KAVAKA 61(4): 87-96 (2025) DOI: 10.36460/Kavaka/61/4/2025/87-96

Edible Mushroom: its Role in Achieving Food Security and Improved Nutrition

Chandan Singh[1,2], Smita Mishra[2], Deepak Vyas[2] and Ram Prasad[3]*

[1]*Department of Agricultural Science, Rani Avantibai Lodhi Vishwavidyalaya, Sagar - 470 002, M.P., India.*
[2]*Lab of Microbial Technology and Plant Pathology, Department of Botany, Dr. Harisingh Gour Vishwavidyalaya, Sagar - 470 003, M.P., India.*
[3]*Department of Botany, Mahatma Gandhi Central University, Motihari - 845 401, Bihar, India.*
**Corresponding author Email: rpjnu2001@gmail.com*

(Submitted on August 1, 2025; Accepted on August 28, 2025)

Abstract:

Mushrooms are well-known source of nutrition and therapeutic properties, offering a good option to address food security and improve nutrition. Many edible mushrooms like *Agaricus bisporus*, *Pleurotus* species, *Lentinus*, *Volvariella*, and *Calocybe indica* are largely cultivated worldwide. They are known for their cheap source of high protein content, dietary fiber, vitamins, and essential minerals. Mushrooms represent a low-cost, protein-rich food source that can be cultivated on a variety of agro-industrial wastes, contributing to sustainable agriculture and environmental conservation. Besides its nutritional values, edible mushrooms also contain bioactive compounds with various health benefits, making them valuable functional foods. The leftover mushroom substrates have nutrient-rich compost, which could serve as biofertilizer, improving soil fertility and crop productivity. Integrating the mushroom production into the farming system would support circular economy practices, will provide livelihood opportunities for rural areas and landless farmers. The global interest in mushrooms as superfoods and sources of novel therapeutic compounds is expanding, with increasing scientific attention towards their health-promoting attributes. Mushrooms have the potential to grow in controlled and natural conditions that make them a promising solution to support agriculture and promote food system resilience, especially under climate change scenarios. This review highlights the multifaceted role of edible mushrooms in contributing to food and nutritional security, their ecological advantages, and their potential as an economic asset. Thus, promoting mushroom cultivation and consumption could serve as a strategic intervention in ensuring sustainable development, improved public health, and enhanced food system sustainability.

Keywords: Mushroom, Functional food, Hidden hunger, Food security, SDGs

INTRODUCTION

The fact that the global human population is increasing and the challenges like climate change, environmental degradation, and persistent malnutrition compel the search for alternative and sustainable, nutritious, and accessible food sources. Edible mushrooms could be a suitable option to mitigate food insecurity, as mushrooms could be grown over various agricultural and forestry residues/wastes. Now, mushrooms cultivated and consumed across various parts of the globe are not only recognised as a healthy source of food but also have nutraceutical potential. Mushrooms as a source of food and medicine have long been recognised and have a long history of use (Gupta *et al.,* 2019; Singh *et al.,* 2020). They are rich in high-quality protein, dietary fibre, essential amino acids, vitamins and many important minerals. These components contribute to a balanced diet and help to combat deficiency of micronutrient to vulnerable populations. Beyond its edibility, it has additional benefits as it also contains various bioactive compounds that exhibit antioxidant, antimicrobial activity, nutritional and medicinal benefits (Bernaś *et al.,* 2006; Mishra *et al.,* 2025). The commonly grown mushrooms for food are *Agaricus* sp., several *Pleurotus* species, *Lentenus* sp., *Volvariella* sp., *Calocybe indica*, *Auricularia* sp., etc. (Anusiya *et al.,* 2021; Mishra *et al.,* 2025). Additionally, the compost leftover after mushroom harvest, called as spent mushroom compost, is a good source of nutrients for plants (Pathak *et al.,* 2020). It is well known that humans have long been on the lookout for novel compounds with the potential to enhance biological processes and render individuals more physically fit and well. The genuine health benefits of edible and medicinal mushrooms are now starting to draw much-needed attention (Elkhateeb, 2022; Devi *et al.,* 2024).

This review article explores the potential of mushrooms in achieving nutritional security, their possibilities in attaining the SDGs goals. Their nutritional and therapeutic advantages and contribution to sustainable livelihoods have been discussed. This demonstrates how edible mushrooms may promote economic growth, environmental sustainability, and public health.

FOOD SECURITY AND GLOBAL FOOD SECURITY

When everyone always has physical, social, and financial access to enough wholesome food that satisfies their dietary requirements and food choices, to have an active and healthy life. Food security is the capacity of people to continuously acquire a sufficient amount of nutrient-dense food that meets their dietary needs and preferences. Global food security is the assurance that every country has access to food through the efficient movement of food resources, especially during events like catastrophes or natural disasters that might cause a food shortage (Strain *et al.,* 2010).

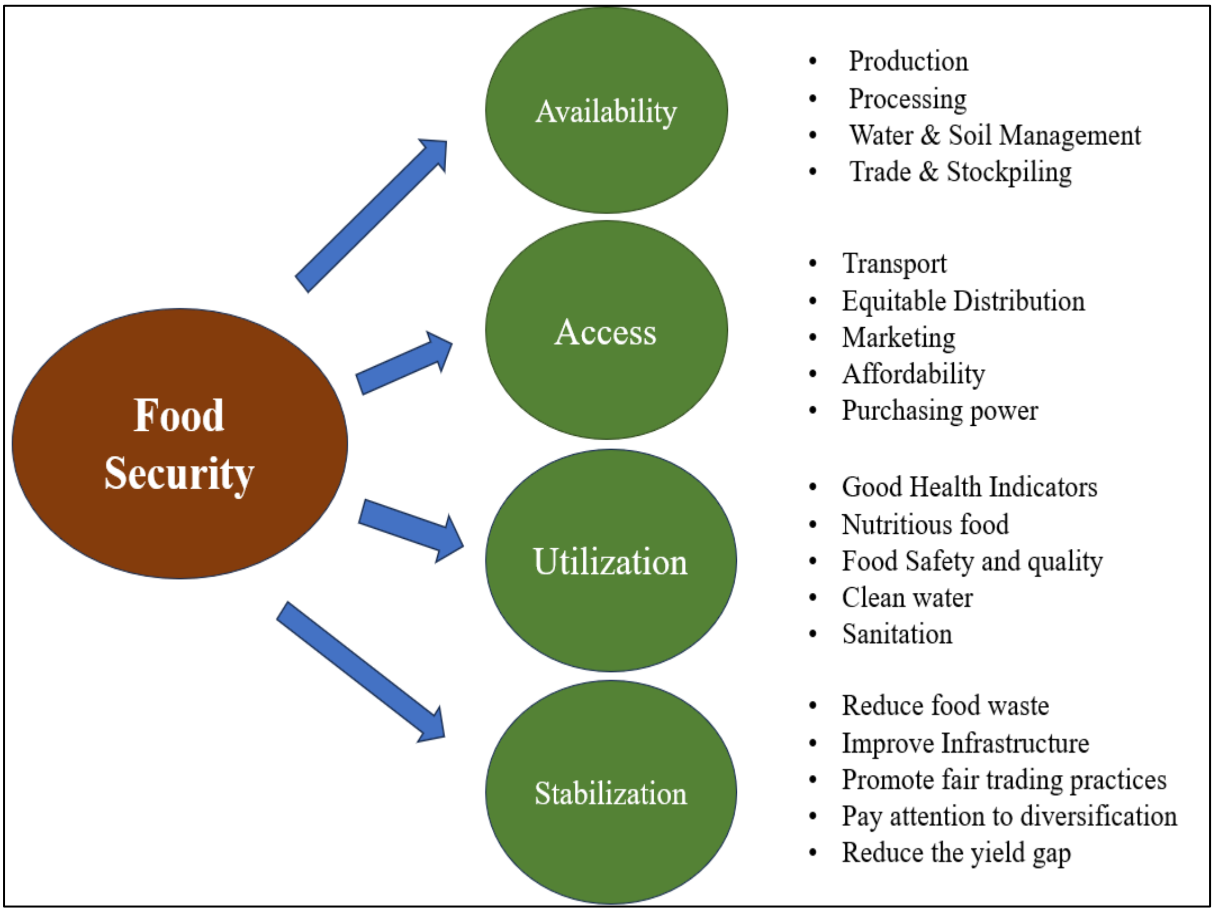

Figure 1: Four Pillars of Food Security Source

Food security has four pillars: availability, access, utilisation, and stabilisation. All these pillars should be intact to fulfil the food security (**Figure 1**). However, recently it has been emphasised that sustainability may be considered as a fifth dimension to food security (Peng & Berry, 2018). Rather than being divided into four "pillars," food security is better understood as a causal, interconnected process that extends several domains, from production to consumption, through distribution to processing. The relationship between food insecurity's pressures and coping mechanisms determines the resulting situation. Food security and food insecurity are dynamic, reciprocal, and time-dependent. It is difficult to find universal metrics for assessing food security. (Jeder *et al.,* 2020). An array of overall economic policies and sector-specific programs impact food security and the agriculture sector's ability to develop sustainably. The link between economic country stability and agriculture is always influenced by the primary factors that determine food security, including agricultural country policies and productivity, sustainability outcomes, price volatility, public-private partnerships, and agricultural potential (Jayaraman *et al.,* 2024; Onyeaka *et al.,* 2024)

WHY DOES FOOD SECURITY MATTER?

One basic human right is food. Nonetheless, 805 million people globally, or one in every nine, endure hunger on every day. There is a more insidious kind of hunger, a hidden hunger due to deficiencies in micronutrients such as iron, Vitamin A, and Zinc, which affects two billion people. (Phulkerd *et al.,* 2023). More than 135 million people in 55 countries and territories are facing a food crisis, having restricted access to vital nutrients (Caritas Australia, 2023). Food security benefits a community's health and well-being by allowing people to focus their efforts on improving their standard of living and being more productive (Onyeaka *et al.,* 2024). Food is one of the most essentials of existence.

Food insecurity can cause societal instability and violence. People are more likely to adopt dramatic measures to feed themselves and their families when they are hungry and in need. This might lead to violence, social turmoil, or even civil war. Thus, addressing food security involves more than simply feeding bellies. It aims towards promoting equality in society and stability. This asks for inclusive policies and programs that address the underlying problems that lead to food insecurity, such as discrimination, poverty, and inequality, and ensure that everyone has equal access to opportunities (Prasad & Kothari, 2022; Shafiee *et al.,* 2022).

FACTORS AFFECTING FOOD SECURITY

Many Indigenous communities experience restricted access to markets and traditional foods due to insufficient transit, high food costs, and economic restraints. Other challenges include the loss of traditional knowledge, low awareness of market foods, poor food quality, and food safety concerns. Climate change exacerbates the consequences on all four pillars of food security (Nisbet *et al.,* 2022). Food poverty causes a twofold illness burden, with early-onset chronic disease later in life as a result of childhood malnutrition. According to the 2020 Global Nutrition Report, 40 million children are overweight, 50 million are malnutrition, and 149 million are stunted by the age of five (Guruswamy *et al.,* 2022).

Climate change, population expansion, growing food prices, and natural catastrophes are all factors that affect food security. Implementing methods and tackling concerns related to global food security are critical. Nonetheless, the benefits of modern technology should be shared equally. Smallholder farmers should be at the forefront of these technological breakthroughs, as they produce the vast majority of the world's food yet typically lack access to resources and technology. To guarantee that no one falls behind in the war for food security, efforts must be made to assist technology transfer and capacity building, and here mushrooms could play a vital role.

MUSHROOMS AS KEY PLAYERS IN FOOD SECURITY

The production of mushrooms can contribute significantly to nutrition, medicine, and food security. Mushroom cultivation is a feasible and alluring pastime for both urban and rural farmers because it does not require access to land.

Mushrooms have a significantly high protein content, around twice that of potatoes and cabbage, four times that of tomatoes and carrots, and six times that of oranges. They are high in B vitamins, including pantothenic acid (B5), niacin (B3), and riboflavin (B2), as well as vital minerals like copper and selenium. A single strain of *Agaricus bisporus* has been shown to have 53 different nitrogen compounds. Furthermore, mushrooms contain approximately 206.27 mg of vitamin C per 100 g of fresh fruiting body, as well as thiamine, riboflavin, niacin, and ascorbic acid, all of which are essential for human health. Various species possess a variety of common dietary fats (Waktola & Temesgen, 2018; Zhao, 2023).

REFINE TO IMPROVE ANIMAL FEED

After collecting mushrooms, any remaining protein and vitamin-rich material can be given to farm animals. Farm animals help to provide food security and provide an abundant supply of protein (Scholtmeijer *et al.,* 2023; Singh *et al.,* 2020). Many studies have shown that eating mushrooms and their mycelium is helpful to agricultural animals including cattle, fish, lambs, poultry, and others (Amara & El-Baky, 2023). Researchers discovered that feeding mushrooms to farm animals improves their overall health, digestion, and resistance to disease. Some of the medical components in medicinal *Cordyceps* mushrooms can also be passed on to the hens' eggs when they are fed, indicating that many new medicinal mushroom-egg-based products may be generated in the future (El Sabry *et al.,* 2018; Rathi *et al.,* 2021).

Table 1: Bioactive compounds and their health benefits from some common edible mushrooms

S. No.	Common Name	Scientific Name	Bioactive Compounds	Health Benefits
1.	Button mushroom	*Agaricus bisporus*	Pyrogallol, hydroxy benzoic acid derivatives, flavonoids, lectins	Anti-inflammatory, enhanced insulin secretion, anti-ageing property
2.	Oyster mushroom	*Pluerotus ostreatus*	Beta-glucans	Anti-oxidant, antimicrobial
3.	Wood ear mushroom	*Auricularia auricula-judae*	Glucan, acidic polysaccharides	Immunomodulatory, anti-tumor, anti-inflammatory, lowers cholesterol and triglycerides, hypoglycaemic activity, immune tonic, and beneficial in coronary heart disease
4.	Enokitake	*Flammulina filliformis*	FVE protein, ribosome inactivating protein	Anti- allergy, antiviral, antibacterial anti-inflammatory,
5.	Shittake mushroom	*Lentinula edodes*	Lentinan	Antifungal, antibacterial, antitumor, apoptosis, antioxidant, regulating immune regulation by inducing the release of cytokines
6.	Enoki mushroom	*Flammulina velutipes*	Peptidoglycan, polysaccharides, flammulin, FVP, proflamin (Glycoprotein), a prolamin (active sugar protein)	Anti-inflammatory, antiviral, anti-tumor, antioxidant, immunomodulatory, anti-ageing property
7.	Paddy straw mushroom	*Volvariella volvacea*	Fip-vvo	Anti-tumor immunomodulatory
8.	Milky mushroom	*Calocybe indica*	Water soluble and insoluble polysaccharide	Prebiotic, antiproliferative, and immunomodulatory, antitumor
9.	King trumpet Mushroom	*Pluerotus eryngii*	Ergotheionine, beta-glucans, selenium, phenolic compounds	Prebiotic, antiproliferative, and immunomodulatory, antioxidant, support bone health
10.	Nameko mushroom	*Pholiota nameko*	Polysaccharides, peptides, lectins, lipids, glycoprotein, triterpenoids,	Anti-inflammatory, antitumor, antioxidants
11.	Hedgehog	*Hednum repandum*	Beta-glucan, rapandiol, sarcodonol D	Antimicrobial, antitumor, antibiotic and cytotoxic
12.	Porcini	*Boletus edulis*	Polysaccharide, phenolic compound, selenium, ergosterol	Antineoplastic, antioxidant

CHEAP AND EASY TO GROW

Mushrooms, due to their low production cost and ease of cultivation, represent a promising tool in achieving food security. They exhibit rapid growth, allowing for harvest within a few weeks of inoculation. Furthermore, mushroom cultivation requires minimal land, making it suitable even in urbanized settings. They can be grown year-round by individuals with limited resources. Common agricultural and industrial wastes such as sawdust, straw, grain residues, and wood chips serve as efficient substrates for their production. The spawn, a blend of mushroom spores and nutritional materials, is used to initiate growth. Globally, mushrooms are not only recognized as nutritious and functional foods, but also valued for their bioactive compounds with applications in nutraceuticals, cosmeceuticals, and mycotherapeutics. Despite their wide-ranging benefits and growing demand, current levels of cultivation remain insufficient (Gupta *et al.,* 2022). Mushroom farming is one of the cheapest sources to overcome the deficiency caused by malnutrition (Khan *et al.,* 2024).

MEDICINAL SUBSTITUTE

Food crops are used as medicine throughout Asia and Sub-Saharan Africa. However, mushrooms can be an effective replacement. They contain anticancer medications and antibodies that can treat cancer and many more, just as they have for thousands of years. Because of their high folic acid content and low carbohydrate content, they are also an effective meal alternative for those with diabetes and anemia. Furthermore, mushrooms can provide even more health benefits than just energy. They can lower cholesterol and have antibacterial properties. They benefit our immune system because they may help prevent or treat cancer, high blood pressure, Parkinson's disease, and Alzheimer's disease (Ma *et al.,* 2018).

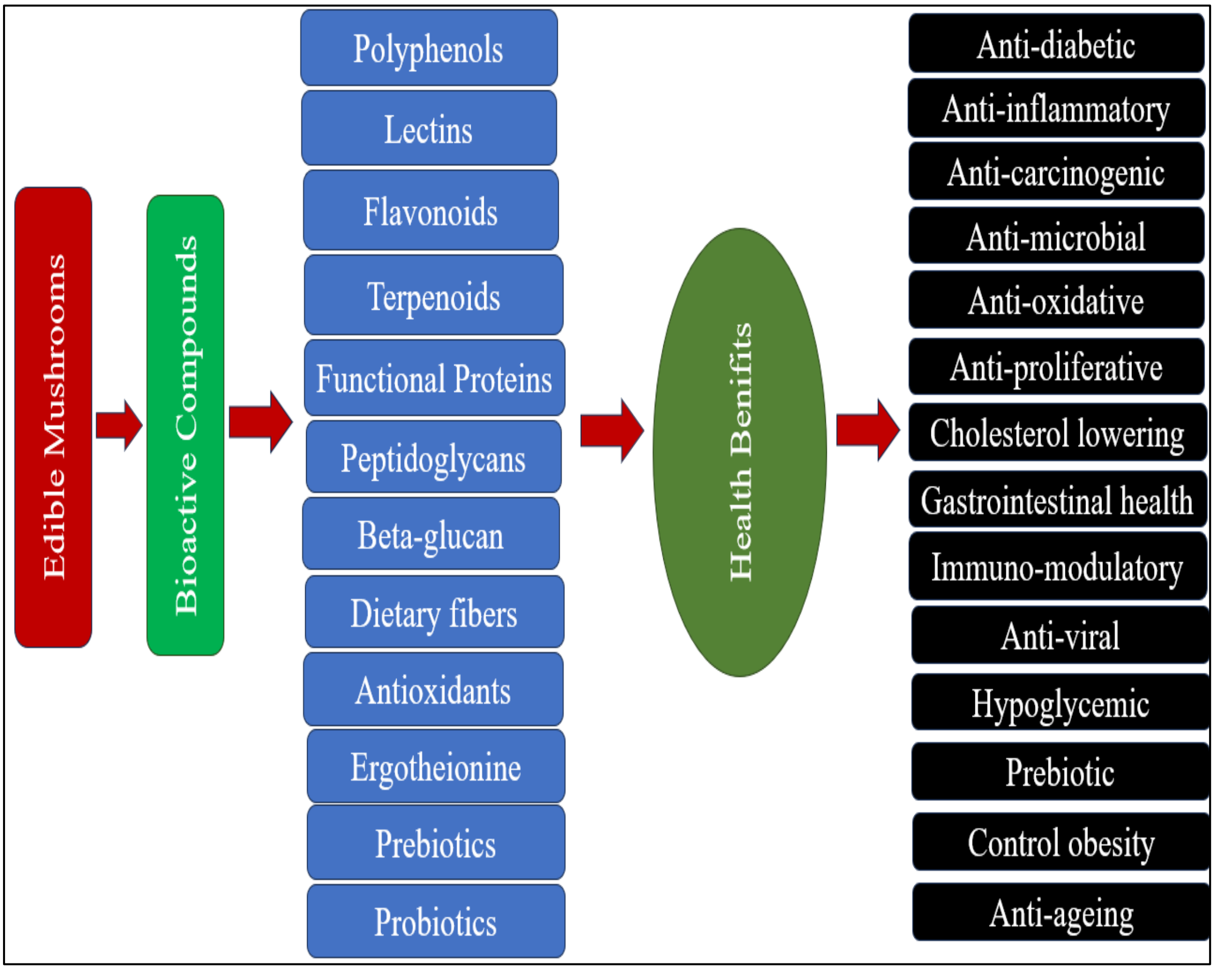

Figure 2: Sustainable Development through Integrated Farm Management of Mushroom and Mushroom Product

MUSHROOM IN SOIL IMPROVEMENT

The cost of improving soil nutrients for agriculture poses a significant barrier to food security in third-world countries. To ensure a high yield, a large number of money is necessary to purchase pesticides and fertiliser. Mushrooms, however, are mycorrhizal fungus, which may significantly improve the overall health and nutritional content of crops, resulting in high production. Fungal colonies form when mushrooms are planted with other crops (Rizwanuddin *et al.,* 2023).

The cost of improving soil nutrients for agriculture poses a significant barrier to food security in third-world countries. To ensure a high yield, a large amount of money is necessary to purchase pesticides and fertilizer. Mushrooms, however, are mycorrhizal fungus, which may significantly improve the overall health and nutritional content of crops, resulting in a high production (Thakur, 2020). Another way mushrooms benefit the soil is through their remains after harvest. It has been shown that incorporating these remains into soil is advantageous. Commercial mushroom compost is offered at certain nurseries, which helps the soil retain more water and minerals. These leftovers are easy to get because the majority of mushroom farmers do not use them (Singh & Vyas, 2021).

Spent Mushroom Compost (SMC) is the residual organic substrate left after the cultivation of mushrooms. It is readily available and typically composed of decomposed wheat straw, horse manure, ground chalk, and other agricultural by-products. Rich in organic matter, enzymes, salts, and essential nutrients, SMC provides a favorable environment for the proliferation of beneficial microorganisms, including bacteria and fungi (Gupta *et al.,* 2019; Pathak *et al.,* 2021). These microbial communities contribute to disease suppression and enhance plant growth. Therefore, SMC holds potential for use in integrated disease management strategies, offering a sustainable means to evaluate and mitigate pathogen severity in agricultural systems (Guevara-Gonzalez & Torres-Pacheco, 2013). Spent Mushroom Substrate (SMS) generally contains approximately 1.9% nitrogen (N), 0.4% phosphorus (P), and 2.4% potassium (K) before weathering. After 8 to 16 months of weathering, these values typically shift to 1.9% N, 0.6% P, and 1.0% K. Fresh SMS exhibits an average carbon-to-nitrogen (C:N) ratio of 13:1 (Bentil *et al.,* 2018; Khan *et al.,* 2024). The nutrient composition of both SMS and Spent Mushroom Compost (SMC) can vary significantly, depending on the mushroom species cultivated and the specific materials used in the growing substrate (Murphy *et al.,* 2022).

THEY CONTAIN A GOOD AMOUNT OF FOOD NUTRIENTS:

Mushrooms are a nutrient-dense dietary source. They are fat-free, low in calories, and high in fibre, protein, and antioxidants. They are also a great source of vitamin D, which is essential for strong bones and overall wellness. Mushrooms contain proteins, vitamins, fats, carbohydrates, amino acids, and minerals (Pashaei *et al.,* 2024).

ENVIRONMENTAL BENEFITS OF MUSHROOMS

Mushroom cultivation is considered a sustainable and environmentally friendly practice, as it utilizes recycled organic waste materials—such as straw, sawdust, and other agricultural residues—as substrates for growth. This process not only promotes the efficient reuse of biomass but also aids in the decomposition of organic waste, thereby reducing the volume of material that would otherwise be disposed of in landfills. Furthermore, mushrooms play a role in the natural carbon cycle by absorbing carbon dioxide and releasing oxygen during their growth, contributing to ecological balance (Bishwambher, 2009; Pathak *et al.,* 2020) Myco-remediation is the process of using fungus, such as mushrooms, to remediate or biodegrade pollutants by a range of processes, including biosorption, bioaccumulation, bioconversion, and biodegradation. Furthermore, myco-remediation is an environmentally safe and efficient technique to tackle the rising problem of terrestrial and marine pollution (Kumla *et al.,* 2020; Singh & Vyas, 2021).

MUSHROOMS AS IN THE BIOECONOMY

A bioeconomy is the process of creating renewable biological resources and converting these resources and waste streams into goods with added value, such as food, feed, bio-based products, and bioenergy (Erjavec *et al.,* 2012). The circular bioeconomy is the intersection of the circular economy and the bioeconomy, with the two concepts working together to provide a sustainable framework and address sustainable concerns. Farmers and business owners may benefit financially from mushroom growing. Mushroom cultivation is a profitable enterprise due to its high yield, short growth cycle, and low production costs; items created from mushrooms are also in high demand, and they can be sold raw or processed into a variety of things, including soup, sauce, canned mushrooms, and other culinary items (Meena *et al.,* 2020; Grimm & Wösten, 2018; Navarro-Simarro *et al.,* 2024).

The circular bioeconomy supports rural development by applying knowledge of resources, technologies, and biological systems to create sustainable products and services. It promotes industrial symbiosis, where waste and byproducts are repurposed as raw materials, reducing landfill use and adding value. This approach helps combat rural depopulation and generates employment through emerging bio-based value chains (Markam, 2014; Muthoosamy *et al.,* 2015). The Business Model Canvas (BMC) is a widely used conceptual tool that helps visualize and understand an organization's business model, fostering creativity and innovation. It consists of nine blocks representing key components of business strategy and is valuable in predicting success and improving performance. When applied to edible mushroom production, the BMC aligns with the Sustainable Development Goals (SDGs), addressing environmental, economic, and social sustainability. Mushroom farming, by utilizing agricultural waste and closing material and energy loops, exemplifies the circular economy and supports food, health, and agricultural sustainability (Linton *et al.,* 2020).

MEASURES TO MITIGATE HIDDEN HUNGER WITH MUSHROOM INTERVENTION

Generally, four interventions have been adopted in curbing malnutrition and hidden hunger. These include dietary diversification, food supplementation, food fortification and biofortification.

DIETARY DIVERSIFICATION

Dietary diversification, or dietary modification, involves consuming a variety of foods to ensure adequate intake of macro- and micronutrients needed to meet recommended dietary allowances (RDA). Since staple foods often lack essential micronutrients like iron, zinc, iodine, and vitamins, relying heavily on them can lead to hidden hunger. Edible mushrooms, being rich in high-quality protein, vitamins (such as B-complex and D), and minerals like iron, zinc, and selenium, serve as an excellent supplement to staple diets, helping to address micronutrient deficiencies and improve overall nutritional quality (Dent *et al.,* 2023).

FOOD SUPPLEMENTATION

Food supplementation involves consuming additional nutrients through pills or syrups to meet the Recommended Dietary Allowance (RDA), commonly used to address deficiencies in developing countries. Mushrooms, rich in natural vitamins and minerals like vitamin D, B-complex, iron, and zinc, offer a sustainable, food-based alternative to synthetic supplements for improving nutritional status (Bouis & Saltzman, 2017).

FOOD FORTIFICATION

Food fortification involves adding essential nutrients to processed foods to restore those lost during processing and supplement dietary gaps. It is increasingly important due to changing food habits in both developing and developed countries. Common examples include iodized salt, iron- and folic acid-fortified wheat, calcium- and vitamin D-enriched milk, and vitamin A-fortified rice. Mushrooms, naturally rich in nutrients like vitamin D, B vitamins, and minerals, can also be used in fortified food products, offering a natural means to enhance nutritional value and support public health (Bouis & Saltzman, 2017).

CONCLUSION

Edible mushrooms are a sustainable, inexpensive, and nutritionally dense food source with enormous promise for solving global food and nutrition security issues. Their cultivation needs little resources and makes good use of agricultural waste, helping to conserve the environment and promote the circular bioeconomy. In addition to high-quality protein, vitamins, and minerals, mushrooms are great functional foods with a variety of therapeutic effects. Their contributions range from enriching diets and eliminating hidden hunger via dietary variety, supplementation, and fortification to enhancing soil health and providing livelihood possibilities, particularly in rural regions. Integrating mushroom growing into farming systems and public nutrition policies can help us achieve numerous Sustainable Development Goals (SDGs), promote health equity, and increase food system resilience in the face of climate change and socioeconomic challenges. Thus, promoting edible mushrooms is both a nutritional approach and a step towards sustainable development.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to Dr. Harisingh Gour Vishwavidyalaya, Sagar, Madhya Pradesh; Rani Avantibai Lodhi Vishwavidyalaya, Sagar, Madhya Pradesh; and Mahatma Gandhi Central University, Motihari, Bihar, India, for support and contribution in providing relevant information and resources essential for the successful completion of this review article.

REFERENCES

Elkhateeb, W.A. 2022. Bioactive potential of some fascinating edible mushrooms *Flammulina, Lyophyllum, Agaricus, Boletus, Lentinula, Pleurotus* as a treasure of multipurpose therapeutic natural product. *Open Access Journal of Pharmaceutical Research*, **6(1)**; doi: 10.23880/oajpr-16000263.

Amara, A.A. and El-Baky, N.A. 2023. Fungi as a source of edible proteins and animal feed. *Journal of Fungi*, **9(1)**; doi: 10.3390/jof90 10073.

Anusiya, G., Gowthama Prabu, U., Yamini, N.V., *et al.,* 2021. A review of the therapeutic and biological effects of edible and wild mushrooms. *Bioengineered*, **12(2)**:11239–11268; doi: 10.1080/21655979.2021.20011 83.

Meena, B., Sivakumar, V., Praneetha, S. 2020. Prospects of biodiversity and distribution of mushroom fungi in India. *GSC Biological and Pharmaceutical Sciences*, **13(1)**:156–163; doi: 10.30574/gscbps.2020.13.1.0329.

Bentil, J.A., Thygesen, A., Mensah, M., *et al.,* 2018. Cellulase production by white-rot basidiomycetous fungi: solid-state versus submerged cultivation. *Applied Microbiology and Biotechnology*, **102(14)**:5827–5839; doi: 10.1007/s00253-018-9072-8.

Bernaś, E., Jaworska, G., Lisiewska, Z. 2006. Edible mushrooms as a source of valuable nutritive constituents. *Acta Scientiarum Polonorum Technologia Alimentaria*, **5(1)**:5–20.

Bishwambher, P. 2009. Green technology for sustainable agriculture development: assessing the policy impact in selected member countries of ESCAP-APCAEM. *Unapcaem*, pp.1–117.

Bouis, H.E. and Saltzman, A. 2017. Improving nutrition through biofortification: a review of evidence from HarvestPlus, 2003 through 2016. *Global Food Security*, **12**:49–58; doi: 10.1016/j.gfs.2017.01.009.

Caritas Australia. 2023. Global food security issues and what we can do to tackle food insecurity for disadvantaged communities. *Global Issues*, pp.1–14.

Dent, E., Wright, O.R.L., Woo, J., *et al.,* 2023. Malnutrition in older adults. *The Lancet*, **401(10380)**:951–966; doi: 10.1016/S0140-6736(22)02612-5.

Devi, P.V., Islam, J., Narzary, P., *et al.,* 2024. Bioactive compounds, nutraceutical values and its application in food product development of oyster mushroom. *Journal of Future Foods*, **4(4)**:335–342; doi: 10.1016/j.jfutfo.2023.11.005.

El Sabry, M.I., McMillin, K.W., Sabliov, C.M. 2018. Nanotechnology considerations for poultry and livestock production systems - a review. *School of Animal Sciences*, **18(2)**:319–334; doi: 10.1515/aoas-2017-0047.

Erjavec, J., Kos, J., Ravnikar, M., *et al.,* 2012. Proteins of higher fungi – from forest to application. *Trends in Biotechnology*, **30(5)**:259–273; doi: 10.1016/j.tibtech.2012.01.004.

Grimm, D. and Wösten, H.A.B. 2018. Mushroom cultivation in the circular economy. *Applied Microbiology and Biotechnology*, **102(18)**:7795–7803; doi: 10.1007/s00253-018-9226-8.

Guevara-Gonzalez, R. and Torres-Pacheco, I. 2013. Biosystems engineering: biofactories for food production in the century XXI. In: *Biosystems Engineering: Biofactories for Food Production in the Century XXI*. Springer, Cham; doi: 10.1007/978-3-319-03880-3.

Gupta, N., Mehta, M., Singh, K. 2022. Benefits, challenges and opportunities in mushroom production: a review. *The Pharma Innovation Journal*, **11(3)**:360–364.

Gupta, S., Summuna, B., Gupta, M., *et al.,* 2019. Edible mushrooms: cultivation, bioactive molecules, and health benefits. In: *Reference Series in Phytochemistry* (Eds.: Mérillon, J.M. and Ramawat, K.G.). Springer, Cham; doi: 10.1007/978-3-319-78030-6_86.

Guruswamy, S., Pojić, M., Subramanian, J., *et al.,* 2022. Toward better food security using concepts from Industry 5.0. *Sensors*, **22(21)**:1–24; doi: 10.3390/s22218377.

Jayaraman, S., Yadav, B., Dalal, R.C., *et al.,* 2024. Mushroom farming: a review focusing on soil health, nutritional security and environmental sustainability. *Farming System*, 2(3):1–65; doi: 10.1016/j.farsys.2024.100098.

Jeder, H., Hattab, S., Frija, I. 2020. An econometric analysis for food security in Tunisia. *New Medit*, **19(4)**:1–14; doi: 10.30682/nm2004a.

Khan, A., Murad, W., Salahuddin, Ali, *et al.,* 2024. Contribution of mushroom farming to mitigating food scarcity: current status, challenges and potential future prospects in Pakistan. *Heliyon*, 10(23):e40362; doi: 10.1016/j.heliyon.2024.e40362.

Kumla, J., Suwannarach, N., Sujarit, K., *et al.,* 2020. Cultivation of mushrooms and their lignocellulolytic enzyme production through the utilization of agro-industrial waste. *Molecules*, **25(12)**:1–41; doi: 10.3390/molecules25122811.

Linton, J.D., Klassen, R., Jayaraman, V., *et al.,* 2020. No 主観的健康感を中心とした在宅高齢者における健康関連指標に関する共分散構造分析Title. *Sustainability (Switzerland)*, **14(2)**.

Ma, G., Yang, W., Zhao, L., *et al.,* 2018. A critical review on the health promoting effects of mushroom nutraceuticals. *Food Science and Human Wellness*, **7(2)**:125–133; doi: 10.1016/j.fshw.2018.05.002.

Markam, S. 2014. Value addition of mushroom. *Journal of Pharmacognosy and Phytochemistry*, **3(4)**:253–256.

Mishra, S., Mishra, M.K., Vyas, D. 2025. Unlocking the mushroom's potential for their biochemicals and market values. *The Journal of Scientific Discourse*, **2(1)**:108–143.

Murphy, R.A., Guo, Y.J., Cordeiro, H.S.M.P., *et al.,* 2022. Food hubs as a means to promote food security in post-secondary institutions: a scoping review. *Nutrients*, **14(19)**:1–8; doi: 10.3390/nu14193951.

Muthoosamy, K., Geetha Bai, R., Abubakar, I.B., *et al.,* 2015. Exceedingly biocompatible and thin-layered reduced graphene oxide nanosheets using an eco-friendly mushroom extract strategy. *International Journal of Nanomedicine*, **10**:1505–1519; doi: 10.2147/IJN.S75213.

Navarro-Simarro, P., Gómez-Gómez, L., Ahrazem, O., *et al.,* 2024. Food and human health applications of edible mushroom by-products. *New Biotechnology*, **81**:43–56; doi: 10.1016/j.nbt.2024.03.003.

Nisbet, C., Lestrat, K.E., Vatanparast, H. 2022. Food security interventions among refugees around the globe: a scoping review. *Nutrients*, **14(3)**:1–44; doi: 10.3390/nu14030522.

Onyeaka, H., Ejiohuo, O., Taiwo, O.R., *et al.,* 2024. The intersection of food security and mental health in the pursuit of Sustainable Development Goals. *Nutrients*, **16(13)**; doi: 10.3390/nu16132036.

Pashaei, K.H.A., Irankhah, K., Namkhah, Z., *et al.,* 2024. Edible mushrooms as an alternative to animal proteins for having a more sustainable diet: a review. *Journal of Health, Population and Nutrition*, **43(1)**; doi: 10.1186/s41043-024-00701-5.

Pathak, P., Singh, C., Chaudhary, N., *et al.,* 2021. Fertilizing with spent mushroom compost. In: *Recent Trends in Mushroom Biology* (Ed.: Dehariya, P.). Global Books Organisation, pp.175–186.

Pathak, P., Singh, C., Chaudhary, N., *et al.,* 2020. Application of biochar, leaf compost, and spent mushroom compost for tomato growth in alternative to chemical fertilizer. *Research Journal of Agricultural Sciences*, **11(6)**:1362–1366.

Peng, W. and Berry, E.M. 2018. The concept of food security. In: *Encyclopedia of Food Security and Sustainability*, Vol. 2. Elsevier, pp.1–7; doi: 10.1016/B978-0-08-100596-5.22314-7.

Phulkerd, S., Thapsuwan, S., Chamratrithirong, A., *et al.,* 2023. Financial hardship on food security in ageing populations. *International Journal of Public Health*, **68**:1–8; doi: 10.3389/ijph.2023.1605755.

Prasad, A. and Kothari, N. 2022. Cow products: boon to human health and food security. *Tropical Animal Health and Production*, **54(1)**; doi: 10.1007/s11250-021-03014-5.

Rathi, A., Singh, C., Pathak, P., *et al.,* 2021. A thematic approach on cordyceps. In: *Recent Trends in Mushroom Biology* (Ed.: Dehariya, P.). Global Books Organisation.

Rizwanuddin, S., Kumar, V., Singh, P., *et al.,* 2023. Insight into phytase-producing microorganisms for phytate solubilization and soil sustainability. *Frontiers in Microbiology*, **14**:1–13; doi: 10.3389/fmicb.2023.1127249.

Scholtmeijer, K., van den Broek, L.A.M., Fischer, A.R.H., *et al.,* 2023. Potential protein production from lignocellulosic materials using edible mushroom forming fungi. *Journal of Agricultural and Food Chemistry*, **71(11)**:4450–4457; doi: 10.1021/acs.jafc.2c08828.

Shafiee, M., Keshavarz, P., Lane, G., *et al.,* 2022. Food security status of indigenous peoples in Canada according to the 4 pillars of food security: a scoping review. *Advances in Nutrition*, **13(6)**:2537–2558; doi: 10.1093/advances/nmac081.

Singh, C., Pathak, P., Chaudhary, N., *et al.,* 2020. Mushrooms and mushroom composts in integrated farm management. *Research Journal of Agricultural Sciences*, **11(6)**:1436–1443.

Singh, C. and Vyas, D. 2021. Biodegradation by fungi for humans and plants nutrition. In: *Biodegradation Technology of Organic and Inorganic Pollutants* (Eds.: Mendes, K.C.M.K.F. and De Sousa, R.). IntechOpen; doi: 10.5772/intechopen.99002.

Strain, J., Caballero, B., Sadler, M. 2010. Encyclopedia of human nutrition. *Encyclopedia of Human Nutrition*, **0**:1–2; doi: 10.1016/C2009-1-03773-3.

Thakur, M.P. 2020. Advances in mushroom production: key to food, nutritional and employment security: a review. *Indian Phytopathology*, **73(3)**:377–395; doi: 10.1007/s42360-020-00244-9.

Waktola, G. and Temesgen, T. 2018. Application of mushroom as food and medicine. *Advances in Biotechnology & Microbiology*, **11(4)**; doi: 10.19080/aibm.2018.11.555817.

Zhao, R.L. 2023. Edible and medicinal macrofungi. *Journal of Fungi*, **9(9)**:4–7; doi: 10.3390/jof9090908.