**Metabolic profiling of the oyster spent mushroom substrate (SMS) extract against the major soil borne fungal plant pathogens**

**ABSTRACT**

This study explores the antimicrobial potential of water extracts from spent mushroom substrate (SMS) of various *Pleurotus* species, a byproduct of oyster mushroom cultivation. LCMS analysis identified several bioactive compounds with known antimicrobial properties: *Pleurotus sajor-caju* SMS contained 3-(o-chlorophenyl)-5-(ptolyloxymethyl)-2-oxazolidone; *Pleurotus sapidus* SMS revealed the presence of Cichoriin, Ethiin, and Cafestol palmitate; while *Pleurotus ostreatus* SMS showed Bronopol and Daphnetin-8-glucoside. These findings demonstrate the presence of natural antimicrobial agents in Oyster mushroom SMS, suggesting its potential as an eco-friendly, sustainable alternative for managing soil-borne fungal plant pathogens. This approach not only supports environmental sustainability but also adds value to agricultural waste through its application in plant disease management.

**Keywords:** *Pleurotus ostreatus, Pleurotus sajorcaju, Pleurotus sapidus,* Antimicrobial, Spent mushroom substrate

1. **Introduction**

Edible mushrooms, classified under the phylum Basidiomycota, naturally thrive on substrates like tree trunks, fallen leaves, roots, and decaying wood (Lindequist *et al*., 2005). For more than two thousand years, mushrooms have been consumed worldwide due to their remarkable nutritional and medicinal properties. They play a crucial role in human health by supplying digestible proteins, carbohydrates, dietary fiber, essential vitamins, minerals, and antioxidants (Acharya *et al*., 2017). Given their diverse benefits, advancing mushroom cultivation is essential to meet the growing global demand and support sustainable agricultural practices. Mushroom farming is environmentally friendly, utilizing agricultural, poultry, and brewery residues (Mahato *et al*., 2022). Currently, shiitake (*Lentinula edodes*), oyster (*Pleurotus* spp.), button (*Agaricus bisporus*), and milky mushrooms (*Calocybe indica*) account for 22%, 19%, 18%, and 15% of the world's total mushroom production, respectively (Manjit Singh *et al*., 2017). In India, five commercial mushroom varieties are cultivated: white button mushroom, oyster, paddy straw (*Volvariella volvacea*), milky, and shiitake. Among these, *Pleurotus* spp. are a unique group within the order *Agaricales* and the family *Tricholomataceae*, with various species (Raman *et al*., 2021). *Pleurotus* spp. are typically cultivated on lignocellulosic substrates. Agricultural byproducts like banana leaves, peanut hulls, corn leaves, mango fruits and seeds, sugarcane leaves, and wheat and rice straw serve as substrates for oyster mushroom production. *P. sajorcaju*, *P. sapidus*, *P. ostreatus*, and *P. florida* are grown using partially decomposed agricultural residues, including wheat straw, maize straw, pea straw, jowar straw, bajra straw, kauri straw, gram seed husk, groundnut seed husk, sugarcane bagasse, cotton waste, and waste paper.

Spent mushroom substrate (SMS) is a byproduct after several mushroom cultivation cycles. According to Ma *et al*. (2014) and Economou *et al.* (2017), each kilogram of mushrooms generates 5 kilograms of SMS. SMS contains carbon, nitrogen (0.4-13.7%), with a carbon-to-nitrogen ratio of 9:1 to 15:1, and essential cations (K+, Na+, Ca2+, Mg2+) and anions (Cl-, NO3-, SO42-) for plant growth. Additionally, SMS may contain beneficial microorganisms with potential antagonistic activity against phytopathogens. The use of oyster mushroom substrates has shown promising results in managing various plant diseases, including bacterial wilt (*Ralstonia solanacearum*) in potatoes, stem rot in onions, damping-off (*Phytophthora drechsleri*) in cucumbers, damping-off (*Rhizoctonia solani*) in tomatoes, and late blight (*Phytophthora capsici*) in peppers. Disease resistance in plants can be enhanced through exposure to water extracts from spent mushroom substrate (Kang *et al*., 2017). Furthermore, fungi isolated from spent oyster mushroom substrates have been effective in suppressing *Fusarium oxysporum* f. sp. *lycopersici* and *Rhizoctonia solani* (Verma *et al*., 2017). Bacterial isolates from these substrates have also demonstrated the ability to inhibit the *in vitro* growth of pathogens such as *Colletotrichum musae* and *Fusarium solani*.

Building upon the work of Bezbaruah *et al*. (2025), this study focuses on the metabolic profiling of oyster spent mushroom substrate (SMS) extract against major soil-borne fungal plant pathogens.

1. **Materials and Methods**

**2.1 Detection of secondary metabolites using LC-MS**

The aqueous extracts of the SMS of the three varieties (*Pleurotus sapidus, P. ostreatus* and *P. sajorcaju*) of mushroom (Bezbaruah *et al.,* 2025) were filtered through 0.22µm syringe filter and was sent to Mr. Biologist, Guwahati for the analysis of the secondary metabolites.

Each sample measuring 20µl was loaded into a UPLC system (Waters, USA). Samples were passed through C18 column with a gradient elution containing Acetronitrile (Solvent A), 0.1% Formic Acid 95:5 H2O:ACN (Solvent B) (Table 1).

**Table 1: Solvent gradient conditions for elution during LC-MS Analysis**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sl. No.** | **Time(min)** | **Flow rate(ml/min)** | **%A** | **%B** |
| 1. | Initial | 0.250 | 5.0 | 95.0 |
| 2. | 1.00 | 0.250 | 5.0 | 95.0 |
| 3. | 6.00 | 0.250 | 30.0 | 70.0 |
| 4. | 12.00 | 0.250 | 60.0 | 40.0 |
| 5. | 16.00 | 0.250 | 60.0 | 40.0 |
| 6. | 20.00 | 0.250 | 80.0 | 20.0 |
| 7. | 24.00 | 0.250 | 80.0 | 20.0 |

The fractions were detected using an EST-QTOF-Mass Spectrometer connected to the UPLC System in a positive ionization mode.

1. **Results**

The bioactive compounds that may be present in water extract of Oyster SMS showing highest inhibitory effect against the pathogens (*Fusarium oxysporum*, *Rhizoctonia solani*, and *Sclerotium rolfsii*) were profiled using chromatographic technique (Table 2, Table 3 and Table 4).

**Table 2: Identified metabolites from aqueous extracts of spent mushroom substrate of *Pleurotus sajorcaju*using LCMS technique**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sl no.** | **Name of the compound** | **Peaks** | **Chemical formula** |
| 1 | Valine | 117.1 | C5H11NO2 |
| 2 | Tranexamic acid | 157.1 | C8H15NO2 |
| 3 | 3-(o-chlorophenyl)-5-(p- tolyloxymethyl)-2- oxazolidone | 317.8 | C10H11Cl2NO |
| 4 | Sodium m- nitrobenzenesulfonate | 225.1 | C6H4NNaO5S |
| 5 | Esculin monohydrate | 340.1 | C15H18O |
| 6 | 3,4,5-tri pentadecanoate | 449.9 | C10H22 |
| 7 | Glycerol tripentadecanoate | 765.1 | C42H80O6 |
| 8 | Ethyl propionate | 102.1 | C5H10O2 |
| 9 | 2-bromo-5-chlorothiophene | 197.6 [M-H]- | C4H2BrCIS |
| 10 | Tocopheryl retinoate | 713.3 | C49H76O3 |

**Table 3: Identified metabolites from aqueous extracts of spent mushroom substrate of *Pleurotus sapidus* using LCMS technique**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sl no.** | **Name of Compound** | **Peaks** | **Chemical formula** |
| 1. | Valine | 117.1 | C5H11NO2 |
| 2. | Tranexamic acid | 157.0 | C8H15NO2 |
| 3. | Ammonium oxalate | 107.2 | C2H10N2O5 |
| 4. | Diisobutyl maleate | 228.9 | C12H20O4 |
| 5. | Cichoriin | 340.0 | C15H16O9 |
| 6. | Ethiin | 165.9 | C9H22O4P2S4 |
| 7. | Sinapinic acid | 224.1 | C11H12O5 |
| 8. | Dimethyl malonate | 132.1 | C5H8O4 |
| 9. | Cadaverine | 102.4 | C5H14N2 |
| 10. | Adipic acid | 146.1 | (CH2)4(COOH)2 |
| 11. | Pentetic acid | 393.1 | C14H23N2O10 |
| 12.  | Cafestol palmitate | 568.8 | C36H58O4 |
| 13. | TEA-lauroylsarcosinate | 420.5 | C15H28NNaO3 |
| 14. | Adenine | 135 | C5H5N5 |

**Table 4: Identified metabolites from aqueous extracts of spent mushroom substrate of *Pleurotus ostreatus*using LCMS technique**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sl no.** | **Name of Compound** |  **Peaks** | **Chemical formula** |
| 1. | Valine | 117.1 | C5H11NO2 |
| 2. | Tranexamic acid | 157.0 | C8H15NO2 |
| 3. | Bronopol | 200.9[M+H]+ | C3H6BrNO4 |
| 4. | Daphnetin-8-glucoside | 340.2 | C9H6O4 |
| 5. | Stigmasterol 3-stearate | 679.3 | C47H82O2 |
| 6. | Erythritol | 122 | C4H10O4 |
| 7. | Triphenyl phosphate | 326.1 | C18H15O4P |
| 8. | Ethyl propionate | 102.1 | C5H10O2 |
| 9. | Disodium fumarate | 160.7 | Na2C4H2O4 |
| 10. | 2-bromo-5-chlorothiophene | 197.5[M-H]- | C4H2BrCIS |
| 11. | Tocopheryl retinoate | 713.2 | C49H76O3 |
| 12.  | 4-bromophenacyl methyl succinate | 329.1 | C13H13BrO5 |
| 13. | Cytochalasin E | 494[M-H]- | C28H33NO7 |
| 14. | n-hexanoyl-d-glucosamine | 277.1 | C12H23NO6 |

1. **Discussion**

The metabolic profiling of water extract obtained from *P.sajorcaju*SMS revealed the presence of antimicrobial compounds like 3-(o-chlorophenyl)-5-(p- tolyloxymethyl)-2- oxazolidone, followed by water extract of *P. sapidus*(SMS)which showed antimicrobial compounds like Cichoriin, Ethiin, Cafestol palmitate and water extract of *P. ostreatus* which showed antimicrobial compounds like Bronopol, Daphnetin-8-glucoside. Oyster mushrooms enable to produce metabolism products in 48 h to inhibit growth of pathogenic bacteria due to produce polysaccharides, proteins, enzymes and triterpenoides of mycelia of *Pleurotus spp.*(Owaid et al., 2015).

Lately, metabolomics-based methodology has been increasingly applied in the study of edible and medicinal mushrooms to understand their chemical constituent and responses to certain environmental stimuli. While *Pleurotus* species have been extensively studied for their phytochemicals, little research exists on *P*. *columbinus*Quél, particularly regarding its phytochemistry, antioxidant properties, and antibacterial activities. This study employed ultra-performance liquid chromatography mass spectrometry (UHPLC-QTOF) along with principal component analysis (PCA) to analyze the metabolome of *P. columbinus* and *P. sajorcaju*, aiming to fill this knowledge gap. The objective of these study was to examine how various agri-flod residues, used as growth substrates for *P. columbinus* cultivation, effect the bioactive chemical composition of the fruiting bodies.

Angelini *et al*. (2021) performed a quantitative analysis using high-performance liquid chromatography coupled with diode array detection and mass spectrometry (HPLC-DAD-MS) to investigate the phenolic and flavonoid chemicals present in *P. columbinus* extracts. This analysis aimed to provide a partial explanation for the reported biological effects associated with these extracts.Many isolated compunds from differentspeciesof *Pleurotus* genus possess nematicide compunds like trans-2-decenedioic acid, 2-hydroxy-(4'-methoxy)- propiophenone, s-coriolic acid, p- anisaldehyde , p- anisyl alcohol, whichhave shown their ability to supress pests, diseases and weeds naturally(Bello *et al*., 2025). Mahato *et al*. 2024 have also found that SMSalong with antogonistic (*Trichoderma asperellum*) microbial inoculants exhibit antifungalvolatile compound 6- Pentyl-2- H-pyran-2-one (22.02%).Different SMS had high levels of trace elements such as Zn, Mn, B, Fe and Cu, which are known to have antifungal properties (Huber, 1980). High concentrations of Zn and Cu inhibit fungal growth by enhancing the production of antifungal compounds, such as 2, 4 diacetylphloroglucinol (DAPG) that controls fungal species such as *Fusarium*. It is reported that these compounds inhibit biosynthesis of fusaric acid by *Fusarium sp*. in the plant cell infection process (Thind and Madan, 1977; Blevins and Lukazewski, 1998; Brown *et al*., 2002). These SMS also suppress fungal growth of *Fusarium oxysporum* and *Rhizoctoniasolani*(Nkosi, 2017). This analysis aimed to provide a partial explanation for the reported biologicaleffects associated with these extracts. Although, proper application and methods are also crucial for maximizing their effectiveness.

1. **Conclusion**

The LCMS analysis of water extract from SMS of *P.sajorcaju*, *P. sapidus* and *P. ostreatus* showed different compounds with antimicrobial activity like having the presence of 3-(o-chlorophenyl)-5-(p-tolyloxymethyl)-2- oxazolidone, Cichoriin, Ethiin, Cafestol palmitate, Bronopol, Daphnetin-8-glucoside, etc. These compounds may be attributed to the antagonistic behaviour of the isolated fungal microflora against the tested pathogens. As majority of SMSs exhibit efficacy as biological control agents and are applied directly as soil conditioners or SMS extracts, this study would be instrumental in that line of work. This study threw some light on the potentiality of aqueous extracts of SMS which may help to reduce the disease incidence by direct antagonistic activity to the pathogens involved or indirectly triggering pathways responsible for defense in host plants. Thus, more work need to be undertaken in such kind of study in future.

**Ethical approval**

This article does not contain any studies with human participants or animals by any of the authors.

**Consent for publication**

Written informed consent was obtained from all the authors for publication.

**Declaration of generative AI and AI-assisted technologies in the writing process**

While preparing this work, we used Quillbot to improve the language. After using this tool/service, we reviewed and edited the content as needed and took full responsibility for the publication’s content.

**Data availability**

No new data has been generated to perform the study.

**Reference**

Acharya K, Das K, Paloi S, Dutta AK, Hembrom ME, Khatua S, Parihar A. Exploring a novel edible mushroom *Ramariasubalpina*: Chemical characterization and Antioxidant activity. Pharmacogn J. 2017; 9(1): 30-34.

Angelini P, Pellegrino RM, Tirillini B, Flores GA, Alabed HB, Ianni F, Blasi F, Cossignani L, Venanzoni R, Orlando G, Menghini L. Metabolomic profiling and biological activities of Pleurotus columbinusQuél. Cultivated on different agri-food byproducts. Antibiotics. 2021;10(10):1245.

Bello AB, Dabban AI, Muhammad WM, Amarachi A, Oko JO, Opeyemi H, Oyewole OA, Adetunji CO. Application of Mushrooms in Management of Soil‐Borne Parasites, Nematodes, Bacteria and Fungi. Mushroom Biotechnology for Improved Agriculture and Human Health. 2025; 20:85-122.

Bezbaruah P, Sharma S, Das A, Upamanya GK, Sarmah D. *In vitro* Efficacy of Oyster Spent Mushroom Substrate (SMS) Extract against Major Soil Borne Fungal Plant Pathogens. Journal of Advances in Biology & Biotechnology*.*2025;28(5):793-800.<https://journaljabb.com/index.php/JABB/article/view/2340>

Blevins DG, Lukaszewski KM. Boron in plant structure and function. Annual review of plant biology. 1998;49(1):481-500.

Brown PH, Bellaloui N, Wimmer MA, Bassil ES, Ruiz J, Hu H, Pfeffer H, Dannel F, Römheld V. Boron in plant biology. Plant biology. 2002;4(02):205-23.

Economou CN, Diamantopoulou PA, Philippoussis AN. Valorization of spent oyster mushroom substrate and laccase recovery through successive solid state cultivation of Pleurotus, Ganoderma and Lentinula strains. Appl MicrobiolBiotechnol. 2017; 101(12):5213–5222

Huber DM (1980). The role of mineral nutrition in defense. In Plant Disease, An Advanced Treatise, Volume 5, How Plants Defend Themselves, in: Horsfall JG, Cowling EB (Eds.), Academic Press, New York, pp. 381-406.

Kang DS, Min KJ, Kwak AM, Lee SY, Kang HW. Defense response and suppression of Phytophthora blight disease of pepper by water extract from spent mushroom substrate of *Lentinula edodes*. Plant Pathol J. 2017; 33(3):264. <https://doi.org/10.5423/PPJ.OA.02.2017.0030>

Lindequist U, Niedermeyer TH, Jülich WD. The pharmacological potential of mushrooms. Evidence‐Based Complementary and Alternative Medicine. 2005; 2(3):285-99. <https://doi.org/10.1093/ecam/neh107>

Ma Y, Wang Q, Sun X, Wang X, Su W, Song N. A study on recycling of spent mushroom substrate to prepare chars and activated carbon. Bioresources. 2014; 9(3):3939–3954.

Mahato D, Khamari B, Sahoo JP. Valorization of Spent Oyster Mushroom Substrate with *Trichoderma asperellum* for Suppression of Sesame Root Rot *In Vitro*. Waste and Biomass Valorization. 2024;15(2):755-69.

Mahato D. Suppression of Plant Diseases by Exploiting Spent Mushroom Substrate. Biotica Research Today. 2022; 4(6):497-499

Manjit Singh MS, Shwet Kamal SK, Sharma VP. Status and trends in world mushroom production-I. Mushroom Res. 2017; 26(1): 1-20

Nkosi ZE. *Use of different spent oyster mushroom substrates as soil amendment on the establishment and growth of Spinacia oleracea L. and Beta vulgaris L* (Doctoral dissertation, North-West University (South Africa)).

Owaid MN, Al-Saeedi SS, Al-Assaffii IA. Antimicrobial activity of mycelia of oyster mushroom species (*Pleurotus* spp.) and their liquid filtrates (*in vitro*). Journal of Medical and Bioengineering Vol. 2015;4(5).

Raman J, Jang KY, Oh YL, Oh M, Im JH, Lakshmanan H, Sabaratnam V. Cultivation and nutritional value of prominent Pleurotus spp.: an overview. Mycobiology. 2021; 49(1):1-4. <https://doi.org/10.1080/12298093.2020.1835142>

Thind KS, Madan M. Effect of various trace elements on the growth and sporulation of four fungi.

Verma S, Kumar A, Singh J, Singh S, Rana RS. Antagonistic Effect of *Trichoderma* Spp. present in spent mushroom substrate against *Rhizoctonia solani* causing damping-off and root rot in tomato. Int J Agric Sci Res. 2017; 7:149-58.