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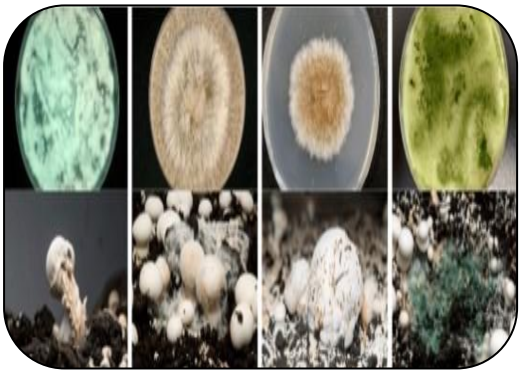
ANTIFUNGAL ACTIVITIES AND THEIR DIVERSITY IN MUSHROOM MYCOFLORA

Dr. Vinay Kumar Singh
Associate Professor, Department of Botany, K. S. Saket PG College Ayodhya
Dr. Ram Manohar Lohia Avadh University, Ayodhya, Uttar Pradesh, India.

ABSTRACT



This study summarizes published reports on the antifungal properties of mushrooms which can cause acute harm to human health and cultivation. Mushrooms are a natural resource for the treatment of infectious diseases and used as effective antibiotics for biological control as well. Basidiomycota mushrooms are a good source for the treatment of several ailments including antifungal, antibacterial, antioxidant, antitumor etc. The antifungal potential was screened against pathogenic fungi viz., Aspergillus niger, Pythium sp., Alternaria brassicicola etc has been investigated. Hence, this review is focused on exploring the antifungal properties of the mushroom and would be helpful to guide researchers to undertake further investigations in this direction.

KEYWORDS: *Antifungal, Mushroom, Basidiomycota, Biological, Cultivation.*

INTRODUCTION

Fungal invasion causes serious reduction in yield and quality of agricultural crops, which brings about enormous economic losses, great loss in humans and other organisms (Sultan *et al.*,2020). Research on Antifungal activity assay of mushrooms may provide ways to boost their resistance against pathogens. Since ancient times, mushrooms have been a component of the human diet, and an important therapeutic due to their medicinal value. The *Basidiomycete* fungus, is a good source of new antifungals viz., Strobilurin A and Oudemansin A (Ma *et al.*,2010). Mushrooms as a wide spectrum of biological resource, possess chemically diverse secondary metabolites and are well known to people all over the Asian countries in the twentieth century (Sridhar *et al.*,2011). The estimation of the existence of different species of mushrooms in the planet is about 1,40,000, however only about 10% is known (Balakumar *et al.*,2011). It has been reported that volatile compounds from fungi have been studied as biological control agents that inhibit the growth of phytopathogenic fungi (Oka *et al.*,2015); they possess the spore bearing fruiting body and a fleshy fungus of edible mushroom. The commonly available edible mushroom, namely *Agaricus bisporus* (button mushroom) is revealed to possess antimicrobial, antioxidant and anticancer activity (Nojedehi *et al.*,2017). The fungi constitute an important source for some compounds including enzymes and antibiotics (Nojedehi *et al.*,2017), secrete antifungal compounds to survive against competing or pathogenic organisms (Romi Singh

2017). Mushrooms are immensely rich in bioactive compounds namely terpenoids, proteins, polysaccharides, peptide, phenolics, flavonoids, alkaloid, protein, sterols are found in secondary metabolites and various cellular components which have been isolated and identified from the fruiting bodies (Gebreyohannes *et al*., 2019). Medicinal mushrooms must secrete a great amount of secondary metabolites that are revealed to possess wide beneficial properties such as anti-inflammatory, antitumoral, antifungal, antiviral, antibacterial, and anti-yeast activities (Owaid *et al*., 2017). The mycelium and fruiting bodies of mushroom shows health promoting values such as immunostimulatory, antioxidative and antibacterial properties (Gebreyohannes *et al*., 2019); antitumor, antiviral, antimicrobial with medicinal effects (Landi *et al*., 2022).

Antifungal Activity of Mushroom Species

Table: Antifungal Activity of certain mushrooms against target fungal specie.

Mushroom	**Target fungal species**	**Results**	**References**
Lactarius deliciosus	*Monilinia fructicola*	The extract of *Lactarius deliciosus* (L.) inhibited fungal growth and phytopathogenic induced mycelial development at a concentration of 1.25 mg/ml.	Volcao *et al*., 2022
Hypsizygus marmoreus	*Alternaria. brassicicola*	All of the stereoisomers with high stereoselectivity exhibited antifungal activity against the *Alternaria brassicicola.*	Anh *et al*., 2022
Mushroom alcohol	*Botrytis cinerea*	Mushroom alcohol vapor showed an inhibitory effect on mycelial growth of *B. cinerea* at 3, 6 or 12 μL L^{-1}.	Wang et al., 2022
Pleurotus eryngii	*Trichophyton rubrum*	The fruiting bodies extract of *Pleurotus eryngii* affected the growth of the dermatophytic fungus. The results showed that ethanolic extract was more effective than the aqueous extract.	Dawood *et al*., 2021
Oyster mushroom (Pleurotus ostreatus)	*Penicillium digitatum*	The results revealed that the treatment with ORWP-coated mushrooms was effective in maintaining the sensory quality of oyster mushrooms. The results showed the minimum inhibitory concentration (MIC) was 0.25 g L-1 and the minimum fungicidal concentration (MFC) was 1.00 g L−1.	Liu *et al*., 2020
Agaricus bisporus	*Aspergillus flavus*	The ethanolic extracts computed in vitro showed maximum effect against *Aspergillus flavus* at concentration 16 mg/ml, with growth rate reaching 2.5 cm.	Sultan *et al*., 2020

Rhizopogon species	*Penicillium chrysogenum*, *Aspergillus niger* and *Alternaria alternata*	The spore germination inhibition was observed in *Penicillium chrysogenum* (87.80%) with zone of inhibition (27.00 ± 1.00), followed by *Aspergillus niger* (71.08%) with zone of inhibition (22.67 ± 2.08) and *Alternaria alternata* (55.10%) with zone of inhibition (18.57 ± 1.52) respectively, at highest concentrations (200 mg/ml).	Talie *et al.*, 2020
Inonotus hispidus (Hymenochaetaceae)	*Aspergillus niger, Aspergillus flavus.*	The results revealed that higher inhibition percentage against *Aspergillus niger* was 12.2% whereas *Aspergillus flavus* showed the lower percentage was 6.3%.	Jaloot *et al.*, 2020
Trametes spp., Trametes, and Microporus spp.	*Candida albicans and Candida parapsilosis*	The results showed the growth inhibition against *C. albicans* and *C. parapsilosis* at MIC value of (1.50±0.87) mg/mL.	Gebreyohannes *et al.*, 2019
Agrocybe aegerita	*Trichoderma asperellum*	The results explored the antifungal activity of both isoforms against *T. asperellum*.	Ragucci *et al.*,2019
Pleurotus sajor-caju	*Candida albicans*	The average particle size (11.68nm) of PSC-AgNPs inhibited the growth of *C. albicans* with MIC and MFC values were 250 mg/L and 500 mg/L, respectively.	Musa *et al.*, 2018
Trametes Gibbosa, Agaricus Bisporus	*Candida albicans, Aspergillus niger, Fusarium oxysporum, Ustilago maydis, Microsporum gypseum and Malassezia furfur*	Mushroom extracts (F=1.44, P=0.24) showed significant difference in growth inhibition of the fungi. The fungal extracts (F=2.88, P=0.025) exhibited significant difference in growth inhibition of the fungal pathogens and also in the inhibition of the fungal pathogens by mushroom and fungal extracts (0.0022).	Waithaka *et al.*, 2017
Agaricus bisporus	*Aspergillus flavus, Aspergillus terreus*	The fabricated AuNPs resulted in high fungicidal effect against *Aspergillus flavus* as compared to the *Aspergillus terreus.*	Nojedehi *et al.*, 2017
Termitomyces	*Aspergillus flavus, Aspergillus niger, Candida albicans, Penicillium notatum, Mucor racemosus*	The methanolic extract of *Termitomyces* was computed against *Penicillium notatum* and showed highest antifungal inhibitory activity of 4.95mm.	Romi Singh 2017

Pleurotus ostreatus (grey), P. ostreatus var. florida, P. cornucopiae var. citrinopileatus and P. salmoneo stramineus	*Trichoderma harzianum, Verticillium sp. and Pythium sp.*	The best inhibition zone was 16 mm against *T. harzianum* by *P. ostreatus*, The highest inhibition activity of 55.56 % was perceived by *P.salmoneo stramineus* against *Verticillium* species. The highest inhibition of 55 and 50% by *P. ostreatus* and *P. salmoneo stramineus* culture filtrates in liquid media against *T. harzianum* and *Verticillium* sp.	Owaid *et al.*, 2017
Sparassis latifolia	*Candida albicans, C. catenulate, C. glabrata, C. rugosa, and Fusarium solani, Fusarium oxysporum*	Authors suggested that the potential of the mushroom lectin isolated from *S. latifolia*, a valuable source of bioactive constituents could be used as a pharmaceutical agent.	Chandrasekaran *et al.*, 2016
Agaricus bisporus	*Neurospora sitophila*	In vitro assay of antifungal activity indicated that a purified antifungal substance strongly inhibited the mycelia growth and spore germination of *N. sitophila.*	Liu *et al.*,2015
Phellinus gilvus, Phellinus rimosus and Phellinus badius	*Alternaria alternata*	*P. gilvus* reported the higher inhibition against the growth of *A. alternata*.	Ayala-Zavala *et al.*, 2012
Schizophyllum commune	*Saccharomyces pombe, Candida albicans and Candida parapsilosis.*	The fungal species were found to be sensitive to the antibiotic nystatin giving very active inhibition ranging from (19 ± 1 mm to 28 ± 1 mm).	Mirfat, *et al.*, 2014
Hypsizygus marmoreus	*Alternaria brassicicola, Alternaria alternata Bipolaris sorokiniana, Botrytis cinerea, Cladosporium cucumerinum , Colletotrichum orbiculare, Corynespora cassiicola, Podosphaera xanthii*	The conidial and mycelial growth of *Alternaria brassicicola* were significantly inhibited by 60 and 100%. The volatile compounds showed antifungal activity against *A. brassicicola* in comparison to others.	Oka *et al.*, 2015.

Lactarius densifolius, Lactarius sp, Lactarius gymnocarpoides, Russula kivuensis, Amanita muscaria and Amanita phalloides	*Candida albicans and Cryptococcus neoformans*	*Amanita muscaria* showed high activity against *Candida albicans* with MIC of 0.78 mg/mL.The *A. muscaria* chloroform extract showed moderate activity against both *C. albicans* and *C. neoformans* (MIC = 1.56 mg/mL).	Chelela *et al.,* 2014
Pleurotus ostreatus (oyster mushroom) and Agaricus bisporus (button mushroom)	*Aspergillus flavus, Aspergillus fumigatus, Penicillium chrysogenum, Sporotrichum carnis, Humicola grisea and Thermoascus aurantiacus*	*Pleurotus ostreatus* exhibited maximum inhibition against *Penicillium chrysogenum*.The extract of *Agaricus bisporus* showed good inhibition against *Humicola grisea*.	Kumar *et al.*, 2014
Basidiomycete macrofungi- Pleurotus sapidus and Pleurotus flabellatus	*Candida albicans, Candida guilliermondii, Candida krusei*	The results showed a zone of inhibition of 29 and 33 mm against *Candida albicans*, *Candida guilliermondii*. The Ketoconazole exhibited zones of inhibition of 28 and 32 mm against Candida albicans. The Ketoconazole and Fluconazole showed the zone of inhibition of 28 and 35 mm against *Candida guilliermondii*.	Shahi *et al.,* 2012

CONCLUSION

The present review focuses on antifungal effects of mushrooms; reports of various extracts of mushrooms were tested against different species of *Candida*, *Aspergillus, Fusarium, Penicillium, Alternaria* while isolated compounds obtained from mushrooms might be more useful for protecting crops and could be used as potential therapeutic agents. Synthesized AuNPs and essential oils had also suitable fungicidal effects against phytopathogens. The mycelium and fruiting bodies of mushrooms show health promoting values such as immunostimulatory, antioxidative and antibacterial properties, antitumor, antiviral, antimicrobial with medicinal effects. Results demonstrated that mushrooms produce antimicrobial metabolites could be an effective alternative for reducing fungal diseases, used as novel biological control agents and proved to be a promising antifungal agent.

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