

TRENDS IN MUSHROOM CULTIVATION AND BREEDING

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Introduction

Over the past few decades, the cultivation of mushrooms has presented a unique combination of agriculture, biotechnology, and sustainability. With the increasing recognition of mushrooms as valuable sources of nutrition, pharmaceuticals, and bioremediation agents, the industry has embraced innovative trends in cultivation and breeding technologies (Tarafder et al., 2024). This article explores the latest trends in mushroom cultivation and breeding, emphasizing technological advancements, sustainability efforts, and emerging market dynamics.

Advances in Cultivation Techniques

1. Substrate Innovation

Substrates are the medium in which mushrooms grow, and the development of new substrates has been central to improving yields and sustainability (Kousar et al., 2024). Conventional substrates such as straw and sawdust are being replaced or supplemented by agricultural byproducts such as coffee ground, rice bran, and sugarcane bagasse. These alternative substrates not only enhance the nutritional quality of mushrooms but also effectively contribute to

waste reduction activities within agricultural circles (Ravlikovsky et al., 2024). Current studies have demonstrated that species such as *Pleurotus ostreatus* grow successfully on coffee waste and thus have economic and ecological benefits (Dedousi et al., 2024; Hultberg et al., 2023).

2. Controlled environment agriculture (CEA)

Since its acceptance, the adoption of CEA technology has significantly and profoundly changed mushroom cultivation. The latest climate control systems enable the maintenance of very subtle conditions involving temperature, humidity, and CO₂ concentrations. This means that mushroom cultivators can achieve ideal conditions throughout all seasons. With this, it would be possible to do that consistently, regardless of the outside conditions being unfavorable (Grant et al., 2023). This specific technique not only facilitates maximum production per square foot of land but also enables many specific varieties of mushrooms whose growth and yield requirements are especially particular and specific and must be met to achieve optimal growth and yield

(Whitmore, 2024). Mushroom farming is increasingly being adopted and encouraged through vertical farms as global concern and momentum toward indoor farming grow and build. This will enable producers to meet the increased demand from consumers in the city while decreasing the amount of land that must be dedicated to and used for agricultural purposes.

3. Automation and Smart Farming

Indeed, advancements in automation technology, especially its agricultural applications, have been particularly prevalent in mushroom cultivation practices. Specifically, automated systems, which are customized for monitoring growth-related conditions and control the lifecycle of mushroom cultivation in general, have evolved into important resources that have come to rely significantly on these tools. Sensors, complex data analytics, and all appropriate calculations are utilized for keeping close tabs on major factors such as humidity, temperature, and substrate moisture levels. Such tight surveillance of all these conditions keeps them optimal and conducive to growing and developing mushrooms. Advanced IoT technology capabilities enable emergent smart farming techniques that are fundamentally important in the collection of real-time data. This capability enhances the decision-making processes of farmers and agricultural professionals, leading to higher yields from their crops (Omar et al., 2024; Sangeetha et al., 2024). Robotics has also increasingly been applied in the harvesting processes of agriculture, reducing labor costs and minimizing the potential for human error in such operations (Huang et al., 2021).

Breeding Innovations

1. Genetic improvement through biotechnology

Breeding in the field has improved much with respect to mushrooms, especially by employing biotechnology techniques, such as molecular markers and even genetic modifications, to increase desirable qualities, such as increased yield with resistance to disease but nutritional value. More recent studies have proven that it is possible to use CRISPR gene editing technology for the production of mutated strains of edible mushrooms. Thus, there is a possibility of developing varieties with improved characteristics, such as low sensitivity to pathogens and accelerated growth rates (Jain et al., 2024).

2. Hybridization Techniques

Hybridization remains the most integral technique for mushroom production, as it can create new strains, with features that make them extraordinary. Scientists have even been able to produce hybrids that present enhanced flavor profiles, improved nutritional content, and better adaptability to various substrates by crossing different species or strains (Barh et al., 2019; Kamal et al., 2021). The results of the present study support the study of hybrid vigor in species of mushrooms, from which critical information will be gathered into breeding programs that target yield and robustness.

3. Focus on Medicinal Mushrooms

With the renewed interest in health and wellness on the part of the consumer, there is emerging demand to breed medicinal mushrooms. Among such species are Reishi, *Ganoderma lucidum*; Lion's Mane, *Hericium erinaceus*; and Turkey Tail, *Trametes versicolor*, which are believed to

have potential health benefits through immune enhancement and anti-inflammatory processes (Vunduk et al., 2022). The current breeding programs have shifted toward the enhancement of medicinal properties through the creation of more bioactive compounds inside the plant, such as polysaccharides and triterpenoids. This has an impact on the culinary business arena within markets and affects the pharmaceutical sector (El-Saadony et al., 2023).

Sustainability and Environmental Awareness

1. Organic Cultivation Practices

With increasing consumer awareness of the origin and production of foods, organic mushroom production has become one of the most important emerging trends. Organic practices always restrict all substrates and their cultivation processes from synthetic applications of chemical fertilizers and pesticides. This makes organic mushrooms more appealing to health-conscious consumers and in combination with larger objectives for agricultural sustainability (El-Saadony et al., 2023; Thakur, 2020). An increasing number of producers seek organic certificates and differentiate their products within the market, thereby attaining a segment willing to pay a premium to organic offerings.

2. Mycoremediation

Fungi are generally well advertised as saprophytic species, mainly in the breakdown of organic pollutants that abound within the environment. Mycoremediation has been coined for this process. Recently, interest in sustainable agriculture and environmental restoration has increased. They are scouting for various species of fungi to break down

contaminants in water and soil; therefore, more effective strategies for their commercialization are being developed (Antunes et al., 2020; Yadav, 2021). The increased concerns about environmental issues may make the best scenario for both the environment and the mushroom industry when fungi are used for bioremediation.

Conclusion

The field of mushroom cultivation and breeding is undergoing a renaissance characterized by innovative cultivation techniques, advanced breeding methodologies, and a strong emphasis on sustainability. Technological change, which manifests in everything from substrate innovation to automation and biotechnological approaches in breeding, is changing the landscape of this industry. Additionally, there are growing concerns and needs for health benefits in public awareness, with a resulting demand for market sources of sustainably cultivated yet genetically optimized mushrooms. Mushroom growth and cultivation look more promising in the near future, with considerable potential for growth in the international market.