

# Alteration in the ultrastructural morphology of mycelial hyphae and the dynamics of transcriptional activity of lytic enzyme genes during basidiomycete morphogenesis

Vetchinkina E., Kupryashina M., Gorshkov V., Ageeva M., Gogolev Y., Nikitina V.  
Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

## Abstract

© 2017, The Microbiological Society of Korea and Springer-Verlag Berlin Heidelberg. The morphogenesis of macromycetes is a complex multilevel process resulting in a set of molecular-genetic, physiological-biochemical, and morphological-ultrastructural changes in the cells. When the xylotrophic basidiomycetes *Lentinus edodes*, *Grifola frondosa*, and *Ganoderma lucidum* were grown on wood waste as the substrate, the ultrastructural morphology of the mycelial hyphal cell walls differed considerably between mycelium and morphostructures. As the macromycetes passed from vegetative to generative development, the expression of the *tyr1*, *tyr2*, *chi1*, *chi2*, *exg1*, *exg2*, and *exg3* genes was activated. These genes encode enzymes such as tyrosinase, chitinase, and glucanase, which play essential roles in cell wall growth and morphogenesis.

<http://dx.doi.org/10.1007/s12275-017-6320-z>

## Keywords

basidiomycete morphogenesis, cell wall ultrastructure, gene expression, lytic enzymes, phenol oxidases

## References

- [1] Ball, D.W. 2006. Concentration scales for sugar solutions. *J. Chem. Educ.* 83, 1489–1491.
- [2] Bartnicki-Garcia, S. 1973. Fundamental aspects of hyphal morphogenesis. *Symp. Soc. Gen. Microbiol.* 23, 245–257.
- [3] Bowman, S.M. and Free, S.J. 2006. The structure and synthesis of the fungal cell wall. *Bioassays* 28, 799–808.
- [4] Cabib, E., Bowers, B., Sburlati, A., and Silverman, S.J. 1988. Fungal cell wall synthesis: the construction of a biological structure. *Microbiol. Sci.* 5, 370–375.
- [5] Feofilova, E.P. 1983. *Fungal Cell Wall*. Nauka, Moscow, p. 248.
- [6] Feofilova, E.P. 2002. Key role of chitin in fungal cell wall, in *Chitin and Chitosan: Production, Properties, and Application*, pp. 91–111. Nauka, Moscow, Russia.
- [7] Fontaine, T., Hartland, R.P., Beauvais, A., Diaquin, M., and Latge, J.P. 1997. Purification and characterization of an endo-1,3- $\beta$ -glucanase from *Aspergillus fumigatus*. *Eur. J. Biochem.* 243, 315–321.
- [8] Gull, K. and Newsam, R.J. 1975. Meiosis in basidiomycetous Fungi I. Fine structure of spindle pole body organization. *Protoplasma* 83, 247–257.
- [9] Herrera-Estrella, A. and Chet, I. 1999. Chitinases in biological control. In Jolles, P. and Muzarelli, R. (eds.), *Chitin and chitinases*, pp. 171–184. Birkhausen Verlag, Basel, Switzerland.
- [10] Jenkinson, T.S., Celio, G.J., Padamsee, M., Dentinger, B.T.M., Meyer, M.L., and McLaughlin, D.J. 2008. Conservation of cytoplasmic organization in the cystidia of *Suillus* species. *Mycologia* 100, 539–547.

- [11] Kamada, T., Fujii, T., Nakagawa, T., and Takenaru, T. 1985. Changes in 1,3- $\beta$ -glucanase activities during stipe elongation in *Coprinus cinereus*. *Curr. Microbiol.* 12, 251-260.
- [12] Kamzolkina, O.V., Mazheika, I.S., Shtaer, O.V., Kudriavtseva, O.A., and Mukhin, V.A. 2014. Endomembrane system of fungi: traditional and modern conceptions. *Tsitologiya* 56, 549-561.
- [13] Kanda, K., Sato, T., Ishii, S., Enei, H., and Ejiri, S. 1996a. Purification and properties of tyrosinase isozymes from the gill of *Lentinus edodes* fruiting body. *Biosci. Biotechnol. Biochem.* 60, 1273-1278.
- [14] Kanda, K., Sato, T., Suzuki, K., Ishi, S., Ejiri, S., and Enei, H. 1996b. Relationships between tyrosinase activity and gill browning during preservation of *Lentinus edodes* fruit-bodies. *Biosci. Biotechnol. Biochem.* 60, 479-480.
- [15] Kozlova, M.V. and Kamzolkina, O.V. 2004. Ultrastructure of the cell wall in vegetative mycelia of *Agaricus bisporus*. *Tsitologiya* 46, 191-201.
- [16] Matrosova, E.V., Mazheika, I.S., Kudriavtseva, O.A., and Kamzolkina, O.V. 2009. Morphogenesis and ultrastructure of basidiomycetes *Agaricus* and *Pleurotus* mitochondria. *Tsitologiya* 51, 490-499.
- [17] Mendoza, C.G. 1992. Cell wall structure and protoplast reversion in basidiomycetes. *World J. Microbiol. Biotechnol.* 1, 36-38.
- [18] Michalenko, G.O., Hohl, H.L., and Rast, D. 1976. Chemistry and architecture of the mycelial wall of *Agaricus bisporus*. *J. Gen. Microbiol.* 92, 252-262.
- [19] Osterman, L.A. 1981. *Methods for Investigation of Proteins and Nucleic Acids: Electrophoresis and Ultracentrifugation*, p. 288. Nauka, Moscow, Russia.
- [20] Perry, C.R., Smith, M., Britnell, C.H., Wood, D.A., and Thurston, C.F. 1993. Identification of two laccase genes in the cultivated mushroom *Agaricus bisporus*. *J. Gen. Microbiol.* 139, 1209-1218.
- [21] Polacheck, Y. and Rosenberger, R.F. 1975. Autolytic enzymes in hyphae of *Aspergillus nidulans*: their action on old and newly formed walls. *J. Bacteriol.* 121, 332-337.
- [22] Raguz, S.I., Yagüe, E., Wood, D.A., and Thurston, C.F. 1992. Isolation and characterization of a cellulose-growth-specific gene from *Agaricus bisporus*. *Gene* 119, 183-190.
- [23] Reynolds, E.S. 1963. The use of lead citrate at high pH as an electron opaque stain in electron microscopy. *J. Cell. Biol.* 17, 208-212.
- [24] Sakamoto, Y., Irie, T., and Sato, T. 2005a. Isolation and characterization of a fruiting body-specific exo-beta-1, 3-glucanase-encoding gene, *exg1*, from *Lentinula edodes*. *Curr. Genet.* 47, 244-252.
- [25] Sakamoto, Y., Minato, K., Nagai, M., Mizuno, M., and Sato, T. 2005b. Characterization of the *Lentinula edodes* *exg2* gene encoding a lentinan-degrading exo-beta-1, 3-glucanase. *Curr. Genet.* 48, 195-203.
- [26] Sakamoto, Y., Nakade, K., and Sato, T. 2009. Characterization of the post-harvest changes in gene transcription in the gill of the *Lentinula edodes* fruiting body. *Curr. Genet.* 55, 409-423.
- [27] Saksena, K.N., Marino, R., Haller, M.N., and Lemke, P.A. 1976. Study on development of *Agaricus bisporus* by fluorescent microscopy and scanning electron microscopy. *J. Bacteriol.* 126, 417-428.
- [28] Suh, S.O., Hirata, A., Sugiyama, J., and Komagata, K. 1993. Septal ultrastructure of basidiomycetous yeasts and their taxonomic implications with observations on the ultrastructure of *Erythrobasidium hasegawianum* and *Sympodiomyopsis paphiopedili*. *Mycologia* 85, 30-37.
- [29] Thurston, C.F. 1994. The structure and function fungal laccase. *J. Microbiol.* 140, 19-26.
- [30] Van Gelder, C., Flurkey, W., and Wichers, H. 1997. Sequence and structural features of plant and fungal tyrosinases. *Phytochem.* 45, 1309-1323.
- [31] Vetchinkina, E.P. and Nikitina, V.E. 2007. Morphological patterns of mycelial growth and fruition of some strains of an edible xylotrophic basidiomycete *Lentinus edodes*. *Izv. Samar. Nauch. Tsent. Ross. Akad. Sci.* 9, 1085-1090.
- [32] Whitaker, J.R. 1995. *Food Enzymes: Structure and Function*, p. 284. In Wong, D. (ed.), Chapman and Hall.