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Button Mushroom Farming: A Critical Review

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Button mushroom (*Agaricus bisporus*) stands as the most widely cultivated edible mushroom globally, owing to its nutritional value, rapid growth cycle, and adaptability to various substrates. This review explores various aspects of button mushroom production, including cultivation methods, substrate utilization, pest and disease management, and socio-economic impacts. The cultivation process is systematically categorized into composting, spawning, casing, and crop management. Pest and disease management remains a critical component, with challenges like Verticillium dry bubble and green mould affecting yield and quality. Economically, button mushroom farming has demonstrated significant potential, especially for small-scale and marginal farmers. Studies indicate that with appropriate training and access to quality inputs, farmers can achieve substantial returns, thereby improving their socio-economic status. Nutritionally, they are low in calories and high in essential nutrients, including B-vitamins, minerals like potassium and phosphorus, and dietary fiber, contributing to heart health, immune support, and metabolic function.

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Medicinally, button mushrooms possess antioxidant, anti-inflammatory, and anticancer properties, with bioactive compounds like ergothioneine and polysaccharides showing potential in disease prevention and treatment. Economically, button mushroom farming offers profitability, especially for small-scale farmers, by providing a sustainable source of income and contributing to rural development. This review underscores the multifaceted value of button mushrooms and highlights the need for continued research to optimize cultivation practices, enhance medicinal applications, and improve postharvest handling to meet global demand.

Keywords: Button mushroom; farming; fungi; nutritional value.

1. INTRODUCTION

Mushrooms are macro fungi belonging to the kingdom Fungi, with some species being edible and others toxic or inedible. While thousands of fungal species exist in nature, only a subset is considered safe for human consumption (Rathod, 2021 and Gadade & Rathod, 2021). Button mushrooms (*Agaricus bisporus*) belong to the phylum Basidiomycota. As a member of this phylum, they reproduce through basidiospores, which are formed on specialized structures called basidia. This classification places button mushrooms among other fungi that develop fruiting bodies, commonly known as mushrooms. Within Basidiomycota, *Agaricus bisporus* falls under the class Agaricomycetes, order Agaricales, and family Agaricaceae. Their biological classification highlights their role in decomposition and nutrient cycling in ecosystems, while their edible nature makes them one of the most commercially cultivated fungi worldwide.

The most widely known and extensively cultivated variety of button mushroom is *Agaricus bisporus*. However, this species includes several different varieties and strains. Broadly, button mushrooms are classified into two main types based on their color: white and brown. Their names also vary depending on their growth stage. In their immature form, they are commonly called white or creamy mushrooms, while at maturity, when their caps and gills fully open, they are referred to as Portobello mushrooms (Chakravarty, 2011).

Since ancient times, mushrooms have been valued for their nutritional benefits and therapeutic properties. They were believed to support overall health, strengthen the body, and promote longevity. Mushrooms were commonly used both as food and as a natural remedy for various ailments. Mushrooms have been recognized as a valuable food source due to their rich nutritional content and medicinal properties. They are a natural source of proteins, vitamins, minerals, and antioxidants, making them beneficial for overall health. In traditional Chinese medicine, mushrooms were believed to enhance vitality, strengthen the immune system, and slow the aging process. Certain varieties, such as *Ganoderma lucidum* (Reishi) and *Lentinula edodes* (Shiitake), were especially prized for their healing properties and were used in herbal medicine to treat various ailments. Across different cultures, mushrooms have played a significant role in both culinary and medicinal practices, highlighting their importance in human history (Safwat & Al Kholi, 2006). *Agaricus bisporus* is known for its strong biological activity, low toxicity, and significant importance in traditional medicine and ethnopharmacology. Beyond its role as a popular food ingredient, it is also used in the production of beverages. Additionally, it has applications in the perfume, cosmetic, and pharmaceutical industries due to its beneficial properties (Caglarırmak, 2009; Dastager, 2009). Wild *Agaricus bisporus* has been favored by consumers for its rich flavor and texture. It is known to contain numerous primary and secondary metabolites that contribute to its therapeutic properties. These bioactive compounds have been reported to play a role in the prevention and treatment of various diseases, including cancer, hyperlipidemia, microbial infections, cardiovascular conditions, liver disorders, and immune system deficiencies (Sadiq *et al.,* 2008).

2. THE POTENTIAL FOR MUSHROOM FARMING IN INDIA

Mushroom cultivation in India has evolved significantly over the decades, transitioning from experimental endeavors to a thriving agricultural sector contributing to rural livelihoods, nutritional enhancement, and economic development. The initial foray into mushroom cultivation in India can be traced back to 1943 when Thomas at the Agricultural College in Coimbatore successfully cultivated paddy straw mushrooms. This achievement marked the beginning of mushroom farming in the country and laid the foundation for subsequent developments (Prakasam, 2012).

During the mid-1960s, E. F. K. Mental from Germany, working as an FAO consultant, initiated further advancements in the field by establishing a modern spawn laboratory in Solan, Himachal Pradesh. He was also instrumental in introducing button mushroom *(Agaricus bisporus)* cultivation to India. In 1961, the Indian Council of Agricultural Research (ICAR), New Delhi, began its first official efforts in button mushroom cultivation at Solan. Later, in 1971, ICAR launched a funded research program with centers established in Solan, Punjab, Bengaluru, and New Delhi. Recognizing the potential of mushroom farming, the Indian Council of Agricultural Research (ICAR) initiated its first button mushroom cultivation project in Solan in 1961. This was followed by the establishment of the National Centre for Mushroom Research and Training (NCMRT) in 1982, which was later upgraded to the Directorate of Mushroom Research (DMR) in 2008. These institutions have played a pivotal role in advancing research, providing training, and promoting best practices in mushroom cultivation across the country. The state of Himachal Pradesh, particularly the Solan district, has been at the forefront of mushroom cultivation in India. Despite being recognized as the "Mushroom City of India," the state faces challenges in production levels compared to other regions. For instance, as of 2019, Himachal Pradesh ranked fourth in mushroom production, with limited large-scale production units. However, the establishment of facilities like the Directorate of Mushroom Research in Solan has contributed to the growth and development of the sector in the region (Sharma *et al.,* 2017).

3. NUTRITIONAL VALUE

3.1 Proteins

Mushrooms possess relatively high protein content compared to many plant-based foods, though generally lower than that of animal-derived meats (Shbeeb *et al.,* 2019). The nutritional and chemical profiles of mushrooms are influenced by various pre-harvest and post-harvest conditions. Additionally, the protein and amino acid composition varies across different developmental stages. *Agaricus bisporus*, in particular, is recognized for its richness in a wide range of amino acids (Guillamón et al., 2010).

3.2 Lipids

Crude fat content in *Agaricus bisporus* is relatively low, it contains a significant proportion of essential fatty acids, particularly linoleic acid. Compared to cultivated strains of *A. bisporus*, wild *Agaricus* species exhibit higher levels of polyunsaturated fatty acids and lower levels of monounsaturated fatty acids (Barros et al., 2008). According to Baars *et al*., (2016) the total fatty acid content in *A. bisporus* ranges from 180 to 5818 mg kg^{-1} dry weight, with linoleic acid accounting for nearly 90% of the total fat content.

3.3 Carbohydrates

Carbohydrates are a fundamental component of the human diet, and mushrooms serve as an important source of both digestible and non-digestible forms including compounds such as mannans, chitin, and β-glucans. In *Agaricus bisporus*, digestible carbohydrates such as glucose and mannitol are present, although in relatively low concentrations. Specific examples of digestible carbohydrates found in mushrooms include trehalose, mannitol, glycogen, and glucose. Among the most abundant polysaccharides in mushrooms are chitin and glucans, along with other hemicelluloses such as mannans, xylans, and galactans (Alam *et al.,* 2008). The content of polysaccharides and dietary fiber varies across species, typically ranging from 36 to 60 g per 100 g of dry fruiting bodies and 10 to 31 g per 100 g of dry weight, respectively (Khan *et al.,* 2008).

3.4 Vitamins

Numerous studies have established that mushrooms are an important source of vitamins. According to Bernas and Jaworska, *Agaricus bisporus* is particularly rich in niacin and riboflavin, with other notable vitamins including α-tocopherol, ascorbic acid, vitamin B1, and vitamin B3 (Bernas & Jaworska, 2016). Caglarırmak further highlighted that *A. bisporus* is abundant in vitamins such as riboflavin, folic acid, thiamine, and niacin, although it contains relatively low levels of vitamin C (Caglarırmak, 2009). In their study, Furlani and Godoy (2008) measured the concentrations of vitamins B1 (thiamine) and B2 (riboflavin) in fresh *A. bisporus* specimens, finding that vitamin B1 and B2 were present at 0.03 mg and 0.25 mg per 100 g, respectively.

4. MEDICINAL VALUE

Agaricus bisporus is a prime example of a mushroom with significant nutritional and medicinal value. It has been utilized in traditional medicine across various regions and cultures for many years. Numerous studies have confirmed that bioactive compounds, as well as powders and extracts derived from *A. bisporus*, can be effective in the prevention and treatment of several serious human diseases. *A. bisporus* exhibits a range of beneficial properties, including anticancer, antioxidant, anti-obesity, and anti-inflammatory effects. It holds potential for managing conditions such as coronary heart disease, cancer, diabetes mellitus, immune-related disorders, and infections caused by viruses, bacteria, and fungi (Muszynska et al., 2017). Therefore, regular consumption of *A. bisporus* may enhance immune function and improve the body's resistance to various illnesses. The growing interest in extracting bioactive compounds from mushrooms is driving the development of functional foods. These compounds, including polysaccharides, terpenoids, phenolic acids, and proteins, are recognized for their antioxidant, anti-inflammatory, and immune-boosting properties (Dhamodharan & Mirunalini, 2010).

5. OPTIMAL TEMPERATURE AND HUMIDITY REQUIREMENTS

The commercial cultivation of button mushrooms is an indoor process that can be carried out year-round, provided that key environmental factors such as temperature, humidity, and air circulation are properly controlled. Notably, large capital investment is not a prerequisite for starting a mushroom farm. Button mushrooms can be successfully cultivated in small-scale, cost-effective structures commonly found in rural areas, such as huts or cottages. Racks for cultivation can be built using inexpensive materials like bamboo or wood, making this setup ideal for seasonal farming. Different growth stages of *Agaricus bisporus* require specific ambient temperatures. During the vegetative phase, when the mushroom spawn is mixed with compost and the mycelium begins to colonize the substrate, a temperature range of 21–25°C is ideal. This stage marks the development of the fungal network beneath the surface. As the crop transitions to the fruiting stage—when mushroom pinheads begin to emerge—a cooler environment is required, with optimal temperatures ranging from 12–18°C. This sudden shift to favorable temperature and moisture conditions triggers rapid development of the fruiting bodies. Maintaining high humidity levels, between 80–90%, is crucial during this phase. Proper ventilation is also essential for successful cultivation. While a high concentration of carbon dioxide is beneficial during mycelial growth, effective air circulation is necessary during the fruiting stage to support healthy mushroom development (Grimm & Wösten, 2018).

6. ORGANIC SUBSTRATE PREPARATION

Button mushroom cultivation requires a specialized compost substrate, with its quality influenced by the carbon-to-nitrogen (C:N) ratio, moisture content, and pasteurization process. The ideal C:N ratio for composting is approximately 25:1 during preparation, reducing to about 16–17:1 in the final compost. Compost is primarily prepared from plant residues such as wheat, paddy, or sugarcane straw, which provide the necessary carbon. Nitrogen sources like chicken or horse manure, urea, and wheat bran are added to achieve the optimal C:N ratio. Additionally, mineral supplements such as gypsum and superphosphate are incorporated to supply essential nutrients and regulate pH levels. Water is uniformly applied to maintain a moisture content of approximately 70–75%, which is crucial for microbial activity during composting (Thakur & Rathod, 2021).

Two primary methods are employed in compost preparation-the long method and the short method. Long Method is a traditional outdoor composting process that spans approximately 28 days. During this period, the compost pile undergoes multiple turnings to ensure uniform decomposition. While this method is traditional, it is labor-intensive and less efficient compared to the short method. Short Method is more modern and efficient approach is typically conducted in controlled indoor environment. First the prepared substrate is stacked and watered to initiate fermentation. Over 10–12 days, the pile is turned several times to maintain temperature and aeration. Secondly, the compost is transferred to insulated tunnels where it is pasteurized at temperatures between 52–60°C for 6–8 hours to eliminate undesirable microorganisms. Following pasteurization, the compost is conditioned at 45–48°C for 5–6 days to promote the growth of beneficial thermophilic microbes (Rahatkar & Rathod, 2021; Kertesz & Thai, 2018).

7. SPAWNING

After the composting process, the next step in mushroom cultivation is known as spawning. This involves introducing mushroom mycelium (spawn) into the compost to initiate the growth of mushrooms.

7.1 Spawning Process

Spawn is typically applied at a rate of 0.5% to 0.75% of the compost's wet weight. This translates to approximately 500 to 750 grams of spawn per 100 kilograms of compost. The spawn should be evenly distributed throughout the compost to ensure uniform colonization. This can be achieved through various methods. The spawn is evenly spread on the top layer of the compost and then mixed to a depth of 3–5 cm. Spawn is mixed in multiple layers within the compost, ensuring thorough distribution. Spawn is uniformly mixed throughout the compost, often using specialized equipment.

8. POST-SPAWNING CARE

8.1 Incubation

After spawning, the compost should be placed in suitable containers, such as polythene bags or trays, and kept in a controlled environment. Maintain temperatures between 23°C and 25°C and relative humidity around 90% to facilitate mycelial growth.

8.2 Spawn Run

This is the period during which the mycelium colonizes the compost, typically taking 12 to 14 days. Proper temperature and humidity are essential to prevent overheating or drying out, which can hinder mycelial development (Kumar & Mahajan, 2022). During this phase of mushroom cultivation, maintaining optimal environmental conditions is crucial for healthy mycelial growth. The ideal temperature range is approximately 23°C±2°C; temperatures above this range can inhibit mycelial development, while lower temperatures may slow down growth. Relative humidity should be maintained around 90% to prevent the substrate from drying out and to support the mycelium's growth (Rathod et al., 2021).

9. CASING

After the spawn run is complete, the compost beds should be covered with a 3–4 cm thick layer of casing soil to induce fruiting in button mushrooms. The casing material must be highly porous, capable of retaining water, and have a pH between 7 and 7.5. Commonly used casing mixtures in India include garden loam soil and sand (4:1), decomposed cow dung and loam soil (1:1), and spent compost (2–3 years old) mixed with sand and lime. Before application, the casing soil should be pasteurized at 66–70°C for 7–8 hours or treated with a 2% formaldehyde solution to eliminate pathogens. The treatment should be completed at least 15 days before use to allow for proper curing. Following the application of the casing layer, the temperature should be maintained at 23–28°C with a relative humidity of 85–90% for 8–10 days to allow the mycelium to colonize the casing. After this period, the temperature is lowered to 13–18°C, and fresh air circulation is increased to stimulate fruiting. Under these favorable conditions, the fruiting bodies of button mushrooms begin to develop (Jarial et al.,2005).

10. FRUITING

The development of fruiting bodies in button mushrooms begins with the formation of pinheads, which gradually mature into button-stage mushrooms under optimal environmental conditions. These conditions include maintaining an initial temperature of 23 ± 2°C for about a week, followed by a reduction to 16°C, ensuring relative humidity remains above 85%, and providing proper ventilation to facilitate fresh air exchange. Additionally, the carbon dioxide concentration should be maintained between 0.08% and 0.15% to support healthy fruiting.

11. HARVEST

In button mushroom cultivation, harvesting typically occurs during the button stage when the caps measure between 2.5 to 4 cm in diameter. This stage is ideal for harvesting as the mushrooms are mature yet still tender. The first flush of mushrooms generally appears about three weeks after casing. To harvest, gently twist the mushrooms to detach them without disturbing the surrounding casing soil. After harvesting, any gaps in the beds should be filled with fresh, sterilized casing material and lightly watered. Regarding yield, under favorable conditions, approximately 10–14 kg of fresh mushrooms can be harvested per 100 kg of fresh compost over a two-month cropping period. Utilizing the short method of compost preparation, which is completed in about 22–26 days, can increase yields to 15–20 kg per 100 kg of compost. This method involves a quicker composting process, leading to higher productivity (Rai & Saxena, 1989).

12. MARKETING

The costs associated with mushroom cultivation can vary significantly based on several factors, including labor expenses, raw material prices, site conditions, and marketing opportunities. For instance, labor costs can constitute a substantial portion of the total expenditure, ranging from approximately 30% to 50% of the operating costs. Additionally, the choice of substrate plays a crucial role; for example, straw, a commonly used substrate, costs around ₹5 to ₹10 per kilogram.

Mushrooms are primarily marketed in three forms: fresh, canned, and freeze-dried. Fresh mushrooms are typically sold in low-density plastic bags and have a short shelf life, lasting only about 2 to 3 days. In contrast, canned and freeze-dried mushrooms offer extended shelf lives; canned mushrooms can last 2 to 5 years when stored properly, while freeze-dried mushrooms can maintain quality for over a year. However, freeze-drying is an energy-intensive process that can be up to five times more expensive than conventional drying methods (Munsi *et al.*, 2010).

13. DISEASES OF BUTTON MUSHROOM

13.1 Wet Bubble (*Mycogone perniciosa*)

Malformed mushrooms exhibit swollen stipes and distorted caps due to infection by the fungal pathogen *Mycogone perniciosa*, responsible for Wet Bubble disease. This infection leads to the development of white, fluffy mycelial growth on the fruiting bodies, which can later turn brown as the tissue decays. Infected mushrooms may also exude amber-colored droplets and emit a foul odor. The pathogen thrives in high-humidity environments and can spread through contaminated casing soil, water splashes, and mechanical means such as flies and pickers (Sharma *et al.,* 2007).

13.2 Dry Bubble (*Verticillium fungicola / Lecanicillium fungicola*)

This disease is identified by distinctive symptoms, including the development of irregular masses of undifferentiated tissue and wart-like soft tissue growths on young, emerging pinheads during the early stages of infection. As the disease progresses, it causes the stipes to dry out and break. In more advanced stages, fully developed mushrooms exhibit slight brown, sunken lesions, eventually leading to cap browning and dryness (Sharma *et al.,* 2007).

13.3 Cobweb (*Cladobotryum dendroides*)

An irregular cottony mass of mycelium, resembling cobweb, appears on the casing soil, typically indicating the onset of infection. This mycelium spreads to cover the fruiting pinheads, resulting in discoloration and soft rot of the mushroom bodies. In many cases, brown, irregular spots also develop on the fruiting structures. As the infection progresses, the cobweb-like growth transforms into a granular, irregular mycelial structure that produces powdery masses of spores (Sharma *et al.,* 2007). Cobweb disease, caused by the fungal pathogen *Cladobotryum mycophilum*, presents a significant threat to cultivated mushrooms, including king oyster mushrooms (*Pleurotus eryngii*). One of the primary symptoms is the appearance of cobweb-like fungal mycelium over the surface of the mushrooms. These colonies rapidly overwhelm the mushrooms, developing numerous spores within 3–4 days. The mycelium can quickly cover debris, pinheads, stalks, pileus, and gills, leading to the decomposition of the entire fruit body. The affected surface turns pale brown or yellow, accompanied by cracking of the stipe surface. Eventually, the fruit body becomes dark brown, rancid, and emits an offensive odor (Kim *et al.,* 2014).

13.4 Green Mould (*Trichoderma viride, Penicillium cyclopium, Aspergillus spp.*)

Green mould disease initially appears as a dense white mycelial mat on the casing soil, and occasionally on the compost surface as well. As the disease progresses, a characteristic green sporulation develops on the casing layer. In cases of severe infestation, symptoms may resemble those of dry bubble disease. The fungus eventually spreads through the casing layer and infects young mushroom primordia, leading to malformed and distorted caps and stipes, severely affecting crop quality and yield (Sharma *et al.,* 2007).

13.5 Ink Caps (*Coprinus spp.*)

It occurs in mushroom beds throughout the spawn run period. It often appears on compost beds during the spawn run phase and can also be observed on freshly cased beds or even around manure piles during fermentation. The disease is characterized by the emergence of ink cap mushrooms, which are typically conical or bell-shaped. These fruiting bodies start off creamy white in color and later turn blue to black, often covered with dry white scales. The stems are strong, rigid, and usually grow in clusters, extending deep into the compost layer. As the disease progresses, the ink caps undergo autodigestion, resulting in their decay and the formation of a slimy black mass on the beds (Sharma *et al.,* 2007).

14. STORAGE LIFE OF MUSHROOMS

Fresh button mushrooms (*Agaricus bisporus*) are highly perishable and typically have a shelf life of only 1–3 days at ambient temperatures (20–25°C). This rapid deterioration is primarily due to their high respiration rate (200–500 mg/kg/h at 20°C), high moisture content (85–95%), and lack of a protective cuticle, making them susceptible to water loss, microbial attack, and enzymatic browning. To maintain their quality during the post-harvest period, mushrooms require careful handling and storage. Implementing quality control measures, such as maintaining high relative humidity (95–98%) and optimal temperatures (0–1.5°C), can help extend their shelf life and preserve their commercial value (Nerya *et al.,* 2006).

Due to their fragile epidermal structure and elevated respiration rate, mushrooms begin to deteriorate within a day after harvest. Consequently, at ambient temperatures, the shelf life of freshly harvested mushrooms is limited to just one to three days (Singh *et al.,* 2016). Maintaining optimal temperature and storage duration is crucial for preserving the quality attributes of mushrooms. Storage temperature significantly influences the quality of mushrooms. Lower temperatures have been shown to reduce weight loss during storage. Studies have indicated a strong correlation between temperature and the metabolic and bacterial activity in mushrooms. Additionally, low relative humidity (RH) accelerates water loss from mushrooms to the surrounding environment, adversely affecting their quality, particularly their firmness during storages (Azevedo *et al.,* 2017).

15. MUSHROOM PROCESSING AND VALUE ADDITION

Mushrooms are globally traded in processed forms such as frozen, canned, pickled, and dried, which enhance their shelf life and market value. In India, however, value addition in mushrooms accounts for approximately 7%, which is lower compared to some developing countries. Despite this, mushroom products are available in various forms, including bakery items like biscuits, bread, and cakes, as well as fast food products such as burgers, cutlets, and pizzas (Harsh & Joshi, 2008). This indicates a growing recognition of the potential of mushrooms in value-added products, though there remains significant scope for expansion in this sector. Canning is a widely utilized method for preserving mushrooms, extending their shelf life up to two years with relatively low storage costs. Despite a decline in its usage over recent years, approximately 38% of mushrooms are still canned, maintaining a significant share in global trade. To ensure optimal quality, mushrooms should be processed promptly after harvest or stored at temperatures between 4°C and 5°C until processing. Additionally, pre-storage at low temperatures for one day before canning has been recommended to reduce weight loss and enhance water retention. Desalted mushrooms can also be effectively used in canning when packed in airtight containers (Ravi & Siddiq, 2011).

16. CONCLUSION

Button mushrooms (*Agaricus bisporus*) are a globally significant crop, offering substantial nutritional and medicinal benefits, while also presenting unique challenges in production, storage, and marketing. Cultivation practices have evolved to incorporate sustainable methods, including the use of locally available substrates. Nutritionally, these mushrooms are low in calories and rich in essential vitamins, minerals, and antioxidants, contributing to various health benefits such as immune support and disease prevention. Additionally, Modified Atmosphere Packaging (MAP) has been utilized to maintain freshness during storage and transportation. The market for button mushrooms continues to expand, driven by the growing demand for plant-based diets and functional foods, with value-added products such as dried mushrooms, powders, and extracts gaining popularity. To sustain and enhance the button mushroom industry, ongoing research and development in cultivation techniques, postharvest technologies, and marketing strategies are essential. By addressing these areas, the industry can meet the increasing global demand while promoting health and sustainability.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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