PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 11(sp4): 01–07
https://doi.org/10.14719/pst.5903

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RESEARCH ARTICLE

Harnessing nature's treasure of bioactive compounds from ethnomedicinal Macromycos *Lentinus squarrosulus* Mont.

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OPEN ACCESS

ARTICLE HISTORY
Received: 17 October 2024
Accepted: 29 October 2024
Available online
Version 1.0 : 25 December 2024

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
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CITE THIS ARTICLE
Saravanan KG, Thiribhuvanamala G, Praveen T, Mahalakshmi P, Angappan K, Revathy N, Anandham R, Jayakanthan M. Harnessing nature's treasure of bioactive compounds from ethnomedicinal Macromycos *Lentinus squarrosulus* Mont. Plant Science Today.2024;11(sp4):01-07. https://doi.org/10.14719/pst.5903

Abstract

Mushrooms are low-calorie foods with a high content of proteins, vitamins B and D, minerals, carbohydrates and fibers (1). Many researchers have shown that edible mushrooms contain numerous bioactive compounds with multiple health-promoting effects such as antiulcer, antioxidant, antiviral, anticancer, antibacterial, hepatoprotective, immunomodulatory antitumor, anticholesterol, anti-inflammatory and antihaemorrhagic effects (2). There arises a pressing need to tap into the potential of medicinal mushrooms like *L. squarrosulus* which has ethnomedicinal values and are used in treating anaemia, ulcer, fever, cough, infertility and fungal infections, as well as to reduce the risk of metabolic diseases (3-5). Global multidrug resistance calls for a search for new potential lead compounds as therapeutic agents. Many macromycos still remain understudied as sources of bioactive compounds. Further investigation of bioactive components found in *L. squarrosulus*, will be informative regarding the biological activity of the organisms as medicinal agents. The ethanol extract of the ethnomedicinal macromycos *L. Squarrosulus* was subjected to GC-MS analysis for bioactive compounds among these thirteen compounds of hits were achieved with bioactive compounds in the ethnomedicinal macromycos. Of these compounds (2E)-Dodec-2-en-1-yl methyl ether (13.95%) formed the largest number while 1,2-15,16-Diepoxyhexadecane (9.03%) constituted the next high number of such compounds. Other amino acids, fatty acids, ethyl esters and other compounds identified included 2 -Methyl-4-(4-methyl-1-piperazinyl)-4-oxo-2-butenoic acid (2.12%), L-Alanine, N-L-alanyl- (0.94%), Benzofuran, 3-methyl- (1.63%), Tauroursodeoxycholic acid (3.75%) and 2'-Hydroxy-à-naphthoflavone (2.53%). Some of these compounds have antioxidant, hepatoprotective, hypocholesterolemic, anti-diabetic, anti-inflammatory, antioxidant, antimicrobial, antiarthritic, anticoronary and immune suppression as well as cancer preventive activities. The present study has identified bioactive components with therapeutic potential in *L. squarrosulus*; it forms a basis for screening, isolating and identifying various bioactive compounds which may be valuable in treating a wide range of ailments, disorders and diseases soon.

Keywords

bioactive compounds; GC-MS analysis; *Lentinus squarrosulus*; therapeutic agents

Introduction

Macromycos are increasingly consumed worldwide for their unique flavour and taste. It also plays a crucial role in human nutrition, offering a diverse array of essential nutrients, including high-quality proteins, vitamins (such as B-complex and D) and minerals (like selenium and copper), which collectively contribute to health outcomes and metabolic functions (6). Among these macromycos, the genus *Lentinus* sp. stands out as a cosmopolitan saprobic Basidiomycete, classified under the Agaricomycetes class and Polyporaceae family (7). Previous studies show macromycos to be involved in the biosynthesis of some secondary metabolites, such as polysaccharides, phenolics, terpenes and fatty acids, which exhibit some form of biological activity- antimicrobial, antioxidant and anticancer (8).

Indigenous macromycos growing in the wild have good sources of amino acids, ascorbic acid, glycogen, lipids, sugars, vitamins and minerals such as calcium, iron, phosphorus, potassium, sodium, magnesium and zinc (9). *L. squarrosulus* is rich in bioactive compounds, including polysaccharides, phenolic compounds and triterpenoids, which contribute to its therapeutic properties. These compounds have been shown to possess immunomodulatory, hepatoprotective and antidiabetic effects highlighting the mushroom's potential as a valuable nutraceutical source (10). A comprehensive assay of these nutraceutical compounds involves identifying and quantifying the key bioactive constituents of *L. squarrosulus*. Understanding the profile and concentration of these bioactive components is crucial for validating the mushroom's therapeutic claims and optimizing its use in dietary supplements and functional foods.

The quest for new therapeutic agents has intensified due to the rising prevalence of treatment-resistant diseases and the limitations of existing pharmaceuticals. As researchers increasingly turn to natural products, fungi, particularly macromycos, have emerged as valuable sources of bioactive compounds (11). Among these, macromycos have garnered attention for their potential to yield novel lead compounds with significant therapeutic applications (12). Previous studies have shown that *L. Squarrosulus* has been used in traditional medicine across Asia and Africa which has ethnobotanical applications and a wide array of medicinal properties, this warrants scientific investigation to substantiate its efficacy and identify its bioactive constituents (13).

Gas Chromatography-Mass Spectrometry (GC-MS) has become a pivotal technique for the qualitative and quantitative analysis of complex mixtures of bioactive compounds, enabling the identification of individual constituents within fungal extracts (14). This technique facilitates a deeper understanding of the bioactive compounds profiling of fungi and supports the discovery of compounds with potential health benefits.

In this study, we investigate the bioactive compounds present in the ethanolic extract of *L. Squarrosulus* using GC-MS analysis. Our aim is to identify and quantify the bioactive constituents that contribute to the macromycos ethnomedicinal properties, thereby providing a scientific basis for its traditional uses and paving the way for future therapeutic applications.

Materials and Methods

Collection of macromycos and identification

Isolated *Lentinus* sp. was collected from Siruvani, Coimbatore, Tamil Nadu, India, and was identified morphologically concerning stipe colour, pileus character, attachment of gills, presence of squamules and subsequently analysed with molecular characterisation for authentic confirmation. The *Lentinus* sp. collected was sub-cultured and maintained in the Department of Plant Pathology laboratory, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. These were utilized for the present studies.

Profiling and characterization of bioactive compounds from L. squarrosulus isolate

The crude metabolites of *L. squarrosulus* isolate were extracted as per the protocol described earlier (15). The *L. Squarrosulus* isolate was cultured in Potato Dextrose Broth (PDB) and kept in an incubator cum shaker for 10 days at 28°C. The mycelial mat was removed and filtered through Whatman No. 1 filter paper. The supernatant was collected by centrifuging at 8000 rpm for 10 min and adjusted to pH 2.0 by adding conc. HCl. An equal volume of solvent was added to the supernatant and kept overnight in the shaker. Using the separating funnel, the contents were separated to get a clear aqueous layer at the top which was collected and allowed to dry using a vacuum flash evaporator and the final fraction was obtained by using methanol and was given for GC/MS analysis. Macromycos sample concentrate was dissolved in GC-MS grade ethyl acetate and filtered through the microfiltration (0.22 µm size) technique. The analysis was performed on a Clarus SQ 8C Gas Chromatography-Mass Spectrometer from Perkin Elmer, which was engaged for analysis. The instrument was set as follows. The injector port temperature was set to 220 °C, the interface temperature was set to 250 °C and the source was kept at 220°C. The oven temperature was programmed as available, set at 75 °C for 2 mins, 150 °C @ 10 °C/min, up to 250 °C @ 10 °C/min. the split ratio was set as 1:12 and the injector used was split less mode. The DB-5 MS capillary standard non-polar column was used whose dimensions were 0.25 mm OD × 0.25 µm ID × 30 meters length procured from Agilent Co., USA. Helium was used as the carrier gas at 1 mL/min. The MS was set to scan from 50 to 550 Da. The source was maintained at 220 °C and 4.5 e^{-6} mtorr vacuum pressure. The ionization energy was -70 eV. The MS also had an inbuilt pre-filter which reduced the neutral particles. The data system had inbuilt libraries for searching and matching the spectrum. The NIST MS Search 2.2v contains more than five lakh references.

Identification of compounds

Interpretation of the mass spectrum of GC-MS was done using the database of the National Institute of Standard and Technology (NIST14). The spectrum of the known component was compared with the spectrum of the known components stored in the inbuilt library (16).

Fig. 1. *Lentinus squarrosulus* grown on a decaying tree trunk.

Results

The morphological characterization of five *Lentinus* sp. isolates collected from Siruvani, Tamil Nadu showed a whitish pileus with a distinct brown depressed center and longer stipe, gills were sub-decurrent and crowded and the unique conspicuous squamules on the isolate and was characterized as *L. squarrosulus*. Molecular characterization confirmed the identity of the isolate as *L. squarrosulus* through genomic DNA amplification (~560 bp) using ITS1/ITS4 primers. Sequence comparison with the NCBI GenBank database showed high similarity to existing *L. squarrosulus* sequences and a unique accession number (OR077745) was obtained.

The GC-MS (Gas Chromatography-Mass Spectrometry) analysis of *L. squarrosulus* mushroom identified a wide array of bioactive compounds (Table 1 and Fig. 2). These compounds belong to various chemical classes, including amino acids, fatty acids, cyclic compounds, terpenes and other organic molecules, many of which have potential biological activities. The following compounds were detected, each with varying degrees of intensity and area percentage, reflecting their relative abundance in the mushroom.

The compound 2-Methyl-4-(4-methyl-1-piperazinyl)-4-oxo-2-butenoic acid, with a retention time of 3.073, was detected with a probability of 16.2% and an area percentage of 2.123%. At a retention time of 6.590, L-alanine and N-L-alanyl were identified with a higher probability of 40.7% and an area percentage of 0.949%. L-alanine is an amino acid derivative known for its involvement in protein biosynthesis and metabolic pathways. Another significant compound identified was Benzofuran, 3-methyl- (RT: 7.700 min), with a probability of 12.4% and an area percentage of 1.633%. Benzofurans are a class of heterocyclic compounds with known antioxidant, anti-inflammatory and anticancer properties. This suggests that *L. squarrosulus* may possess potential health benefits related to oxidative stress and inflammation modulation. The analysis also detected various bioactive compounds namely Tauroursodeoxycholic acid, 2'-Hydroxy-α-naphthoflavone, Bicyclo[3.1.1]heptan-3-one, 2,6,6-trimethyl-, (1α,2α,5α), Cyclohexylmethanol, trifluoroacetate (ester), Isopimaric acid; 1,2,4-Triazolo[2,3-a]quinazolin-2-amine, 4,5,6,7,8,9-hexahydro-5,5-pentamethylene-, 3-odecanone, (2E)-Dodec-2-en-1-yl methyl ether, 2-(3-Methyl-undec-3-enyl)-[1,3]dioxolane and 1,2-15,16-Diepoxyhexadecane. The identification of compounds like tauroursodeoxycholic acid, isopimaric acid and flavonoids highlight the therapeutic potential of *L. squarrosulus*, particularly in the context of liver health, inflammation management, antimicrobial, anticancer effects and oxidative stress reduction (Table 2).

Table 1. Profiling and characterization of bioactive compounds from *L. squarrosulus* isolate

S. No	Retention time	Compound Name	Probability	Area %	Pubchem ID
1	3.073	2-Methyl-4-(4-methyl-1-piperazinyl)-4-oxo-2-butenoic acid	16.2	2.123	1674610
2	6.590	L-Alanine, N-L-alanyl-	40.7	0.949	5484352
3	7.700	Benzofuran, 3-methyl-	12.4	1.633	88939
4	9.326	Tauroursodeoxycholic acid	63.4	3.75	9848818
5	12.207	2'-Hydroxy-à-naphthoflavone	37.5	2.533	676302
6	12.782	Bicyclo[3.1.1]heptan-3-one, 2,6,6-trimethyl-, (1à,2à,5à)-	16.3	0.608	11038
7	18.430	Cyclohexylmethanol, trifluoroacetate (ester)	9.9	0.969	543382
8	19.570	Isopimaric acid	91.9	0.648	442048
9	20.445	1,2,4-Triazolo[2,3-a]quinazolin-2-amine, 4,5,6,7,8,9-hexahydro-5,5- pentamethylene-	11.5	1.209	612141
10	20.916	3-Dodecanone	16.9	0.612	15229
11	21.616	(2E)-Dodec-2-en-1-yl methyl ether	20.8	13.954	88030105
12	22.256	2-(3-Methyl-undec-3-enyl)-[1,3]dioxolane	25.8	1.610	5368016
13	25.317	1,2-15,16-Diepoxyhexadecane	23.1	9.036	543423

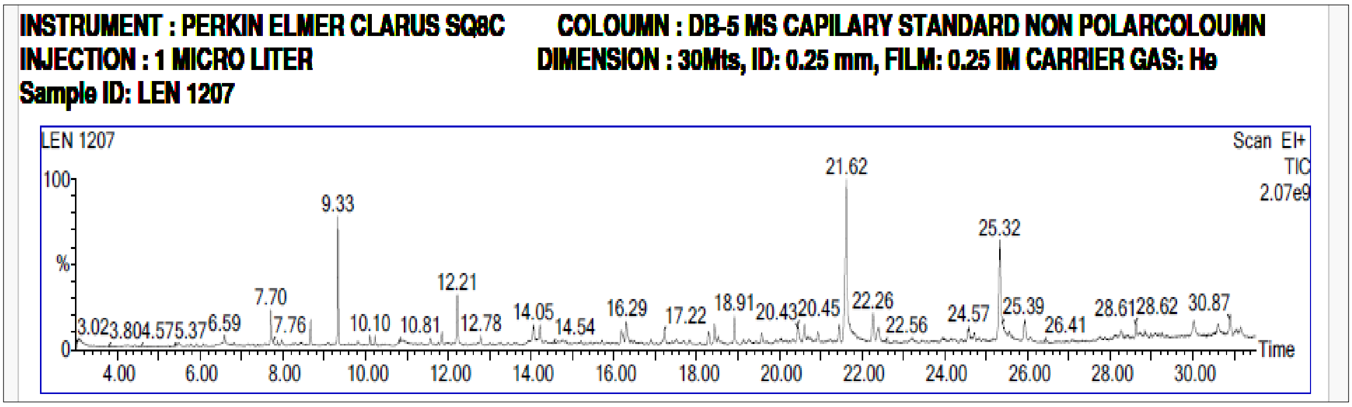
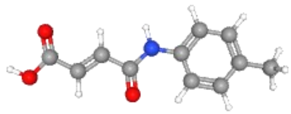
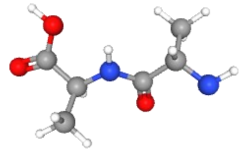
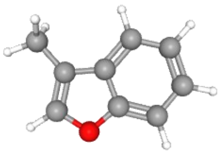
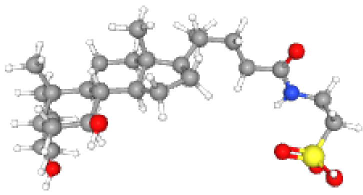
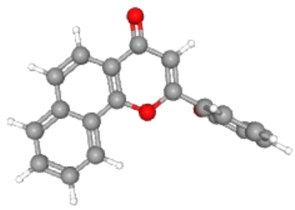
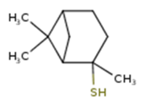
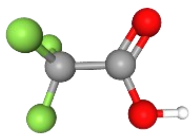
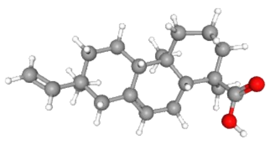
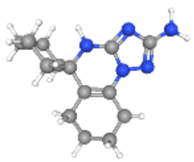
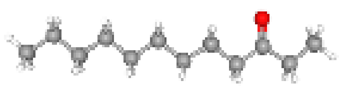
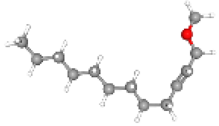
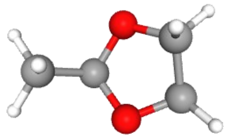
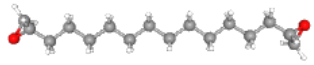


Fig. 2. GC-MS spectra of *L. squarrosulus* ethanolic extract.

Table 2. Exploring the activity spectrum and structural perspective of *L. squarrosulus* isolate GC-MS compounds

S. No	Compound Name	Activity	Compound Structure	Pubchem ID
1	2-Methyl-4-(4-methyl-1-piperazinyl)-4-oxo-2-butenoic acid	Anti-proliferative activity against human tumour cell lines, Analgesic and anti-inflammatory activities.		1674610
2	L-alanine, N-L-alanyl-	Has many medicinal uses like strengthening the immune system, balances the moisture levels of the skin, which can improve hydration. It is also used to make protein		5484352
3	Benzofuran, 3-ethyl-	Anti-inflammatory, antimicrobial, antifungal, antihyperglycemic, analgesic, antiparasitic and antitumor activities		88939
4	Tauroursodeoxycholic acid	Enhances the synthesis of bile acids in the liver and reduces cholesterol in the serum and liver. It inhibits cell apoptosis by disrupting the mitochondrial pathway of cell death		9848818
5	2'-Hydroxy-à-naphthoflavone	Commonly used as a cytochrome enzyme inhibitor in biochemical and pharmacological research. It is involved in the metabolism of various xenobiotics. The compound helps study enzyme kinetics, drug metabolism and toxicology.		676302
6	Bicyclo[3.1.1]heptan-3-one, 2,6,6-trimethyl-, (1à,2à,5à)-	Used as a topical analgesic and anti-inflammatory agent, often found in creams and ointments to relieve pain and itching		11038
7	Cyclohexylmethanol, trifluoroacetate (ester)	It is used in pharmaceutical and material science research for its reactivity and functional properties.		543382
8	Isopimaric acid	Antimicrobial, anti-inflammatory and anticancer properties, making it a compound of interest in drug research and development		442048
9	1,2,4-Triazolo[2,3-a]quinazolin-2-amine, 4,5,6,7,8,9-hexahydro-5,5-pentamethylene-	Antidepressants, anxiolytics, sedatives due to their interaction with neurotransmitter receptors or ion channels, antimicrobial, anti-inflammatory properties.		612141
10	3-Dodecanone	Used as a chemical intermediate in organic synthesis, contributing to the development of pharmaceuticals, agrochemicals and other specialized chemical products.		15229

11	(2E)-Dodec-2-en-1-yl methyl ether	Used in pest control, as it mimics certain insect pheromones, making it useful in traps or repellents.		88030105
12	2-(3-Methyl-undec-3-enyl)-[1,3] dioxolane	Used in perfumes, cosmetic products and personal care Additionally, it can be used as a flavouring agent in food and beverages, offering delicate fruity or floral notes.		5368016
13	1,2-15,16-Diepoxyhexadecane	It has antioxidant activity.		543423

Discussion

Macromycos features prominent fruiting bodies visible to the naked eye and encompass both edible and nonedible varieties (17). Certain macromycos are valued for their nutritional content and used in culinary activities, while others have been utilized in traditional medicine practices considering their therapeutic properties (18). Despite extensive research on the medicinal properties of macromycos, there is limited literature on the bioactive components of pharmacological significance in the ethnomedicinal macromycos *L. squarrosulus*. The ethanolic extract of the macromycos investigated in this research contains amino acids, fatty acids and their ethyl esters, along with other compounds whose biological functions remain largely unexplored. In order to dive into new therapeutic options, this ethnomedicinal macromycos have the notable effects of anti-diabetic, anti-inflammatory, anti-cancer, antioxidant, hypocholesterolemic, antimicrobial, antiarthritic, anticoronary, antieczemic, nematicide, antiacne, hepatoprotective and immune suppression as similar to the previous reports where it is found with similar properties in other medicinal macromycos like *Ganoderma lucidum* and *Trametes versicolor* (19, 20).

The GC-MS analysis of *L. squarrosulus* mushroom identified a range of bioactive compounds with potential therapeutic properties including amino acids, fatty acids, cyclic compounds and terpenes. Notably, compounds such as 2-Methyl-4-(4-methyl-1-piperazinyl)-4-oxo-2-butenoic acid, L-alanine and Benzofuran demonstrated varying degrees of intensity and area percentages, indicating their prevalence in the mushroom and possible biological activity. Benzofurans, in particular, are known for their antioxidant, anti-inflammatory and anticancer properties, suggesting that *L. squarrosulus* could have applications in managing oxidative stress, inflammation and chronic diseases like cancer (21). Additionally, compounds such as tauroursodeoxycholic acid and isopimaric acid could offer hepatoprotective, antimicrobial and anti-inflammatory benefits, further highlighting the therapeutic potential of *L. squarrosulus* for liver health and infection management (22, 23). The presence of flavonoids like 2'-Hydroxy-α-naphthoflavone further suggests anticancer activity, reinforcing the value of this mushroom species as a functional food with significant health-promoting properties (24).

Numerous therapeutic benefits of fatty acids are known, such as their anti-inflammatory and antioxidant qualities (25). Previous research suggests that omega-6, -7 and -9 fatty acids are essential dietary components that provide a number of health advantage (26). Although the body is unable to produce omega-6 fatty acids from scratch, it is possible to obtain them via egg yolks, organ meats and vegetable oils that contain linoleic acid (27). Healthy skin naturally contains omega-7 mono-unsaturated fatty acids, such as palmitoleic acid (28). Furthermore, the majority of omega-9 mono-unsaturated fatty acids in olive oil, such as oleic acid, have been shown to help lower cholesterol and minimize the risk of atherosclerosis (29).

N-3 and N-6 polyunsaturated fatty acids serve various therapeutic functions, including roles in blood clotting, lowering blood pressure, regulating inflammation, maintaining cell membrane integrity and managing lipid metabolism (30). An imbalance between these omega fatty acids may lead to the development of several chronic conditions, such as heart disease, cancer, asthma and arthritis (31). The monosaturated fatty acid Cis-2,3-Epoxyoctane, an oxidative form of conjugated oleic acid, acts as an antioxidant and provides membrane protection (32). Thus, this study posits that the incorporation of the ethnomedicinal macrofungus *L. squarrosulus* into the diet could potentially offer similar therapeutic benefits, especially in the context of an unbalanced diet.

Conclusion

This study successfully identified thirteen bioactive compounds from the ethanolic extract of the fruiting body of *L. squarrosulus* through Gas Chromatography-Mass Spectrometry (GC-MS) analysis. The identified compounds, such as 2-Methyl-4-(4-methyl-1-piperazinyl)-4-oxo-2-butenoic acid, Benzofuran, 3-methyl- and Tauroursodeoxycholic acid, highlight the macromycos potential as a rich source of bioactive substances with diverse therapeutic properties. The presence of compounds known for their antimicrobial, anticancer, hepatoprotective and potential antioxidant activities underscores the ethnomedicinal significance of *L. squarrosulus*. This lays the groundwork for further investigations into the isolation, characterization and biological activities of these compounds, with the potential to develop novel therapeutic agents for various health conditions. Ultimately, this study contributes to the growing body of knowledge regarding the pharmacological potential of ethnomedicinal macromycos, advocating for their incorporation into modern medicinal practices.

Acknowledgements

Gratitude was expressed to the GOI-MoEFC&C scheme, New Delhi and Tamil Nadu Agricultural University for providing financial support for conducting this research.

Authors' contributions

KGS was responsible for the methodology, investigation and drafting the original manuscript. GT contributed to the conceptualization of the study, provided supervision and participated in reviewing and editing the manuscript. KA, TP, NR, RA and MJ were involved in reviewing and editing the manuscript, ensuring its overall quality and coherence.

Compliance with ethical standards

Conflict of Interest: Nil

Ethical issues: None

References

1. Kumar H, Bhardwaj K, Kuča K, Sharifi-Rad J, Verma R, Machado M, et al. Edible mushrooms' enrichment in food and feed: A mini review. International Journal of Food Science & Technology. 2022;57(3):1386-98. https://doi.org/epdf/10.1111/ijfs.15546
2. Ugbogu EA, Dike ED, Okoro BC, Adurosakin OE, Uche ME, Nosiri CI, et al. *Lentinus squarrosulus*: nutritional composition, phytochemistry, health-promoting activities and toxicity profile. Food and Humanity. 2024:100296. https://doi.org/10.1016/j.foohum.2024.100296
3. Lau BF, Abdullah N. Bioprospecting of *Lentinus squarrosulus* Mont., an underutilized wild edible mushroom, as a potential source of functional ingredients: a review. Trends in Food Science & Technology. 2017;61:116-31. https://doi.org/10.1016/j.tifs.2016.11.017
4. Narh Mensah DL, Obodai M. Morphological characteristics of mycelia growth of two strains of indigenous medicinal mushroom, *Lentinus squarrosulus* Mont. (Singer), on solid media. African Journal of Agricultural Research. 2014;9(23):1753-60.
5. Ugbogu EA, Akubugwo EI, Ude VC, Emmanuel O, Okomba NO, Ibe C, et al. Safety evaluation of an aqueous extract of *Termitomyces robustus* (Agaricomycetes) in wistar rats. Int J Med Mushrooms. 2019;21(2). https://doi.org/10.1615/IntJMedMushrooms.2018029737
6. Wal P, Dwivedi J, Kushwaha S, Yadav A, Singh SP, Hanumanthachar KJ. A comprehensive review on nutritional and medicinal properties of *Pleurotus ostreatus*: an oyster mushroom. Current Nutrition & Food Science. 2023;19(4):386-98.
7. Niveiro N, Popoff OF, Albertó EO. *Mycena holoporphyra* (Mycenaceae, Agaricomycetes), primer registro para la Argentina. Darwiniana, nueva serie. 2011;49(2):252-6.
8. Khatua S, Ghosh S, Acharya K. Chemical composition and biological activities of methanol extract from *Macrocybe lobayensis*. Journal of Applied Pharmaceutical Science. 2017;7(10):144-51. https://doi.org/10.7324/JAPS.2017.71021
9. Altaf U, Lalotra P, Sharma YP. Nutritional and mineral composition of four wild edible mushrooms from Jammu and Kashmir, India. Indian Phytopathology. 2020;73:313-20.
10. Thongbai B, Rapior S, Hyde KD, Wittstein K, Stadler M. *Hericium erinaceus*, an amazing medicinal mushroom. Mycological Progress. 2015;14:1-23. https://doi.org/10.1007/S11557-015-1105-4
11. Niego AG, Rapior S, Thongklang N, Raspé O, Jaidee W, Lumyong S, et al. Macrofungi as a nutraceutical source: Promising bioactive compounds and market value. Journal of Fungi. 2021;7(5):397. https://doi.org/10.3390/jof7050397
12. Abdelshafy AM, Belwal T, Liang Z, Wang L, Li D, Luo Z, et al. A comprehensive review on phenolic compounds from edible mushrooms: Occurrence, biological activity, application and future prospective. Critical Reviews in Food Science and Nutrition. 2022;62(22):6204-24 https://doi.org/10.1080/10408398.2021.1898335
13. Abdullah S, Abdullah N, Sabaratnam V, Yap KC. CUPRAC assay-guided profiling of antioxidant compounds in methanol extract of *Lentinus squarrosulus* Mont. mycelium. Acta agriculturae Slovenica. 2018;111(1):101-9.
14. Adeoye-Isijola MO, Olajuyigbe OO, Jonathan SG, Coopoosamy RM. Bioactive compounds in ethanol extract of *Lentinus squarrosulus* Mont-a Nigerian medicinal macrofungus. African Journal of Traditional, Complementary and Alternative Medicines. 2018;15(2):42-50.
15. Azzollini A, Boggia L, Boccard J, Sgorbini B, Lecoultre N, Allard P-M, et al. Dynamics of metabolite induction in fungal co-cultures by metabolomics at both volatile and non-volatile levels. Frontiers in Microbiology. 2018;9:72. https://doi.org/10.3389/fmicb.2018.00072
16. Pandiyan R, Ilango K. GC-MS analysis of bioactive compounds present in different extracts of an endemic tree *Huberantha senjiana* (Annonaceae) leaves. Research Journal of Pharmacy and Technology. 2023;16(4):1581-6. http://doi.org/10.52711/0974-360X.2023.00258
17. Hembrom ME, Parihar A, Das K. Three interesting wood rotting macro-fungi from Jharkhand, India. Journal of Threatened Taxa. 2016;8(2):8518-25.
18. Zaini NAM, Azizan NAZ, Abd Rahim MH, Jamaludin AA, Raposo A, Raseetha S, et al. A narrative action on the battle against hunger using mushroom, peanut and soybean-based wastes. Frontiers in Public Health. 2023;11. https://doi.org/10.3389/fpubh.2023.1175509
19. Muniyappan G, Gurudevan T, Thangaraj P, Balamurali AS, Iyadurai AP, Suppaiah R, et al. Benzothiazole - an antifungal compound derived from medicinal mushroom *Ganoderma lucidum* against mango anthracnose pathogen *Colletotrichum gloeosporioides* (Penz and (Sacc.)). Molecules. 2023;28(6):2476. https://doi.org/10.3390/molecules28062476
20. Gurudevan T, Seethapathy P. 285 *Trametes versicolor*. Edible and medicinalmushrooms of the Himalayas: CRC Press; 2024;285-99.
21. Chin KY, Shuid AN, Ibrahim SF. Nutraceuticals modulation for oxidative stress in disease and health. Frontiers Media SA. 2023;1199293. https://doi.org/10.3389/fphar.2023.1199293
22. Ugbogu EA, Akubugwo IE, Ude VC, Gilbert J, Ekeanyanwu B. Toxicological evaluation of phytochemical characterized aqueous extract of wild dried *Lentinus squarrosulus* (Mont.) mushroom in rats. Toxicol Res. 2019;35:181-90. https://doi.org/10.5487/tr.2019.35.2.181
23. Mhd Omar NA, Abdullah S, Abdullah N, Kuppusamy UR, Abdulla MA, Sabaratnam V. *Lentinus squarrosulus* (Mont.) mycelium enhanced antioxidant status in rat model. Drug Design, Development and Therapy. 2015:5957-64. https://doi.org/10.2147/DDDT.S90746
24. Das AK, Nanda PK, Dandapat P, Bandyopadhyay S, Gullón P, Sivaraman GK, et al. Edible mushrooms as functional ingredients for development of healthier and more sustainable muscle foods: A flexitarian approach. Molecules. 2021;26(9):2463.
25. Vega OM, Abkenari S, Tong Z, Tedman A, Huerta-Yepez S. Omega-3 polyunsaturated fatty acids and lung cancer: nutrition or pharmacology? Nutrition and Cancer. 2021;73(4):541-61. https://doi.org/10.1080/01635581.2020.1761408
26. Deckelbaum RJ, Torrejon C. The omega-3 fatty acid nutritional landscape: health benefits and sources. The Journal of Nutrition. 2012;142(3):587S-91S. https://doi.org/10.3945/jn.111.148080

27. Tavakkoli Kakhki M, Motavasselian M, Mosaddegh M, Esfahani MM, Kamalinejad M, Nematy M, et al. Omega-3 and omega-6 content of medicinal foods for depressed patients: implications from the Iranian traditional medicine. Avicenna Journal of Phytomedicine. 2014;4(4):225.

28. Bischoff Ferrari HA, Vellas B, Rizzoli R, Kressig RW, Da Silva JAP, Blauth M, et al. Effect of vitamin D supplementation, omega-3 fatty acid supplementation, or a strength-training exercise program on clinical outcomes in older adults: the DO-HEALTH randomized clinical trial. Jama. 2020;324(18):1855-68.

29. Alves JL, Figueira ASC, Lopes IL, Mendes PJ, Quinta-Ferreira RM, Quinta Ferreira ME. Effect of oleic acid on neuronal zinc signals. Waste and Biomass Valorization. 2021;12:3019–25.

30. Martinat M, Rossitto M, Di Miceli M, Layé S. Perinatal dietary polyunsaturated fatty acids in brain development, role in neurodevelopmental disorders. Nutrients. 2021;13(4):1185. https://doi.org/10.3390/nu13041185

31. Zhang X, Ritonja JA, Zhou N, Chen BE, Li X. Omega-3 polyunsaturated fatty acids intake and blood pressure: a dose-response meta-analysis of randomized controlled trials. Journal of the American Heart Association. 2022;11(11):e025071. https://doi.org/10.1161/JAHA.121.025071

32. Bogdanov VP, Semivrazhskaya OO, Belov NM, Troyanov SI, Markov VY, Ioffe IN, et al. Stepwise regioselective hydrogenation of cis-2-C60 (CF2) 2 Homofullerene with [6, 6]-open/closed valence tautomerism. Chemistry-A European Journal. 2016;22(43):15485-90. https://doi.org/10.1002/chem.201602351