"FROM DECOMPOSERS TO SUPERHEROES": UNLEASHING THE HIDDEN POWERS OF FUNGI TO SAVE OUR PLANET

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Abstract

Fungi, often overlooked but omnipresent, hold remarkable potential to address some of the most pressing environmental challenges facing our planet. This article explores the multifaceted roles of fungi, transcending their conventional image as decomposers, and showcases how they emerge as unsung superheroes in the battle for environmental sustainability. From mycorrhizal symbiosis enhancing plant growth to bioremediation activities cleansing polluted environments, fungi play pivotal roles in diverse ecological processes. This article examines the promising applications of fungi in sustainable agriculture, food production, waste decomposition, and the production of biofuels, highlighting their capacity to revolutionise these fields. Furthermore, the medicinal and biotechnological contributions of fungi are also explored, revealing a rich source of bioactive compounds with potential pharmaceutical applications. The role of fungi in the production of various fermented foods and their capacity to combat pests biologically underscore their significance in sustainable food production. Fungi also proves vital in carbon sequestration, erosion control, and soil stabilisation, contributing to global efforts in mitigating climate change and preserving ecosystems. By delving into the world of fungal biodiversity, the paper emphasises the importance of conservation efforts in maintaining ecosystem resilience and preventing the loss of critical ecological functions. This article sheds light on the transformative potential of fungi, urging a paradigm shift in how we perceive and harness these organisms. As our understanding of fungal biology deepens, recognising the vast number of undescribed and unexplored species becomes increasingly important. With their remarkable adaptations and ecological significance, Fungi continue to captivate the scientific community and underscore the need for sustained exploration and conservation efforts in this diverse and understudied kingdom. Recognising fungi as environmental superheroes provides a novel perspective that could inspire innovative solutions for sustainable development and the preservation of our planet's health.

Keywords: Ascomycetes, Basidiomycetes, Drug discovery, Renewable energy, Sustainable agriculture

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Introduction

Fungi, a diverse kingdom of eukaryotic organisms, represent a critical component of Earth's biodiversity, occupying a unique ecological niche and playing indispensable roles in various ecosystems (Hyde et al., 2020). Elias Magnus Fries (1794–1878) made a prognostication in 1825 that fungi would be the largest group in the vegetable (plant) world, similar to how insects are the largest group in the animal kingdom. Even though fungi are not technically considered a part of the plant world, it is remarkable how accurate his prediction has proven to be as its 200th anniversary draws near. Various estimates emerged regarding the number of fungal species, ranging from 500,000 to nearly 10 million, with a consensus among mycologists settling around 1.5 to perhaps 5 million. Recent studies even posit the potential existence of up to 2.2 to 3.8 million species globally (Hawksworth & Lücking, 2017; Hawksworth, 2001; Hyde et al., 2020). This renewed focus on fungal biodiversity underscores Fries' visionary insight and highlights the critical role fungi play in our understanding of the intricate web of life on Earth.

Despite their abundance and importance, only around 120,000 fungal species have been formally described and classified to date, underscoring the vast untapped reservoir of fungal diversity awaiting exploration (Antonelli et al., 2020; Hyde et al., 2020). Classifying fungi is a complex task due to their diverse morphologies, lifestyles, and reproductive strategies. Traditionally, fungi were classified based on morphological characteristics, such as the structure of reproductive organs and the type of spores produced. However, advances in molecular biology have revolutionised fungal taxonomy by allowing researchers to examine genetic relationships among species (Hibbett et al., 2016; Hyde et al., 2020). Fungi are taxonomically organised into several major phyla, including Ascomycota, Basidiomycota, Mucoromycota, Chytridiomycota, and Glomeromycota. Ascomycota and Basidiomycota are the most prominent and well-studied phyla, encompassing familiar fungi like yeasts, moulds, and mushrooms (Antonelli et al., 2020; Hyde et al., 2020). Ascomycota, characterised by sac-like structures (asci) that contain spores, includes diverse groups such as truffles and morels. Basidiomycota, identified by club-shaped reproductive structures (basidia), houses well-known fungi like agarics and puffballs (Antonelli et al., 2020). The naming and classification of fungi follow the principles of mycological nomenclature. Each formally described species is assigned a scientific name based on the binomial system. Fungi are constantly undergoing taxonomic revisions as new information emerges, and advances in genetic analysis continue to refine our understanding of their evolutionary relationships (Hibbett et al., 2016).

Fungi's complex roles transcend their conventional image as decomposers, demonstrating how they emerge as unsung superheroes in the fight for environmental sustainability. The imperative of addressing environmental conservation arises from its profound influence on the well-being of our world (Maroney, 2018). Given the concerning increase in pollution, deforestation, and climate change, it is imperative to comprehend the origins and importance of environmental conservation to safeguard our natural resources, maintain biodiversity, and secure a sustainable future for future generations. Fungi are essential components of ecosystems, as they break down organic matter and return nutrients to the environment through decomposition (Gadd et al., 2008. In addition, they establish symbiotic associations with plants, facilitating their uptake of water and nutrients from the soil (Rouland-Lefèvre, 2000). In addition, fungi play a crucial role in maintaining the health of ecosystems by regulating populations of other creatures and facilitating the decomposition of contaminants (Gadd et al., 2008). This paper aims to review existing literature and present a comprehensive analysis of the role of fungi, highlighting their various ecological functions and importance for overall ecosystem stability.

Role of fungi in nutrient cycling and decomposition

Understanding the fundamental processes of nutrient cycling and decomposition is paramount for grasping the intricate web of life on Earth. Often overlooked but omnipresent, Fungi emerge as key players in these processes. Fungi are essential for recycling nutrients and the breakdown of organic matter in ecosystems. They decompose organic debris, such as deceased flora and fauna, into more basic molecules that other species can recycle and utilise (Aerts, 2003). In addition, fungi are highly efficient in breaking down intricate organic compounds, thereby releasing vital nutrients back into the soil and rendering them accessible for plant absorption (Aerts, 2003; Gadd et al., 2008). Gaining a comprehensive understanding of the complex mechanisms via which fungi perform these roles is crucial for preserving the well-being of ecosystems and guaranteeing the long-term viability of natural resources (Lodge, 1993). Ascomycetes and Basidiomycetes play vital roles in the decomposition of leaf litter in terrestrial ecosystems (Figure 1)—white and brown-rot fungi, such as *Ganoderma* spp., *Perenniporiopsiss* spp., *Phanerochaete* spp. *Phellinus spp.* and *Pyrrhoderma* spp. are adept at breaking down lignin in wood, releasing nutrients back into the ecosystem (Karaman et al., 2012; Daly et al., 2021; Konara et al., 2022; Thambugala et al., 2023). This process is crucial for carbon cycling in forest ecosystems. Numerous studies demonstrate the beneficial relationships between mycorrhizal fungi and plants (Bonfante & Genre, 2010; Mohammadi et al., 2011; Chen et al., 2018,). Mycorrhizae enhances nutrient uptake, particularly phosphorus, and improves plant growth and health. *Glomus* spp., forming Arbuscular Mycorrhizae (AM) associations with the roots of plants, enhances nutrient uptake (phosphorus and nitrogen) by facilitating the transfer of nutrients between soil and plant roots (Nanjundappa et al., 2019). This symbiosis is crucial for the functioning of various ecosystems, including forests and grasslands. In boreal forests, Ectomycorrhizal fungi like *Suillus* spp. Form symbiotic associations with trees, contributing to nutrient cycling and the establishment of plant communities (Sarwar et al., 2018).

Figure 1: Some wood decomposing basidiomycetes and ascomycetes collected from Sri Lanka: a. *Pycnoporus* sp., b. *Ganoderma* sp., c. *Coprinellus* sp., d. *Sarcoscypha* sp.

Mycorrhizal fungi contribute to sustainable agriculture by improving plant nutrient uptake, water absorption, and disease resistance (Mohammadi et al., 2011; Chen et al., 2018). Research shows that incorporating mycorrhizal fungi into agricultural practices can reduce the need for chemical fertilisers and enhance crop yields (Igiehon & Babalola, 2017). For example, *Aspergillus* (Figure 2) and *Trichoderma* species break down crop residues, release essential nutrients for subsequent plant growth, and promote sustainable agriculture (Borin et al., 2015). Nevertheless, Arbuscular mycorrhizal fungi, such as *Rhizophagus irregularis,* enhance nitrogen uptake by forming symbiotic relationships with crop plants, reducing the reliance on synthetic fertilisers (Ramírez-Flores et al., 2019).

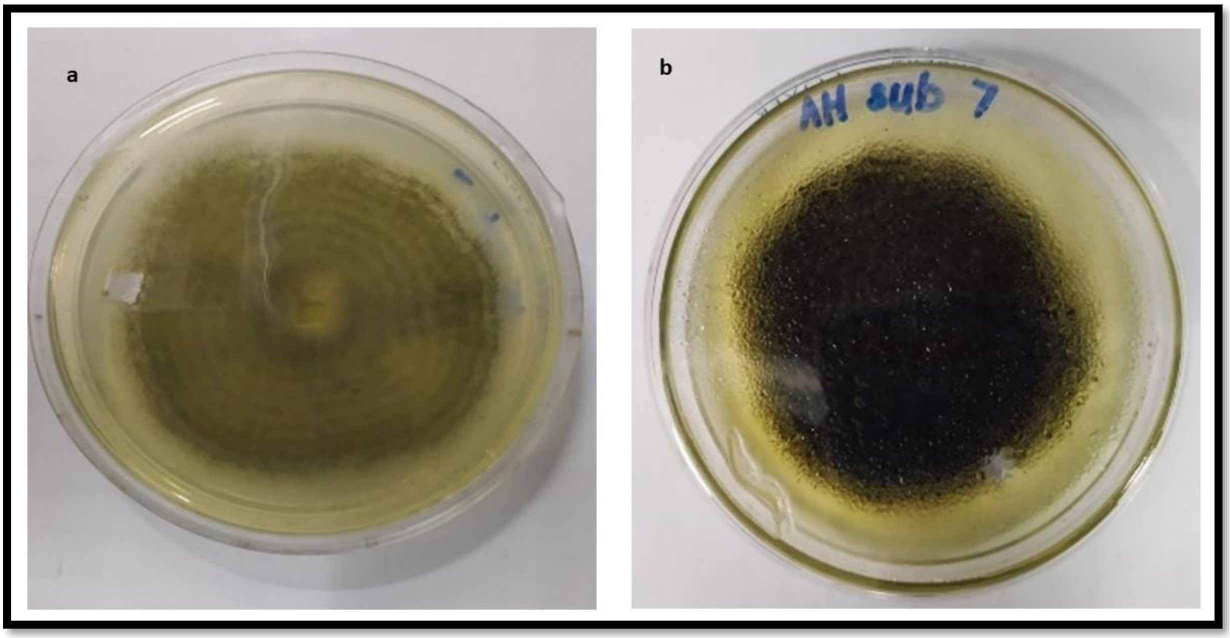

Figure 2: *Aspergillus niger* isolated from the soil samples; a. lower surface., b. upper surface.

Mycorrhizal fungi play a crucial role in carbon sequestration by promoting the creation of durable organic substances in soils, influencing the global carbon balance. Studies demonstrate that these fungi have a pivotal function in the formation of soil, the process of nutrient circulation, and the overall well-being of the soil (De Deyn & Kooistra, 2021). *Agaricus bisporus,* a basidiomycete, contributes to soil structure by producing glomalin, a glycoprotein that enhances soil aggregation and water retention (Fan et al., 2021).

Fungi as Bioindicators

Fungi, essential elements of ecosystems, demonstrate a subtle susceptibility to environmental contaminants, displaying unique reactions that act as indicators of ecological well-being. The dynamic shifts influence the sensitivity of these organisms in the makeup of their community and variations in metabolic activity that occur in response to environmental stress. When fungi are exposed to high levels of heavy metal contamination, they display an impressive ability to adapt or vulnerability, leading to noticeable changes in their community composition (Millar & Bennett, 2016). Research undertaken in contaminated habitats, such as industrial sites or regions with high levels of metals, regularly demonstrates changes in the quantity and variety of fungal species (Newbound et al., 2010; Lenart-Boroń & Boroń, 2014). The variations observed in the fungi's behaviour indicate their ability to react to the existence of heavy metals, offering vital knowledge about the quantities and varieties of contaminants found in the surroundings (Gadd, 2008). The observed alterations in fungal communities indicate environmental disruption and provide a nuanced viewpoint on the precise characteristics and magnitude of pollution, thus establishing fungi as dependable bioindicators for evaluating pollution levels in various ecosystems.

Fungi have a complex role in maintaining environmental health through mycorrhizal dynamics. Changes in mycorrhizal associations can provide valuable information about nutrient availability and soil health in ecosystems (Johnson et al., 2013). The phenomena are driven by the symbiotic interactions established between fungi, specifically arbuscular mycorrhizal fungi (AMF), and the roots of plants. Mycorrhizal associations exhibit adaptive responses to changes in soil nutrient supply. When nutrient levels vary, the number and activity of arbuscular mycorrhizal fungi adapt accordingly. The responsiveness observed in this context is based on the mutualistic symbiosis between the fungi and the plant host. The fungi improve the plant's ability to absorb nutrients, while the plant supplies the fungi with carbohydrates (Johnson et al., 2010).

An example that clearly demonstrates the dynamics of mycorrhizal relationships may be seen in the association between the reactions of arbuscular mycorrhizal fungus and the nutrient level of the soil (Johnson et al., 2013). Research undertaken in various ecosystems, including agricultural areas and natural habitats, has consistently shown that the presence and behaviour of arbuscular mycorrhizal fungus can be used as accurate indicators of the nutrient cycling processes taking place in the soil (Soka & Ritchie, 2014). The alterations in the composition and performance of these fungi yield vital insights into the general well-being of the ecosystem, indicating their ability to recycle and transport nutrients efficiently throughout plant communities. Bothe et al. (2010) highlight the complex relationship between fungi and the movement of nutrients. It emphasises that mycorrhizal connections are crucial for evaluating the overall health of ecosystems and the mechanisms involved in the cycling of nutrients.

Fungal communities in freshwater ecosystems have become important indicators for assessing water quality and determining the effects of agricultural runoff and industrial contaminants. Through the examination of the structure and variety of aquatic fungi, scientists acquire significant insights into the well-being of aquatic ecosystems (Khatri & Tyagi, 2014; Morin-Crini et al., 2022). Changes in the composition of fungal communities can serve as indicators of nutrient imbalances, pollution levels, and the overall ecological health of freshwater ecosystems (Morin-Crini et al., 2022). These findings enhance our understanding of conservation and management techniques by emphasising the importance of fungal communities as reliable indicators of water quality in many aquatic habitats.

Researchers are studying urban microbiomes to evaluate air quality and understand the complex connections between fungal diversity and pollution levels in metropolitan areas. By examining changes in fungal variety and abundance, researchers can deduce the air quality and assess the environmental well-being of urban regions (Leung et al., 2014; Moelling & Broecker, 2020). Research has shown a clear connection between specific types of fungi and the level of air pollutants, providing a new method for monitoring air quality (Pollegioni et al., 2023). Utilising fungal indicators in urban settings serves the dual purpose of comprehending the ecological ramifications of pollution and supplying vital data for urban planning and environmental management.

Fungal Community Responses to Climate Change

Utilising fungal indicators in urban settings serves the dual purpose of comprehending the ecological ramifications of pollution and supplying crucial data for urban planning and environmental management. Fungi exhibit dynamic responses to climate change, utilising several mechanisms such as changes in their geographical range, timing of biological events, and interactions with host organisms (Chakraborty, 2013). The answers are tightly connected to the delicate interaction between fungi and their surroundings. Fungi undergo alterations in their distribution, the timing of crucial life cycle stages, and their interactions with other organisms as climatic circumstances change (Bahram & Netherway, 2021). These strategies jointly enhance the ability of fungi to adjust to climate change and have a vital impact on altering ecosystem dynamics.

Studies undertaken in alpine ecosystems have demonstrated the crucial role of fungi in serving as indicators of the impacts of climate change (Broadbent et al., 2021). These investigations explore changes in the variety of fungi and their interactions with mycorrhizae, offering useful insights into the effects of shifting climatic circumstances. Researchers have found changes in the makeup of fungal communities in alpine locations, where the impacts of climate change are especially noticeable. Fluctuations in the population and variety of fungi act as early signs of environmental pressures and offer a thorough comprehension of the ecological consequences of climate change (Moscatelli et al., 2017). Moreover, the alterations in mycorrhizal connections due to shifting climate circumstances highlight the complex way fungi contribute to the adaptation and resilience of ecosystems amid a swiftly changing climate. These findings improve our comprehension of how fungi react to climate change and highlight the importance of fungi as bioindicators in monitoring and predicting larger ecological changes.

Fungal Enzymes in Biofuel Production and Bioenergy Applications

The enzymatic machinery possessed by fungi demonstrates their exceptional ability in the field of biofuel production. The importance of fungal enzymatic complexes, such as cellulases, hemicellulases, and ligninases, is emphasised by scientific evidence (Aro et al., 2005). These highly efficient hydrolytic enzymes are crucial in converting complex plant biomass into simpler sugars. This metabolic conversion is a fundamental process in the manufacturing of biofuels (Aro et al., 2005), offering a viable and environmentally friendly substitute for conventional fossil fuels. Cellulases specifically target cellulose, the main structural component of plant cell walls. Conversely, hemicellulases focus on the more diverse hemicellulose, while ligninases are responsible for breaking down the challenging lignin matrix (Silva et al., 2017). The coordinated activity of these enzymes enables the breakdown of plant material, releasing sugars that can be further transformed into biofuels.

Exploring further into the field of fungal enzymology uncovers the unique contributions of specific species that make certain fungi stand out in terms of their effectiveness in converting biofuels (Aro et al., 2005). Species of the genera *Aspergillus* and *Trichoderma* have gained recognition for their remarkable ability to produce enzymes (Cologna et al., 2015; de França Passos et al., 2018). The scientific community has thoroughly investigated the enzymatic profiles of these fungi, revealing the intricacies of their metabolic machinery. This examination has uncovered their proficiency in enzyme production and their distinct enzymatic characteristics that make them especially suitable for effective biofuel conversion. The intrinsic traits of *Aspergillus* and *Trichoderma* species, including their capacity to thrive in many substrates and environmental circumstances, enhance their attractiveness as leaders in biofuel production (Seiboth et al., 2011; Grujić et al., 2015; Bischof et al., 2016).

Cellulosic ethanol production is a revolutionary bioenergy application that utilises fungal enzymes, specifically cellulases, to produce ethanol from cellulose (Seiboth et al., 2011). The scientific evidence strongly emphasises the crucial function of fungal cellulases in this process since numerous investigations have consistently shown their effectiveness in converting cellulose from plant biomass into sugars that can be fermented. The enzymatic conversion of cellulose, a complex carbohydrate that forms the structural framework of plant cell walls, is an essential process in generating cellulosic ethanol (Kango et al., 2019). Due to their proficient cellulase synthesis, Fungi have a crucial function in decomposing resistant cellulose into more basic carbohydrates such as glucose. The sugars undergo fermentation by microorganisms, producing ethanol, which serves as a sustainable and renewable substitute for conventional fossil fuels (Seiboth et al., 2011). The efficacy of fungal cellulases in this bioconversion procedure highlights their importance in promoting the generation of cellulosic ethanol for an environmentally friendly and enduring energy environment.

The enzymatic degradation of lignocellulosic biomass using fungal enzymes is a potential approach in the quest for sustainable biofuel production (Saini & Sharma, 2021). The exploration of this process as a sustainable approach for converting various plant feedstocks into high-quality biofuels is emphasised by Saini and Sharma (2021). Lignocellulosic biomass, which consists of cellulose, hemicellulose, and lignin, presents a complicated problem because of its resistant characteristics. Fungal enzymes have demonstrated significant potential in addressing this difficulty by effectively targeting and degrading these components. The enzymatic release of sugars initiates the subsequent biofuel manufacturing steps, providing a sustainable and renewable energy source. The continuous scientific investigation of lignocellulosic biomass conversion showcases the capacity of fungal enzymes to facilitate the conversion of various plant feedstocks into superior biofuels, hence promoting the achievement of a more sustainable and environmentally friendly energy future (Srivastava et al., 2018).

Medicinal Compounds from Fungi

Scientific evidence demonstrates that fungi, commonly recognised as nature's pharmacists, possess a significant abundance of bioactive chemicals that hold great promise for medicinal applications (Lee & Yun, 2011). An exemplary instance of this phenomenon is penicillin, the inaugural antibiotic obtained from the fungus *Penicillium* (Figure 3). This significant innovation transformed the field of medicine, marking the beginning of the antibiotic era and preserving innumerable lives. The scientific community continues investigating fungal biodiversity for pharmaceutical compounds beyond penicillin, uncovering a wide range of bioactive chemicals with various therapeutic qualities.

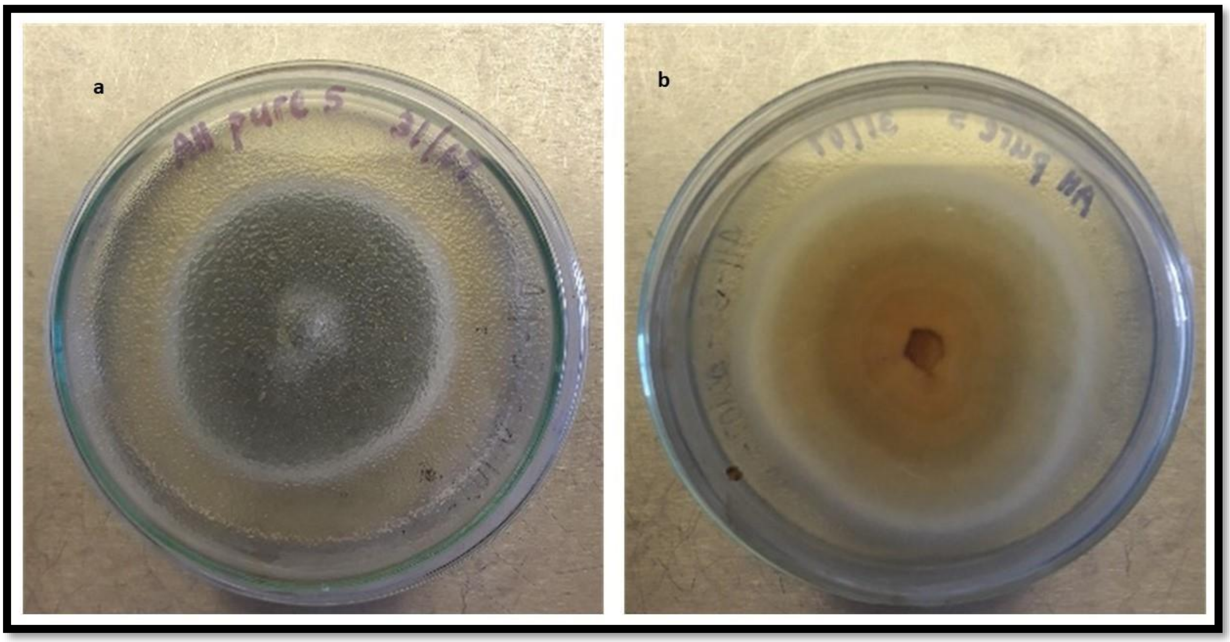

Figure 3: ***Penicillium*** **sp. a. lower surface., b. upper surface.**

Fungi have produced numerous substances that exhibit strong antibacterial efficacy. Continuing research has discovered secondary metabolites derived from different fungal species that demonstrate effectiveness against a broad spectrum of bacteria, viruses, and fungi. Compounds derived from *Acremonium*, such as cephalosporins, and from *Aspergillus*, such as statins, exhibit both antibacterial properties and serve as important models for the creation of novel antibiotics (Saxena et al., 2019). In addition, *Ganoderma* species, a group of medicinal mushrooms, have been used in traditional Chinese medicine for thousands of years to maintain vivacity and longevity. Some of these species are well-known for being abundant sources of highly active bioactive substances like polysaccharides, proteins, steroids, and triterpenoids (Konara et al., 2022).

Fungal metabolites have become a promising reservoir of anticancer medicines, exemplified by molecules such as paclitaxel derived from *Taxomyces andreanae*, which exhibit significant antitumor properties (Ismaiel et al., 2017). The ongoing investigation into the variety of fungi is uncovering new substances that demonstrate specific toxicity toward cancer cells, offering promising possibilities for the creation of innovative cancer treatments.

Fungi also have a role in immunosuppression by producing certain chemicals that have the ability to modify the immune system. Compounds such as cyclosporin A, which originate from *Tolypocladium inflatum*, have played a crucial role in organ transplantation by regulating the immune response and reducing rejection (Ganjoo et al., 2022). Continuing study endeavours to discover supplementary immunosuppressive substances with enhanced effectiveness and diminished adverse effects.

Despite the significant potential of discovering pharmaceutical compounds from fungi, some obstacles need to be overcome. These include identifying new compounds, understanding how they work, and optimising them for therapeutic purposes (Ganjoo et al., 2022). Progress in genomics, metabolomics, and synthetic biology provide novel means to fully use the therapeutic capabilities of fungal metabolites (Ismaiel et al., 2017). Ultimately, fungi remain abundant providers of therapeutic substances, significantly influencing the field of contemporary pharmacology. Fungi possess a wide range of bioactive compounds that have the potential to address medical requirements that have not yet been met, including the discovery of new antibacterial, anticancer, and immunosuppressive medicines (Ismaiel et al., 2017). This includes the significant breakthrough of penicillin in history. The study of fungal biodiversity continues to be a rapidly evolving and captivating field, with the potential to enhance our collection of therapeutic options by discovering natural fungal medicines.

Fungi as Food and in Food & Beverage Production

Fungi are essential in several culinary customs globally, serving as ingredients and independent delicacies. Mushrooms and fungal-based products provide a wide range of flavours, textures, and nutritional advantages, enhancing the variety and creativity of recipes. Mushrooms are the most renowned and extensively ingested fungi. Mushrooms such as portobellos, shiitakes, and morels offer diverse flavours and textures that enhance various cuisines (Figure 4). From a scientific standpoint, mushrooms are acknowledged for their nutritional composition, encompassing vital vitamins, minerals, and antioxidants. For instance, the savoury taste of shiitake mushrooms is enhanced by substances such as lentinan, which has been extensively researched for its possible health advantages (Das et al., 2021). Shiitake mushrooms (*Lentinula edodes*), highly valued in Asian culinary traditions, are esteemed for their savoury umami taste and acknowledged for their scientifically proven nutritional composition (Das et al., 2021). The research reveals the presence of bioactive chemicals, specifically lentinan, recognised for their potential health advantages, including their ability to modulate the immune system (Petrovic et al., 2022). Portobello mushrooms, scientifically known as *Agaricus bisporus*, are highly favoured for their sturdy texture and distinct earthy taste, making them a popular option for various culinary creations (Ramos et al., 2019). Scientific inquiries explore the nutritional makeup of these substances, uncovering a plentiful supply of vitamins, minerals, and antioxidants. Maitake mushrooms, formally recognised as *Grifola frondosa*, are renowned for their distinctive frond-like appearance and well-documented potential to enhance health (Kubo & Nanba, 1996). The research investigates the bioactive chemicals, such as beta-glucans, present in Maitake mushrooms, uncovering their ability to reduce inflammation and modulate the immune system (Mori et al., 2008).

Figure 4: Most cultivated oyster mushroom species in Sri Lanka. a. Pink Oyster mushrooms (*Pleurotus djamor*) (3.50%), b. Abalone (*Pleurotus cystidiosus*) (34.30%), c. American Oyster mushrooms (*Pleurotus ostreatus*) (96.20%), d. Bhutan Oyster (*Pleurotus eous*) (12.10%)

Mycoprotein, a high-protein fungal product, exemplifies the use of fungus as a food source. Mycoprotein, generated from *Fusarium venenatum,* is used as a substitute for meat in various vegetarian and vegan goods (Hashempour-Baltork et al., 2020; Lonchamp et al., 2022). Significantly, it serves as the primary component in renowned products like Quorn (Lonchamp et al., 2022). Fermenting and harvesting mycoprotein has undergone scientific improvements to guarantee its nutritional value and a pleasing texture, rendering it a viable protein option for individuals searching for plant-based alternatives.

Truffles are a type of fungi that are highly valued for their strong scent and taste. They are found underground near the roots of specific trees. Truffles, scientifically called mycorrhizal fungus, establish symbiotic associations with tree roots, enhancing their distinct flavour characteristics. The cultivation and study of truffles require thoroughly comprehending soil conditions, tree connections, and the complex factors that influence their growth (Chauhan et al., 2021).

Fungi, highly regarded for their culinary abilities, have a fundamental part in food production through commonly used fermentation procedures. Fungi, scientifically recorded and recognised for their considerable impact, play a crucial role in producing many types of food. They improve the taste and texture and help with preservation. The delicate symbiotic link between fungi and the food industry has resulted in a diverse range of gastronomic delicacies, including the fermentation of bread, the intricate ageing process of cheeses, and the rich umami flavour of soy sauce. In bread production, fungi, specifically *Saccharomyces cerevisiae*, play a crucial role as indispensable catalysts in fermentation (Struyf et al., 2017). The yeast species undergoes fermentation of carbohydrates present in the dough, resulting in the production of carbon dioxide. This gas is responsible for the leavening of the bread, giving it its distinctive texture. Scientific investigations have clarified the biochemical processes involved, providing insights into the role of fungus in producing the soft, light texture and pleasant smell of freshly baked bread (Struyf et al., 2017).

Fungi have a key role in the maturing phase of cheese-making. The known scientific interactions between fungi, specifically *Penicillium roqueforti* in blue cheeses, and the cheese matrix lead to unique flavours and sensations. The deliberate cultivation of particular fungal strains during the ageing process helps the development of distinct flavour profiles, showcasing the scientific comprehension of fungi's involvement in the intricate realm of cheese manufacturing (Dumas et al., 2020).

Fungi are essential in the fermentation process of soy sauce and are a fundamental ingredient in several culinary traditions. *Aspergillus oryzae* plays a crucial role in the fermentation process of soybeans by decomposing intricate chemicals into more elemental, flavorful elements. The scientific comprehension of the enzymatic activities of fungi in the fermentation of soy sauce establishes a basis for enhancing production methods and guaranteeing the uniform excellence and taste of this indispensable condiment (Li et al., 2023).

Fungi play a significant role in forming and retaining flavours in several culinary applications, extending beyond specific food products. Fungi break down proteins and carbohydrates through fermentation, producing several taste compounds that enhance the richness and complexity of fermented foods (Chávez et al., 2023). In addition, fungi produce organic acids and antibacterial substances that help preserve food, prolonging its shelf life and maintaining its safety (Li et al., 2023).

In addition to their culinary contributions, fungi play a significant role in beverage production by imparting unique flavours and textures to various drinks. Fungi-based fermentation processes play a crucial role in the production of beverages, adding complexity and distinct characteristics to different libations (Challa et al., 2019). A notable illustration is beer production, in which fungi, particularly strains of *Saccharomyces cerevisiae*, play a pivotal role in fermentation. Scientific investigations explore the complex molecular mechanisms in understanding how yeast converts carbohydrates into alcohol and carbon dioxide (Chandrasekaran et al., 2015). This fermentation process adds carbonation to beer and introduces a wide range of flavour compounds, demonstrating the scientific knowledge of how fungi contribute to the art and science of brewing.

In the realm of wines, fungi, including *Saccharomyces* and non-Saccharomyces yeast strains, play a vital role in fermentation and maturing processes. Scientific research investigates the influence of particular yeast strains on the smell and flavour characteristics of wines. In certain wine styles, fungi such as *Brettanomyces* may contribute to the overall complexity and depth (Masneuf-Pomarede et al., 2016).

This article explores the role of fungi beyond their traditional function as decomposers, revealing them as underappreciated champions in the effort to maintain the well-being of our world. The scientific data emphasises the crucial role of fungi in various areas, including biodiversity protection, bioenergy generation, climate change resilience, and medical advancements. The intrinsic capacity of fungi to decompose intricate organic substances, generate biofuels, and manufacture medicinal molecules highlights their promise as environmentally benign solutions to global concerns. In addition, fungi serve as bioindicators, meaning they can provide valuable information about the health of an ecosystem. They also exhibit dynamic reactions to environmental stressors and are crucial in nutrient cycling. These characteristics highlight how fungi contribute to our understanding of ecosystem health. The review study highlights the role of fungi as environmental champions. It emphasises the significance of continuous scientific research in fully harnessing these extraordinary organisms' potential to protect our planet's future.

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