JMBFS

Journal of Microbiology, Biotechnology and Food Sciences

International peer-reviewed scientific online journal

Published by Faculty of Biotechnology and Food Sciences

ASPECTS OF MUSHROOMS AND THEIR EXTRACTS AS NATURAL ANTIMICROBIAL AGENTS

Arzoo Agarwal[1], Varsha Gupta[1], Ajar Nath Yadav[2], Devki[1], Ravi Kant Rahi[1], Sweta Parimita Bera[3] and Deepesh K Neelam[1]*

Address(es):
[1]Department of Microbiology, JECRC University, Jaipur, Rajasthan, India 303905.
[2]Department of Biotechnology, Dr. Khem Singh Gill Akal College of Agriculture, Eternal. University, Baru Sahib, Sirmour, Himachal Pradesh, India 173101.
[3]Department of Microbiology, P P Savani University, Surat, Gujarat, India 394125.

*Corresponding author: deepesh40neelam@gmail.com; deepesh.neelam@jecrcu.edu.in

https://doi.org/10.55251/jmbfs.9191

ARTICLE INFO

Received 12. 7. 2022
Revised 27. 3. 2023
Accepted 17. 4. 2023
Published 1. 6. 2023

Regular article

OPEN ACCESS

ABSTRACT

Nowadays, multidrug antimicrobial resistance is a very common issue globally. Antimicrobial resistance is fueling the fire, and it has been noted that infectious disease incidence and deaths are rising throughout the world. Many pathogens have been reported to develop resistance to these synthetic and semi-synthetic drugs leading to minimized efficacy and resulting in substantial economic losses all over the world. A new approach for choosing natural extracts of plants and fungi as medicines and natural antibacterial agents has been developed to address this challenge. According to recent investigations and research, mushrooms and their extracts contain bioactive compounds that can be used as a natural antibacterial alternative against a number of bacterial species. In addition to having medical properties like antibacterial, anticancer, and antioxidant activity, mushrooms are a highly nutritious food source. The present study emphasized on the antimicrobial resistance, mechanisms and antibacterial properties of mushrooms.

Keywords: Antimicrobial resistance, Mushroom diversity, Natural extract, Medical application

INTRODUCTION

Antimicrobial resistance (AMR) is a natural biological phenomenon that occurs when microbes respond to an antimicrobial drug's selective pressure, for example production of beta-lactamases by the bacteria is the most important mechanism associated with beta-lactam antibiotic resistance (**Barker, 1999; Sharma *et al.*, 2005; Smith and Cost, 2002**). Antimicrobial resistance indicates that organisms can defend themselves against bacteria, fungi, and other microbes. Toxins are secreted by microbes that kill the organisms they attack. Antibiotics are effective against these toxins (**Smith and Cost, 2002)**. The misuse of natural antimicrobial resistance, such as the ongoing use of it for subpar medications, hinders it. This results in the creation of medications with weak disease-prevention capabilities (**Kumar *et al.*, 2013**). Infectious diseases related to antimicrobial resistance are measured as a parameter to represent vital public health problems. Antibiotics can be resisted by bacteria in two ways: by preventing higher concentration of the antibiotics to reach their target; or by altering the target on which the antibiotics work (**Martinez and Baquero, 2014**). Several bacterial enzymes that can inactivate the activity of antibiotics are another method of resistance. Beta-lactamase destroys the beta-lactam ring component of a synthetic antibiotic like penicillin (**Tanwar *et al.*, 2014**). In order to pump out the antibiotics, bacteria attach an efflux pump to their cell membrane. This pump then expels the antibiotics from the body. When the DNA of bacteria is altered, more pumps are created. The growing burden of AMR around the world has yet to be adequately addressed (**Acar and Rostel, 2001**). The occurrence of antibiotic resistance presence is linked to microorganisms or humans. Antibiotic resistance refers to specific features of bacterial evolution that humans cannot normally stop, such as bacterial mutation, which is one of the defining determinants of resistance. Even before the emergence of antibiotic resistance in microbes, there was substantial interest in research studies of natural products for the medicinal treatment of disorders caused by these organisms (**Harbarth *et al.*, 2015**). Mushrooms have long been recognised as useful foods and as a source for medical and nutraceuticals development such as *Laetiporus sulphureus*, *Ganoderma lucidum* and *Lentinus edodes*, are sources of natural antibiotics that have already shown antibacterial activity (**Gao *et al.*, 2015; Turkoglu *et al.*, 2007; Garcia *et al.*, 2021**). Humans' widespread usage of antimicrobials provides opportunities for bacteria to develop massive antimicrobial resistance responses. If we do not find a solution to the current AMR scenario, it will most likely endure for a long time (**Michael *et al.*, 2014**).

MUSHROOM AS AN ANTIMICROBIAL AGENT

Mushrooms are enormous eatable fruiting bodies with stalks and caps that are part of macrofungi. These mushrooms are large because to their multi-colored appearance, delicious flavours, and fragrances, as well as a nutritional and therapeutic value comparable to high protein content, fat-rich carbs, and vitamin D, as well as their ability to function as medications (**Hafdani and Sadeghinia, 2011**). Mushrooms tend to naturally produce specific chemicals in various conditions as self mechanism. These chemicals have many health benefits and when exploited more gave immense utilities in developing therapeutic drugs **(Valverde *et al.*, 2015)**. They produce a range of carbohydrates, proteins, adipose acids, phenolic groups, and indole acids. Vitamins like vitamin B7, vitamin B6, vitamin C and vitamin E are few of the examples for the same. The protein that mushrooms make is a kind of macromolecules called biopolymers that include amino acids. They help in the making of bio-molecules that help as building blocks for many different activities. Many researchers in their recent research have found micro-fungi capable of producing higher protein and their nutritional analysis conferred them to be better than the regular plant based protein. Lectin is one of the well known fungal proteins it is known to inactivate the laccase enzyme and caused immunomodulatory affects **(Valverde *et al.*, 2015)**.

The lipids produced by the mushroom have immense solubility effect and thus are utilized as organic cleansers. The adipose acids sterols and phospholipids generated by the mushrooms help in growth and reproductive mechanisms. They have extended hydrocarbon chains with methyl group at one end and a carboxyl on the other. Overall they have good characteristic application in the health welfare and biological applications. In recent years natural antimicrobials, such as plants and fungi, have sparked renewed interest in their various properties, including antimicrobial activity, due to their non-harmful impact and effectiveness against microbes. In fact, in the case of antimicrobial resistance, mushrooms are an immense substitute representative which shows potential effects against microbes shown in Tab 1 (**Lindequist *et al.*, 2005**). Edible and wild mushrooms have a high level of natural bioactive potential, facilitating medical and health benefits. The antibacterial activity of various mushroom bioactive resources has been discovered through research. As a result, the use of various types of mushrooms and their extracts containing bio metabolites can help in for various medical causes. There were few evidences in which it was noticed that the extracts produced by the mushrooms have both bacteriostatic in addition to bactericidal effect on microorganisms (**Sitati *et al.*, 2021; Gebreyohannes *et al.*, 2019**).

Every year nearly four million people are affected due to such infections in Europe alone. This in turn results in raise in the mortality rate (**Barros *et al.*, 2008**) Apart

from this, the antimicrobial medicines were already used in precautionary purposes for various serious illness related treatment. The growth in the new antimicrobial substances has resulted in pathogenic resistant to conventional treatments, figure 1.

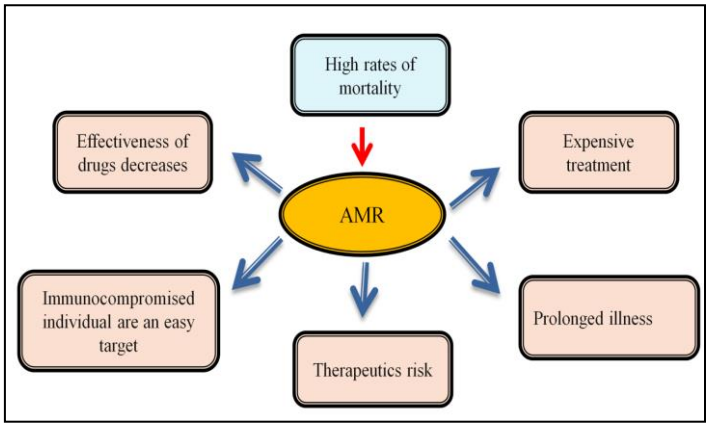

Figure 1 Various problems related to antimicrobial resistance

Table1 Antimicrobial action of bioactive compounds of different mushrooms against various microorganisms

S. No.	*Name of mushroom*	*Antimicrobial activity*	*Bioactive compounds*	*Extract type*	*Reference*
1	*Agaricus bisporus*	*Staphylococcus aureus, Escherichia coli, Pseudomonas* sp. *and Bacillus* sp.	Beta-glucans, ergosterol, ergothioneine and vitamin D	Methanol	**(Atilla at al., 2019; Narasimaha *et al.*, 2011; Blumfield *et al.*, 2020; Karnwa *et al.*, 2020)**
2	*Ganoderma lucidum*	*Staphylococcus aureus, Escherichia coli, Bacillus subtilis, Salmonella, Klebsiella typhimurium, Klebsiella pneumoniae, Escherichia coli and Salmonella typhi*	Terpenes, Flavonoids	Methanol, ethanol, acetone	**(Siwulski *et al.*, 2015; Quereshi *et al.*, 2010; Kmra and Bhatt, 2012)**
3	*Ganoderma pfeifferi*	*Bacillus subtilis, Staphylococcus aureus and Escherichia coli*	Farnesyl hydroquinones and Triterpenoids	Methanol, chloroform, ethyl acetate	**(Tamilselvan and Rajesh, 2019; Lindequist, 2015; Robles-Hernández *et al.*, 2021)**
4	*Pleurotus ostreatus*	*Bacillus subtilis* and *Escherichia coli*	β-D-Glucan	Ethyl acetate	(**Deepalkshmi and Mirunalini, 2014; Cohan *et al.*, 2002; Kaisun *et al.*, 2022**)
5	*P. sajor-caju*	*Salmonella typhi* and *Staphylococcus aureus*	*p*-Hydroxybenzoic, *p*-coumaric and cinnamic acids	Methanol	**(Han *et al.*, 2015; Cohan *et al.*, 2002; Kandasamy *et al.*, 2020)**
6	*Schizophyllum commune*	*Bacillus cereus, Bacillus subtilis, Enterococcus faecalis, Staphylococcus aureus, Plesiomonas shigelloides, Pseudomonas aeruginosa, Proteous vulgaris* and *Salmonella* sp.	Hydroxybenzoic acid, protocatechuic acid and tocopherol	Methanol	**(Mayakrishna et al., 2013; Mohd Rashidi and Yang, 2016; Kandasamy *et al.*, 2020)**
7	*Tremetes versicolor*	*Staphylococcus aureus, Bacillus* sp., *Salmonella enteritidis* and *P. Aeruginosa*	Polyphenols	Methanol	**(Hobbes, 2005; Alves *et al.*, 2012; Mirfat *et al.*, 2014)**
8	*Auricularia auricular*	*Staphylococcus aureus, Escherichia coli, Bacillus cereus* and *Pseudomonas aeruginosa*	Tannins, steroids/triterpenoids	Methanol, ethyl acetate , hexane	(**Puia *et al.*, 2018; Matijasevic *et al.*, 2016; Cai *et al.*, 2015; Sukmawati *et al.*, 2019**)
9	*Volvariella volvacea*	*Escherichia coli, Staphylococcus aureus, Klebsiella pneumoniae, Pseudomonas aeruginosa* and *Streptococcus pyogenes*	Homoglucans	Acetone and methanol	(**Gebreyohalles *et al.*, 2019; Ziaf *et al.*, 2016; Perera *et al.*, 2001; Kumar, 2022**)
10	*Stereum ostrea*	*Micrococcus* sp., *Pseudomonas aeruginosa, Klebsiella* sp.	Sesquiterpenoids, Illudalane, Norilludalane , Polyketides and Benzofuran	Ethanol	(**Sukmawati *et al.*, 2019; Tian *et al.*, 2020; Imtiaj *et al.*, 2007**)
11	*Calocybe indica*	*Staphylococcus aureus, Streptococcus pyrogenes* and *Pseudomonas aeruginosa*	Biochanin-A, caffeic acid, chlorogenic acid, ferulic acid, formononetin, gallic acid, hesperetin, homogentisic acid, naringenin, naringin,	Ethanol, acetone, methanol, ether	**(Roy *et al.*, 2014; Perera *et al.*, 2001; Shashikant *et al.*, 2022; Alam *et al.*, 2019)**

			protocatechuic acid, resveratrol and vanillin		
12	*Pleurotus eryngii*	*Escherichia coli, Bacillus subtilis, Trichophyton metagrophyte and Fusarium oxysporum oxysoporum, Klebsiella pneumoniae, Staphylococcus aureus* and *Micrococcus luteus*	Chitosan nanoparticles	Ethanol and acetone	(**Appiah *et al.*, 2017; Prust *et al.*, 2014; Vijaykumar *et al.*, 2014; Yu *et al.*, 2018**)
13	*Lactarius deliciosus and L.piperatus*	*Escherichia coli* and *Klebsiella pneumoniae*	Flavonoids, Ascorbic acid, B-carotene and Lycopene	Methanol	**Vijaykumar *et al.*, 2014; Roy and Prasad, 2014; Stanković *et al.*, 2022)**
14	*Cordyceps sinensis*	*Escherichia coli, Pseudomonas aeruginosa, Bacillus subtilis, Staphylococcus aureus* and *Salmonella typhi*	Chalcones, Flavonol, Flavanone, Flavone, Anthocyanins and Isoflavanoids	Aqueous	**(Roy and Prasad, 2014; Stajic *et al.*, 2009; Adanacioglu *et al.*, 2017)**
15	*Cantharellus cibarius*	*Staphylococcus aureus, Enterococcus faecalis, Bacillus cereus, Listeria monocytogenes, Helicobactor pylori* and *Staphylococcus aureus*	Pleuromutilin and Chanterellins	Ethyl acetate, acetone, chloroform and ethanol extracts	(**Samsudin *et al.*, 2020; Akyuz and Kirbag, 2009; kozarski *et al.*, 2017; Vlasenko *et al.*, 2019)**
16	*Lepista nuda*	*Micrococcus luteus, Mariniluteicoccus flavus, Staphylococcus aureus, Bacillus cereus, Salmonella enteritidis, Bacillus subtilis, Escherichia coli, Pseudomonas aeruginosa* and *Staphylococcus aureus*	Behenic acid, tricosanoic acid, lignoceric acid and nervonic acid	Ethanol	(**Barros Vlasenko *et al.*, 2007; Chen *et al.*, 2013; Mercan *et al.*, 2006; Pinto *et al.*, 2013)**
17	*Laetiporus sulphureus*	*B. subtilis, B. cereus, M. luteus, M. flavus* and *L. Monocytogenes*	Beauvericin, Masutakeside I, Masutakic acid, Egonol, ±)-Laetirobin, 3-oxosulphurenic acid and Eburicoic acid	Methanol	**(Zheng *et al.*, 2006; Agrawal and Sandhu, 2020; Sułkowska-Ziaja *et al.*, 2018; Petrović *et al.*, 2014)**

ANTIBACTERIAL ACTIVITY OF BIOMETABOLITES FROM MUSHROOM EXTRACTS

Mushrooms coming from the basidiomycete's family have multitudinous varieties of mushroom species. They have different varieties of metabolites with nutraceutical and curative implication. The therapeutic and nutritional properties of mushrooms are being studied all over the world. Experimenters were providing crucial data on bioactive composites in it (**Anusiya et al., 2021**). Boletes are the tube-bearing or poroid components, while lamellate members are referred to as "mushrooms" or "toadstool" depending on whether they are edible or toxic (**Barros *et al.*, 2012**). Consumable mushrooms are also obtained from nature or produced and harvested under strict quality control standards for size, shape, tenderness, and delectability. Secondary metabolites are created primarily after active growth, and many of them have peculiar chemical structures. Intervenes in the conflation of cell elements such as amino acids and nucleotides, as well as the product of lipids, vitamins, and polysaccharides, are also of enormous beneficial relevance in today's assiduity. Secondary metabolites, such as therapeutic proteins and peptides, are a significant source of antimicrobial bioactive components produced by various mushroom species (**Sharma *et al.*, 2014**).

Agaricus bisporus, also known as white button mushroom, is an edible mushroom that is widely cultured in India, Europe, and North America and its surface consists of a stalk white or brownish cap and dark brown gills (**Dhamodharan and Mirunalini, 2010**). Stripes and total protein extract from *A. bisporus*, as well as silver nanoparticles (AgNPs), a biosynthetic product of white button mushroom, were found to have antibacterial action against *S. Aureus* (**Atila *et al.*, 2019**). They produce silver nanoparticles when incorporated with pathogen as an effect of antibacterial activity with both gram bacteria like *E. coli*, *Staphylococcus* sp., *Pseudomonas* sp. and *Bacillus* sp. (**Narasimha *et al.*, 2011**). Ethanol and a cold-water extract from *A. bisporus* effectively suppressed the growth of two bacterial species, *E. coli* and *S. aureus* (**Usman *et al.*, 2021**).

Ganoderma lucidum, also known as Reishi, is a medicinal mushroom that grows on both alive and deceased wood of deciduous trees and this mushroom produces fruiting bodies with red, shiny, and reddish-brown caps (**Siwulski *et al.*, 2015**). Antibacterial property of *G. lucidum* mushroom methanol extract consists of terpenes and flavonoids bioactive compounds gives significant response against human pathogenic bacteria including *S. aureus, E. coli, B. subtilis* and S. *Typhimurium* (**Kamra and Bhatt, 2012**). Antibacterial activity of acetone extract of similar mushroom gives a noticeable response against *K. pneumoniae*, *E. coli* and *S. Typhi* (**Qureshi *et al.*, 2010**). *G. lucidum* ethanol extract has a considerable antibacterial effect, especially against S. aureus and *P. Aeruginosa* (**Tamilselvan and Rajesh, 2019**).

Ganoderma pfeifferi another species revealed that it consists of bioactive compounds called farnesyl hydroquinones named ganomycins and triterpenoids having antibacterial properties mainly against gram-positive bacteria (**Lendequist *et al.*, 2015**). The volatile oil of *G. pfeifferi* was tested for antimicrobial activity and it expresses the highest antibacterial activity against *B. subtilis*, *S. aureus* and *E. coli* (**Al-Fatimi *et al.*, 2016**). *Pleurotus ostreatus* (oyster mushroom) primarily grown in tropical and subtropical climates. *It has a broad, fan form and is white, grey, or dark brown in colour* (**Deepalakshmi and Mirunalini, 2014**). Oyster mushrooms consist of two extracts, mainly petroleum ether and ethanol, which are evidenced for antibacterial properties against gram positive and gram-negative bacteria (**Pauliic and Dorica, 2013**). Acetone and Ethyl acetate extracts of the oyster mushroom illustrated the antibacterial activity against *B. subtilis* and *E. coli* (**Han *et al.*, 2015**). Oyster mushrooms consist mainly β-D-Glucan as a secondary metabolite which have antibacterial activity (**Cohen *et al.*, 2002**). Antimicrobial activity of *P. ostreatus* extracts against *P. aeruginosa* and *S. aureus* (**Perez *et al.*, 2020**).

P. sajor-caju is also known as grey oyster mushroom due to its resemblance to an oyster shell which is mainly harvesting in tropical and subtropical regions (**MohdRashidi and Yang, 2016**). *P.sajor-caju* mushroom consist of methanolic extract which inhibits microbial growth and holds antibacterial activity against *S. typhi* strain (**Kandasamy *et al.*, 2020**). The antibacterial activity of *P. sajor-caju* methanolic extract and most potent inhibitory activity were observed against *S. aureus.* The lowest inhibitory activity was found against *B. Cereus* (**Gogavekr *et al.*, 2014**).

Schizophyllum commune, also known as "split fold," is a medicinal mushroom. This mushroom's habitat is primarily in light, sunny, dry areas of the forest, with a texture that is small, thin, flexible, whitish in colour and grown in layers that overlap on each other (**Hobbs, 2005**). *S. commune* mushroom having four bioactive compounds consisting antimicrobial activity namely methanol, dichloromethane, ethyl acetate and water against *B. cereus, B. subtilis, E. faecalis, S. aureus, P. shigelloides, P. aeruginosa, P. vulgaris, Salmonella* sp. (**Alves *et al.*, 2012**). The dichloromethane extract of *S. commune is used* as an antibacterial agent and inhibit the activity of *S. sanguis* bacteria (**Mirfat *et al.*, 2014**).

Trametes versicolor, also known as *Coriolus versicolor* or turkey tail, is another type of medicinal mushroom. White rot fungi that can be found on a variety of trees such as prunus and oak, as well as conifers such as fin of pine trees (**Puia *et al.*, 2018**). Bacterial species, mainly *S. aureus* was inhibited by *Coriolus versicolor* extracts in methanol, ethyl acetate, dichloromethane, and acetone whereas *Bacillus* sp., *S. enteritidis* and *P. aeruginosa* were sensitive to methanol extract and acetone extract, respectively due to the presence of high concentration of polyphenols (**Matijasevic *et al.*, 2016**). It also showed highest antibacterial activity against *S. aureus, P. aeruginosa, B. subtilis*, and *E. coli* (**Pranitha *et al.*,

2014). The inhibitory antimicrobial activities of hot water extract of *Trametes* spp., chloroform and ethanol (70%) were observed against *S. aureus and P. aeruginosa* (**Gebreyohannes *et al.*, 2019**).

Auricularia auricula, also recognised as the jelly mushroom, is an edible mushroom that grows primarily on wood logs, dead trees, and the roots of woody plants. Its fruiting body is divided into two sections: the upper sterile portion and the lower fertile portion (**Ziaf *et al.*, 2016**). *A. auricula* ethyl acetate extracts having antibacterial properties against *S. aureus* (**Cai *et al.*, 2015**). *A. auricula* concentrated extract contains alkaloids (ethanol), tannins, and steroids/triterpenoids, which were active compounds with antimicrobial activity against *S. aureus*, *E. coli*, *B. cereus* and *P. aeruginosa* by altering the properties of the targeted bacteria's cell walls and destroys the cytoplasmic membrane (**Sukmawati *et al.*, 2019**). Sometime some extracts, such as chloroform and ethanol extracts of *Auricularia*, have lower antimicrobial activity and there are a few reasons behind this, first is the lack of bioactive compounds in the extracts, second is the destruction of functionality due to variances in the amount and last one is the type of active compounds present in the extracts (**Vallavan *et al.*, 2020**).

Volvariella volvacea is an edible mushroom commonly known as paddy straw because of its texture, which includes pink-coloured spores, free lamellae, and a velvet base (**Roy *et al.*, 2014**). *V. volvacea* which is a basidiomycete fungi used for research and studied antimicrobial screening against *E. coli* (**Perara *et al.*, 2001**). Secondary metabolite of *V. volvacea* consist of Homoglucans which have pharmaceutical importance (**Mandal, 2019**). *V. volvacea* methanol extracts were found to have antibacterial action against *S. aureus, K. pneumoniae, P. aeruginosa*, and *S. pyogenes* (**Appiah *et al.*, 2017**).

Stereum ostrea, also known as "false turkey tail," grows densely on dead hardwood wood, forming a shape resembling a fuzzy cup with different colour zones such as brown, red, and orange (**Prust *et al.*, 2014**). Mushroom *S. osterus* has two components: methanol extract and crude cultural filtrate. Methanol extracts have a strong inhibitory effect on *Micrococcus* sp. and crude cultural filtrate has the highest antimicrobial activity against *B. subtilis*, followed by *Micrococcus* sp., *P. aeruginosa*, and *Klebsiella* sp. (**Praveen *et al.*, 2012**).

Calocybe indica, also known as milky white mushroom or "Dhuth chatta," is a tropical edible mushroom native to India that is found in West Bengal and eastern India. It has a high nutritional value and high-quality protein (**Vijaykumar *et al.*, 2014**). Petroleum ether extract of *C. indica*, illustrated the antimicrobial action against *S. aureus*, *S. pyrogenes* and *P. aeruginosa* (**Padmavathy *et al.*, 2014**). The methanolic extract of *C. indica* gave significant response against *P. aeruginosa* (**Roy and Prasad, 2014**).

Pleurotus eryngii also known as the king oyster mushroom is a nutritional and medicinal mushroom that is widely distributed and used in North Africa, Europe, and Asia (**Stazic *et al.*, 2009**). In the another study, chitosan nanoparticles of *P. eryngii's* extract given antimicrobial inhibition for E. *coli* and *B. subtilis*. Turmeric chitosan nanoparticles have antimicrobial activity against *T. mentagrophyte* and *F. oxysporum* (**Acay *et al.*, 2020**). *P. eryngii* ethyl acetate and chloroform extract was found to be effective against *B. megaterium*, *K. pneumoniae*, *S. aureus* and *M. luteus* (**Samsudin *et al.*, 2020**). Pleurotus eryngii was predicted to have high polysaccharide content and antibacterial capabilities to prevent *E. coli* bacteria from growing (**Akyuz and Kirbag, 2009**).

Lactarius species are also known as saffron milk cap mushrooms because they have a good texture, delicious taste, and aromas. (**Adanacioglu *et al.*, 2017**). *L. deliciosus* and *L. piperatus* are two edibles wild *Lactarius* species found in Portugal. These two mushroom species contain different bioactive compounds such as flavonoids, phenol, ascorbic acid, B-carotene and lycopene. *E. coli* activity was inhibited by *L. piperatus* and the antimicrobial activity of *L. deliciosus* against *K. pneumoniae* was determined (**Barros *et al.*, 2007**).

Cordyceps sinensis is a traditional Chinese medicinal mushroom with potent pharmaceutical properties (**Chant *et al.*, 2013**). *C. sinensis* mushroom contains various polyyphenolic flavonoids components with six subgroups (chalcones, flavonol, flavanone, flavone, anthocyanins, and isoflavanoids). Moreover, these components showed antimicrobial activity against *E. coli*, *P. aeruginosa*, and *B. Subtilis* (**Mehrotra *et al.*, 2015**). An antibacterial protein from *C. sinensis*, was isolated from cultured mycelia of *C. sinensis* (CSAP), had potent antibacterial activity against *S. aureus*, *S. typhi* and *E. coli* (**Zheng *et al.*, 2006**). *B. subtilis*, *E. coli*, *S. typhi*, *S. aureus*, *V. cholerae, and K. pnuemoniae* were all examined and *C. sinensis* butanolic extract had the highest zone of inhibition against all of them (**Agrawal and Sandhu, 2020**).

Cantharellus cibarius, which is mostly cultivated in Europe, is a fruiting mushroom with an apricot-like aroma and a great texture (**Valentao *et al.*, 2005**). *C. cibarius* antimicrobial activity shown in their methanol extract, which were primarily effective against *S. aureus*, *E. faecalis*, *B. cereus* and *L. monocytogenes* (**Kozarski *et al.*, 2015**). Two metabolites of *C. cibarius* such as pleuromutilin and chanterellins hold antimicrobial property (**Salihovic *et al.*, 2019**). Other extract of *C. cibarius* consists of dichloromethane, cyclohexane and methanol which give significant response against *S. aureus* and *H. pylori* respectively (**Kolundzic *et al.*, 2017**).

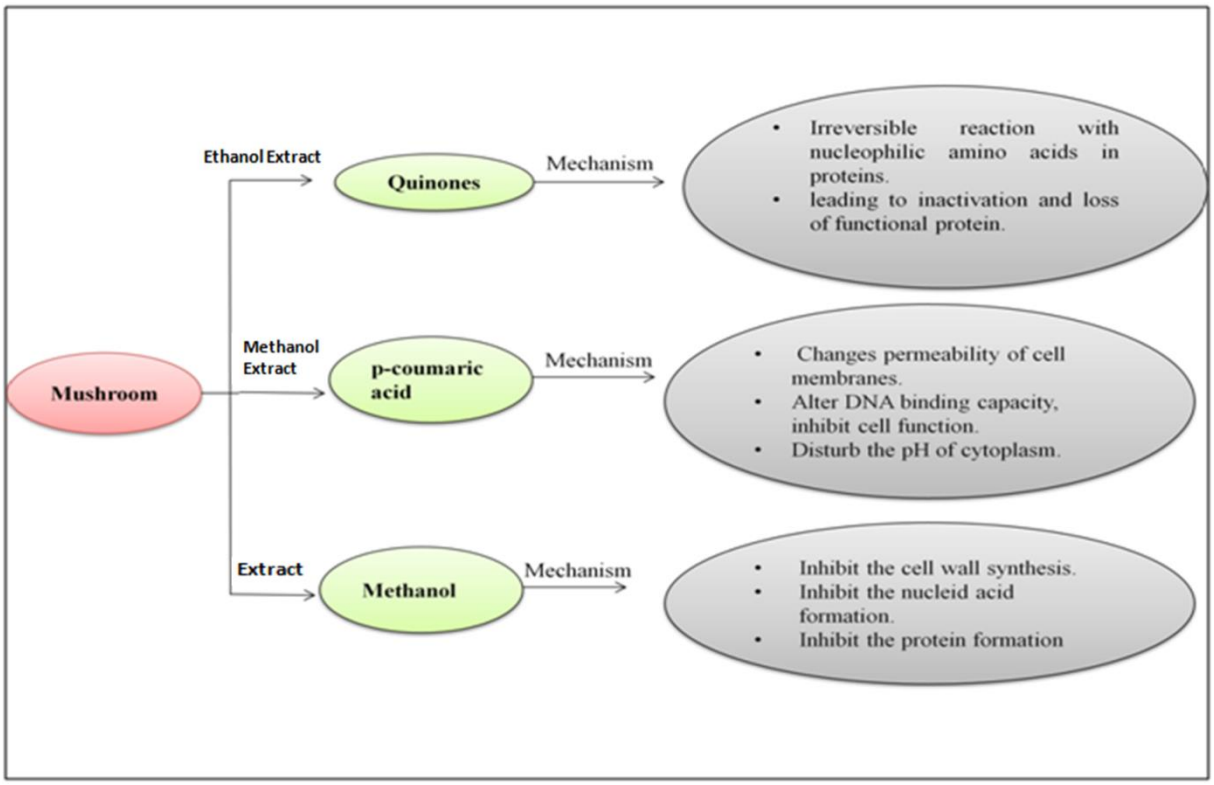

Figure 2 Antimicrobial mechanism of mushroom extracts

Lepista nuda is an edible woodland mushroom that is primarily cultivated in Asia, Africa, America, Australia and Europe. It has an iilac-colored texture, a strong aroma, and delicate flavours with pharmacological properties (**Hsu *et al.*, 2015**). The antimicrobial activity of *L. nuda* was determined by ethanol extract which inhibited the activity of *M. luteus*, *M. flavus*, *S. aureus*, *B. cereus* and *S. enteritidis* (**Marcan *et al.*, 2006**). *B. subtilis*, *E. coli*, *P. aeruginosa* and *S. aureus* were also found to be susceptible to *L. nuda* methanolic extract (**Dulger *et al.*, 2002**).

Laetiporus sulphureus appeared as a sulphur yellow with bright pores and is locally known as the "Chicken of the woods". It has high nutritional value along with the beneficial medicinal effects (**Khatua *et al.*, 2017**). Antimicrobial properties of *L. sulphureus* were determined by ethyl alcohol extract which showed significant response against *B. subtilis*, *B. cereus* and *M. luteus* (**Turkoglu *et al.*, 2007**). *M. flavus* and *L. monocytogenes* were strongly suppressed by the

antibacterial action of *L. sulphureus* aqueous extract (**Siljegovic *et al.*, 2011**).

MODE OF ACTION AGAINST BACTERIA BY MUSHROOM EXTRACT

Organic compounds produced from methanol and ethanol extracts of mushroom *Coriolus versicolor* are being studied for their effect and activity against gram positive and negative bacteria, figure 2. The hydroxyl group in phenol and phenolic acid determines their toxicity to microorganisms. Quinones are another bioactive molecule that reacts irreversibly with nucleophilic amino acids in proteins, resulting in protein inactivation and loss of function (**Matijasevic *et al.*, 2016**). Other chemicals, such as p-coumaric acid, are effective against gram-negative bacteria such as *S. typhimurium*, *S. dysenteriae*, and *E. coli*. These acids affect cell membrane permeability, DNA binding capacity, and cell function by slowing or inhibiting it (**Alves *et al.*, 2013**). Natural extract antimicrobials change the pH of the cytoplasm and have the capacity to damage microbe membranes through their processes (**Gonelimali et al., 2018**). Moreover, mushroom extracts (organic compounds) with the antimicrobial activity genrally involves in interaction with bacterial cell wall polypeptides, membrane-bound enzymes and surface-exposed adhesins to kill the bacteria (**Matijasevic *et al.*, 2016).**

CONCLUSIONS

Antimicrobial resistance has exploded into a major public health issue with economic and social level. The issue of switching resistance patterns will continue to pose a threat to both developed and developing countries and it will cause a tremendous deal of disruption in the healthcare industry, making it harder to cure infections. In this time of widespread threat, natural antimicrobial agents like plants and fungi seem to be a significant advantage. As a result, mushrooms have a significant antibacterial activity. Earlier studies showed that various kinds of mushrooms such as edible mushrooms, wild mushrooms, and therapeutic mushrooms showing the antimicrobial activity in different solvent extracts such as in methanol, ethanol, acetone, n-hexane, diethyl ether, water, chloroform and phenol, as well as also contains bioactive compounds i.e., ascorbic acid, phenolic compounds, flavonoids, flavonol, organic acids and sterols. These extracts have either a significant activity or a mild inhibition zone in bacterial cells. Some Gram-positive bacteria are more susceptible to these natural antibacterial mushroom extracts than gram negative bacteria, according to research. These extract activities revealed potential modifications in bacteria resistance mechanisms in two ways: they deliberate the function, and fully break down their resistance mechanism. These novel antimicrobial drugs are significant since they are widely available, inexpensive and nearly without adverse effects. Natural antimicrobials are more effective than manufactured antibiotics, according to a study (**Quinto *et al.*, 2019)**. More research and exploration of the numerous mushroom bioactive components as antibacterial agents is required. To substantiate pre-clinical and clinical information based on relevant data and to advance the assessment of mushrooms' therapeutic benefits, new studies are required. This research paper focused to connect the medicinal and antibacterial capabilities of mushroom extract, indicating that it will revolutionize the medical field which is particularly economically advantageous in underdeveloped nations.

Acknowledgements: All listed author(s) are thankful to Department of Microbiology, JECRC University, Department of Biotechnology, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University and P P Savani University for providing the related support to compile this work.

REFERENCES

Acar, J., Rostel, B. (2001). Antimicrobial resistance: an overview. *Revue scientifique et technique*, 20, (3):797-810. https://doi.org/10.20506/rst.20.3.1309

Acay, H., Yildirim, A., ErdemGüzel, E., Kaya, N., Baran, MF. (2020). Evaluation and characterization of *Pleurotus eryngii* extract-loaded chitosan nanoparticles as antimicrobial agents against some human pathogens. *Preparative Biochemistry and Biotechnology*, 50(9): 897-906. https://doi.org/10.1080/10826068.2020.1765376

Adanacioglu, N., TaN, A., Karabak, S., Guzelsoy, N., Firat, AYAS., Aykas, L., Taylan T. (2017). Economically Important Wild Mushroom Saffron Milk Cap [*Lactarius deliciosus* (L.) Gray] of Aegean Region turkey. *Anadolu Ege Tarımsal Araştırma Enstitüsü Dergisi*, 27(2): 91-96.

Agrawal, DG., Sandhu, SS. (2020). Antibacterial and fibrinolytic potential of Himalayan soft gold mushroom *Cordyceps sinensis*. *Indian journal of biotechnology*, 19: 38-44.

Akyuz, M., Kirbag, S. (2009). Antimicrobial activity of *Pleurotus eryngii* var. ferulae grown on various agro-wastes. *EurAsian Journal of BioSciences*, 3(1): 58-63. https://doi.org/10.5053/ejobios.2009.3.0.8

Alam, N., Sikder, M.M., Karim, M.A., Amin, S.M.R. (2019). Antioxidant and antityrosinase activities of milky white mushroom. *Bangladesh Journal of Botany*. 48(4): 1065-1073. https://doi.org/10.3329/bjb.v48i4.49054

Al-Fatimi, M., Wurster, M., Lindequist, U. (2016). Chemical composition, antimicrobial and antioxidant activities of the volatile oil of *Ganoderma pfeifferi*. Bres Medicines 3(2): 10. https://doi.org/10.3390/medicines3020010

Alves, MJ., Ferreira, IC., Dias, J., Teixeira, V., Martins, A., Pintado, M. (2012). A review on antimicrobial activity of mushroom (Basidiomycetes) extracts and isolated compounds. *Planta Medica*, 78:1707-1718. https://doi.org/10.1055/s-0032-1315370

Alves, MJ., Ferreira, ICFR., Froufe, HJC. (2013). Antimicrobial activity of phenolic compounds identified in wild mushrooms, SAR analysis and docking studies. *Journal of Applied Microbiology*. 115(2): 346-357. https://doi.org/10.1111/jam.12196

Anusiya, G., Gowthama Prabu, U., Yamini, N.V., Sivarajasekar, N., Rambabu, K., Bharath, G., Banat, F. (2021). A review of the therapeutic and biological effects of edible and wild mushrooms. *Bioengineered*. 12(2): 11239-11268. https://doi.org/10.1080/21655979.2021.2001183

Appiah, T., Boakye, YD., Agyare, C. (2017). Antimicrobial activities and time-kill kinetics of extracts of selected Ghanaian mushrooms. *Evidence-Based Complementary and Alternative Medicine*. https://doi.org/10.1155/2017/4534350

Atila, F., Owaid, MN., Shariati, MA. (2019). The nutritional and medical benefits of *Agaricus bisporus*: a review. *Journal of Microbiology, Biotechnology and Food Sciences*, 7(3):281-286. https://doi.org/10.15414/jmbfs.2017/18.7.3.281-286

Barker, K.F. (1999). Antibiotic resistance: a current perspective. *British Journal of Clinical Pharmacology*. 48: 109-124.

Barros, L., Baptista, P., Estevinho, LM., Ferreira, IC. (2007). Effect of fruiting body maturity stage on chemical composition and antimicrobial activity of Lactarius sp. Mushrooms. *Journal of Agricultural and Food Chemistry*, 55(21): 8766-8771. https://doi.org/10.1021/jf071435

Barros, L., Cruz, T., Baptista, P., Estevinho, LM., Ferreira, IC. (2008). Wild and commercial mushrooms as source of nutrients and nutraceuticals. *Food and Chemical Toxicology*, 46(8):2742-2747. https://doi.org/10.1016/j.fct.2008.04.030

Blumfield, M., Abbott, K., Duve, E., Cassettari, T., Marshall, S., Fayet-Moore, F. (2020). Examining the health effects and bioactive components in *Agaricus bisporus* mushrooms: A scoping review. *The Journal of Nutritional Biochemistry*. 84: 1-17. https://doi.org/10.1016/j.jnutbio.2020.108453

Cai, M., Lin, Y., Luo, YL., Liang, HH., Sun, P. (2015). Extraction, antimicrobial, and antioxidant activities of crude polysaccharides from the wood ear medicinal mushroom *Auricularia auricula*-judae (higher basidiomycetes). *International Journal of Medicinal Mushrooms*, 17(6):591-600. https://10.1615/intjmedmushrooms.v17.i6.90

Chen, PX., Wang, S., Nie, S. (2013). Properties of Cordycepssinensis: A review. *Journal of Functional Foods*, 5(2): 550-569. https://doi.org/10.1016/j.jff.2013.01.034

Cohen, R., Persky, L., Hadar, Y. (2002). Biotechnological applications and potential of wood-degrading mushrooms of the genus *Pleurotus*. *Applied Microbiology and Biotechnology*, 58(5): 582-594. https://doi.org/ 10.1007/s00253-002-0930-y

Deepalakshmi, K., Mirunalini, S. (2014). *Pleurotus ostreatus*: an oyster mushroom with nutritional and medicinal properties. *Journal of biochemical* technology, 5(2):718-726.

Dhamodharan, G., Mirunalini, S. (2010). A novel Medicinal Characterization of *Agaricus bisporus* (white button mushroom). *Pharmacologyonline*, 2: 456-463.

Dulger B, Ergul CC, Gucin F (2002) Antimicrobial activity of the macrofungus *Lepista nuda*. Fitoterapia 73: 695-697. https://doi.org/10.1016/S0367-326X(02)00233-2

Gao, Y., Tang, W., Gao, H., Chan, E., Lan, J., Li, X., Zhou, S. (2005). Antimicrobial Activity of the Medicinal Mushroom *Ganoderma*. *Food Reviews International*, 21(2):211–229. https://doi.org/10.1081/fri-200051893

Garcia, J., Afonso, A., Fernandes, C., Nunes, F.M., Marques, G., Saavedra, M.J. (2021). Comparative antioxidant and antimicrobial properties of *Lentinula edodes Donko* and *Koshin* varieties against priority multidrug-resistant pathogens. *South African Journal of Chemical Engineering*. 35(1): 98-106. https://hdl.handle.net/10520/ejc-chemeng-v35-n1-a12

Gebreyohannes, G., Nyerere, A., Bii, C., Berhe Sbhatu, D. (2019). Determination of antimicrobial activity of extracts of indigenous wild mushrooms against pathogenic organisms. *Evidence-Based Complementary and Alternative Medicine*. https://doi.org/10.1155/2019/6212673

Gogavekar, SS., Rokade, SA., Ranveer, RC. (2014). Important nutritional constituents, flavour components, antioxidant and antibacterial properties of *Pleurotus sajor-caju*. *Journal of Food Science* and *Technology*, 51(8): 1483-1491. https://doi.org/10.1007/s13197-012-0656-5

Gonelimali, FD., Lin, J., Miao, W. (2018). Antimicrobial properties and mechanism of action of some plant extracts against food pathogens and spoilage microorganisms. *Frontiers in Microbiology*, 9:1-9. https://doi.org/10.3389/fmicb.2018.01639

Hafdani, FN., Sadeghinia, N. (2011). A review on application of chitosan as a natural antimicrobial. *World academy of engineering and technology*, 50: 252-256. https://doi.org/10.5281/zenodo.1062688

Han, SR., Kim, KH., Lim, KO., Oh, TJ. (2015). Biological activity analysis of different solvent extracts from *Pleurotus ostreatus*. *Indian Journal of Science and Technology*, 8(26):1-8. https://doi.org/10.17485/ijst/2015/v8i26/80610

Harbarth, S., Balkhy, HH., Goossens, H. (2015). Antimicrobial resistance: one world, one fight. *Antimicrobial Resistance* and *Infection Control*, 1-15. https://doi.org/10.1186/s13756-015-0091-2

Hobbs, C. (2005). The chemistry, nutritional value, immunopharmacology, and safety of the traditional food of medicinal split-gill fugus *Schizophyllum commune* Fr.: Fr.(Schizophyllaceae) A literature review. *International Journal* of Medicinal, 7, 127-140. https://doi.org/10.1615/IntJMedMushr.v7.i12.130

Hsu, JH., Li, IC., Jiang, YM. (2015). Toxicological evaluation of *Lepista nuda* (Bull. ex Fr.) cooke mycelium produced by an in vitro culture methodology. *International Journal* of *Pharmacy* and *Pharmaceutical Sciences*, 7(10): 363-70.

Imtiaj, A., Jayasinghe, C., Lee, G.W., Lee, T.S. (2007). Antibacterial and antifungal activities of *Stereum ostrea*, an inedible wild mushroom. *Mycobiology*. 35(4): 210-214.

Kamra, A., Bhatt, AB. (2012). Evaluation of antimicrobial and antioxidant activity of *Ganoderma lucidum* extracts against human pathogenic bacteria. *International Journal* of *Pharmacy* and *Pharmaceutical Sciences*. 4(2): 359-362.

Kandasamy, S., Chinnappan, S., Thangaswamy, S., Balakrishnan, S., Khalifa, AY. (2020). Assessment of Antioxidant, Antibacterial Activities and Bioactive Compounds of the Wild Edible Mushroom *Pleurotus sajor-caju*. *International Journal of Peptide Research and Therapeutics*, 26(3):1575-1581. https://doi.org/10.1007/s10989-019-09969-2

Karnwal, A., Kaur, M. (2020). Assessment of *Agaricus bisporus* S-II extract as a bio-controlling agent against human pathogenic bacterial species. *Archives of Razi Institute*. *75*(1): 123-130. https://doi.org/10.22092/ARI.2019.128088.1403

Khatua, S., Ghosh, S., Acharya, K. (2017). *Laetiporus sulphureus* (Bull.: Fr.) Murr as food as medicine. *Pharmacognosy Journal*, 9(6):1-15. https://doi.org/10.5530/pj.2017.6s.151

Kolundžić, M., Stanojković, T., Radović, J., Tačić, A., Dodevska, M., Milenković, M., Kundaković, T. (2017). Cytotoxic and antimicrobial activities of *Cantharellus cibarius* Fr. (Cantarellaceae). *Journal of Medicinal Food*, 20(8):790-796. https://doi.org/10.1089/jmf.2016.0176

Kozarski, M., Klaus, A., Vunduk, J., Zizak, Z., Niksic, M., Jakovljevic, D., Van Griensven, LJ. (2015). Nutraceutical properties of the methanolic extract of edible mushroom *Cantharellus cibarius* (Fries): primary mechanisms. *Food and Function*, 6(6): 1875-1886. https://doi.org/10.1039/C5FO00312A

Kumar, S. (2022). Studies on evaluation of antibacterial activities of some cultivated mushrooms against human pathogenic bacteria. *Mushroom Research*. 31(1): 81-91. https://doi.org/10.36036/mr.31.1.2022.326408

Kumar, SG., Adithan, C., Harish, BN. (2013). Antimicrobial resistance in India: A review. *Journal of Natural Science, Biology and Medicine*, 4, (2):286-291. https://doi.org/10.4103/0976-9668.116970

Lesa, K.N., Khandaker, M.U., Mohammad Rashed Iqbal, F., Sharma, R., Islam, F., Mitra, S., Emran, T.B. (2022). Nutritional value, medicinal importance, and health-promoting effects of dietary mushroom (*Pleurotus ostreatus*). *Journal of Food Quality*. 2022: 1-9. https://doi.org/10.1155/2022/2454180

Lindequist, U., Jülich, WD., Witt, S. (2015). Ganoderma pfeifferi–A European relative of *Ganoderma lucidum*. *Phytochemistry*, 114:102-108. https//doi.org/10.1016/j.phytochem.2015.02.018

Lindequist, U., Niedermeyer, THJ., Jülich, WD. (2005). The pharmacological potential of mushrooms. *Evidence-Based Complementary and Alternative Medicine*, 2(3): 285-299. https://doi.org/10.1093/ecam/neh107

Mandal, P. (2019). Screening, isolation and documentation of pharmaceutical importance macro fungi of kulik raiganj wildlife sanctuary, West Bengal, India. *Journal for All Subjects*, 7631(48514):1-9.

Martínez, JL., Baquero, F. (2014). Emergence and spread of antibiotic resistance: setting a parameter space. *Upsala Journal of Medical Sciences*, 119, (2):68-77. https://doi.org/10.3109/03009734.2014.901444

Matijasevic, D., Pantic, M., Raskovic, B., Pavlovic, V., Duvnjak, D., Sknepnek, A., Niksic, M. (2016). The antibacterial activity of *Coriolus versicolor* methanol extract and its effect on ultrastructural changes of *Staphylococcus aureus* and *Salmonella Enteritidis*. *Frontiers in Microbiology*. 7: 1-15. https://doi.org/10.3389/fmicb.2016.01226

Mayakrishnan, V., Abdullah, N., Abidin, M.H.Z., Fadzil, N.H.M., Johari, N.M.K., Aminudin, N., Abidin, N.Z. (2013). Investigation of the antioxidative potential of various solvent fractions from fruiting bodies of *Schizophyllum commune* (Fr.) mushrooms and characterization of phytoconstituents. *Journal of Agricultural Science*. 5(6): 58-68. https://doi.org/10.5539/jas.v5n6p58

Mehrotra, S., Kirar, V., Vats, P., Nandi, S., Negi, PS., Misra, K. (2015). Phytochemical and antimicrobial activities of Himalayan Cordycepssinensis (Berk.) Sacc. *India Journal of Experimental Biology*, 53: 36-43.

Mercan, N., Duru, ME., Turkoglu, A. (2006). Antioxidant and antimicrobial properties of ethanolic extract from *Lepista nuda* (Bull.) Cooke. *Annals of microbiology* ,56(4): 339-344. https://doi.org/10.1007/BF03175028

Michael, CA., Howes, DD., Labbate, M. (2014). The antimicrobial resistance crisis: causes, consequences, and management. *Frontiers in Public Health*, 16(2): 145. https://doi.org/10.3389/fpubh.2014.00145

Mirfat, AHS., Noorlidah, A., Vikineswary, S. (2014). Antimicrobial activities of split gill mushroom *Schizophyllum commune* Fr. *American Journal of Research Communication*, 2(7): 113-124.

Mohd Rashidi, AN., Yang, TA. (2016). Nutritional and antioxidant values of oyster mushroom (*P. sajor-caju*) cultivated on rubber sawdust. *International Journal on Advanced Science, Engineering and Information* Technology, 6(2): 161-164. https://doi.org/10.18517/ijaseit.6.2.610

Narasimha, G., Praveen, B., Mallikarjuna, K. (2011). Mushrooms (*Agaricus bisporus*) mediated biosynthesis of sliver nanoparticles, characterization and their antimicrobial activity. *International Journal of Nano Dimension*, 2:29-36. https://doi.org/10.7508/IJND.2011.01.004

Padmavathy, M., Sumathy, R., Manikandan, N., Kumuthakalavalli, R. (2014). Antimicrobial activity of mushrooms against skin infection causing pathogens. *Research Journal of Biotechnology*, 5(2): 22-26.

Pauliuc, I., Dorica, B. (2013). Antibacterial activity of *Pleurotus ostreatus* gemmotherapic extract. *Journal of Horticultural Science and Biotechnology*, 17: 242-245.

Perera, WASW., Abeytunga, DTU., Wijesundara, RLC. (2001). Antibacterial activities of *Volvariella volvacea*. 29: 1-8.

Perez Cruz, C., Villa Martinez, BG., Perez Santiago, AD., Sánchez-Medina, M. A., García-Montalvo, I. A. (2020). Antioxidant and antimicrobial activity of *Pleurotus ostreatus*. *Journal of Biology and Nature*, 12 (1) 47-56.

Petrovic, J., Stojkovic, D., Reis, F.S., Barros, L., Glamoclija, J., Ciric, A., Ferreira, I.C., Sokovic, M. (2014). Study on chemical, bioactive and food preserving properties of *Laetiporus sulphureus* (Bull.: Fr.) Murr. *Food & function*. 5(7): 1441-1451. https://doi.org/https://doi.org/10.1039/C4FO00113C

Pinto, S., Barros, L., Sousa, M.J., Ferreira, I.C. (2013). Chemical characterization and antioxidant properties of *Lepista nuda* fruiting bodies and mycelia obtained by in vitro culture: Effects of collection habitat and culture media. *Food research international*. 51(2): 496-502. https://doi.org/10.1016/j.foodres.2013.01.009

Pranitha, V., Krishna, G., Singara-Charya, MA. (2014). Evaluation of antibacterial and antifungal activity of fruiting body extracts of *Trametes versicolor*. *Biolife*, 2(4): 1181-1184.

Praveen, K., Usha, KY., Naveen, M., Rajasekhar, BR. (2012). Antibacterial activity of a mushroom-*Stereum ostrea*. *Journal* of *Biology*, *Agriculture* and *Healthcare*, 2(1): 1-5.

Prust, AM., Samad, L., Rout, A., Patra, A. (2014). In vitro antibacterial activity of *Stereum ostrea* a wood decaying macro fungus. *Journal of Microbiology Research and Reviews*, 2:12-18.

Puia, IC., Aida, Puia., Chedea, VS., Leopold, N., Bocsan, IC., Buzoianu, AD. (2018). Characterization of *Trametes versicolor*: Medicinal mushroom with important health benefits. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 46(2): 343- 349. https://doi.org/10.15835/NBHA46211132

Quereshi, S., Pandey, A.K., Sandhu, S.S. (2010). Evaluation of antibacterial activity of different *Ganoderma lucidum* extracts. *Journal of Scientific Research*. 3: 9-13.

Quinto, E.J., Caro, I., Villalobos-Delgado, L.H., Mateo, J., De-Mateo-Silleras, B., Redondo-Del-Rio, M.P. (2019). Food safety through natural antimicrobials. *Antibiotics*. 8(4): 208-237. https://doi.org/10.3390/antibiotics8040208

Robles-Hernandez, L., Salas-Salazar, N.A., Gonzalez-Franco, A.C. (2021). Purification and Characterization of Antibacterial Activity against Phytopathogenic Bacteria in Culture Fluids from *Ganoderma lucidum*. *Molecules*. 26(18): 1-12. https://doi.org/10.3390/molecules26185553

Roy, A., Prasad, P., Gupta, N. (2014). *Volvariella volvacea*: A macrofungus having nutritional and health potential. Asian Journal of Pharmacy and Technology, 4 (2):110-113.

Salihović, M., Šapčanin, A., Špirtović-Halilović, S., Mahmutović-Dizdarević, I., Jerković-Mujkić, A., Veljović, E., Zećiri, S. (2019). Antimicrobial activity of selected wild mushrooms from different areas of Bosnia and Herzegovina. *In International Conference on Medical and Biological Engineering*, pp. 539-542. https:// doi.org/10.1007/978-3-030-17971-7 80

Samsudin, A., Dzulkifli, NAA., Jalani, MAAK., Sellathoroe, S., Ahmad, R. (2020). Extraction and Antimicrobial Properties of Polysaccharide from *Pleurotus Eryngii*. *Insan Junior Researcher Conference*, 249-253.

Sharma, AK., Jana, AM., Srivastav, A. (2014). Antimicrobial properties of some edible mushrooms: A review. *World Journal of Pharmacy and Pharmaceutical Sciences*, 3(5):1009-1023.

Sharma, R., Chaman, L.S., Kapoor, B. (2005). Antibacterial resistance: current problems and possible solutions. *Indian Journal of Medical Sciences*, 59,120-129. https://doi.org/10.4103/0019-5359.15091

Shashikant, M., Bains, A., Chawla, P., Sharma, M., Kaushik, R., Kandi, S., Kuhad, R.C. (2022). In-vitro antimicrobial and anti-inflammatory activity of modified solvent evaporated ethanolic extract of *Calocybe indica*: GCMS and HPLC characterization. *International Journal of Food Microbiology*. 376: 109741. https://doi.org/10.1016/j.ijfoodmicro.2022.109741

Siljegović, JD., Stojković, DS., Nikolić, MM .(2011). Antimicrobial activity of aqueous extract of *Laetiporus sulphureus* (Bull.: Fr.) Murill. *Zbornik Matice Srpske za Prirodne Nauke Matica Srpska*, 120: 299-305. https://doi.org/10.2298/ZMSPN1120299S

Sitati, C.N., Ogila, K.O., Waihenya, R.W., Ochola, L.A. (2021). Phytochemical profile and antimicrobial activities of edible mushroom *Termitomyces striatus*. *Evidence-Based Complementary and Alternative Medicine*. 2021: 1-10. https://doi.org/10.1155/2021/3025848

Siwulski, M., Sobieralski, K., Sokół, S. (2015). *Ganoderma lucidum* (Curt.: Fr.) Karst.–health-promoting properties. A review. 61(3): 105-118.

https://doi.org/10.1515/hepo-2015-0026
Smith, R.D., Coast, J. (2002). Antimicrobial resistance: a global response. *Bulletin World Health Organization*, 80:126-133.
Stajic, M., Vukojevic, J., Duletic´-Lauševic,´S. (2009). Biology of *Pleurotus eryngii* and role in biotechnological processes: a review. *Critical Reviews in Biotechnology*, 29(1): 55- 66. https://doi.org/10.1080/07388550802688821
Stankovic, M., Mitic, V., Stankov Jovanovic, V., Dimitrijevic, M., Nikolic, J., Stojanovic, G. (2022). Selected fungi of the genus *Lactarius*-screening of antioxidant capacity, antimicrobial activity, and genotoxicity. *Journal of Toxicology and Environmental Health, Part A*. 85(17): 1-16. https://doi.org/10.1080/15287394.2022.2075502
Sukmawati, I.K., Susilawati, E., Putri, S.D. (2019). Antibacterial activity of extracts and fractions of wood ear mushroom (*Auricularia auricula*). *Pharmaciana*. 9(1): 157-166. http://dx.doi.org/10.12928/pharmaciana.v9i1.11879
Sulkowska-Ziaja, K., Muszynska, B., Gawalska, A., Salaciak, K. (2018). *Laetiporus sulphureus*: chemical composition and medicinal value. *Acta Scientiarum Polonorum. Hortorum Cultus*. 17(1): 87-96. https://doi.org/10.24326/asphc.2018.1.8
Tamilselvan, N., Rajesh, K. (2019). Antimicrobial efficacy of medicinal mushroom *Ganoderma lucidum. International Journal of Trend in Scientific Research and Development*, 3:1798-1800. https://doi.org/10.31142/ijtsrd23522
Tanwar, J., Das, S., Fatima, Z. (2014). Multidrug resistance: an emerging crisis. *Interdisciplinary Perspectives* on *Infectious Diseases*, 1-8. https://doi.org/10.1155/2014/541340
Tian, M., Zhao, P., Li, G., Zhang, K. (2020). In depth natural product discovery from the basidiomycetes *Stereum* species. *Microorganisms*. 8(7): 1-22. https://doi.org/10.3390/microorganisms8071049
Turkoglu, A., Duru, M.E., Mercan, N., Kivrak, I., Gezer, K. (2007). Antioxidant and antimicrobial activities of *Laetiporus sulphureus* (Bull.) Murrill. *Food chemistry*. 101(1): 267-273. https://doi.org/10.1016/j.foodchem.2006.01.025
Usman, M., Murtaza, G., Ditta, A. (2021). Nutritional, Medicinal, and Cosmetic Value of Bioactive Compounds in Button Mushroom (*Agaricus bisporus*): A Review. *Applied science*, 11(13):5943. https://doi.org/ 10.3390/app11135943
Valentão, P., Andrade, PB., Rangel, J. (2005). Effect of the conservation procedure on the contents of phenolic compounds and organic acids in chanterelle (*Cantharellus cibarius*) mushroom. *Journal of Agricultural and Food Chemistry*, 53(12):4925-4931. https://doi.org/10.1021/jf0580263
Vallavan, V., Krishnasamy, G., Zin, NM., Abdul Latif, M. (2020). A review on antistaphylococcal secondary metabolites from basidiomycetes. *Molecules*, 25(24):5848. https://doi.org/10.3390/molecules25245848
Valverde, ME., Hernández-Pérez, T., Paredes-López, O. (2015). Edible mushrooms: improving human health and promoting quality life. *International journal of microbiology*, 2015: 1-15. https://doi.org/10.1155/2015/376387
Vijaykumar, G., John, P., Ganesh, K. (2014). Selection of different substrates for the cultivation of milky mushroom (*Calocybe indica* P & C). *Indian Journal of Traditional Knowledge*, 13(2):434-436.
Vlasenko, V., Turmunkh, D., Ochirbat, E., Budsuren, D., Nyamsuren, K., Samiya, J., Ganbaatar, B., Vlasenko, A. (2019). Medicinal potential of extracts from the chanterelle mushroom, *Cantharellus cibarius* (Review) and prospects for studying its strains from differs plant communities of ultracontinental regions of the Asia. *BIO Web of Conferences*, *EDP Sciences*. 16: 1-4. https://doi.org/10.1051/bioconf/20191600039
Yu, E.J., Han, S.R., Kim, K.H., Park, B.R., Lim, K.O., Oh, T.J. (2018). Antibacterial and Antioxidant Activity of *Pleurotus eryngii* Extracts. *Indian Journal of Public Health Research & Development*. 9(12): 2206-2213.
Zhang, JJ., Li, Y., Zhou, T., Xu, DP., Zhang, P., Li, S., Li, HB. (2016). Bioactivities and health benefits of mushrooms mainly from China. Molecules 21(7):938. https://doi.org/10.3390/molecules21070938
Zheng, H., Maoqing, Y., Liqiu, X., Wenjuan, T., Liang, L., Guolin, Z. (2006). Purification and characterization of an antibacterial protein from the cultured mycelia of *Cordyceps sinensis*. *Wuhan University journal of natural sciences*. 11(3): 709-714. https://doi.org/10.1007/BF02836695
Ziaf, K., Khan, A., Karim, W., Zahid, A. (2016). Nutritional and chemical profiles of *Auricularia auricular* mushrooms: A review. *International Journal of Agriculture and Environmental Research* , 2(3): 225-233.