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Microbiological biotechnological interventions for mushroom improvement: A comprehensive review

Ashishkumar G. Vala *

Department of Biotechnology, Junagadh Agricultural University, Junagadh-362001, Gujarat, India.

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Abstract

The scope of this comprehensive review is to explore the multifaceted landscape of microbiological biotechnological interventions within the domain of mushroom cultivation. By investigating pivotal aspects such as mycorrhizal symbiosis, biological control agents, substrate microbiota, disease suppression, nutrient cycling, bioremediation, and microbial consortia, this paper sheds light on the integral role of microorganisms in influencing the development, productivity, and caliber of cultivated mushroom

Keywords: Biotechnological; Disease suppression; Microbiological; Mushroom cultivation; Mycorrhizal symbiosis

1. Introduction

Mushroom cultivation, once confined to age-old traditional practices, has undergone a profound transformation, evolving into a vibrant and dynamic industry that carries far-reaching socio-economic implications (1). The cultivation of mushrooms has transcended its humble origins, assuming a pivotal role in addressing various nutritional challenges, generating livelihood opportunities, and promoting sustainable agricultural practices. This review aims to shed light on the intricate interplay between microorganisms and biotechnological strategies within the context of mushroom cultivation—a domain that holds immense potential for mushroom improvement (2). Mushrooms, often celebrated for their culinary attributes and unique flavors, possess qualities that extend far beyond their taste. They are increasingly recognized as functional foods that can tackle malnutrition and nutritional deficiencies(3). Rich in essential nutrients, mushrooms offer a source of high-quality proteins, vitamins, and minerals. Their inclusion in diets can contribute to combating protein-energy malnutrition and mitigating deficiencies in vital micronutrients(4). Furthermore, mushrooms are heralded for their medicinal properties, as they contain bioactive compounds with potential health benefits. As the demand for nutrient-rich food grows, mushrooms offer an alternative source to conventional staples. Beyond their nutritional contributions, mushroom cultivation has demonstrated the potential to uplift rural economies and create sustainable livelihoods(5). The adaptability of mushroom cultivation to various environmental conditions and relatively low capital requirements makes it an accessible option for small-scale farmers and marginalized communities. This, in turn, empowers local economies and enhances food security(6). The cultivation of mushrooms also has the capacity to mitigate environmental challenges. It involves recycling agricultural residues and organic waste materials as substrates, reducing the burden of waste disposal and contributing to a circular economy. The contemporary mushroom industry is, however, not devoid of challenges(7). Ensuring consistent and high-quality mushroom production remains a goal, necessitating innovative approaches. This is where microorganisms and biotechnological interventions come into play. Microorganisms, including bacteria, fungi, and yeasts, are integral to mushroom ecosystems. They influence growth, development, and health through intricate interactions with mushroom mycelium. Harnessing these interactions through biotechnological strategies can offer a suite of benefits for mushroom improvement. Biotechnological interventions encompass a range of practices, from traditional methods to cutting-edge

* Corresponding author: Ashish Vala

techniques(8). Beneficial microorganisms can be employed to enhance disease resistance, improve nutrient availability, and promote growth. The use of microbial consortia in substrate preparation can optimize composting processes and eventually influence mushroom yield and quality. Biotechnological tools(9), such as genetic engineering(10) and molecular breeding(11), hold potential for developing novel mushroom varieties with improved traits, such as increased yield, enhanced flavor, and enhanced resistance to pathogens. The utilization of microbial communities in mushroom cultivation extends beyond production enhancements(12). Mycorrhizal associations, for instance, can improve soil structure, enhance nutrient uptake, and contribute to the overall health of agricultural ecosystems. These associations exemplify the intricate web of interactions that underpin the success of mushroom cultivation. Research into understanding and manipulating these interactions can lead to breakthroughs in sustainable agricultural practices and ecosystem management.

1.1. Mycorrhizal Symbiosis

Mycorrhizal fungi form intricate symbiotic relationships with plant roots, including those of mushrooms. This section delves into the mechanisms of mycorrhizal interactions, emphasizing the mutualistic exchange of nutrients between the fungus and the host plant. The potential benefits of incorporating mycorrhizal fungi into mushroom cultivation are discussed, highlighting enhanced nutrient absorption, particularly phosphorus, which is crucial for optimal mushroom growth(13).

1.2. Biological Control Agents

Biocontrol agents, such as Trichoderma and Bacillus species, play an essential role in managing fungal pathogens that threaten mushroom crops. This section provides an in-depth exploration of the mechanisms underlying the antagonistic interactions between biocontrol agents and pathogens. It underscores the promise of biological control as a sustainable alternative to chemical fungicides, contributing to disease management and crop protection(14).

2. Composting and Substrate Microbiota

Microbial communities underpin the composting process, converting organic matter into nutrient-rich substrates. This section investigates the dynamic interplay between microorganisms during composting, emphasizing the significance of microbial diversity in creating substrates conducive to mushroom growth. The intricate relationships between microorganisms and substrate properties are highlighted, shaping the foundation for successful cultivation(15).

2.1. Disease Suppression and Biofungicides

Microbial-derived biofungicides serve as effective tools in mitigating fungal diseases in mushroom crops. The detailed mechanisms by which biofungicidal compounds are produced by microorganisms are explained. This section presents case studies illustrating the potential of biofungicides in suppressing pathogens, providing real-world examples of their application in safeguarding mushroom yield and quality(16).

2.2. Nutrient Cycling and Decomposition

Microorganisms contribute to nutrient cycling and organic matter decomposition, essential processes for providing essential elements to mushroom mycelium. This section explores the microbial-driven breakdown of complex organic compounds, releasing nitrogen, carbon, and other nutrients crucial for mushroom growth. It showcases studies that emphasize the dynamic relationships between microorganisms, substrate decomposition, and nutrient availability(17).

2.3. Biodegradation of Agricultural Residues

Certain mushroom species possess the remarkable ability to degrade lignocellulosic agricultural residues. The potential for utilizing these fungi to transform crop residues into substrates for mushroom cultivation is explored in-depth. Case studies demonstrate the biotechnological applications of these fungi, illustrating their role in converting waste into a valuable resource for sustainable mushroom production(18).

2.4. Bioremediation Potential

Mushrooms exhibit an intriguing capacity to accumulate heavy metals and pollutants, presenting opportunities for bioremediation. This section delves into the mechanisms by which mushrooms can extract contaminants from soil environments, thereby aiding in environmental cleanup. Real-world examples highlight the potential of mushroom-based bioremediation as a dual-purpose approach, offering both waste management and edible mushroom production(19).

2.5. Microbial Consortia for Enhanced Yield

The concept of assembling microbial consortia to synergistically enhance mushroom yield takes center stage. This section dissects the rationale behind designing microbial partnerships, showcasing how complementary functions, such as nutrient mobilization and disease suppression, are harnessed to amplify mushroom cultivation outcomes. Studies exemplifying the benefits of microbial consortia provide concrete evidence of their potential(20).

2.6. Challenges and Future Directions

While the promise of microbiological biotechnological interventions is substantial, challenges exist. This section addresses the complexities of implementation, including regulatory considerations and the need for tailored approaches. Looking forward, the discussion extends to potential frontiers such as genetic engineering and precision manipulation of microbial communities, underscoring the evolving landscape of mushroom biotechnology(21).

3. Conclusion

The review culminates in a synthesized overview of the multifaceted contributions of microbiological biotechnological interventions to mushroom cultivation. It reiterates the importance of microorganisms in shaping the industry's future and underscores the imperative for continued interdisciplinary collaboration to unlock the full potential of these interventions.

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