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WHERE STANDS THE MUSHROOM CULIVATION IN THE PROSPECT OF SMART AGRICULTURE?

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Abstract
Mushrooms represents a highly nutritious and sustainable food source. These are a vital food source due to their high protein content, vitamins, and minerals. They are low in fat and calories, making them a healthy choice. Their importance is particularly more pronounced in regions where access to animal protein is limited. They are a good option as they contain less calories and fat. Mushroom cultivation has gained significant attention in recent years due to its nutritional benefits, environmental sustainability, and economic potential. With the advent of smart agriculture, traditional farming practices are being revolutionized through automation, IoT (Internet of Things), AI (Artificial Intelligence), and data-driven approaches. This article explores the current state of mushroom cultivation within the framework of smart agriculture, highlighting technological advancements, challenges, and future prospects. The integration of precision farming, automated climate control, AI-based disease detection, and blockchain for supply chain transparency is transforming mushroom production. However, high implementation costs, lack of technical expertise, and resistance to change among small-scale farmers remain barriers. The paper concludes with recommendations for policymakers, researchers, and farmers to embrace smart agriculture for sustainable and efficient mushroom production.

Keywords: Mushroom cultivation, smart agriculture, IoT, AI, automation, precision farming, sustainable agriculture.

Introduction

Mushrooms are a vital food source due to their high protein content, vitamins, and minerals. They are low in fat and calories, making them a healthy choice. They are a good option as they contain less calories and fat. Particularly in areas where access to animal protein is restricted, their nutritional makeup makes them a vital food source. Mushroom cultivation occupies a unique position in modern agriculture due to its low land requirement, rapid growth cycle, and ability to utilize agricultural waste as substrate. Nutritionally, mushrooms are considered a high-value food, offering essential amino acids, vitamins (B-complex and D), minerals, and antioxidants (Chang & Miles, 2004). Furthermore, it is low in calories and fat, mushrooms are perfect for a good diet.

Table 1: Global Mushroom Market Growth

Year	Market Size (USD Billion)	Source
2018	42.4	Grand View Research (2023)
2019	45.0	Grand View Research (2023)
2020	46.5	Grand View Research (2023)
2021	48.3	Grand View Research (2023)
2022	50.3	Grand View Research (2023)
2025*	~65.0 (Projected)	Grand View Research (2023)

The global mushroom market has experienced substantial growth, reaching approximately USD 50.3 billion in 2022 (Grand View Research, 2023). Despite this expansion, traditional mushroom farming faces several limitations, including environmental sensitivity, labour dependency, and susceptibility to contamination.

Table 7: Comparative Performance

Parameter	Value	Source
Traditional yield	~250 kg	Kumar et al. (2021)
Smart yield	~320 kg	Kumar et al. (2021)
Crop loss (traditional)	~20%	Li et al. (2022)
Crop loss (smart)	~8%	Li et al. (2022)
Profit margin increase	25% → 45%	World Bank (2019)

Smart agriculture, also referred to as precision agriculture, involves the application of advanced technologies to optimize agricultural processes. Precision farming, sometimes known as smart agriculture, is the application of contemporary technologies to maximise agricultural operations, increase efficiency, and so support sustainability. In mushroom cultivation, where environmental control is critical, smart agriculture offers significant advantages by enabling real-time monitoring, automation, and predictive decision-making. Traditional farming does, however, have difficulties including environmental considerations and human effort. To raise productivity, quality, and sustainability, technological developments include biotechnology-based advances, automated farming systems, and controlled environment agriculture are sorely needed. By improving output, reducing resource waste, and guaranteeing constant crop quality, smart agriculture—also known as precision farming—has transformed mushroom growing.

Smart agriculture, also referred to as precision farming, involves the use of modern technologies to optimize agricultural processes, improve efficiency, and promote sustainability. In the context of mushroom cultivation, the integration of smart agriculture techniques has revolutionized traditional farming methods by enhancing productivity, minimizing resource waste, and ensuring consistent crop quality.

By improving output, reducing resource waste, and guaranteeing constant crop quality, the integration of smart agricultural technologies has transformed conventional farming methods in the framework of mushroom production.

The Role of Smart Agriculture in Mushroom Cultivation:

(a) IoT & Sensor-Based Monitoring: Mushroom growth is highly sensitive to environmental parameters such as temperature, humidity, carbon dioxide concentration, and light intensity. IoT-enabled sensors facilitate continuous monitoring and real-time adjustments of these parameters. Studies show that sensor-based climate control systems can increase productivity by up to 30% while reducing resource wastage (Kumar et al., 2021). These systems allow farmers to remotely manage growing conditions through mobile applications, ensuring consistency and minimizing human error. From a critical perspective, while IoT enhances efficiency, its effectiveness depends on reliable internet connectivity and infrastructure, which may be lacking in rural areas.

(b) Harvesting and Processing Automation: Artificial Intelligence (AI) and Machine Learning (ML) have emerged as powerful tools for disease detection and crop management. Image recognition systems can identify early signs of fungal infections or contamination, enabling timely intervention (Li et al., 2022). Moreover, AI models can predict yield, optimize harvesting schedules, and recommend environmental adjustments. This reduces uncertainty and improves decision-making. Automation technologies, including robotics and computer vision, address labour-intensive aspects of mushroom cultivation. Robotic systems can identify mature mushrooms and harvest them with precision, reducing damage and labour dependency (Zhang et al., 2020). However, the adoption of AI in mushroom farming remains limited due to high costs and the need for large datasets, which are often unavailable in developing regions. Computer vision-enabled robotic harvesting systems are able to recognise and safely harvest mature mushrooms. Systems for automated sorting and packaging increase productivity even more.

2. Blockchain for Transparency in the Supply Chain:

Blockchain technology enhances transparency and traceability in the agricultural supply chain. By recording each stage of production and distribution in a decentralized ledger, it ensures data integrity and reduces fraud. From farm to consumer, blockchain technology guarantees traceability in the

mushroom supply chain. This increases consumer trust and improves food safety. To lower the danger of fraud and contamination, Walmart has deployed blockchain technology to track shipments of mushrooms (Forbes, 2022). It is a good example of Block chain for Transparency in the Supply Chain. However, its implementation requires digital literacy and infrastructure, which may limit its applicability in resource-constrained settings.

1. **Difficulties in Implementing Smart Agriculture for Mushroom Growing**

(a) High Initial Outlay: Small-scale farms find the expenses of IoT devices, artificial intelligence systems, and automation tools intolerable. Small and marginal farmers often lack access to capital, limiting adoption. Cooperative farming ideas and government subsidies help to lessen this problem.

(b) Absence of Technical Knowledge: The operation and maintenance of advanced technologies require specialized knowledge. Many farmers lack the necessary training, creating a gap between technological availability and practical implementation.

(c) Against Transformation: Unfamiliarity or mistrust can make traditional farmers unwilling to adopt smart farming techniques. Traditional farming practices are deeply rooted, and farmers may be hesitant to adopt unfamiliar technologies without clear evidence of benefits. Pilot initiatives and awareness efforts help to inspire acceptance.

2. Future Opportunities and Suggestions

Integration with Vertical farming paired with smart agriculture can maximise space use and productivity in urban mushroom cultivation. Future systems could use artificial intelligence to forecast ideal harvest dates and market demand, therefore lowering waste and raising profitability. Funding Support for Policies Governments should encourage smart farming via grants, low-interest loans, and research money.

(a) Integration with Vertical Farming: Combining mushroom cultivation with vertical farming systems can maximize space utilization, particularly in urban areas. This approach supports sustainable urban agriculture and reduces land pressure.

(b) AI-Driven Predictive Analytics: Future advancements may enable AI systems to predict market demand, optimize supply chains, and reduce post-harvest losses. This will enhance profitability and sustainability.

(c) Policy and Institutional Support: Governments and institutions must play a proactive role by providing subsidies and financial incentives, supporting research and innovation and by promoting digital literacy among farmers.

Conclusion

Mushroom cultivation is well-positioned to benefit from the advancements in smart agriculture due to its reliance on controlled environmental conditions. Technologies such as IoT, AI, automation, and blockchain have the potential to significantly enhance productivity, quality, and sustainability.

However, the transition to smart mushroom farming is constrained by economic, technical, and social challenges. Addressing these barriers through policy support, training, and innovation is essential for widespread adoption.

In conclusion, smart agriculture represents a transformative pathway for mushroom cultivation, offering opportunities for sustainable growth, improved food security, and economic development.

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