Scholars Academic Journal of Biosciences
Abbreviated Key Title: Sch Acad J Biosci
ISSN 2347-9515 (Print) | ISSN 2321-6883 (Online)
Journal homepage: https://saspublishers.com

OPEN ACCESS

Environmental

Medical Fungi, Their Importance and Harms in Our Lives

Khetam Ibrahim Mohammed[1*], Mohammed Mudhafar Alkhuzaie[2], Abtisam Jasim Abbas[3]

[1]University of Al-Qadisiyah, College of Science, Environment Research & Prevention Pollution Unit, Iraq
Email: Khetam.ibrahim@qu.edu.iq
[2]University of Al-Qadisiyah, College of Science, Department of Pathological Analyses, Iraq
Email: mohammed.mudhafar@qu.edu.iq
[3]University of Al-Qadisiyah, College of Science, Department of Environment, Iraq
Email: abtisam.jasim@qu.edu.iq

DOI: https://doi.org/10.36347/sajb.2025.v13i05.003 | **Received:** 24.03.2025 | **Accepted:** 29.04.2025 | **Published:** 05.05.2025

***Corresponding author:** Khetam Ibrahim Mohammed
University of Al-Qadisiyah, College of Science, Environment Research & Prevention Pollution Unit, Iraq

Abstract **Review Article**

The Fungi play an important role in human life, both positively and negatively. Among the most important fungi are *Aspergillus, Penicillium and Candida*. These fungi have a great impact on human health, whether as pathogens or as sources of medicines. For example, *Aspergillus* fungi, which causes serious diseases such as aspergillosis, especially in people with weak immunity. While some for it are used in the pharmaceutical industry to produce some important enzymes, as for *Penicillium* fungus is considered the most important in the history of medicine for the discovery of the antibiotic penicillin, which is used as an antibacterial. In addition, it helps in the production of cheese and some industrial enzymes. Also, Candida fungus lives naturally in the human body, but it causes fungal infections such as candidiasis when there is an imbalance in the bacterial balance or weak immunity, and it can cause skin infections There are also cryptococcosis, dermatophytes and many other fungi that are highlighted in this review to identify the most aggressive fungi that cause diseases in human In return, identifying other fungi that are beneficial for it in the creation of antibiotics and other applications used in the medical area, such as *Tolypocladium* and *Trichoderma* fungus, and used in the food industry, such as the Saccharomyces fungi. Knowing the function of these fungi aids in the development of novel approaches to the treatment and prevention of fungal illnesses as well as strategies for utilizing and profiting from them in industrial settings.

Keywords: Biological Activates, Medical Fungi, Harmful Fungi, Dermatophytes, *Penicillum, Aspergillus, Histoplasma, Cryptococcus Saccharomyces, Tolypocladium, Trichoderma, Candida*.

INTRODUCTION

The Kingdom Fungi, which includes eukaryotes with wonderfully varied life histories that are vital to human industry, research, medicine, and the biosphere, is home to molds, yeast, lichens, rusts, smuts, and mushroom. (Stajich *et al*., 2009; Liolios *et al*., 2008). Essentially, all species share the same morphology, we refer to filaments, single-celled yeast, or both as dikarya (Heitman, *et al*., 2006). Although there are an estimated 1.5 million fungal species, only approximately 80,000 to 120,000 have been described too far (Webster & Weber 2007; Hawksworth 2001)

Using morphological methods of species recognition, it is feasible to propose two non-exclusive explanations for the apparent disparity in the geographic range sizes of microscopic and macroscopic eukaryotic species. Microbial species often have fewer morphological characteristics, and organisms with less complex growth and fewer cells would have a slower pace of morphological change. (Taylor *et al*., 2006).

Many medically significant fungus, such as *Aspergillus*, *Candida*, *Cryptococcus*, and members of the class Zygomycetes, have been demonstrated to infect and kill invertebrates, including fruit flies, wax moths, and roundworms. According to these results, a number of genes linked to fungal virulence in mammalian models also play a significant pathogenic role in mini-host species. (Chamilos *et al*., 2007). Numerous essential medicinal fungi invade host cells that are typically nonphagocytic, including endothelium and epithelial cells. Adhesion and invasion are the two stages of host cell invasion, The most effective methods for studying these host cell invasion mechanisms have been *Candida albicans* and *Cryptococcus neoformans*. (Sheppard, D. C., & Filler, S. G. 2015; Gilbert *et al*., 2015)

The immune system's inability to identify fungal pathogens or an overreaction of the inflammatory response are two possible causes. Few fungi meet all the requirements ((High temperature tolerance, the capacity to penetrate the human host, the lysis and absorption of human tissue, and immune system resistance are the four fundamental requirements for human infection) for a healthy human host because the effective human immune system evolved in response to interactions with potential fungal diseases. The innate immune system is well-equipped to identify and eradicate harmful fungi because it contains specialized cells that express a wide range of pattern recognition receptors.(Romani 2011; Köhler *et al*., 2017; Drummond *et al*., 2015; Köhler *et al*., 2015) Not everyone is equally vulnerable to fungi infections, especially when they have the same risk factors, despite the fact that they are typically linked to external problems like immunosuppression, environmental factors, and contaminated people, things, or surfaces. A genetic tendency to fungal infection exists in certain families (García-Romero & Arenas 2015)

The Most Important Medically Important Fungi
A-Some of Them Cause Diseases in Humans and Animals

Many fungal species can cause infections in humans as well as animals. These disorders range from skin infections to those affecting interior organs (Mavor *et al*., 2005; Hyde *et al*., 2018; Seyedmousavi *et al*., 2018; Jain *et al*., 2010), including:

Aspergillus

Among the most prevalent fungi worldwide, *Aspergillus* is a varied group of fungi. It is capable of both sexual and asexual reproduction, the 200 or so species of *Aspergillus* fungi are important to public health because they are food pollutants that create poisons, human and animal diseases, and helpful fungi in both conventional and contemporary biotechnological processes.(Schaechter, M 2012; Krijgsheld *et al*., 2013) The most prevalent variety of *Aspergillus fumigatus* is responsible for invasive aspergillosis, which can lead to dangerous lung infections and perhaps spread to other body organs. After *Aspergillus fumigatus*, *Aspergillus flavus* is the second most frequent causative agent of invasive aspergillosis (IA). *A. flavus*, In addition to its ability to infect the respiratory system, this species produces aflatoxins, which are toxic and carcinogenic substances that affect the liver. (Latgé & Chamilos 2019; Dagenais & Keller 2009; Rudramurthy *et al*., 2019) Additionally, *Aspergillus niger* causes respiratory infections and can result in otitis externa and other problems. Additionally, it causes "black mold" on fruits and vegetables. (Enyiukwu *et al*., 2018; Roszell & Olmstead 2014 ; Sharma *et al*., 2021) Diseases caused by these fungi range from mild allergic reactions to serious, life-threatening infections, depending on the individual's immune system and the type of fungus involved.

Aspergillus fungal species listed below are responsible for plant diseases, some of which affect grains and others that affect vegetables, causing them to deteriorate and release toxins*: Aspergillus Flavus, Aspergillus niger, Aspergillus Ochraceus* (Zakaria, L. 2024; Plascencia-Jatomea *et al*., 2014; Pfliegler *et al*., 2020).

Candida

The fungus known as *Candida* is found naturally in the human body, particularly in the skin, mouth, vagina, and vagina. When Candida is absent, the human microbiome's fluidity is preserved, supporting a number of bodily processes. However, Candida may grow uncontrollably and cause infections and disease symptoms when this diversity is disrupted, as may happen with a weakened immune system or with the use of antibiotics in particular (Calderone & Clancy 2011; Polke *et al*., 2015; Lass-Flörl *et al*., 2024). *Candida* contributes to the body's microbial balance and helps the immune system learn how to properly deal with bacteria and fungi. Allison *et al*., 2016; Hameed *et al*., 2021)

One of the most prominent diseases caused by *Candida*: Oral Candidiasis, Vaginal Candidiasis, Esophageal Candidiasis, Cutaneous Candidiasis, Candida UTI and Systemic Candidiasis, most of them are caused by *Candida albicans* (Talapko *et al*., 2021; Di Cosola *et al*., 2021; Lopes & Lionakis 2022; McCarty, *et al*., 2021; Pereira *et al*., 2021)

Dermatophytes

The primary cause of fungal skin diseases is dermatophytes. Species like *Trichophyton*, *Microsporum*, and *Epidermophyton* are among them. Tinea capitis, tinea pedis, tinea corporis, and tinea unguium are among the illnesses they cause. Chanyachailert *et al*., 2023; Durdu & Ilkit 2021; Zorab *et al*., 2023; Achterman & White 2013) Modern classification of dermatophytes has classified them into six pathogenic genera: *Microsporum*, *Trichophyton*, *Epidermophyton*, *Nannizzia*, *Lophophyton*, and *Arthroderma* (Begum *et al*., 2020). These fungi present a growing harm to human health care; research on the physiology, genetics, pathology, and immune response of cutaneous fungi is crucial for the advancement of novel diagnostic methods, treatment regimens, and preventive tactics. (Junior *et al*., 2022). Skin, hair, and nail infections are caused by superficial dermatophyte invasions. Not everyone is equally vulnerable to dermatophyte infections, especially when they have the same risk factors, despite the fact that they are typically linked to external problems like immunosuppression, environmental factors, and contaminated people, things, or surfaces. A genetic tendency to fungal infection exists in certain families, although these skin problems are generally not life-threatening, they are among the most common diseases and disorders in humans. (García-Romero & Arenas 2015; Ortiz *et al*., 2024; White *et al*., 2014)

Histoplasma

The fungus that causes Histoplasmosis, which mainly affects the lungs but can occasionally spread to other organs and it is dimorphic environmental fungus, is called *Histoplasma capsulatum*. Inhaling fungal spores from soil tainted with bat or bird droppings, particularly in moist areas like caves and farms, is how the fungus is spread, *Histoplasma capsulatum var. capsulatum* and *Histoplasma capsulatum* var. duboisii are the two varieties of this fungus (Linder & Kauffman 2019; Tobón & Gómez 2021; Jasim 2015). Although severe disease is more likely to occur in the environment of reduced cellular immunity, the acquisition of the fungus by mammalian hosts can be clinically quiet or result in life-threatening systemic disease. This can happen in hosts that are immunologically robust or deficient. (Mittal *et al*., 2019; Develoux *et al*., 2021). Because *H. capsulatum* yeast cells may successfully live in intracellular niches in specific phagocytic cells, they are highly suited to the mammalian host. (Mittal *et al*., 2019).

Furthermore, mediastinal fibrosis, lymphadenitis, acute or chronic pneumonia, and chronic cavitary lung infection are clinical syndromes commonly linked to histoplasmosis. Another possibility is a disseminated infection, which affects several organ systems. Up to 10% of cases involve histoplasmosis infection of the central nervous system, which can happen with or without widespread infection. (Riddell & Wheat 2019; de Almeida *et al*., 2020.; Graham & Bloch 2025), When this pathogen enters the central nervous system, it can result in potentially fatal damage that are linked to localized lesions (abscesses, histoplasmomas), spinal cord injuries, and meningitis symptoms. (Ramírez *et al*., 2023)

Cryptococcus

For a number of reasons, the scientific community has placed a high value on *Cryptococcus neoformans* among fungal pathogens. This fungus is the cause of cryptococcosis, a condition that manifests as meningoencephalitis and is primarily linked to HIV immunosuppression. Each year, cryptococcal meningitis causes hundreds of thousands of deaths. The pathogenic species of *Cryptococcus* can generate the pigment melanin, grow at body temperature, and form a polysaccharide capsule. Considering the capsular polysaccharides' immunologic characteristics (Zaragoza 2019; Zhao *et al*., 2019; Zhao *et al*., 2023).

Certain parts of the cell wall of Cryptococcus yeasts are extremely immunogenic and trigger humoral and cellular reactions when infected. (Erwig and Gow 2016; Garcia-Rubio *et al*., 2020)

B-Some of Them Are Used in the Production of Some Treatments or Intervention in Various Industries

Those fungi that produce medically important metabolites or can cause the production of identified medically active compounds, including antibiotics, anti-cancer drugs, cholesterol inhibitors, psychotropic substances, immunosuppressive drugs, and even harmful fungicides. (Zheng *et al*., 2010; Wesa *et al*., 2015; Money, N. P. 2016).

Penicillium

The genus *Penicillium* is widespread and found all over the world. Its species are major organic material decomposers. *Penicillium* is a prevalent fungus that may be found in nearly every type of habitat and has a significant economic impact on human life. (Visagie *et al*., 2014; Srinivasan *et al*., 2020). And Alexander Fleming developed the antibiotic penicillin in 1928, and one of its main sources is *Penicillium*. Millions of lives were saved by penicillin, the first antibiotic to be widely used to treat bacterial infections. (Haider, R, 202; Bud, R. 2007; Derderian 2007; Chhabra *et al*., 2024).

Penicillium has industrial use in the production of cheese, where certain varieties are utilized to impart a particular flavor and texture. Another application is in the synthesis of vital enzymes for the food and pharmaceutical industries, which are produced by Penicillium fungus. (Kour *et al*., 2019; Rathnayake *et al*., 2020; Paul & Joshi 2022; Falih *et al*., 2024)

Applying to the environment, *Penicillium* fungi aid in the decomposition of organic materials, which promotes nutrient recycling. Utilizing it as a biopesticide to manage agricultural pests contributes to its role in pest control as well. (Seenivasagan & Babalola 2021; Ferreyra-Suarez, D *et al*., 2024; Hernández-Fernández *et al*., 2021).

Other medications, such cholesterol-lowering statins, are also made with *penicillium*. Since some of its compounds are used to treat immunological diseases, it is also utilized in immunotherapy. For its function in the synthesis of organic acids, it is employed in the production of citric acid, a flavoring and preservative used in the food companies. (Bouhoudan *et al*., 2024; Datta, K., & Hamad 2015; Chávez *et al*., 2012; Schlösser, I., & Prange, A. 2018).

In addition to the medical and economic importance of *Penicillium* fungi, it can cause diseases in some plants. By providing nutrients, particularly soluble P, and plant growth hormones like gibberellic acid and indole-3-acetic acid, many *Penicillium* species have a beneficial interaction with crop plant roots and promote plant growth. Certain species produce antibiotics that have antagonistic effect against plant infections. They also protect plants by triggering various defensive responses and causing systemic resistance (Chávez *et al*., 2006)

Saccharomyces

A common yeast species in the culinary, pharmaceutical, and environmental sectors is

Saccharomyces cerevisiae. At the same time, S. cerevisiae is crucial for many biotechnological uses, some of which have been around for thousands of years. It is the most widely utilized microbe in commerce. The unique biological properties of S. cerevisiae, such as its ability to ferment and produce alcohol and CO2, as well as its resistance to unfavorable osmolarity and low pH conditions, are what make it beneficial for biotechnology. (Parapouli *et al*., 2020; Peris *et al*., 2018; Onyema *et al*., 2023)**,** Numerous industries, including food, brewing, the chemical industry, medicine, and the production of functional foods and food additives, use *Saccharomyces cerevisiae*. (Zhang *et al*., 2022; Massoud *et al*., 2019).

One of the most widely used yeast strains for producing recombinant proteins is *Saccharomyces cerevisiae*, which grows quickly, is relatively manageable, and is tolerant to many genetic modifications. Recombinant human insulin has been made mainly with Saccharomyces cerevisiae for therapeutic application in humans. Recombinant proteins made in yeast are appropriately folded and glycosylated to a degree comparable to that expressed in mammalian cells. (Baeshen *et al*., 2014; *et al*., 2005; Mansur M, *et al.*, 2005; Vajo *et al*., 2001).

Other common Saccharomyces yeasts, such as *Saccharomyces pastorianus, Saccharomyces bayanus,* and *Saccharomyces kudriavzevii*, have also been seen to play a major role in industrial processes. (Krogerus *et al*., 2017)

Trichoderma

Trichoderma is a genus of soilborne, green-spored ascomycetes that are distributed worldwide. One of the fungus that presently has three species' genomes available is *Trichoderma*. The genus's effective biocontrol strains are being developed as potential biological fungicides. The biotechnological workhorse of the genus, *Trichoderma reesei*, produces significant industrial output in the form of cellulases. Along with providing intriguing new insights into the biology of these fungi, genetic engineering has also resulted in notable advancements in their industrial operations. (Schuster, A., & Schmoll 2010)

The genus fungus *Trichoderma* species are economically significant as sources of enzymes, antibiotics, plant growth promoters, xenobiotic decomposers, and commercial biofungicides. Trichoderma has a wide range of uses in both industry and medicine. (Daniel & Rodrigues Filho 2007; Hermosa *et al*., 2012).

For the creation of silver nanoparticles, *Trichoderma reesei* is another excellent option. Numerous areas of medical tissue specialization have found extensive use for metal nanoparticles. (Vahabi & Dorcheh 2014; Herrera Pérez *et al*., 2024).

Malaria, an infectious illness that infects humans and other animals, is spread by mosquitoes. An innovative method of control is the use of *Trichoderma asperellum* as an entomopathogenic fungus against the malaria-carrying Anopheles mosquito. (Podder, D., & Ghosh, S. K. 2019; Vivekanandhan *et al*., 2025).

Tolypocladium Inflatum

The fungus *Tolypocladium inflatum* produced cyclosporine, a cyclic undecapeptide metabolite, which was isolated and structurally characterized in the early 1970s. Cyclosporin A (CsA), an immunosuppressive drug used in organ transplantation, was developed and approved in 1983. Cyclosporin has a wide range of pharmacological characteristics, such as immunosuppressive action, immunosuppressive activity, antiparasitic and antifungal (Bushley *et al*., 2013; *et al*., 2011).

CONCLUSION

As the number of immunocompromised individuals from AIDS, cancer, steroid medication, and chemotherapy has skyrocketed, human fungal pathogens have emerged as a significant medical concern. As a result of human expansion into formerly uninhabited areas and the globalization of travel. Virulence factors for the medically significant fungus were largely unknown until recently. After getting to know some fungi, we found that some beneficial fungi can also cause diseases in plants or humans, in addition to some dangerous and pathogenic fungi. For instance, certain plants may become unwell due to the *Penicillium* fungus. By supplying plant development hormones and nutrients, especially soluble P, it encourages the growth of plants. Antibiotics produced by some species have an antagonistic effect on plant diseases. By inducing systemic resistance and a variety of defensive reactions, it also protects plants.

REFERENCES

- Achterman, R. R., & White, T. C. (2013). Dermatophytes. *Current Biology*, *23*(13), R551-R552.
- Allison, D. L., Willems, H. M., Jayatilake, J. A. M. S., Bruno, V. M., Peters, B. M., & Shirtliff, M. E. (2016). Candida–bacteria interactions: their impact on human disease. *Virulence Mechanisms of Bacterial Pathogens*, 103-136.
- Baeshen, N. A., Baeshen, M. N., Sheikh, A., Bora, R. S., Ahmed, M. M. M., Ramadan, H. A., ... & Redwan, E. M. (2014). Cell factories for insulin production. *Microbial cell factories*, *13*, 1-9.
- Begum, J., Mir, N. A., Lingaraju, M. C., Buyamayum, B., & Dev, K. (2020). Recent advances in the diagnosis of dermatophytosis. *Journal of basic microbiology*, *60*(4), 293-303.

- Bouhoudan, A., Bakkach, J., Khaddor, M., & Mourabit, N. (2024). Anticancer Effect of Mycotoxins From Penicillium aurantiogriseum: Exploration of Natural Product Potential. *International Journal of Microbiology*, *2024*(1), 5553860.
- Bud, R. (2007). *Penicillin: triumph and tragedy*. OUP Oxford.
- Bushley KE, Raja R, Jaiswal P, Cumbie JS, Nonogaki M, Boyd AE, Owensby CA, Knaus BJ, Elser J, Miller D, Di Y, McPhail KL, Spatafora JW. 2013. The genome of *Tolypocladium inflatum*: evolution, organization, and expression of the cyclosporin biosynthetic gene cluster. *PLoS Genet* 9:e1003496.
- Calderone, R. A., & Clancy, C. J. (Eds.). (2011). *Candida and candidiasis*. American Society for Microbiology Press.
- Chamilos, G., Lionakis, M. S., Lewis, R. E., & Kontoyiannis, D. P. (2007). Role of mini-host models in the study of medically important fungi. *The Lancet Infectious Diseases*, *7*(1), 42-55.
- Chanyachailert, P., Leeyaphan, C., & Bunyaratavej, S. (2023). Cutaneous fungal infections caused by dermatophytes and non-dermatophytes: an updated comprehensive review of epidemiology, clinical presentations, and diagnostic testing. *Journal of Fungi*, *9*(6), 669.
- Chávez, R., Bull, P., & Eyzaguirre, J. (2006). The xylanolytic enzyme system from the genus Penicillium. *Journal of biotechnology*, *123*(4), 413-433.
- Chávez, R., Fierro, F., Rico, R. O. G., & Laich, F. (2012). Mold-fermented foods: Penicillium spp. as ripening agents in the elaboration of cheese and meat products. In *Mycofactories* (pp. 73-98). Bentham Science Publishers.
- Chhabra, S., Taksande, A. B., & Munjewar, P. (2024). The penicillin pioneer: Alexander Fleming's journey to a medical breakthrough. *Cureus*, *16*(7).
- Dagenais, T. R., & Keller, N. P. (2009). Pathogenesis of Aspergillus fumigatus in invasive aspergillosis. *Clinical microbiology reviews*, *22*(3), 447-465.
- Daniel, J. F. D. S., & Rodrigues Filho, E. (2007). Peptaibols of trichoderma. *Natural Product Reports*, *24*(5), 1128-1141.
- Datta, K., & Hamad, M. (2015). Immunotherapy of fungal infections. *Immunological investigations*, *44*(8), 738-776.
- de Almeida, S. M., Imano, E. C., Vicente, V. A., Gomes, R. R., Trentin, A. P., Zamarchi, K., ... & de Hoog, G. S. (2020). Primary central nervous system infection by Histoplasma in an immunocompetent adult. *Mycopathologia*, *185*, 331-338.
- Derderian, S. L. (2007). Alexander Fleming's miraculous discovery of Penicillin. *Rivier academic journal*, *3*(2), 1-5.
- Develoux, M., Amona, F. M., & Hennequin, C. (2021). Histoplasmosis caused by Histoplasma capsulatum var. duboisii: a comprehensive review of cases from 1993 to 2019. *Clinical infectious diseases*, *73*(3), e543-e549.
- Di Cosola, M., Cazzolla, A. P., Charitos, I. A., Ballini, A., Inchingolo, F., & Santacroce, L. (2021). Candida albicans and oral carcinogenesis. A brief review. *Journal of Fungi*, *7*(6), 476.
- Drummond, R. A., Gaffen, S. L., Hise, A. G., & Brown, G. D. (2015). Innate defense against fungal pathogens. *Cold Spring Harbor perspectives in medicine*, *5*(6), a019620\
- Durdu, M., & Ilkit, M. (2021). Dermatophytic infections: a group of imitator diseases. *Ankara: Akademisyen Kitabevi*, 59-112.
- Enyiukwu, D. N., Ononuju, C. C., & Maranzu, J. O. (2018). Plant pathogenic fungi–Novel agents of human diseases: Implications for public health. *Greener J Epidemiol Public Health*, *6*(1), 001-019.
- Erwig, L. P., and Gow, N. A. (2016). Interactions of fungal pathogens with phagocytes. *Nat. Rev. Microbiol.* 14, 163–176. doi: 10.1038/nrmicro.2015.21
- Falih, M. A., Altemimi, A. B., ALKaisy, Q. H., Awlqadr, F. H., Abedelmaksoud, T. G., Amjadi, S., & Hesarinejad, M. A. (2024). Enhancing safety and quality in the global cheese industry: A review of innovative preservation techniques. *Heliyon*.
- Ferreyra-Suarez, D., García-Depraect, O., & Castro-Muñoz, R. (2024). A review on fungal-based biopesticides and biofertilizers production. *Ecotoxicology and Environmental Safety*, *283*, 116945.
- García-Romero, M. T., & Arenas, R. (2015). New insights into genes, immunity, and the occurrence of dermatophytosis. *Journal of Investigative Dermatology*, *135*(3), 655-657.
- Garcia-Rubio, R., de Oliveira, H. C., Rivera, J., & Trevijano-Contador, N. (2020). The fungal cell wall: Candida, Cryptococcus, and Aspergillus species. *Frontiers in microbiology*, *10*, 2993.
- Gilbert, A. S., Wheeler, R. T., & May, R. C. (2015). Fungal pathogens: survival and replication within macrophages. *Cold Spring Harbor perspectives in medicine*, *5*(7), a019661.
- Graham, B., & Bloch, K. C. (2025). Central nervous system infection due to Histoplasma capsulatum. In *Neurobiology of Infectious Diseases* (pp. 497-504). Academic Press.)
- Haider, R. (2023). Penicillin and the antibiotics revolution global history. *Asian Journal of Pharmaceutical Research*, *13*(1), 55-62.
- Hameed, S., Hans, S., Monasky, R., Thangamani, S., & Fatima, Z. (2021). Understanding human microbiota offers novel and promising therapeutic options against Candida infections. *Pathogens*, *10*(2), 183.

- Hawksworth, D. L. (2001). The magnitude of fungal diversity: the 1· 5 million species estimate revisited. *Mycological research*, *105*(12), 1422-1432.
- Heitman, J., Filler, S.G., and Mitchell, A.P. eds. (2006). Molecular Principles of Fungal Pathogenesis (Washington DC: ASM Press)
- Hermosa, R., Viterbo, A., Chet, I., & Monte, E. (2012). Plant-beneficial effects of Trichoderma and of its genes. *Microbiology*, *158*(1), 17-25
- Hernández-Fernández, M., Cordero-Bueso, G., Ruiz-Muñoz, M., & Cantoral, J. M. (2021). Culturable yeasts as biofertilizers and biopesticides for a sustainable agriculture: a comprehensive review. *Plants*, *10*(5), 822.
- Herrera Pérez, G. M., Castellano, L. E., & Ramírez Valdespino, C. A. (2024). Trichoderma and mycosynthesis of metal nanoparticles: role of their secondary metabolites. *Journal of Fungi*, *10*(7), 443.
- Hyde, K. D., Al-Hatmi, A. M., Andersen, B., Boekhout, T., Buzina, W., Dawson, T. L., ... & Tsui, C. K. (2018). The world's ten most feared fungi. *Fungal Diversity*, *93*, 161-194.
- Jain, A., Jain, S., & Rawat, S. (2010). Emerging fungal infections among children: A review on its clinical manifestations, diagnosis, and prevention. *Journal of Pharmacy and Bioallied Sciences*, *2*(4), 314-320.
- Jasim ,N.,2015.detection of Histoplasma capsulatum in bats dropping by using Polymerase chain reaction (PCR)at the first time in Iraq .journal of natural sciences research ,5,pp.57-59.
- Junior, D. C., Ramos, M. L. M., Almeida-Paes, R., & Frases, S. (2022). New Insights in Dermatophytes: Microsporum spp. and Nannizzia spp. *Current Tropical Medicine Reports*, *9*(1), 15-27.
- Köhler, J. R., Casadevall, A., & Perfect, J. (2015). The spectrum of fungi that infects humans. *Cold Spring Harbor perspectives in medicine*, *5*(1), a019273.
- Köhler, J. R., Hube, B., Puccia, R., Casadevall, A., & Perfect, J. R. (2017). Fungi that infect humans. *Microbiology spectrum*, *5*(3), 10-1128.
- Kour, D., Rana, K. L., Yadav, N., Yadav, A. N., Singh, J., Rastegari, A. A., & Saxena, A. K. (2019). Agriculturally and industrially important fungi: current developments and potential biotechnological applications. *Recent advancement in white biotechnology through fungi: Volume 2: Perspective for value-added products and environments*, 1-64.
- Krijgsheld, P., Bleichrodt, R. V., Van Veluw, G. J., Wang, F., Müller, W. H., Dijksterhuis, J., & Wösten, H. A. B. (2013). Development in aspergillus. *Studies in mycology*, *74*(1), 1-29.
- Krogerus, K., Magalhães, F., Vidgren, V., & Gibson, B. (2017). Novel brewing yeast hybrids: creation and application. *Applied Microbiology and Biotechnology*, *101*, 65-78.
- Lass-Flörl, C., Kanj, S. S., Govender, N. P., Thompson III, G. R., Ostrosky-Zeichner, L., & Govrins, M. A. (2024). Invasive candidiasis. *Nature Reviews Disease Primers*, *10*(1), 20.
- Latgé, J. P., & Chamilos, G. (2019). Aspergillus fumigatus and Aspergillosis in 2019. *Clinical microbiology reviews*, *33*(1), 10-1128.
- Linder, K. A., & Kauffman, C. A. (2019). Histoplasmosis: epidemiology, diagnosis, and clinical manifestations. *Current Fungal Infection Reports*, *13*, 120-128.
- Liolios, K., Mavromatis, K., Tavernarakis, N., and Kyrpides, N.C. (2008). The Genomes On Line Database (GOLD). Nucleic Acids Res. 36, D475–D479
- Lopes, J. P., & Lionakis, M. S. (2022). Pathogenesis and virulence of Candida albicans. *Virulence*, *13*(1), 89-121.
- Mansur M, Cabello C, Hernandez L, Pais J, Varas L, Valdes J, Terrero Y, Hidalgo A, Plana L, Besada V, Garcia L, Lamazares E, Castellanos L, Martinez E: Multiple gene copy number enhances insulin precursor secretion in the yeast Pichia pastoris. Biotechnol Lett. 2005, 27: 339-345. 10.1007/s10529-005-1007-7.
- Massoud, R., Hadiani, M. R., Hamzehlou, P., & Khosravi-Darani, K. (2019). Bioremediation of heavy metals in food industry: Application of Saccharomyces cerevisiae. *Electronic Journal of Biotechnology*, *37*, 56-60.
- Mavor, A. L., Thewes, S., & Hube, B. (2005). Systemic fungal infections caused by Candida species: epidemiology, infection process and virulence attributes. *Current drug targets*, *6*(8), 863-874.
- McCarty, T. P., White, C. M., & Pappas, P. G. (2021). Candidemia and invasive candidiasis. *Infectious Disease Clinics*, *35*(2), 389-413.
- Mittal, J., Ponce, M. G., Gendlina, I., & Nosanchuk, J. D. (2019). Histoplasma capsulatum: mechanisms for pathogenesis. *Fungal Physiology and Immunopathogenesis*, 157-191.
- Money, N. P. (2016). Fungi and biotechnology. In *The fungi* (pp. 401-424). Academic Press
- Onyema, V. O., Amadi, O. C., Moneke, A. N., & Agu, R. C. (2023). A Brief Review: Saccharomyces cerevisiae biodiversity potential and promising cell factories for exploitation in biotechnology and industry processes–West African Natural yeasts contribution. *Food Chemistry Advances*, *2*, 100162.
- Ortiz, B., Ballesteros-Monrreal, M. G., Rosales-Tamashiro, J., Bush, M., Salmanton-García, J., & Fontecha, G. (2024). Global Insights and Trends in Research on Dermatophytes and Dermatophytosis: A Bibliometric Analysis. *Mycoses*, *67*(10), e13803.

- Parapouli, M., Vasileiadis, A., Afendra, A. S., & Hatziloukas, E. (2020). Saccharomyces cerevisiae and its industrial applications. *AIMS microbiology*, *6*(1), 1.
- Paul, S., & Joshi, S. R. (2022). Industrial perspectives of fungi. In *Industrial Microbiology and Biotechnology* (pp. 81-105). Singapore: Springer Singapore
- Pereira, R., dos Santos Fontenelle, R. O., De Brito, E. H. S., & De Morais, S. M. (2021). Biofilm of Candida albicans: formation, regulation and resistance. *Journal of applied microbiology*, *131*(1), 11-22.
- Pfliegler, W. P., Pócsi, I., Győri, Z., & Pusztahelyi, T. (2020). The Aspergilli and their mycotoxins: Metabolic interactions with plants and the soil biota. *Frontiers in microbiology*, *10*, 2921.
- Plascencia-Jatomea, M., Susana, M., Gómez, Y., & Velez-Haro, J. M. (2014). Aspergillus spp.(Black mold). In *Postharvest decay* (pp. 267-286). Academic Press.
- Podder, D., & Ghosh, S. K. (2019). A new application of Trichoderma asperellum as an anopheline larvicide for eco friendly management in medical science. *Scientific reports*, *9*(1), 1108.
- Polke, M., Hube, B., & Jacobsen, I. D. (2015). Candida survival strategies. *Advances in Applied Microbiology*, *91*, 139-235.
- Porro D, Sauer M, Branduardi P, Mattanovich D: Recombinant protein production in yeasts. Mol Biotechnol. 2005, 31: 245-259. 10.1385/MB:31:3:245.
- Ramírez, J. A., Reyes-Montes, M. D. R., Rodríguez-Arellanes, G., Pérez-Torres, A., & Taylor, M. L. (2023). Central nervous system histoplasmosis: an updated insight. *Pathogens*, *12*(5), 681.
- Rathnayake, A. U., Saravanakumar, K., Abuine, R., Abeywickrema, S., Kathiresan, K., MubarakAli, D., ... & Wang, M. H. (2020). Fungal genes encoding enzymes used in cheese production and fermentation industries. *Fungal Biotechnology and Bioengineering*, 305-329.
- Riddell IV, J., & Wheat, L. J. (2019). Central nervous system infection with Histoplasma capsulatum. *Journal of Fungi*, *5*(3), 70.
- Romani, L. (2011). Immunity to fungal infections. *Nature Reviews Immunology*, *11*(4), 275-288.
- Roszell, E., & Olmstead, C. (2014). A fungus in the haystack: An unusual pediatric case of otomycosis from a rural farming area. *University of Western Ontario Medical Journal*, *83*(1), 56-57.
- Rudramurthy, S. M., Paul, R. A., Chakrabarti, A., Mouton, J. W., & Meis, J. F. (2019). Invasive aspergillosis by Aspergillus flavus: epidemiology, diagnosis, antifungal resistance, and management. *Journal of Fungi*, *5*(3), 55.
- Schaechter, M. (Ed.). (2012). *Eukaryotic microbes*. Academic Press.
- Schlösser, I., & Prange, A. (2018). Antifungal activity of selected natural preservatives against the foodborne molds Penicillium verrucosum and Aspergillus westerdijkiae. *FEMS Microbiology Letters*, *365*(13), fny125.
- Schuster, A., & Schmoll, M. (2010). Biology and biotechnology of Trichoderma. *Applied microbiology and biotechnology*, *87*, 787-799.
- Seenivasagan, R., & Babalola, O. O. (2021). Utilization of microbial consortia as biofertilizers and biopesticides for the production of feasible agricultural product. *Biology*, *10*(11), 1111.
- Seyedmousavi, S., Bosco, S. D. M., De Hoog, S., Ebel, F., Elad, D., Gomes, R. R., ... & Guillot, J. (2018). Fungal infections in animals: a patchwork of different situations. *Medical mycology*, *56*(suppl_1), S165-S187.
- Sharma, P., Javeria, S., Deep, S., Sharma, M., & Manokaran, R. (2021). Diagnosis and Diversity Analysis of Alternaria brassicae and A. brassicicola in Vegetable Cruciferous Crops. *Innovative Approaches in Diagnosis and Management of Crop Diseases*, 325-363.
- Sheppard, D. C., & Filler, S. G. (2015). Host cell invasion by medically important fungi. *Cold Spring Harbor perspectives in medicine*, *5*(1), a019687.
- Srinivasan,R., Prabhu, G., Prasad, M., Mishra, M., Chaudhary, M., & Srivastava, R. (2020). Penicillium. In *Beneficial Microbes in Agro-Ecology* (pp. 651-667). Academic Press.Penicillium. *Studies in mycology*, *78*(1), 343-371.
- Stajich, J. E., Berbee, M. L., Blackwell, M., Hibbett, D. S., James, T. Y., Spatafora, J. W., & Taylor, J. W. (2009). The fungi. *Current Biology*, *19*(18), R840-R845.
- Survase SA, Kagliwal LD, Annapure US, Singhal RS. 2011. Cyclosporin A—a review on fermentative production, downstream processing and pharmacological applications. *Biotechnol Adv* 29:418–435.
- Talapko, J., Juzbašić, M., Matijević, T., Pustijanac, E., Bekić, S., Kotris, I., & Škrlec, I. (2021). Candida albicans—the virulence factors and clinical manifestations of infection. *Journal of Fungi*, *7*(2), 79.
- Taylor, J. W., Turner, E., Townsend, J. P., Dettman, J. R., & Jacobson, D. (2006). Eukaryotic microbes, species recognition and the geographic limits of species: examples from the kingdom Fungi. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *361*(1475), 1947-1963.
- Tobón, A. M., & Gómez, B. L. (2021). Pulmonary histoplasmosis. *Mycopathologia*, *186*(5), 697-705.
- Vahabi, K., & Dorcheh, S. K. (2014). Biosynthesis of silver nano-particles by Trichoderma and its medical applications. In *Biotechnology and biology of Trichoderma* (pp. 393-404). Elsevier.

- Vajo, Z., Fawcett, J., & Duckworth, W. C. (2001). Recombinant DNA technology in the treatment of diabetes: insulin analogs. *Endocrine reviews*, *22*(5), 706-717.
- Visagie, C. M., Houbraken, J., Frisvad, J. C., Hong, S. B., Klaassen, C. H. W., Perrone, G., ... & Samson, R. A. (2014). Identification and nomenclature of the genus
- Vivekanandhan, P., Alarfaj, A. A., Alfarraj, S., Ansari, M. J., & Kamaraj, C. (2025). Biocontrol toxicity of Trichoderma harzianum (Hypocreales: Hypocreaceae) derived chemical molecules against malarial mosquito Anopheles stephensi with molecular docking studies. *Biotechnology Letters*, *47*(1), 1-19.
- Webster, J., & Weber, R. (2007). *Introduction to fungi*. Cambridge university press.
- Wesa, K. M., Cunningham-Rundles, S., Klimek, V. M., Vertosick, E., Coleton, M. I., Yeung, K. S., ... & Cassileth, B. R. (2015). Maitake mushroom extract in myelodysplastic syndromes (MDS): a phase II study. *Cancer Immunology, Immunotherapy*, *64*, 237-247.
- White, T. C., Findley, K., Dawson, T. L., Scheynius, A., Boekhout, T., Cuomo, C. A., ... & Saunders, C. W. (2014). Fungi on the skin: dermatophytes and Malassezia. *Cold spring harbor perspectives in medicine*, *4*(8), a019802.
- Zakaria, L. (2024). An overview of Aspergillus species associated with plant diseases. *Pathogens*, *13*(9), 813.
- Zaragoza, O. (2019). Basic principles of the virulence of Cryptococcus. *Virulence*, *10*(1), 490-501.
- Zhang, Y., Qiu, X. M., Sun, H., Guo, L., & Hong, H. S. (2022). The industrial applications of Saccharomyces cerevisiae. ;
- Zhao, Y., Lin, J., Fan, Y., & Lin, X. (2019). Life cycle of Cryptococcus neoformans. *Annual review of microbiology*, *73*(1), 17-42.
- Zhao, Y., Ye, L., Zhao, F., Zhang, L., Lu, Z., Chu, T., ... & Wang, L. (2023). Cryptococcus neoformans, a global threat to human health. *Infectious Diseases of Poverty*, *12*(02), 1-18.
- Zheng, W., Miao, K., Liu, Y., Zhao, Y., Zhang, M., Pan, S., & Dai, Y. (2010). Chemical diversity of biologically active metabolites in the sclerotia of Inonotus obliquus and submerged culture strategies for up-regulating their production. *Applied microbiology and biotechnology*, *87*, 1237-1254.
- Zorab, H. K., Amin, S. Q., Mahmood, H. J., Mustafa, H. H., & Abdulrahman, N. M. A. (2023). Dermatophytosis. *One Health Triad*, *3*, 99-106.