strain IUM 1726 (Imtiaj et al. 2008b), fructose, mannose, maltose, dextrin for *Coriolus pubescens* (Jo et al. 2010).

However, glucose is a fundamental building block of different saccharides like disaccharides (lactose, maltose and sucrose), polysaccharides (dextrin, cellulose, starch), and oligosaccharides like raffinose. Hence, it can be concluded, that glucose as well as its structural or stereoisomers (fructose and galactose, respectively), epimer (mannose) and polymers are the best carbon sources for the mycelia growth for the majority of analyzed basidiomycetes. Glucose can be treated as universal carbon source due it building in various sugars as Subunit, and because it fast catabolization by fungi to produce cellular energy easily (Garraway & Evans 1984).

Nitrogen is another essential element required for fungal growth. This is one of the keys in physiological control, regulation of metabolisms, synthesis of nitrogen-containing compounds, and enzymes or metabolite production (Becker 1988). By their nature fungi are non-diazotrophic. They cannot fix nitrogen and require the supply of nitrogenous compounds. It is generally accepted, that fungi can use different nitrogen compounds for their needs.

Another important part of the trophic characteristics for fungi in culture is the establishment of suitable nitrogen sources for their growth and development. The current knowledge on preferred N-source(s) for the growth of analyzed fungi is summarized in Table 4. The known tendency for fungi to prefer organic nitrogen as compared to inorganic forms of nitrogen is also observed for the analyzed basidiomycetes. Basidiomycetes are able to utilize a wide variety of organic (amino acids, peptides, complex organic nitrogen compounds, protein) and inorganic (ammonium salts, nitrates) nitrogen sources. A preference for one certain nitrogen source, which provides the best growth, was typical for the most of the analyzed fungal species as well as strains. Various amino acids were found as favorable during the cultivation of many basidiomycetes. Their nitrogen preference level, depending on the efficiency of use, can be represented as follows: asparagine > alanine = glycine > arginine > tryptophan. Amino acids containing shorter chains are better absorbed than those with long chains (Becker 1988). Growth stimulating effect was also provided by complex organic

nitrogen compounds, in particular peptone as well yeast extract, less often malt extract, and very rare urea. Effectively supported growth of some fungal species different form of peptone like tryptone, casein, soypeptone, polypeptone. Also, other organic form of nitrogen natural original like beef extract, soybean powder, corn steep powder and liquid, wheat bran, skim milk, albumin bovine- BSA were able to promote the growth activity of single fungal species. Generally, preference for naturally originated complex nitrogen organic forms may occur owing to their rich contents of combined amino acids, protein and vitamins, which are supportive of the fungal growth. Nitrates, in particular calcium nitrate as well as sodium nitrate, and rarely potassium nitrate were more appropriate than nitrogen in the form of ammonium. However, a number of basidiomycetes are able to consume ammonium salts. According to the degree of demand, it can be placed in the next order: ammonium phosphate > ammonium acetate > ammonium chloride. Ammonium sulfate is a commonly used nitrogen source in fungal growth media since it also provides a source of utilizable sulfur (Becker 1988).

Table 4 Influence of different carbon and nitrogen sources on the growth of fungi mycelium

Fungal species and strains	**Preferred carbon sources** (concentration %)	**Preferred nitrogen sources** (concentration %)	**Reference**
Agaricus bisporus	glucose	yeast extract	Ma et al. (2014)
A. bisporus (strains: 1946, 1947, 1948, 1955, 1956, 2029, 2097, 2102, 2107, 2177, 2178)	mannose (strains 1946, 1947), maltose (strain 1948), sucrose (strains: 1955, 2097, 2178), dextrin and sucrose (strains: 1956, 2029, 2102, 2107, 2177)	glycine (strains: 1946, 1947, 1948, 1955, 1956, 2029, 2097), alanine (strain 2102), glycine and urea (strain 2107), arginine and calcium nitrate (strain 2178), ammonium acetate (strain 2177)	Ismail et al. (2016)
A. brasiliensis (strain ATCC 76739)	sucrose, glucose	-	Shu & Xu (2007)
Antrodia cinnamomea (strain BCRC 35396)	xylose	casein	Lin & Sung (2006)
Auricularia auricula	black sugar (5%)	soybean powder (0.3%)	Yu et al. (2013)
A. auricula-judae (strains: GBAA-01, GBAA-02, GBAA-03, ASI 6009, ASI 6033)	mannose (strain GBAA-01), sorbitol (strain GBAA-03), dextrin and sorbitol (strain GBAA-02), mannitol and sorbitol (strain ASI 6033)	yeast extract (strains: GBAA-01, GBAA-02, GBAA-03), malt extract and yeast extract (strain ASI 6033)	Jo et al. (2014)
A. polytricha	glucose (1.6%)	peptone (0.8%), tryptophan (0.9%)	Jonathan et al. (2009)
A. polytricha (strain ASI 6009)	mannitol, dextrin and lactose	yeast extract	Jo et al. (2014)
Calocybe indica	xylose	yeast extract	Phutela & Phutela (2012)
Coprinus comatus (strains: GMCC 54001, GMCC 67001, GMCC 67002, MCC 67003, GMCC 67004)	maltose, sucrose and starch	tryptone (strains: 54001, 54003, 67001, 67002, 67003, 67004), peptone (strain 54002)	Jang et al. (2009)
Coriolus brevis (Current name: ***Cerrena zonata*** (Berk.) H.S. Yuan) (strain ASI 16007)	dextrin	yeast extract	Jo et al. (2010)
C. pubescens (strain ASI 16002)	dextrin, maltose, fructose, mannose	yeast extract	Jo et al. (2010)

Table 4 Continued.

Fungal species and strains	Preferred carbon sources (concentration %)	Preferred nitrogen sources (concentration %)	Reference
C. versicolor (strains: ASI 16003, ASI 16006, ASI 16008, GBCV-01)	starch (strain ASI 16003), dextrin (strain 1608) dextrin, mannose (strain ASI 16006), dextrin, lactose (strain GBCV-01)	yeast extract	Jo et al. (2010)
Fomitopsis betulina (strain IBK 327)	cellulose	asparagine	Krupodorova et al. (2019)
Ganoderma applanatum	glucose (8%)	corn steep powder (10%)	Jeong et al. (2009)
G. applanatum (strains: ASI 50167, ASI 52821, ASI 52822, ASI 52823, ASI 53399, GBGA-01,GBGA-02)	starch (strains: GBGA-01, ASI 50167), starch, mannose (strains: GBGA-02, ASI 52821,), mannose, dextrin, fructose (strain ASI 52822), dextrin (strains: ASI 52823, ASI 53399)	yeast extract	Jo et al. (2009)
G. applanatum *(*strains: IBK 1530, IBK 1896, IBK 1897, IBK 1898, IBK 1899, IBK 920, IBK 1552, IBK 1553, IBK 1701, IBK 1672, IBK 1572, IBK 1593, IBK 1895)	glucose (strains: IBK 920, IBK 1672, IBK 1896, IBK 1593, IBK 1530), sucrose (strain IBK 1572), starch (strains: IBK 1899, IBK 1895, IBK 1552, IBK 1553), glucose, starch (strain IBK 1898), sucrose, starch (strain IBK 1897), glucose, sucrose, starch (strain IBK 1701)	ammonium sulphate (strain IBK 1701), asparagine (strains: IBK 1530, IBK 1896, IBK 1897, IBK 1898, IBK 920, IBK 1552, IBK 1553, IBK 1593, IBK 1895), ammonium sulphate, asparagine (strains: IBK 1672, IBK 1899), asparagine, sodium nitrate (strain IBK 1572)	Bisko et al. (2012)
G. lucidum (strain ASI 7125)	dextrin, mannitol	calcium nitrate, malt extract	Jo et al. (2009)
G. lucidum (strains: IUM 0037, IUM 0047, IUM 0637, IUM 0751, IUM 0757, IUM 0805, IUM 0938, IUM 1027)	dextrin (strains: IUM 0037, IUM 0047, IUM 0805), mannose (strain IUM 0637), galactose, xylose (strains: IUM 0757, IUM 1027), maltose, fructose (strain IUM 0938), mannose, galactose, dextrose, maltose (strain IUM0751)	ammonium acetate (strains: IUM 0037, IUM 0751, alanine (strain IUM 0757), ammonium phosphate (strain IUM 0805), arginine (strain IUM 1027), alanine, ammonium acetate (strain IUM 0637), alanine, arginine, glycine, urea, calcium nitrate (strains: IUM 0047, IUM 0938)	Jayasinghe et al. (2008)
G. lucidum (27 strains)	starch	asparagine (6 strains), sodium nitrate, ammonium sulphate (3 strains), asparagine and sodium nitrate (9 strains), asparagine and ammonium sulphate (5 strains), asparagine, ammonium sulphate and sodium nitrate (5 strains)	Bisko et al. (2012)
Grifola frondosa	xylose	-	Imtiaj et al. (2007)
G. frondosa	fructose	-	Khandakar et al. (2009)
G. frondosa (strains: IBK 332, IBK 962, IBK 1790, IBK 1794)	glucose (strains: IBK 962, IBK 1790), starch (strain IBK 1794), glucose, starch (strain IBK 332)	peptone (strains: IBK 332, IBK 962, IBK 1790, IBK 1794)	Linovyts'ka et al. (2011)

Table 4 Continued.

Fungal species and strains	Preferred carbon sources (concentration %)	Preferred nitrogen sources (concentration %)	Reference
G. umbellata (Current name: ***Polyporus umbellatus*** (Pers.) Fr.)	glucose (3 %)	skim milk (0.2%, 0.5%), yeast extract	Huang & Liu (2008)
Hericium erinaceus (strains: IUM0217, IUM1128, IUM2876, IUM 3271)	dextrin (strain IUM 3271), fructose (strain IUM 1128), glucose, dextrin (strain IUM 2876), fructose, xylose (strain IUM 0217)	alanine (strains: IUM0217, IUM1128, IUM2876), ammonium acetate, glycine (strain IUN3271)	Imtiaj et al. (2008a)
Inonotus obliquus (strain B-26)	glucose, xylose	ammonium sulphate	Bisko et al. (2012)
Lactarius deliciosus	glucose, sucrose, arabinose	albumin bovin-BSA	Lazarevič et al. (2016)
Laetiporus sulphureus (strain 205)	starch	peptone, yeast extract	Bisko et al. (2012)
Lentinula edodes	glucose	ammonium chloride	Kim et al. (2002)
L. edodes	fructose	yeast extract, sodium nitrate	Osman et al. (2009)
L. edodes	glucose	yeast-powder	Feng et al. (2010)
L. edodes	maltose	wheat bran	Petre et al. (2012)
L. edodes	dextrose, mannitol	peptone, sodium nitrate	Deepa Rani & Das (2015)
L. edodes	cellulose, glucose	asparagine	Krupodorova et al. (2019)
L. edodes (stain IBK 2541)	glucose	asparagine	Bisko et al. (2020)
Lentinus subnudus	fructose	yeast extract	Gbolagade et al. (2006)
Leucocalocybe mongolica (strain MCCJLAU2015C1)	maltose, starch, cellobiose	yeast extract, beef powder, beef extract	Lu et al. (2017)
Lyophyllum decastes	lactose	yeast extract	Pokhrel & Ohga (2007)
Macrolepiota gracilenta (Current name: ***Macrolepiota mastoidea*** (Fr.) Singer)	glucose, starch	ammonium sulphate	Petcharat & Khuntong (1999)
M. procera	maltose	glycine	Shim et al. (2005)
M. procera	glucose, mannose	peptone, yeast extract, D-alanine	Gbolagade et al. (2006)
M. procera	dextrose	peptone, malt extract	Pekşen & Kibar (2016)
M. procera	glucose	peptone, yeast extract	Pekşen & Kibar (2020)
Mycena leptocephala	glucose	yeast extract	Vahidi et al. (2004)
Oudemansiella radicata (strain UM00779)	xylose	alanine	Kim et al. (2005)
O. radicata	sucrose	peptone	Zou (2005)
Phellinus alni (strain IUM3151)	dextrin	ammonium phosphate	Hur et al. (2018)
P. baumi (strain IUM3169)	lactose	ammonium phosphate	Hur et al. (2018)
P. cavicola (strain IUM3164)	sucrose	ammonium phosphate	Hur et al. (2018)
P. chrysoona (strain IUM3149)	maltose	ammonium phosphate	Hur et al. (2018)
P. conchaatus (strain IUM3150)	fructose	ammonium phosphate	Hur et al. (2018)
P. linteus (strain IUM3161)	fructose	potassium nitrate	Hur et al. (2018)
P. lundellii (strain IUM3153)	glucose	ammonium phosphate	Hur et al. (2018)
P. popaceus (strain IUM3156)	sucrose	ammonium phosphate	Hur et al. (2018)

Table 4 Continued.

Fungal species and strains	Preferred carbon sources (concentration %)	Preferred nitrogen sources (concentration %)	Reference
P. populicola (strain IUM3155)	sucrose	ammonium phosphate	Hur et al. (2018)
P. robustus (strain M-10)	fructose, rye flour	peptone	Bisko et al. (2020)
P. torulosus (strain IUM3158)	xylose	ammonium phosphate	Hur et al. (2018)
P. tremulae (strain IUM3157)	glucose	ammonium acetate	Hur et al. (2018)
P. vorax (strain IUM3163)	mannose	ammonium phosphate	Hur et al. (2018)
Pleurotus citrinopileatus	fructose, galactose, maltose	soypeptone	Wu et al. (2008)
P. cystidiosus (strain AG 2041)	glucose (1~3 %), dextrose (1~3 %), sucrose (1~3 %)	ammonium chloride (0.03% ~ 0.05%)	Hoa & Wang (2015)
P. eryngii	dextrin	ammonium acetate, arginine	Alam et al. (2015)
P. ferulae	glucose (5 %)	polypeptone (1.0%)	Choi et al. (2005)
P. florida	fructose	ammonium chloride	Sharma et al. (2018)
P. ostreatus	glucose (9 %)	peptone (5%)	Nwokoye et al. (2010)
P. ostreatus (strain ATHUM 4438)	xylose	corn steep liquor	Papaspyridi et al. (2010)
P. ostreatus	mannitol	urea	Adebayo-Tayo et al. (2011)
P. ostreatus	dextrose	peptone + yeast extract (1:1)	Horincar et al. (2014)
P. ostreaus (strain AG 2042)	glucose (1~5%), molasses (1~5%), sucrose (1~5%)	ammonium chloride (0.03% ~ 0.09%)	Hoa & Wang (2015)
P. sajor-caju	starch	ammonium chloride	Sharma et al. (2018)
P. salmoneostramineus	sucrose, starch	yeast extract, peptone	Abd El-Zaher et al. (2015)
Psathyrella atroumbonata Pegler	glucose	yeast extract	Jonathan & Fasidi (2001)
Russula sanguinaria (Schumach.) Rauschert (strain JQ685712)	glucose, dextrin	diammonium phosphate, calcium nitrate, albumin bovin-BSA	Lazarević et al. (2016)
Schizophyllum commune (strains: IUM 0207, IUM 0395, IUM 0669, IUM 1020, IUM 1097, IUM 1114, IUM 1452, IUM 1649, IUM 1690, IUM 1726)	sucrose (strain IUM 0395), fructose (strains: IUM0669, IUM 1452), glycose (strain IUM 1649), dextrin (strain IUM 1690), dextrin, sucrose (strain IUM 1020), dextrin, glycose (strain IUM 1114), dextrin, xylose (strain IUM 1097), dextrin, xylose (strain IUM 1097), dextrin, maltose, mannose, sucrose (strain IUM 0207), fructose, maltose, mannose, dextrin, sorbitol (strain IUM 1726)	calcium nitrate (strains: IUM 0207, IUM 0395, IUM 1020, IUM 1114, IUM 1690), alanine (strains: IUM 0669, IUM 1726), glycine (strain IUM 1452), potassium nitrate, calcium nitrate (strain IUM 1097), glycine and alanine (strain IUM 1649)	Imtiaj et al. (2008b)
S. commune (strains: (IUM 1763, IUM 1768, IUM 0137, IUM 0157, IUM 0202, IUM 0395, IUM 0548, IUM 2324, IUM 2650, IUM 2659, IUM 3353, IUM 3566)	sucrose (strain IUM-0202), fructose (strain IUM-0548), dextrin (strains: IUM-0137, IUM-0157, IUM-2324, IUM- 3353), dextrin, xylose (strain IUM-1768), fructose, sucrose (strains: IUM-0395,	calcium nitrate (strains: IUM-0137, IUM-0202, IUM-0395, IUM-0548, IUM-1768, IUM-2650, IUM-3566), alanine (strain IUM-2324), potassium nitrate, calcium nitrate (strain IUM-2659), calcium nitrate,	Alam et al. (2010)

Table 4 Continued.

Fungal species and strains	Preferred carbon sources (concentration %)	Preferred nitrogen sources (concentration %)	Reference
	IUM-2659), glucose, fructose (strain IUM-3566), dextrin, maltose, sucrose (strain IUM-2650)	glycine (strain IUM-3353)	
Suillus collinitus (Fr.) Kuntze (strain JQ685733)	sucrose	diammonium phosphate, calcium nitrate	Lazarević et al. (2016)
Suillus granulatus (L.) Roussel (strain JQ685727)	sucrose	diammonium phosphate, calcium nitrate	Lazarević et al. (2016)
Trametes gibbosa (Pers.) Fr. (strains: IBK 1937, IBK 2167)	maltose (strain IBK 1937), glucose (strain IBK 2167)	peptone	Klechak et al. (2014)
T. hirsuta (Wulfen) Lloyd (strains: IBK 338, IBK 358, IBK 5018)	starch (strains: IBK 358, IBK 5018), sucrose (strain IBK 338)	peptone	Klechak et al. (2014)
T. pubescens (Schumach.) Pilát (strains: IBK 332, IBK 1699)	glucose	peptone	Klechak et al. (2014)
T. serialis (L.) Fr (Current name: ***Neoantrodia serialis*** (Fr.) Audet) (strain IBK 1698)	sucrose, starch	peptone	Klechak et al. (2014)
T. suaveolens Berk. (strains: IBK 5024, IBK 1524)	glucose, sucrose	peptone	Klechak et al. (2014)
T. trogii (strains: IBK 333, IBK 5097)	maltose (strain IBK 333), glucose, starch, maltose (strain IBK 5097)	peptone	Klechak et al. (2014)
T. versicolor (L.) Lloyd (IBK 353, IBK 5095, IBK 5131)	sucrose (strains: IBK 5095, IBK 353), maltose (strain IBK 5131)	peptone	Klechak et al. (2014)
T. zonata (Current name: ***Trametes ochracea*** (Pers.) Gilb. & Ryvarden) (strains IBK 301, IBK 1570, IBK 5303)	starch (strain IBK 301), maltose (strain IBK 1570), sucrose (strain IBK 5303)	peptone	Klechak et al. (2014)
Tremella mesenterica Retz.: Fr.	mannitol, glycerol	corn steep liquor	Wasser et al. (2003)
Tricholoma batchii (strain JQ685729)	dextrin, glucose, arabinose	diammonium phosphate	Lazarević et al. (2016)
T. imbricatum (strain JQ685731)	dextrin, sucrose	diammonium phosphate, calcium nitrate	Lazarević et al. (2016)
T. terreum	dextrose, xylose	yeast extract, malt extract	Kibar & Peksen (2011)

Some of basidiomycetes have an appropriate growth at two or three N-sources at the same level. The growth of some fungal species as well as strain promoted two organic forms of nitrogen: glycine and urea, glycine and alanine, malt and yeast extracts, peptone and tryptophan, yeast extract and peptone, peptone and malt extract; peptone and yeast extract; alanine and beef powder, yeast and beef extracts. More often growth of some basidiomycetes on an equal footing supported by two different forms of nitrogen (organic and inorganic): ammonium acetate and glycine; ammonium sulphate and asparagine; calcium nitrate and arginine; calcium nitrate and glycine; calcium nitrate and malt extract; sodium nitrate and peptone;

sodium nitrate and yeast extract; sodium nitrate and asparagine; asparagine and ammonium sulphate. Seldom basidiomycetes preferred only inorganic forms of nitrogen: ammonium sulphate and sodium nitrate in case of 5 strains of *G. lucidum* (Bisko et al. 2012), potassium nitrate and calcium nitrate in case of *S. commune*, strain IUM 1097 (Imtiaj et al. 2008b). In contrast, wood decay fungi able to consume with equal efficiently a wide range of different nitrogen sources: alanine, arginine, glycine, urea, and calcium nitrate in case of *G lucidum* strain IUM 0047 and IUM 0938 (Jayasinghe et al. 2008).

Among analyzed basidiomycetes a clear preference for certain nitrogen sources can be noted only for wood decay fungi from two genera: ammonium phosphate in case of *Phellinus* spp., and peptone in case of *Trametes* spp.

At the same time, the fungal requirements of carbon and nitrogen are related to each other. The optimal C/N ratio characterizes the nutrient balance of substances in the medium, where the mycelium builds its cells, receives energy and synthesizes nitrogen-containing cellular components, such as nucleic acids, amino acids, enzymes and DNA. However, the adsorption ability of carbon and nitrogen sources can greatly vary depending on the nature of investigated fungus. Moreover, the nitrogen rate contains 5-6 times less than carbon in the mycelium. However, in nutrient media, it is necessary to maintain a C/N ratio of about 40/1 (for example, in Czapek's medium), which is explained by the use of carbon compounds as an energy source. As a result, carbon is kept in the micellar part to a relatively small extent, while nitrogen serves as energy source (ammonia oxidation or processing of deaminated amino acids) with a few exceptions when its compounds remain in it entirely (Becker 1988).

According to our observation, C/N ratios were determined by a small number of researchers and above-mentioned ratios 5:1 and 40:1 are rarely meet through reports. At the same time, its numerical value ranged from 1:1 (Jo et al. 2009, 2014) to 20:1 (Kim et al. 2005, Ma et al. 2014, Bisko et al. 2020). It is noteworthy that different strains of the same fungi need different C/N ratios: 5 strains of *A. auricula-judae* – from 1/1 to 5/1 (Jo et al. 2014), 7 strains of *G. applanatum* – from 1/1 to 10/1 (Jo et al. 2009). At the same time, 4 strains of *C. versicolor* need for optimal growth in the ratio 10/2 (Jo et al. 2010). Several fungi may actively grow at different C/N ratios: *A. auricula-judae strain* GBAA-03 – 2/1 and 5/1 (Jo et al. 2014), *Calocybe indica* – 12/1 and 14/1 (Phutela & Phutela 2012), *G. applanatum* strain GBGA-01 – 1/1 and 2/1, strain GBGA-02 –2/1and 5/1, strain ASI 52821 – 1/1, 2/1, 5/1, and 10/1, strain ASI 52823 – 2/1, 5/1, and 10/1, strain ASI 53399 – 1/1 and 2/1 (Jo et al. 2009), *G. lucidum* strain ASI 7125 – 1/1 and 2/1 (Jo et al. 2009).

Hence, basidiomycetes have relatively simple nutritional demands. Considering the growth phenotype, it was established the differences of the mycelial growth on carbon and nitrogen sources and their ratio in the medium. In general, basidiomycetes species and strains due to their efficient enzymatic systems are characterized by significant selectivity in the most favorable carbon sources. In general, a low selectivity in nitrogen sources is observed among the basidiomycete's species and strains. Their ability to grow on a variety of carbon and nitrogen sources clearly indicates the multi-adopted strategy of consuming when all of the available nutritional sources are going to adopt. Fungal capability for adjusting may appear as the individual epigenetic response to the variated habitat conditions.

Conclusion

Due to significant economic, ecological, food, and therapeutic potential of utilization in fungal biotechnology provides whips to the intensification of development of the fungal cultivation technologies. Hereby, their yield enlargement while preserving their biodiversity in nature is an important and urgent task. As more optimal cultivation conditions are determined for the fungal biomass growth, the more beneficial fungi can be obtained. The integral part of the successful biotechnological process leading to the production of the desired final naturally appeared outputs is the result of management of the biosynthetic processes in cellular and metabolic activity.

The current review devoted to the analysis of abiotic requirements and nutritional preferences for the growth augmentation of basidiomycetes belonged to various systematic group orders. We

included in comparison reviewing such genera as Agaricales (45 species), Polyporales (40 species), Hymenochaetales (15 species), Auriculariales (3 species), Russulales (3 species), Cantharellales (2 species), Boletales (2 species), Thelephorales (1 species), Atheliales (1 species), and Tremellales (1 species). Accomplished analysis of data according to the cultivation parameters to the basidiomycetes is exhibited and based on the 20 years worldwide scientific reports.

The mycelial growth along with the therapeutically-important metabolites synthesis mainly depends on the culture medium that provides the appropriate conditions for the fungal development. The analyzed results reveal the fact that the mycelium of various basidiomycetes grow with different intensity on a wide range of media. The differentiation is observed after comparison of the results getting from differently originated media: synthetic media, semi-synthetic and in media based on agricultural and food raw waste materials.

The effect of culture media on the mycelial development can vary depending on the fungal species and their strains as well. Nutrient media such as PDA or PGA, followed by MEA and MCM showed as the best choice for the growth of the majority of mushrooms. However, the agricultural and food wastes contain a sufficient amount of natural-based substances, that can provide better biomass growth, than synthetic and semi-synthetic media. It must be borne in mind that the use of food waste is safe, since food products comply with regulatory documents containing safety requirements.

The optimal cultivation temperature is often associated with the genetic origin of the fungus and the temperature conditions of its growth in nature. Most of described basidiomycetes vegetate at optimal temperature between 20ºC and 30ºC, although some species prefer high temperature rates 35ºC–37ºC.

The mycelium of various fungal species could grow in a wide range of pH levels. The optimal pH meaning is a kind of susceptible value for successful fungi growth. Its value depends on the separate strains characteristics as a discrete unit in shared species content. On the other hand, it can be concluded, that slightly acidic and neutral pH are more appropriate for the growth of the most investigated fungi.

Basidiomycete's species and strains due to their efficient enzymatic systems are characterized by significant selectivity in the choice of the most favorable carbon sources for their growth. However, considering, that glucose is a fundamental building block of the different saccharides, it can be concluded, that glucose as well as its structural or stereoisomers, epimer and polymers are the best carbon sources for the mycelia growth of the most fungal genera. There is a lower selectivity and certain tendency among the species and strains of basidiomycetes, that gives the preference to a certain source of desirable nitrogen to maintain their viability. Growth stimulating effect is provided mainly by organic nitrogen sources, such as amino acids, complex organic nitrogen compounds, peptide, and inorganic nitrogen sources like nitrates and ammonium salts.

In general, more experimental works often describe the influence of one-factor experiments. However, it is important to consider the mutual influence of different cultivation conditions on each other. So, the ideal result can only be achieved during a multivariate experiment. Also, different strains of the same fungus require different cultivation conditions, such as culture media, temperature, pH, carbon and nitrogen sources, C/N ratios. Differences in the response to basic nutritional demands indicate the intraspecific diversity within the fungus species. It might be attributed to genetic differences among fungi species and their adaptation capacity to the individual growth conditions. The nutritional preferences of fungal strains expand our insight into morpho-genetic variability and also is a definite step in the understanding of how fungi can function under changed or controlled conditions.

Moreover, it is obvious that cultivation conditions affect the obtaining of the maximum amount of biomass. However, they may differ from the asserted conditions implying the maximal augmentation of biologically active metabolites. Hence, this fact may directly affect both the production and manifestation of maximum therapeutic activity by the fungi. Obviously, it is necessary to achieve cultivation conditions that provide the optimal ratio of biomass to therapeutically active metabolites.

Reports with description of various cultivation conditions influence on the mycelium growth may help to develop a protocol according to the gaining of the maximal biomass amount for biotechnological and industrial purposes. Additionally, this is directly considered about further storing of a viable form of mushrooms, and to preserve the fungal biodiversity due to their re-introduction in nature.

Acknowledgements

This work was financed by the National Academy of Sciences of Ukraine (State Registration Number 0112U000435, Number 0118U003812) and grateful to the Kempe Foundation provided support to work this review.

References

Abd El-Zaher EHF, Mostafa AA, Abu El-Souod SM, El-Gaar EM. 2015 – Optimization and characterization of exopolysaccharides from *Pleurotus salmoneo-stramineus* and its possible application. Egyptian Journal of Experimental Biology (Botany) 11(2), 181–188.

Abdel Aziz NH, Yousef NS, El-Haddad ME, El-Tayeb TS. 2018 – Influence of nutritional and climatic conditions on mycelial growth of three Oyster Mushroom strains. Arab Universities Journal of Agricultural Sciences, Special Issue 26(2A), 1165–1173. Doi 10.21608/ajs.2018.28368

Abon MD, Dulay RMR, Kalaw SP, Romero-Roman ME et al. 2020 – Effects of culture media and physical factors on the mycelial growth of the three wild strains of *Volvariella volvacea* from Ecuador. Journal of Applied Biology & Biotechnology 8(6), 60–63. Doi 10.7324/JABB.2020.80610

Adebayo-Tayo BC, Jonathan SG, Popoola OO, Egbomuche RC. 2011 – Optimization of growth conditions for mycelial yield and exopolysaccharide production by *Pleurotus ostreatus* cultivated in Nigeria. African Journal of Microbiology Research 5(15), 2130–2138. Doi 10.5897/AJMR11.328

Ahlborn J, Stephan A, Meckel T, Maheshwari G et al. 2019 – Upcycling of food industry side streams by basidiomycetes for production of a vegan protein source. International Journal of Recycling of Organic Waste in Agriculture 8(Suppl 1), 447–455. Doi 10.1007/s40093-019-00317-4

Akinyele BJ, Adetuyi FC. 2005 – Effect of agrowastes, pH and temperature variation on the growth of *Volvariella volvacea*. African Journal of Biotechnology 4(12), 1390–1395.

Akinyele JB, Fakoya S, Adetuyi CF. 2012 – Anti-growth factors associated with *Pleurotus ostreatus* in a submerged liquid fermentation. Malaysian Journal of Microbiology 8(3), 135–140.

Alam N, Cha YJ, Shim MJ, Lee TS, Lee UY. 2010 – Cultural conditions for mycelial growth and molecular phylogenetic relationship in different wild strains of *Schizophyllum commune*. Mycobiology 38(1), 17–25.

Alam N, Shim MJ, Lee MW, Shin PG et al. 2009 – Vegetative growth and phylogenetic relationship of commercially cultivated strains of *Pleurotus eryngii* based on ITS sequence and RAPD. Mycobiology 37(4), 258–266.

Alavi A, Goltape EM, Kashy A, Arzani K, Asadi E. 2004 – Investigation on cultivation of wild King Oyster Mushroom (*Pleurotus eryngii* DC: Fr. Quel) of Charmahal va Bakhtiary Province (Iran). Proceedings of The Fourth International Iran & Russia Conference, 692–696.

Ali MA, Khan SM, Nawaz A, Iqbal Q et al. 2015 – Mycelial growth and primordial initiation of *Agaricus bitorquis* and related species on agar media. Pakistan Journal of Life and Social Sciences 13(1), 42–48.

Aminah MHS, Sam ST, Zakaria Z. 2020 – Influence of pH and temperature on in vitro mycelial growth performance of wild edible *Schizophyllum commune* of northern Malaysia. AIP Conference Proceedings 2291, 020100. Doi 10.1063/5.0023889

Antonenko LO, Klechak IR. 2011 – Tekhnolohichni osoblyvosti hlybynnoho kul'tyvuvannia bazydial'nykh hrybiv rodu *Coriolus*. Vostochno-Evropeyskiy zhurnal peredovykh tekhnologiy: nauchnyy zhurnal 6/6(54), 4–13 (In Ukrainian).

Antonenko LO, Klechak IR, Lazarenko LM, Trokhymenko OP. 2011 – Trofichni potreby i biotekhnolohichni parametry rostu vyshchykh bazydial'nykh hrybiv rodu *Coriolus*. Zbirnyk naukovykh prats' Dniprodzerzhyns'koho derzhavnoho tekhnichnoho universytetu: (tekhnichni nauky) 2(17), 260–264 (In Ukrainian).

Arana-Gabriel Y, Burrola-Aguilar C, Alcala-Adan A, Zepeda-Gomez C, Estrada Zuniga ME. 2020 – Mycelial growth of the edible wild mushrooms *Floccularia luteovirens* in different culture mediums and pH. Agro Productividad 13(10), 33–38. Doi 10.32854/agrop.v13i10.1745

Badalyan SM, Gharibyan NG, Iotti M, Zambonelli A. 2019 – Morphological and ecological screening of different Italian collections of medicinal white-rot bracket fungus *Ganoderma adspersum* (Schulzer) Donk (Agaricomycetes, Polyporales). Journal of Mycology 48, 1–15.

Barshteyn V, Krupodorova T. 2016 – Utilization of agro-industrial waste by higher mushrooms: modern view and trends. Journal of Microbiology, Biotechnology & Food Sciences 5(6), 563–577. Doi 10.15414/jmbfs.2016.5.6.563-577

Becker ZE. 1988 – Physiology and Biochemistry of Fungi. Moscow University Press, Moscow, 230 p. (In Russian).

Beltrame G, Hemming J, Yang H, Han Z, Yang B. 2021 – Effects of supplementation of sea buckthorn press cake on mycelium growth and polysaccharides of *Inonotus obliquus* in submerged cultivation. Journal of Applied Microbiology 131(3): 1318–1330. Doi 10.1111/jam.15028

Bi F, Barad S, Ment D, Luria N et al. 2016 – Carbon regulation of environmental pH by secreted small molecules that modulate pathogenicity in phytopathogenic fungi. Molecular Plant Pathology 17(8), 1178–1195.

Bisko NA, Babitskaia VG, Bukhalo AS, Krupodorova TA et al. 2012 – Biologicheskie svoystva lekarstvennykh makromitsetov v kul'ture. Sbornik nauchnykh trudov v dvukh tomakh. Tom 2. Kiev: Institut botaniki im. N.G. Kholodnogo NAN Ukrainy, 459 c (In Russian).

Bisko N, Mustafin K, Al-Maali G, Suleimenova Z et al. 2020 – Effects of cultivation parameters on intracellular polysaccharide production in submerged culture of the edible medicinal mushroom *Lentinula edodes*. Czech Mycology 72(1), 1–17.

Cervantes-Chavez JA, Ortiz-Castellanos L, Tejeda-Sartorius M, Scott G, Ruiz-Herrera J. 2010 – Functional analysis of the pH responsive pathway Pal/Rim in the phytopathogenic basidiomycete *Ustilago maydis*. Fungal Genetics and Biology 47, 446–457. Doi 10.1016/j.fgb.2010.02.004

Chauhan R. 2016 – Optimization of physical parameters for the growth of a white rot fungus – *Trametes versicolor*. International Journal of Information Research and Review 3(11), 3125–3128.

Chechan RA, Mohyaddin MO, Abdul-Qader ZM, Amar MM. 2017 – Prepration of new national media for cultivation and effect of some enviromental factors on growth rate of Oyster Mushroom. The Iraqi Journal of Agricultural Sciences 48(5), 1304–1175.

Choi DB, Kang SH, Song YH, Kwun KH et al. 2005 – Exo-polysaccharide production in liquid culture of *Pleurotus ferulae*. Journal of Microbiology and Biotechnology 15(2), 368–375.

Colauto NB, Aizono PM, Carvalho de LRM, Paccola-Meirelles LD, Linde GA. 2008 – Temperature and pH conditions for mycelial growth of *Agaricus brasiliensis* on axenic cultivation. Journal Semina Ciencias Agrarias, Londrina 29(2), 307–312.

Colla IM, Oliveira Filho OBQ de, Freitas JDS de, Bertéli MBD et al. 2020 – Mycelial biomass cultivation of *Lentinus crinitus*. Bioscience Journal 36(6), 2238–2246. Doi 10.14393/BJ-v36n6a2020-51183

Dawidowicz L, Jasińska A, Siwulski M. 2018 – The effect of selected cultivation factors on the growth of mycelium of *Pleurotus cystidiosus* Miller. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 46(1), 156–160. Doi 10.15835/nbha46110959

Deacon JW. 2006 – Fungal biology. (4th edn.), Blackwell Publishing, Oxford. 380 p.
Deepa Rani CV, Das L. 2015 – Effect of different carbon and nitrogen sources on the vegetative growth of Shiitake mushroom (*Lentinula edodes* (Berk.) Pegler). International Journal of Applied and Pure Science and Agriculture 1, 14–19.
De Leon AM, Guinto LJZG, De Ramos PDV, Kalaw SP. 2017 – Enriched cultivation of *Lentinus squarrosulus* (Mont.) Singer: A newly domesticated wild edible mushroom in the Philippines. Mycosphere 8(3), 615–629. Doi 10.5943/mycosphere/8/3/9
Deshaware S, Marathe SJ, Bedade D, Deska J, Shamekh S. 2021 – Investigation on mycelial growth requirements of *Cantharellus cibarius* under laboratory conditions. Archives of Microbiology. Doi 10.1007/s00203-020-02142-0
Dresch P, D'aguanno MN, Rosam K, Grienke U et al. 2015 – Fungal strain matters: colony growth and bioactivity of the European medicinal polypores *Fomes fomentarius*, *Fomitopsis pinicola* and *Piptoporus betulinus*. AMB Express 5, 1–14. Doi 10.1186/s13568-014-0093-0
Dulay RMR, Cabrera EC, Kalaw SP, Reyes RG. 2021 – Optimization of culture conditions for mycelial growth and fruiting body production of naturally-occurring Philippine mushroom *Lentinus swartzii* Berk. Journal of Applied Biology & Biotechnology 9(3), 17–25. Doi 10.7324/JABB.2021.9303
Elisashvili V. 2012 – Submerged cultivation of medicinal mushrooms: bioprocesses and products (Review). International Journal of Medicinal Mushrooms 14(3), 211–239.
Emayavarman S, Singh S. 2021 – Efficacy of different physiological parameters on mycelial growth of elm oyster mushroom [*Hypsizygus ulmarius* (Bull) Redhead]. Plant Archives 21, Supplement 1, 1441–1445. Doi 10.51470/PLANTARCHIVES.2021.v21.S1.226
Emelyanova EV. 2005 – Effects of cultivation conditions on the growth of the basidiomycete *Coriolus hirsutus* in a medium with pentose wood hydrolyzate. Process Biochemistry 40, 1119–1124.
Fang QH, Zhong JJ. 2002 – Effect of initial pH on production of ganoderic acid and polysaccharide by submerged fermentation of *Ganoderma lucidum.* Process Biochemistry 37, 769–774.
Fasidi IO. 1996 – Studies on *Volvariella esculenta* (Mass) Singer: Cultivation on agricultural wastes and proximate composition of stored mushrooms. Food Chemistry 55(2), 161–163.
Feng YL, Li WQ, Wu XQ, Cheng JW, Ma SY. 2010 – Statistical optimization of media for mycelial growth and exo-polysaccharide production by *Lentinus edodes* and a kinetic model study of two growth morphologies. Biochemical Engineering Journal 49, 104–112. Doi 10.1016/j.bej.2009.12.002
Fletcher I, Freer A, Ahmed A, Fitzgerald P. 2019 – Effect of temperature and growth media on mycelium growth of *Pleurotus ostreatus* and *Ganoderma lucidum* strains. Cohesive Journal of microbiology & infectious disease 2(5). Doi 10.31031/CJMI.2019.02.000549
Fraatz MA, Naeve S, Hausherr V, Zorn H, Blank LM. 2014 – A minimal growth medium for the basidiomycete *Pleurotus sapidus* for metabolic flux analysis. Fungal Biology and Biotechnology 1, 1–9.
Frljak J, Husić Mulabećirović A, Isaković S, Karahmet E, Toroman A. 2021 – Biological Active Components of Selected Medical Fungi. Open Journal of Preventive Medicine 11(01). Doi 10.4236/ojpm.2021.111002
Furlan SA, Virmond LJ, Miers DA, Bonatti M et al. 1997 – Mushroom strains able to grow at high temperatures and low pH values. World Journal of Microbiology & Biotechnology 13, 689–692.
Garcia BL, Undan JR, Dulay RMR, Kalaw SP, Reyes RG. 2020 – Molecular identification and optimization of cultural conditions for mycelial biomass production of wild strain of *Chlorophyllum molybdites* (G. Mey) Massee from the Philippines. Journal of Applied Biology & Biotechnology 8(6), 1–6. Doi 10.7324/JABB.2020.80601
Gastillo G, Nihoul A, Demoilin V. 2004 – Correlation between the *in vitro* growth response to temperature and the habitat of some lignicolous fungi from Papua New Guinea coastal forests. Cryptogamie, Mycologie 25(1), 57–81.

Garraway MO, Evans RC. 1984 – Fungal nutritional and physiology. A Wiley-Interscience publication, 401 p.

Gbolagade JS, Fasidi IO, Ajayi EJ, Sobowale AA. 2006 – Effect of physico-chemical factors and semi-synthetic media on vegetative growth of *Lentinus subnudus* (Berk.), an edible mushroom from Nigeria. Food Chemistry 99, 742–747.

Geffert A, Geffertova J, Dudiak M. 2019 – Direct method of measuring the pH value of wood. Forests 10, 852. Doi 10.3390/f10100852

Gorai B, Sharma R. 2018 – Determination of optimum temperature and pH for mycelial growth of *Pleurotus* spp. strains. International Journal of Microbiology Research 10(6), 1287–1289.

Gregori A, Švagelj M, Pohleven J. 2007 – Cultivation techniques and medicinal properties of *Pleurotus* spp. Food Technology and Biotechnology 45(3), 238–249.

Hoa HT, Wang CL. 2015 – The effects of temperature and nutritional conditions on mycelium growth of two oyster mushrooms (*Pleurotus ostreatus* and *Pleurotus cystidiosus*). Mycobiology 43(1), 14–23. Doi 10.5941/MYCO.2015.43.1.14

Horincar VB, Popa A, Parfene G, Balaes T. 2014 – Study of preliminary biotechnological conditions for *Pleurotus ostreatus* cultivation on submerged system. Innovative Romanian Food Biotechnology 15, 58–62.

Huang HC, Liu YC. 2008 – Enhancement of polysaccharide production by optimization of culture conditions in shake flask submerged cultivation of *Grifola umbellate*. Journal of the Chinese Institute of Chemical Engineers 39, 307–311.

Hur H, Imtiaj A, Lee MW, Lee TS. 2008 – Suitable conditions for mycelial growth of *Phellinus* spp. Mycobiology 36(3), 152–156.

Hussain S, Ali AM, Ahsan A, Ali H, Siddique M. 2004 – Temperature requirement of button mushroom *Agaricus bitorquis* for mycelial growth on three different composts. Journal of Agricultural Research 42(3-4), 313–318.

Hyde KD, Xu J, Rapior S, Jeewon R et al. 2019 The amazing potential of fungi: 50 ways we can exploit fungi industrially. Fungal Diversity 97, 1–136. Doi 10.1007/s13225-019-00430-9

Imtiaj A, Alam S, Islam AKMR, Kim SB, Lee TS. 2007 – Screening of optimal culture condition for the mycelial growth of edible and medicinal mushrooms. Bangladesh Journal of Mushroom 1(1), 71–78.

Imtiaj A, Jayasinghe C, Lee GW, Shim MJ et al. 2008a – Vegetative growth of four strains of *Hericium erinaceus* collected from different habitats. Mycobiology 36(2), 88–92.

Imtiaj A, Jayasinghe C, Lee GW, Kim HY et al. 2008b – Physicochemical requirement for the vegetative growth of *Schizophyllum commune* collected from different ecological origins. Mycobiology 36(1), 34–39.

Imtiaj A, Jayasinghe C, Lee GW, Lee TS. 2009 – Comparative study of environmental and nutritional factors on the mycelial growth of edible mushrooms. Journal of Culture Collections 6(1), 97–105.

Inglet RS, Song M, Hensen CL, Hwang S. 2006 – Cultivation of *Lentinula edodes* mycelia using whey permeate as an alternative growth substrate. Journal of Dairy Science 89, 1113–1115.

Ismail M, Kibriya G, Hossain J, Nasiruddin M, Imtia A. 2016 – Effect of physicochemical components on mycelial growth of *Agaricus bisporus* a popular edible mushroom. Plant Environment Development 5(1), 7–12.

Jacob MS, Xiao L, Stephano MF, Anran X. 2020 – Studies on Optimization of Culture Conditions and Medium Components for the Production of Mycelial Biomass of *Auricularia delicata* under Submerged Fermentation. Asian Journal of Biology 10(4), 56–67.

Jang MJ, Lee YH, Liu JJ, Ju YC. 2009 – Optimal conditions for the mycelial growth of *Coprinus comatus* strains. Mycobiology 37(2), 103–108.

Jayasinghe C, Imtiaj A, Hur H, Lee GW et al. 2008 – Favorable culture conditions for mycelial growth of Korean wild strains in *Ganoderma lucidum*. Mycobiology 36(1), 28–33.

Jeong YT, Jeong SC, Yang BK, Islam R, Song CH. 2009 – Optimum conditions for the mycelial growth and exo-biopolymer production by a submerged culture of *Ganoderma applanatum*. Mycobiology 37(2), 89–93.

Jo WS, Cho YJ, Cho DH, Park SD et al. 2009 – Culture conditions for the mycelial growth of *Ganoderma applanatum*. Mycobiology 37(2), 94–102.

Jo WS, Kang MG, Choi SY, Yoo YB et al. 2010 – Culture conditions for mycelial growth of *Coriolus versicolor*. Mycobiology 38(3), 195–202. Doi 10.4489/MYCO.2010.38.3.195

Jo WS, Kim DG, Seok SJ, Jung HY, Park SC. 2014 – The culture conditions for the mycelial growth of *Auricularia auricula-judae*. Journal of Mushrooms 12(2), 88–95. Doi 10.14480/JM.2014.12.2.88

Jo WS, Park JR, Oh SR, Kang MG et al. 2016 – Culture conditions for mycelial growth of *Poria cocos*. Journal of Mushrooms 14(1), 6–13. Doi 10.14480/JM.2016.14.1.6

Jonathan SG, Bawo DDS, Adejoye DO, Briyai OF. 2009 – Studies on biomass production in *Auricularia polytricha* collected from Wilberforce Island, Bayelsa State, Nigeria. American Journal of Applied Sciences 6(1), 182–186.

Jonathan SG, Fasidi IO. 2001 – Effect of carbon, nitrogen and mineral sources on growth of *Psathyerella atroumbonata* (Pegler), a Nigerian edible mushroom. Food Chemistry 72, 479–483.

Kapoor P, Sharma BM. 2014 – Studies on different growth parameters of *Ganoderma lucidum*. International Journal of Science, Environment and Technology 3(4), 1515–1524.

Khandakar J, Uddin N, Sarker NC, Basunia MA et al. 2009 – Effect of culture media and environmental factors on the mycelial growth of *Grifola frondosa*. Bangladesh Journal of Mushroom 3(1), 15–20.

Kibar B, Peksen A. 2011 – Nutritional and environmental requirements for vegetative growth of edible ectomycorrhizal mushroom *Tricholoma terreum*. Žemdirbystė Agriculture 98(4), 409–414.

Kim DH, Yang BK, Jeong SC, Park JB et al. 2001 – Production of a hypoglycemic, extracellular polysaccharide from the submerged culture of the mushroom, *Phellinus linteus.* Biotechnology Letters 23, 513–517.

Kim SB, Kim SH, Lee KR, Shim JO et al. 2005 – The optimal culture conditions for the mycelial growth of *Oudemansiella radicata*. Mycobiology 33(4), 230–234.

Kim SW, Hwang HJ, Park JP, Cho YJ et al. 2002 – Mycelial growth and exo-biopolymer production by submerged culture of various edible mushrooms under different media. Letters in Applied Microbiology 34, 56–61.

Kim YR. 2003 – Production of polysaccharide by the edible mushroom, *Grifola frondosa*. Mycobiology 31(4), 205–208.

Klechak IR, Bisko NA, Mytropolska NY, Antonenko LO. 2014 – The Influence of carbon and nitrogen sources in nutrient media on biomass accumulation by basidiomycetes medicinal mushrooms genus *Trametes* (Fr.). Naukovi Visti NTUU KPI 3, 52–57 (In Ukrainian).

Klomklung N, Karunarathna SC, Hyde KD, Chukeatirote E. 2014 – Optimal conditions of mycelial growth of three wild edible mushrooms from northern Thailand. Acta Biologica Szegediensis 58(1), 39–43.

Krupodorova TA. 2011 – Growth of *Ganoderma applanatum* (Pers.) Pat. and *G. lucidum* (Curtis) P. Karst. strains and synthesis of polysaccharides in submerged culture. Biotechnology 4(6), 60–67 (In Ukraine).

Krupodorova TA, Barshteyn VYu. 2012 – Alternative substrates for medicinal and edible mushrooms cultivation. Microbiology & Biotechnology 1, 47–56 (In Ukrainian).

Krupodorova TA, Barshteyn VYu. 2015 – Alternative substrates for higher mushrooms mycelia cultivation. Journal of BioScience and Biotechnology 4(3), 339–347.

Krupodorova TA, Barshteyn VYu. 2020 – The effect of cultivation conditions on growth and therapeutic activity of *Pleurotus eryngii*. pp. 331-350. In: Litwińczuk, Z. (ed.) Actual

problems of natural sciences: modern scientific discussions. University of Life Sciences in Lublin. Riga: Izdevniecība "Baltija Publishing", 684 p. Doi 10.30525/978-9934-588-45-7.19
Krupodorova TA, Barshteyn VYu, Kizitska TO, Pokas EV. 2019 – Effect of cultivation conditions on mycelial growth and antibacterial activity of *Lentinula edodes* and *Fomitopsis betulina*. – Czech Mycology 71(2), 167–186. Doi 10.33585/cmy.71204
Kumar NK, Krishnamoorthy AS, Kamalakannan A, Amirtham D. 2016 – Influence of temperature and pH on mycelial growth and chlamydospore production of Paddy Straw Mushroom *Volvariella volvaceae* (Bull. Ex Fr.) The Journal of Research ANGRAU 44(1 & 2), 1–7.
Kumar V, Mishra SK, Kaur M. 2019 – Effect of different media, temperature and pH on radial mycelial growth of *Lentinula edodes* strain Le-17-04. Journal of Pharmacognosy and Phytochemistry 8(1), 345–348.
Kumla J, Suwannarach N, Jaiyasen A, Bussaban B, Lumyong S. 2013 – Development of an edible wild strain of Thai oyster mushroom for economic mushroom production. Chiang Mai Journal of Science 40, 161–172.
Landingin HRR, Francisco BE, Dulay RMR, Kalaw SP, Reyes RG. 2020 – Optimization of Culture Conditions for Mycelial Growth and Basidiocarp Production of *Cyclocybe cylindracea* (Maire). CLSU International Journal of Science & Technology IV (1), 1–17.
Lazarević J, Stojičić D, Keča N. 2016 – Effects of temperature, pH and carbon and nitrogen sources on growth of *in vitro* cultures of ectomycorrrhizal isolates from *Pinus heldreichii* forest. Forest Systems 25(1), e048. Doi 10.5424/fs/2016251-07036
Lee C, Lee S, Cho KJ, Hwang S. 2011 – Mycelial cultivation of *Phellinus linteus* using cheese-processing waste and optimization of bioconversion conditions. Biodegradation 22, 103–110. Doi 10.1007/s10532-010-9380-x
Lee SJ, Kim HH, Kim SH, Kim IS, Sung NJ. 2018 – Culture conditions of liquid spawn and the growth characteristics of *Pleurotus ostreatus*. Journal of Mushrooms 16 (3), 162–170.
Liang CH, Wu CY, Ho WJ, Liang ZC. 2020 – Influences of carbon and nitrogen source addition, water content, and initial pH of grain medium on hispidin production of *Phellinus linteus* by solid-state fermentation. Journal of Bioscience and Bioengineering 130(6), 616–621. Doi 10.1016/j.jbiosc.2020.08.002
Lin ES, Sung SC. 2006 – Cultivating conditions influence exopolysaccharide production by the edible Basidiomycete *Antrodia cinnamomea* in submerged culture. International Journal of Food Microbiology 108, 182–187.
Lin HC, Hewage RT, Lu YC, Chooi YH. 2019 – Biosynthesis of bioactive natural products from Basidiomycota. Organic & Biomolecular Chemistry 17, 1027–1036.
Linovyts'ka VM, Bukhalo AS, Duhan OM. 2011 – Pidbir umov hlybynnoho kul'tyvuvannia Grifola frondosa iak osnovy dlia stvorennia biotekhnolohiy otrymannia likuval'no-profilaktychnykh preparativ. Naukovi visti NTUU "KPI" 3, 56-60.
Lu T, Bau T, Ohga S. 2017 – Physiological study of the wild edible mushroom *Leucocalocybe mongolica*. Journal of the Faculty of Agriculture, Kyushu University 62 (1), 1–8.
Luangharn T, Karunarathna SC, Khan S, Xu JC et al. 2017 – Antibacterial activity, optimal culture conditions and cultivation of the medicinal *Ganoderma australe*, new to Thailand. Mycosphere 8(8), 1108–1123.
Ma Y, Guan CY, Meng XJ. 2014 – Biological characteristics for mycelial growth of *Agaricus bisporus*. Applied Mechanics and Materials 508, 297–302.
Marim RA, Avelino KV, Linde GA, Colauto NB, Valle JS. 2018 – *Lentinus crinitus* strains respond differently to cultivation pH and temperature. Genetics and Molecular Research 17(1). Doi 10.4238/gmr16039885
Min GJ, Park HS, Lee EJ, Lee CJ. 2020 – Culture Characteristics and Optimal Conditions for Mycelial Growth of *Calocybe indica*. Korean Journal of Mycology 48(3), 273–284. Doi 10.4489/KJM.20200027

Moyib OK, Adejoye OD, Sodique FR. 2019 – Chemo-characterization and optimization of macro and micro nutrients for exopolysaccharides and mycelia growth in *Pleurotus tuberregium* (RUMPH, EX FR) Food Science and Technology (Campinas) 39(2), 286–293.

Mshandete AM, Mgonja JR. 2009 – Submerged liquid fermentation of some Tanzanian basidiomycetes for the production of mycelial biomass, exopolysaccharides and mycelium protein using wastes peels media. Journal of Agricultural and Biological Science 4(6), 1–13.

Muthu N, Shanmugasundaram K. 2015 – Effect of five different culture media on mycelial growth of *Agrocybe aegerita*. International Journal of Pharmaceutical Sciences and Research 6(12), 5193–5197. Doi 10.13040/IJPSR.0975-8232.6(12).5193-97

Neina D. 2019 – The role of soil pH in plant nutrition and soil remediation. Applied and Environmental Soil Science, Article ID 5794869, 9 pages. Doi 10.1155/2019/5794869

Nguyen BTT, Ngo NX, Le VV, Nguyen LT et al. 2019 – Optimal culture conditions for mycelial growth and fruiting body formation of Ling Zhi mushroom *Ganoderma lucidum* strain GA3. Vietnam Journal of Science, Technology and Engineering. Life Sciences 61(1), 62–67.

Nwokoye AI, Kuforiji OO, Oni PI. 2010 – Studies on mycelial growth requirements of *Pleurotus ostreatus* (Fr.) Singer. International Journal of Basic & Applied Sciences IJBAS-IJENS 10(2), 47–53.

Okwulehie IC, Okwujiako IA. 2009 – The effects of some physical and nutritional factors on the vegetative growth of *Pleurotus ostreatus* var. *florida* Eger. under tropical conditions. Dynamic Biochemistry, Process Biotechnology and Molecular Biology 2(1), 41–44.

Osman ME, Hassan FRH, Khattab OH, Ahmed WA, El-Henawy HE. 2009 – Physiological studies on growth of two different strains of *Lentinus edodes*. Australian Journal of Basic & Applied Sciences 3, 4094–4103.

Pant A, Kumar V, Bisht SS, Upadhyay S, Bahuguna P. 2020 – Effect of different media, pH and temperature on growth of *Pleurotus ostreatus*. Journal of Bio Innovation 9(2), 132–140.

Papaspyridi LM, Katapodis P, Gonou-Zagou Z, Kapsanaki-Gosi E, Christakopoulos P. 2010 – Optimization of biomass production with enhanced glucan and dietary fibres content by *Pleurotus ostreatus* ATHUM 4438 under submerged culture. Biochemical Engineering Journal 50(3), 151–158.

Pekşen A, Kibar B. 2016 – Effects of various carbon and nitrogen sources on mycelial biomass production of *Macrolepiota procera* and *Polyporus squamosus* in submerged culture. Anadolu Journal of Agricultural Sciences 31(1), 16–24.

Pekşen A, Kibar B. 2020 – Determination of optimum culture conditions for mycelial growth of *Macrolepiota procera* mushroom. Acta Scientiarum Polonorum Hortorum Cultus 19(1), 11–20. Doi 10.24326/asphc.2020.1.2

Peksen A, Kibar B, Yakupoglu G. 2013 – Favourable culture conditions for mycelial growth of *Hydnum repandum*, a medicinal mushroom. African Journal of Traditional, Complementary and Alternative Medicines 10(6), 431–434.

Penalva MA, Tilburn J, Bignell E, Arst JHN. 2008 – Ambient pH gene regulation in fungi: making connections. Trends in Microbiology 16, 291–300. Doi 10.1016/j.tim.2008.03.006

Pereima IV, Ivanova TV. 2017 – Stimulation of growth of species of the fungus of the genus *Pleurotus* (fr.) P. Kumm. At a glucose nutrition. Biotechnologia Acta 10(6), 45–52. Doi 10.15407/biotech10.06.045

Petcharat V, Khuntong P. 1999 – Cultivation of wild mushroom: XII Hed Hnang Klong (*Macrolepiota gracilenta* (Krombh.) Moser). Songklanakarin Journal of Science and Technology 21(1), 33–39.

Petre M, Teodorescu A, Giosanu D, Patrulescu F. 2012 – Biotechnology of vineyard and winery wastes recycling through in vitro cultures of some edible mushroom species. Current Trends in Natural Sciences 1, 142–146.

Phadke MV, Jadhav AC, Dhavale MC, Hasabnis SN et al. 2020 – Effect of cultural variability on mycellial growth of eleven mushroom isolates of *Pleurotus* spp. Journal of Pharmacognosy and Phytochemistry 9(6), 881–888.

Phutela UG, Phutela RP. 2012 – Effect of Physical and Chemical factors on growth of *Calocybe indica* (P & C). International Journal of Advanced Life Sciences (IJALS) 2, 8–16.

Pokhrel CP, Ohga S. 2007 – Submerged culture conditions for mycelial yield and polysaccharides production by *Lyophyllum decastes*. Food Chemistry 105, 641–646.

Postemsky P, Matute RG, Figlas D, Curvetto N. 2006 – Optimizing *Grifola sordulenta* and *Grifola gargal* growth in agar and liquid nutrient media. Micologia Aplicada International 18(1), 7–12.

Prusky D, McEvoy JL, Leverentz B, Conway WS. 2001 – Local modulation of host pH by Colletotrichum species as a mechanism to increase virulence. Molecular Plant-Microbe Interactions 14(9), 1105–1113.

Rachmawati YS, Akbar ZA, Chaidir L, Roosda AA. 2021 – Growth of mycelium oyster mushroom (*Pleurotus ostreatus*) in medium rice wastewater with coconut water. IOP Conf. Series: Materials Science and Engineering 052008. Doi 10.1088/1757-899X/1098/5/052008

Reddy BPK, Rajashekhar AU, Harikrishna P, Lavanya AVN. 2017 – Cultural and physiological studies on wild mushroom specimens of *Schizophyllum commune* and *Lentinula edodes*. International Journal of Current Microbiology and Applied Sciences International Journal of Current Microbiology and Applied Sciences 6(7), 2352–2357. Doi 10.20546/ijcmas.2017.607.278

Reyes RG, Grassel W, Rau U. 2009 – Coconut water as a novel culture medium for the biotechnological production of schizophyllan. Journal of Nature Studies 7 (2), 43–48.

Rizal LM, Hyde KD, Chukeatirote E, Kakumyan P, Chamyuang S. 2014 – Optimal mycelial conditions and spawn production for the domestication of *Macrolepiota detersa*. The 26th Annual Meeting of the Thai Society for Biotechnology and International Conference, 175–181.

Rizal LM, Hyde KD, Chukeatirote E, Karunarathna SC et al. 2016 – First successful cultivation of the edible mushroom *Macrolepiota dolichaula* in Thailand. Chiang Mai Journal of Science 43(5), 959–971.

Rosnan ND, Chuen N, Ngadin AA. 2019 – First record of *in vitro* growth evaluation of wild mushroom, *Schizophyllum commune* from Pulau Kapas in Malaysia. Asian Journal of Agriculture and Biology 7(4), 602–609.

Rozsa S, Măniutiu DN, Gocan TM, David S, Butuza BFS. 2016 – Research on the biology of the *Agaricus blazei* Murrill mushroom mycelium. Journal of Horticulture, Forestry and Biotechnology 20(1), 123–126.

Ryu JS, Kim MK, Kwon JH, Cho SH et al. 2007 – The growth characteristics of *Pleurotus eryngii*. The Korean Journal of Mycology 35(1), 47–53.

Sagar S, Thakur M, Sharma I, Tripathi A. 2020 – Optimization of mycelia growth parameters for Wild white rot fungi *Trametes elegans* and *Trametes versicolor*. Asia Life Sciences 12(1), 5–14.

Salem MFM, Salem KFM, Hanna ET, Nouh NE. 2014 – Effect of nutrient sources and environmental factors on the biomass production of Oyster Mushroom (*Pleurotus ostreatus*). Journal of Chemical, Biological and Physical Sciences. Section B: Biological Sciences 4(4), 3413–3420.

Salmones D, Gaitan-Hernandez R, Mata G. 2018 – Cultivation of Mexican wild strains of *Agaricus bisporus*, the button mushroom, under different growth conditions *in vitro* and determination of their productivity. Biotechnologie, Agronomie, Société et Environnement 22(1), 45–53.

Sardar H, Ali MA, Ayyub CM, Ahmad R. 2015 – Effects of different culture media, temperature and pH levels on the growth of wild and exotic *Pleurotus* species. Pakistan Journal of Phytopathology 27(02), 139–145.

Sardar H, Anjum MA, Nawaz A, Naz S et al. 2020 – Effect of different agro-wastes, casing materials and supplements on the growth, yield and nutrition of milky mushroom (*Calocybe indica*). Folia Horticulturae 32(1), 115–124. Doi 10.2478/fhort-2020-0011

Sharma PK, Singh F, Singh S, Dhawan A. 2018 – Effect of physiological parameters on mycelial growth of Blue Oyster [*Hypsizygus ulmarius* (Bull.: Fr.) Redhead] Mushroom. International Journal of Current Microbiology and Applied Sciences 7(06), 2440–2445. Doi 10.20546/ijcmas.2018.706.290

Sharma V, Jaitly AK. 2017 – Optimization of growth of two wild species of *Pycnoporus* collected from foothill of Uttarakhand. International Journal of Agriculture Innovations and Research 6(1), 91–94.

Shih IL, Tsai KL, Hsieh C. 2007 – Effects of culture conditions on the mycelial growth and bioactive metabolite production in submerged culture of *Cordyceps militaris.* Biochemical Engineering Journal 33(3), 193–201.

Shim SM, Oh YH, Lee KR, Kim SH et al. 2005 – The characteristics of cultural conditions for the mycelial growth of *Macrolepiota procera*. Mycobiology 33(1), 15–18.

Shu CH, Lung MY. 2004 – Effect of pH on the production and molecular weight distribution of exopolysaccharide by *Antrodia camphorata* in batch cultures. Process Biochemistry 39(8), 931–937. Doi 10.1016/S0032-9592(03)00220-6

Shu CH, Xu CJ. 2007 – Medium optimization for producing bioactive exopolysaccharides by *Agaricus brasiliensis* S. Wasser et al. (= *A. blazei* Murrill ss. Heinem) in submerged culture. Food Technology and Biotechnology 45(3), 327–333.

Simonić J, Stajić M, Glamočlija J, Vukojević J et al. 2008 – Optimization of submerged cultivation conditions for extra- and intracellular polysaccharide production by medicinal Ling Zhi or Reishi Mushroom *Ganoderma lucidum* (W. Curt.: Fr.) P. Karst. (Aphyllophoromycetideae). International Journal of Medicinal Mushrooms 10(4), 351–360.

Singh S, Singh G. 2018 – Effect of different pH, temperature and media on redial growth of Oyster Mushrooms (*Pleurotus djamor*). Bulletin of Environment, Pharmacology and Life Sciences 7(11), 73–77.

Soylu MK, Boztok K, Esiyok D. 2016 – Mycelial growth performance of the *Pleurotus eryngii* species complex strains on different temperatures. ISHS Acta Horticulturae 1123: XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): International Symposium on High Value Vegetables, Root and Tuber Crops, and Edible Fungi Production, Supply and Demands. Doi 10.17660/ActaHortic.2016.1123.29

Sravani B, Chandra R. 2020 – Influence of media, pH and temperature on the growth of *Sclerotium rolfsii* (Sacc.) causing collar rot of chickpea. Journal of Pharmacognosy and Phytochemistry 9(1), 174–178.

Teoh YP, Don MM. 2016 – Effect of temperature on *Schizophyllum commune* growth and 4H-pyran-4-one,2,3-dihydro-3, 5-dihydroxy-6-methyl- production using a bubble column bioreactor. Chiang Mai Journal of Science 43(3), 461–468.

Vahidi H, Kobarfard F, Namjoyan F. 2004 – Effect of cultivation conditions on growth and antifungal activity of *Mycena leptocephala*. African Journal of Biotechnology 3(11), 606–609.

Vargas-Isla R, Ishikawa NK. 2008 – Optimal conditions of in vitro mycelial growth of *Lentinus strigosus*, an edible mushroom isolated in the Brazilian Amazon. Mycoscience 49, 215–219. Doi 10.1007/s10267-007-0404-2

Wasser SP, Elisashvili VI, Tan KK. 2003 – Effects of carbon and nitrogen sources in the medium on *Tremella mesenterica* Retz.: Fr. (Heterobasidiomycetes) growth and polysaccharide production. International Journal of Medicinal Mushrooms 5, 49–56.

Wu CY, Mau JL, Liang ZC. 2008 – The influence of cultivation conditions on mycelial growth and exopolysaccharide production of culinary-medicinal mushroom *Pleurotus citrinopileatus* Singer (Agaricomycetideae). International Journal of Medicinal Mushrooms 10(3), 279–292.

Xu DQ, Fu ML, Chen QH, Liu J. 2011 – Effect of submerged culture conditions on exopolysaccharides production by *Armillaria luteo-virens* Sacc QH and kinetic modeling. Bioprocess and Biosystems Engineering 34, 103–111. Doi 10.1007/s00449-010-0451-5

Yadav MK, Chandra R. 2014 – Effect of culture media, pH and temperature on mycelial growth of *Agaricus bisporus* strains. Journal of Pure and Applied Microbiology 8(3), 1–5.

Yang BK, Ha JY, Jeong SC, Jeon YJ et al. 2002 – Hypolipidemic effect of an exo-biopolymer produced from submerged mycelial culture of *Auricularia polytricha* in rats. Biotechnology Letters 24, 1319–1325.

Yang FC, Huang HC, Yang MJ. 2003 – The influence of environmental conditions on the mycelial growth of *Antrodia cinnamomea* in submerged cultures. Enzyme and Microbial Technology 33, 395–402.

Yang FC, Liau CB. 1998 – Effects of cultivating conditions on the mycelial growth of *Ganoderma lucidum* in submerged flask cultures. Bioprocess Engineering 19, 233–236.

Yang FC, Ma TW, Chuang YT. 2012 – Medium modification to enhance the formation of bioactive metabolites in shake flask cultures of *Antrodia cinnamomea* by adding citrus peel extract. Bioprocess and Biosystems Engineering 35, 1251–1258. Doi 10.1007/s00449-012-0712-6

Yu YJ, Choi KH, Jeong JS, Lee GK, Choi SR. 2013 – Study on characteristic of mycelial culture in ear mushroom. Journal of Mushroom Science and Production 11(1), 15–20.

Zervakis G, Philippoussis A, Ioannidou S, Diamantopoulou P. 2001 – Mycelium growth kinetics and optimal temperature conditions for the cultivation of edible mushroom species on lignocellulosic substrates. Folia Microbiologica 46(3), 231–234.

Zharare GE, Kabanda SM, Poku JZ. 2010 – Effects of temperature and hydrogen peroxide on mycelial growth of eight *Pleurotus strains*. Scientia Horticulturae 125, 95–102.

Zou X. 2005 – Optimization of nutritional factors for exopolysaccharide production by submerged cultivation of the medicinal mushroom *Oudemansiella radicata*. World Journal of Microbiology & Biotechnology 21, 1267–1271. Doi 10.1007/s11274-005-1941-5