journal homepage: https://journal.pktm.com.my/

International Journal of Technical Vocational and Engineering Technology

e-ISSN2710-7094, Vol. 6, No. 2 (2025)

Proof Of Concept: Integrating Deep Learning And IOT In Oyster Mushroom Farming

Maz Azleena Azahari[1], Niza Asyadi Hamzah[1], Abdul Hardy Suparna[1] , Dwiny Meidelfi[2]

[1]Kolej Komuniti Chenderoh, 33300, Kuala Kangsar, Perak, Malaysia

[2]Politeknik Negeri Padang, 25163, Padang, West Sumatera, Indonesia

*Corresponding Author email: azleena@kkche.edu.my

ARTICLE INFO
Article History:
Received 2 July 2025
Revised 10 September 2025
Accepted 22 October 2025
Published 30 October 2025

Keywords:
Deep Learning;
IoT;
Oyster Mushroom;
Precision Agriculture;
Smart Farming;
Harvest Prediction

ABSTRACT
This proof-of-concept study explores the integration of deep learning and Internet of Things (IoT) technologies in oyster mushroom (Pleurotus ostreatus) farming to overcome challenges of manual monitoring, inconsistent yields, and resource inefficiency. The objective was to design and evaluate an intelligent system for automated environmental control and harvest prediction. Guided by the design thinking framework, the study progressed from problem identification to prototype development and testing. A solar-powered mushroom house (4 × 6 ft) was equipped with IoT sensors for temperature, humidity, air quality, and light, integrated with actuators for misting, ventilation, and lighting. Convolutional neural network models, trained using collected and historical datasets, enabled accurate harvest readiness prediction. Experimental results showed prediction accuracy of 85–92% and effective environmental regulation with reduced human intervention. Despite challenges related to sensor calibration, dataset size, and scalability, the findings validate the feasibility of IoT–deep learning integration. The novelty of this work lies in combining real-time sensing with predictive analytics, offering a sustainable and scalable pathway toward intelligent mushroom farming for smallholder agriculture.

1.0 Introduction

1.1 Background of the Study

Smart agriculture is rapidly transforming traditional farming practices by integrating digital technologies to enhance productivity, resource efficiency, and sustainability. Among these technologies, the convergence of the Internet of Things (IoT) and deep learning has introduced new capabilities for intelligent monitoring, prediction, and automation in crop production (Sharma et al., 2022). IoT systems enable real-time tracking of environmental variables through interconnected sensors and devices, while deep learning models extract patterns from data to support predictive decision-making and autonomous control (Patel et al., 2021).

Oyster mushroom (Pleurotus ostreatus) farming has gained popularity due to its nutritional benefits, low capital requirements, and short growth cycle. However, optimal cultivation depends on precise environmental conditions—particularly humidity, temperature, and CO_2 levels—which are typically regulated manually, leading to inconsistencies in yield and quality

(Ahmed et al., 2020). Manual methods are also labour-intensive and often rely on subjective assessments by growers.

The integration of deep learning and IoT offers a promising solution to these challenges. By combining sensor data with predictive algorithms, such systems can enable real-time environmental control, harvest stage prediction, and reduced dependency on human intervention. This proof of concept explores the potential of such integration in oyster mushroom farming to improve productivity and operational efficiency.

1.2 Research Problem

Despite increased interest in precision agriculture, existing IoT systems in mushroom farming are often limited to monitoring functions without intelligent prediction or automation features. Furthermore, the adoption of such technologies among small and medium-scale growers remains low due to a lack of affordable, scalable solutions. This research addresses these issues by presenting a proof-of-concept that support the integration of deep learning with IoT infrastructure to automate and optimize environmental conditions in an oyster mushroom house, while also predicting harvest readiness.

1.3 Aim and Objectives

This study aims to develop and evaluate a proof of concept for an integrated deep learning and IoT system in an oyster mushroom farming house. The specific objectives are:

1.3.1. To evaluate the effectiveness of deep learning in improving decision-making, reducing resource consumption, and increasing operational efficiency in mushroom cultivation.

1.3.2. To assess the challenges and feasibility of implementing a scalable IoT and deep learning system in traditional mushroom farming practices.

1.4 Scope of the Study

This study is conducted as a proof of concept and limited to a small-scale, controlled oyster mushroom cultivation environment. The prototype includes basic environmental sensors, deep learning models trained on collected and existing datasets, and simple automation mechanisms. The implementation is focused on functionality and feasibility rather than large-scale deployment or commercialization.

1.5 Significance of the Study

This study contributes to the growing body of research on smart agriculture by demonstrating the feasibility of integrating deep learning and IoT technologies in mushroom cultivation. The findings provide insights for researchers, agro-tech developers, and practitioners seeking to adopt intelligent farming solutions in resource-constrained settings. Additionally, it highlights the potential for cost-effective automation in traditional farming systems.

2.0 Literature Review

2.1 Internet of Things (IoT) in Precision Agriculture

The Internet of Things (IoT) has significantly reshaped modern agriculture by enabling real-time monitoring and control of farming environments. Through a network of interconnected sensors and actuators, farmers can track parameters such as temperature, humidity, soil moisture, light intensity, and CO_2 levels with precision (Sharma et al., 2022). These data points not only provide visibility into current conditions but also allow for the automation of climate regulation systems, which are particularly important in controlled environments such as greenhouses and mushroom houses.

In mushroom cultivation, IoT systems have been implemented to monitor and control environmental conditions critical to fungal growth (Ahmed et al., 2020). Previous studies such as

Boonmee et al. (2021) demonstrated how IoT-based environmental control improved stability in mushroom cultivation, although their systems were limited to monitoring rather than predictive automation. However, most existing systems function primarily as data loggers or alert systems, lacking intelligent features such as predictive analytics or adaptive automation. The absence of integration with learning algorithms limits the potential of these technologies to fully optimize production efficiency and yield quality.

2.2 Deep Learning in Agriculture

Deep learning—a subset of machine learning involving artificial neural networks with multiple layers—has emerged as a powerful tool in agriculture due to its ability to process large volumes of complex, unstructured data (Patel et al., 2021). Common applications include crop disease detection, yield forecasting, growth stage classification, and climate condition prediction.

Models such as Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks have been widely used in agricultural tasks. CNNs excel at image-based analysis, such as identifying plant diseases or classifying phenological stages (Dinh et al., 2023), while LSTMs effectively analyse time-series sensor data for forecasting environmental parameters like humidity and temperature (Singh et al., 2022).

Despite the proven effectiveness of deep learning in broader agricultural contexts, its application in mushroom farming remains limited. There is a clear research opportunity to develop systems that combine deep learning’s predictive capabilities with environmental data from IoT systems to enhance cultivation outcomes.

2.3 IoT and Deep Learning Integration in Smart Farming

The convergence of IoT and deep learning technologies is a major trend in precision agriculture. This integration allows for closed-loop systems where sensor data not only inform but also trigger automated responses based on intelligent predictions (Sharma et al., 2022). For instance, systems can predict when to irrigate or ventilate based on forecasts generated by trained models, reducing manual intervention and resource waste.

Jou et al. (2022) highlighted the potential of autonomous IoT platforms in mushroom cultivation, aligning with the shift towards mobile and adaptive smart farming solutions. Implementation requires coordination between hardware (sensors and actuators), communication protocols (e.g., MQTT), edge computing devices (e.g., Raspberry Pi, ESP32), and software frameworks (e.g., TensorFlow). Case studies have shown improvements in yield prediction accuracy and operational cost reduction when such systems are effectively implemented (Rahman et al., 2021).

2.4 Applications in Mushroom Cultivation: Gaps and Opportunities

Mushroom farming presents a unique environment for precision agriculture, characterized by enclosed microclimatic conditions. While IoT-based monitoring systems visualize environmental data, few studies extend into predictive automation using AI models (Surige et al., 2021; Sujatanagarjuna et al., 2023). The dynamic nature of mushroom growth stages—particularly rapid changes before harvest—presents an opportunity for deep learning models to predict readiness and trigger timely interventions.

2.5 Research Gap and Justification

Current literature demonstrates the individual effectiveness of IoT for monitoring and deep learning for prediction. However, very few studies combine both specifically for mushroom farming. This study fills that gap by developing a proof-of-concept system that integrates deep learning with IoT for oyster mushroom cultivation. Elewi et al. (2024) emphasized cost-awareness in smart mushroom cultivation systems, highlighting affordability as a critical factor for adoption in low-resource settings.

3.0 Methodology

3.1 Research Design

This study adopted a proof-of-concept research design, which emphasizes the early-stage development and validation of an integrated deep learning and Internet of Things (IoT) system in oyster mushroom farming. The approach is exploratory and evaluates technical feasibility and functional potential in a controlled oyster mushroom farming environment.

3.2 Integration Approaches

This study identified IoT-based sensing combined with data driven (deep learning) control was the most common integration strategy in mushroom farming. Real-time data processing was frequently reported, with several studies using cloud platforms (such as ThinkSpeak or web applications) for visualizations and alerts. The automation workflows varied from simple actuator control (fans, pumps) to fully automated harvesting (Sujatanagarjuna et al., 2023). Other than that, integration of advisory support or digital twins for enhanced decision-making and scalability was described in some studies (Guragain et. Al., 2024; Sujatanagarjuna et. al, 2023).

3.3 Design Thinking Framework

To structure the methodological approach, the process was aligned with the five phases of the Design Thinking framework; Empathize, Define, Ideate, Prototype, and Test, commonly applied in technology-driven innovation research.

3.3.1 Emphasize

The research began by identifying the challenges encountered in small-scale oyster mushroom cultivation, particularly the dependency on manual monitoring, inconsistent yields due to environmental fluctuations, and the absence of affordable automation solutions. A comprehensive review of existing literature on IoT and artificial intelligence in agriculture was conducted to gain insights into farmers' pain points and to contextualize the research within current technological developments. The thematic analysis of IoT system architecture and environmental control strategies is shown in Table 1.

Table 1.1: Thematic analysis of IoT system architecture and environmental control strategies

Study	Study Focus	Control Method	Environmental Parameters	Accuracy Metrics	Cost Consideration
Taupa et al., 2025	Harvest readiness prediction in oyster mushrooms	IoT plus Convolutional Neural Networks (CNNs)	Temperature, humidity, air quality, light	Harvest prediction: 85% accuracy, F1 score 89%	Solar reduces operation costs
Guragain et al., 2024	Centralized IoT ecosystem for oyster mushrooms	IoT ecosystem, disease detection model	No mention found	Disease detection: 98.33%, yield +49%	Low-cost focus
Sujatanagarjuna et al., 2023	Modular indoor system for gourmet mushrooms	Mask Region-based Convolutional Neural Network (Mask R-CNN), digital twin	Temperature, humidity, air quality	Maturity detection: 91.7%	Lower environmental impact
Nuankaew et al., 2025	Disease detection in oyster mushrooms (growing bags)	DenseNet201 CNN	Temperature, humidity	Disease detection: 92.5%	No mention found
Elewi et al., 2024	Smart system for oyster mushrooms in low-resource settings	Smart system	Temperature, humidity, air quality, illumination	No mention found	Cost-effective

3.3.2 Define

Based on the insights gained, the problem statement was formulated: there is a critical need for a cost-effective, intelligent system capable of monitoring and optimizing environmental conditions in mushroom farming. The study specifically sought to address the limitations of existing IoT-based systems that are largely restricted to data logging and alert functions without predictive or automated decision-making capabilities.

3.3.3 Ideate

Possible integration strategies were examined by reviewing prior applications of IoT and deep learning in agriculture. Several alternatives were considered, including sensor-based environmental control, cloud-based visualization platforms, and the incorporation of predictive algorithms such as Convolutional Neural Networks (CNNs). The ideation phase converged on the concept of a proof-of-concept system that combines real-time IoT sensing with deep learning models for harvest readiness prediction and automated environmental control.

3.3.4 Prototype

A functional prototype was designed and implemented in a controlled cultivation environment (a 4 × 6 ft mushroom house). The system architecture integrated IoT sensors (temperature, humidity, air quality, and light), actuators (misting system, ventilation fans, and artificial lighting), and a Raspberry Pi as the central processing unit. Machine learning models were trained using both collected and historical growth data to predict the optimal harvest period. The prototype also incorporated a solar-powered energy system to ensure sustainability and was connected to a web-based application for real-time monitoring and automated actuation.

3.3.5 Test

The prototype underwent experimental validation in a small-scale cultivation setting. System performance was assessed in terms of its ability to regulate environmental parameters, predict harvest readiness, and reduce manual intervention. Results demonstrated that the integrated system achieved high accuracy in harvest prediction (85–92%) while maintaining resource efficiency through solar-powered operation. However, several challenges were identified, including sensor calibration, dataset limitations, and the need for scalability testing. These findings informed the study’s recommendations for future research, including adaptive control mechanisms, expanded datasets, and field-based deployment.

4.0 System Implementation

The framework of this study integrates solar-powered IoT technology with machine learning, aligning with the principles of precision agriculture. A controlled cultivation system was established to monitor critical growth parameters, including temperature, humidity, air quality, and light intensity. Continuous real-time data acquisition allowed for consistent tracking of environmental conditions throughout the cultivation process. The collected data were analysed using a machine learning algorithm designed to predict harvest readiness. By incorporating historical growth metrics, the models were trained to improve predictive performance, enabling accurate determination of the optimal harvest period. To ensure uninterrupted operation and reduce energy consumption, the entire monitoring system was powered by solar energy, supporting both sustainability and operational efficiency.

4.1 System Architecture

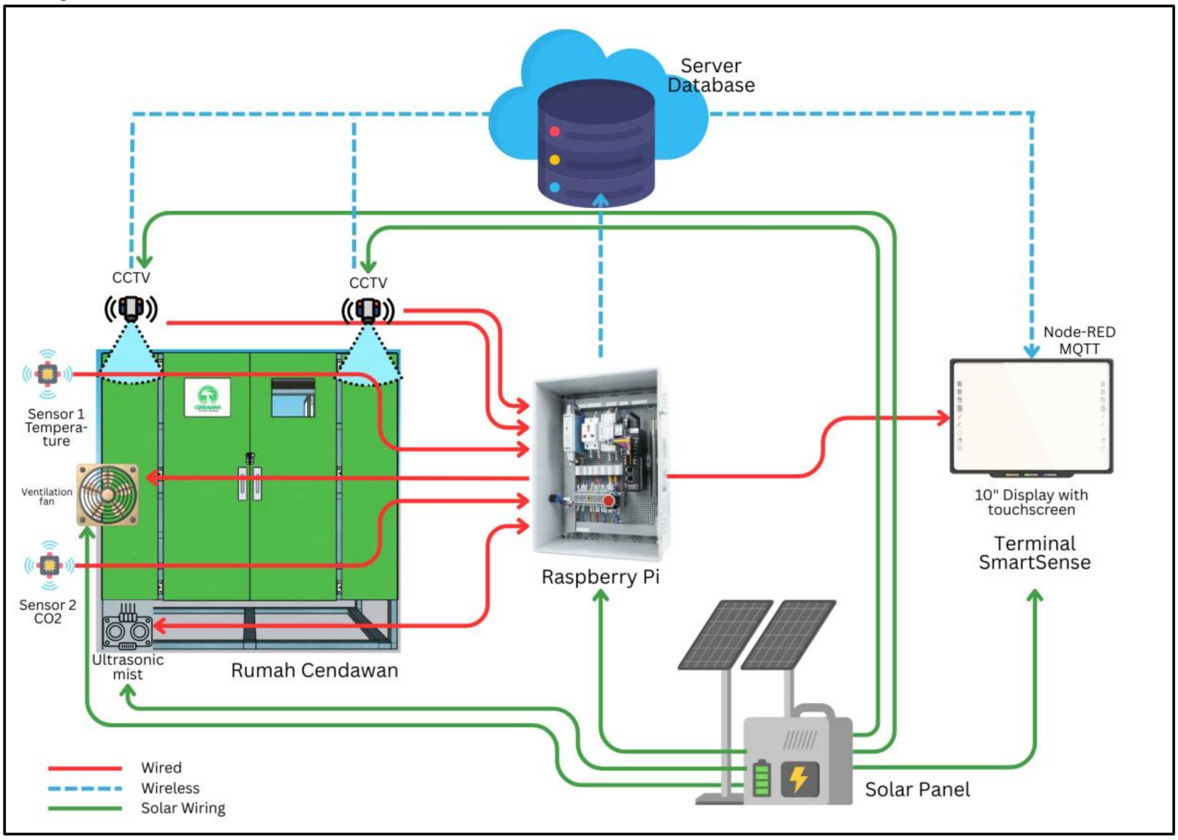

Figure 1.1: Proposed System Architecture

This proposed system (Figure 1.1) was designed and implemented in a 4 × 6-feet mushroom house. This system integrates sensing, actuation, image processing, and machine learning to automate environmental monitoring and growth stage detection. The central processing unit (CPU) of the system is a Raspberry Pi, which collects data from sensors, processes images, and controls actuators to maintain optimal cultivation conditions.

Environmental monitoring was achieved using a DHT11 sensor for temperature and humidity, along with light intensity and air quality sensors. These sensors provide real-time data essential for maintaining the growing environment. Actuators, including a misting system, exhaust fans, and artificial lighting, were integrated to regulate temperature, humidity, air circulation, and illumination.

The system was integrated with a web-based application for real-time monitoring and control. Automated decision logic activated the misting system, ventilation, and lighting when environmental parameters exceeded predefined thresholds, ensuring continuous optimization of the growing environment without human intervention.

5.0 Conclusion and Future Research

The reviewed studies provide a comprehensive technical overview of the integration of deep learning and Internet of Things (IoT) technologies for smart environmental control and yield prediction in oyster mushroom cultivation.

5.1 Technical Integration

Most of the reported systems combined IoT-based sensing with either rule-based mechanisms (e.g., fuzzy logic) or data-driven approaches such as deep learning. These systems frequently incorporated real-time data processing and cloud-based platforms for visualization and alert notifications.

5.2 Reported Performance

In studies where performance data were available, artificial intelligence components demonstrated high levels of accuracy (ranging between 85% and 99%) in tasks including harvest prediction, disease detection, and yield estimation. However, it is important to note that the majority of these results originated from prototypes or abstract-only publications, which limits the confidence in their broader applicability.

5.3 Environmental Control

Across the studies, temperature and humidity emerged as the most frequently monitored environmental parameters. Some systems reported enhanced control accuracy or faster response times when compared to traditional ON-OFF control mechanisms. Nevertheless, quantitative evidence supporting these improvements remained limited.

5.4 Practical Considerations

Several studies highlighted cost-effectiveness, resource efficiency, and scalability as key design considerations. User interfaces varied across systems, ranging from web-based and mobile applications to open-source digital twin platforms. Despite these advancements, much of the evidence was derived from small-scale prototypes or simulation-based studies. Similar IoT-integrated automation has been reported in crop seeding systems (Murugiah et al., 2024), reflecting the broader potential of intelligent robotics in precision agriculture.

In summary, the available literature demonstrates promising technical strategies for the integration of deep learning and IoT in oyster mushroom farming. However, the current evidence remains constrained to early-stage investigations, and further research is necessary to establish the generalizability and practical value of these systems in large-scale, field-based applications. However, the proof of concept validated the technical feasibility of an IoT–deep learning system for oyster mushroom cultivation, demonstrating accurate environmental forecasts and harvest predictions, reduced labour, and resource optimization.

5.5 Future Research

The integration of IoT and deep learning enhanced decision-making, automation, and resource efficiency in oyster mushroom farming, consistent with smart agriculture research. Challenges include data volume, environmental variability, sensor maintenance, and adoption barriers. Modular design supports scaling, with future directions including adaptive control and expanded datasets. Therefore, we would recommend these suggestions for future research.

- Expand and diversify datasets for robust model training.
- Integrate adaptive control algorithms (e.g., reinforcement learning).
- Test in varied and outdoor environments.
- Develop intuitive dashboards and mobile interfaces.
- Conduct longitudinal cost–benefit analyses.
- Collaborate with agricultural extension services for knowledge transfer.

Acknowledgements

The authors would like to thank Kolej Komuniti Chenderoh for the continuous support in conducting this study.

Author Contributions

Azahari M. A.: Conceptualization, Methodology, Writing- Original Draft Preparation; **Hamzah N. A.**: Validation, Supervision; **Suparna A. H.**: Validation, Writing-Reviewing and Editing; **Meidelfi D.**: Writing-Reviewing and Editing.

Conflicts of Interest

The manuscript has not been published elsewhere and is not being considered by other journals. All authors have approved the review, agree with its Submission and declare no conflict of interest in the manuscript.

6.0 References

Ahmed, R., Mohamad, M. H., Abdullah, S. N. H. S., & Rahman, R. A. (2020). Environmental monitoring system for mushroom farming using IoT. *Journal of Physics: Conference Series*, *1529*(4), 042040. https://doi.org/10.1088/1742-6596/1529/4/042040

Boonmee, S., Chaisricharoen, R., & Srisawatsakul, P. (2021). IoT-based environmental control system for mushroom cultivation. *International Journal of Agricultural Technology*, *17*(3), 781–790.

Dinh, T. H., Nguyen, T. A., & Bui, H. M. (2023). Deep learning application for plant growth stage classification using CNN. *Computers and Electronics in Agriculture*, *204*, 107530. https://doi.org/10.1016/j.compag.2023.107530

Elewi, A., Hajhamed, A., Khankan, R., Duman, S., & Souag, A. (2024). Design and implementation of a cost-aware and smart oyster mushroom cultivation system. *Smart Agricultural Technology*, *5*, Article 100178. https://doi.org/10.1016/j.atech.2024.100439

Guragain, D. P., Shrestha, B., & Bajracharya, I. (2024). A low-cost centralized IoT ecosystem for enhancing oyster mushroom cultivation. *Journal of Agriculture and Food Research*, *16*, Article 101513. https://doi.org/10.1016/j.jafr.2023.100952

Jou, R., Li, W.-J., Shih, H., & Chiu, H.-C. (2022). Research on autonomous mobile intelligent IoT platform in mushroom cultivation. In *Proceedings of the International Conferences on Knowledge Innovation and Invention* https://doi.org/10.1109/ICKII55100.2022.9983567

Md Hussin, M. H. F.**,** Zakaria, N. F.**, &** Wei, F. J. (2023). Shoulder physio monitoring device using ESP32 microcontroller and web applications. *International Journal of Technical Vocational and Engineering Technology, 4*(1), 41–49.

Murugiah, N.**,** Mahendra, V.**,** Purushotaman, P.**,** Rassiah, K., & Karudin, A. (2024, October 31). Review on AutoSeed: Smart seeding tray robot with IoT integration. *International Journal of Technical Vocational and Engineering Technology, 5*(2), 32–38. https://journal.pktm.com.my/

Patel, H., Gandhi, R., & Thakkar, A. (2021). A survey on applications of artificial intelligence, machine learning and deep learning for agriculture. *Artificial Intelligence in Agriculture*, *5*, 18–31. https://doi.org/10.1016/j.aiia.2021.03.001

Rahman, A., Islam, M., & Hossain, M. A. (2021). Design and development of a low-cost intelligent irrigation system using IoT and machine learning. *Heliyon*, *7*(8), e07759. https://doi.org/10.1016/j.heliyon.2021.e07759

Sharma, K., Garg, A., & Kaushik, B. K. (2022). IoT and deep learning-based smart agriculture: Recent advances and future directions. *Sustainable Computing: Informatics and Systems*, *35*, 100754. https://doi.org/10.1016/j.suscom.2022.100754

Singh, J., Rathore, A. S., & Sharma, V. (2022). Environmental parameter forecasting for smart agriculture using LSTM. *Materials Today: Proceedings*, *56*, 2069–2073. https://doi.org/10.1016/j.matpr.2021.10.412

Taupa, G. J., Villarica, M. V., & Vinluan, A. (2025). Enhancing oyster mushroom cultivation with solar-powered IoT and machine learning: Predicting harvest readiness. *Journal of Information Systems Engineering & Management*, *10*(33s). https://doi.org/10.52783/jisem.v10i33s.5551

Sujatanagarjuna, A., Kia, S., Briechle, D., & Leiding, B. (2023). MushR: A smart, automated, and scalable indoor harvesting system for gourmet mushrooms. *Agriculture*, *13*(3), Article 677. https://doi.org/10.3390/agriculture13081533

Surige, Y. D., Perera, W. S. M., Gunarathna, P. K. N., Ariyarathna, K. P. W., & Gamage, N. (2021). IoT-based monitoring system for oyster mushroom farming. In *Proceedings of the International Conference on Automation and Computing*. https://doi.org/10.1109/ICAC54203.2021.9671112