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Development of IoT Based Temperature, Humidity, and Substrate pH level Control System for Oyster Mushroom *(Pleurotus Spp.)* Cultivation

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Abstract

The environment is a crucial aspect that must be regulated in mushroom cultivation. Mushrooms are less grown in temperatures above 28°C and grow beds must maintain a pH level of 5.5 to 6 for optimal growth. Thus, the focus of this study is on establishing an autonomous environmental control system to offer optimal conditions in the mushroom production area. This project is presenting an implementation of Internet of Things (IoT) monitoring and environmental control for indoor cultivation of Oyster Mushroom. Environmental factors considered in the study were temperature and humidity of the area and the pH level of the grow beds. The system employed a soil pH level sensor to monitor the current pH level in the grow beds and DHT11 for temperature and humidity. When the temperature rises above 28°C, the cooling fan turns on automatically. This reduces the temperature in the culture space, which is required for mushroom development. The humidifier is set to activate every ten (10) minutes and shuts off after five (5) minutes. This will assist to maintain the humidity of the area, which is also important in mushrooms. Likewise, when the pH of the grow beds falls below 5, the system will automatically pump and inject an appropriate amount of liquid lime to adjust the pH level until it reaches the suitable pH level of 6. Moreover, all of these data can be accessed remotely via internet using PC or smartphone. In conclusion, the system was evaluated using ISO 25010 and consisted of the following components: functional suitability, reliability, portability, usability, performance efficiency, security, compatibility and maintainability. The overall rating of the system was 4.64, which indicated an “excellent“ grade. Thus, the system provides significant help in the optimum growth of the Oyster Mushroom.

Keywords: Oyster Mushroom; IoT; Physicochemical; Sensor

Introduction

Creative Industries are regarded as one of the fastest expanding industries in the global economy, contributing considerably to industrialized countries' Gross Domestic Product (GDP). The Philippines is a growing country with a rich cultural past and a reservoir of creative minds that have the ability to enhance the economy through their creative goods. Internet of Things (IoT)-enabled technologies are one of its research priorities for the years 2024-2028. (DOST HNRD Agenda 2022-2028).

With the advent of new technologies such as the Internet of Things (IoT), enhancing the productivity of agriculture and farming operations is critical for increasing yields and cost-effectiveness. IoT, in particular, has the potential to improve agricultural and farming operations' efficiency by eliminating the need for human interaction through automation. Due to technical advances such as sensors, gadgets, machinery, and information technology, modern farms and agricultural operations are significantly different from those just a few decades ago. Using sensors and actuators to control their ideal environmental conditions may result in higher grade mushrooms. (Nisha Aggarwal, Dinesh Singh, 2022).

Oyster mushroom cultivation is common in tropical areas and is regarded one of the marketable and edible varieties of mushrooms. Using sensors and actuators, controlling their ideal environmental conditions could produce better quality mushrooms. Oyster mushroom growth usually optimal at temperatures around 22-28°C and humidity around 70-90%. This problem is often encountered in the cultivation of oyster mushrooms (Rebaka Sultana, et al., 2018). Hence, it is very important to control the temperature and humidity of the room of oyster mushroom cultivation. Also, the soil pH has a vital role on nutrition and morphological development of mushrooms. The optimum range of pH for mycelium growth is about 5.5 and 6.5 and the optimum range of pH was different in different strains of *Pleurotus spp* (P Sihombing, et al., 2017).

Mushroom farming does not require a large amount of area for growing; in fact, indoor mushroom culture is becoming increasingly popular. Farmers use the conventional method in managing the environmental conditions of the cultivation area such as temperature and the pH level content of the mushroom beds that resulted to decreasing of yield of the oyster mushroom. These implications are considered vital to the sustainability of the mushroom's growth.

Presently, mushrooms are cultivated inside a room with highly closed environment in order to obtain the required temperature and humidity. In order to regulate the temperature when it rises above 28˚C the farmer manually sprinkle water in the area. Similarly, farmers do not have the technology to monitor the pH level of the grow beds in the cultivation area. The farmers only using the calendar technique to regulate the pH level of the grow beds by pouring liquid chemicals every two (2) weeks without knowing the exact pH level content in the grow beds. By engaging in such methods, the required level of temperature, humidity and pH level is not attained, resulting in a reduced yield of mushrooms and a low profit.

Oyster mushroom farming is a practical and appealing pastime for both rural farmers and peri-urban people because it does not require access to the vast land. Presently, farmers use the conventional method in managing the environmental conditions of the cultivation area. Some issues such as uncontrolled room temperature and imprecise pH assessment have arisen as a result of this strategy. This action is considered important to the sustainability of the mushroom's growth. Furthermore, no technology is currently prearranged to assess these conditions for oyster mushroom production. Mushroom cultivation can help reduce poverty vulnerability and boost livelihoods by providing a high-yielding, nutritious food source as well as a consistent source of income. However, the yield of oyster mushrooms is lesser in the conventional method. To improve the yield of mushrooms, controlling the physicochemical parameters such as temperature, humidity and pH level must be attained.

Thus, the goal of this study is to design and develop an automation system that will manage the growth of the oyster mushroom. As a result, an interior temperature and humidity controller and an automated system for monitoring and regulating the pH level content of mushroom beds were developed. This innovation will be critical to the long-term viability of oyster mushroom production. On this study, an integration of technology into oyster mushroom cultivation is being applied. This technology-integration allows for precision agriculture such as yield monitoring, temperature control and determining substrate pH level for oyster mushroom production.

Objectives

The study aimed to develop an IoT based temperature, humidity and pH level automation system that manages and maintain the requirements in growing oyster mushroom.

The following are the specific objectives:

1. To design and develop a system that effectively monitors and controls indoor temperature, humidity and pH level in the oyster mushroom cultivation area using sensors.

2. To evaluate the developed IoT system based on ISO 25010 standards in terms of functional suitability, reliability, portability, usability, performance efficiency, security, compatibility, and maintainability.

Technical Background

Internet of Things (IoT)-based automation of agricultural events can change the agriculture sector from being static and manual to dynamic and smart, leading to enhanced production with reduced human efforts. Precision Agriculture (PA) along with Wireless Sensor Network (WSN) are the main drivers of automation in the agriculture domain. PA uses specific sensors and software to ensure that the crops receive exactly what they need to optimize productivity and sustainability (Khalid Bin Muhammad, et al., 2022).

The concept of this study is to design and develop an automation system to improve the growth of the oyster mushroom *pleurotus spp.* by controlling its environment.

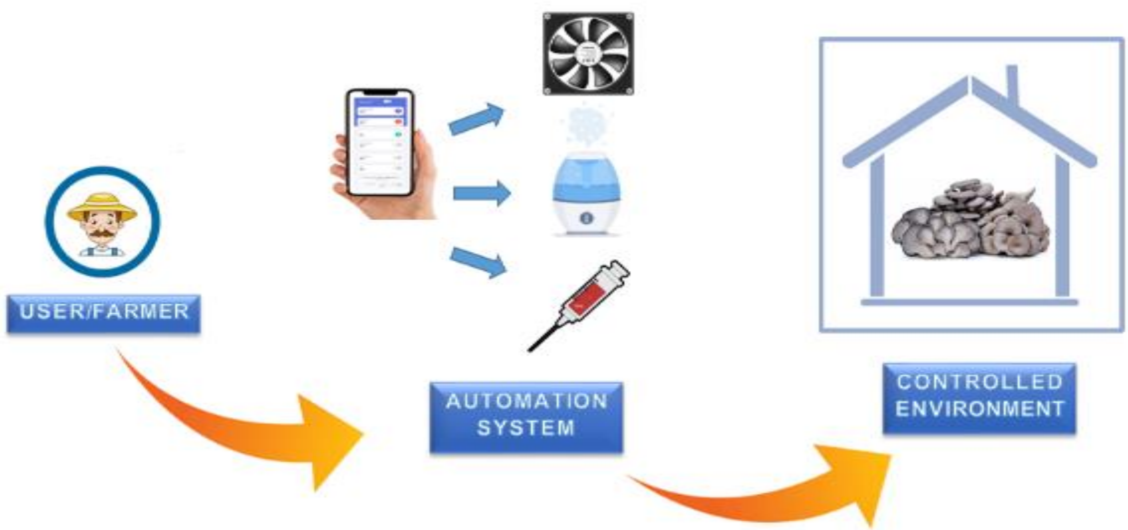

Fig. 1. System Architecture

Figure 1 shows the system architecture of the developed system. The user/farmer can access the system using smart phones or PC via internet connection. Once the farmer access the system, the farmer can now monitor the status of the environment in terms of temperature, humidity and substrate pH level as well as the state of the devices in real-time. The farmer can also override the control of all the devices integrated in the system such as cooling fan, humidifier and liquid pump. As a result, the environment of the cultivation area could reach its optimum requirements for the growth of the oyster mushroom.

Methods

The methodology is presented in this chapter. The project was carried out utilizing experimental research and a developmental strategy.

IoT based Technology

The first step in building any IoT-based paradigm was to gather data by researching oyster mushroom production and interviewing farmers. The farmer's controlled behavior was achieved through data variation. The system was created using the gathered data and with a specialized development cycle for Internet of Things-based systems exclusively.

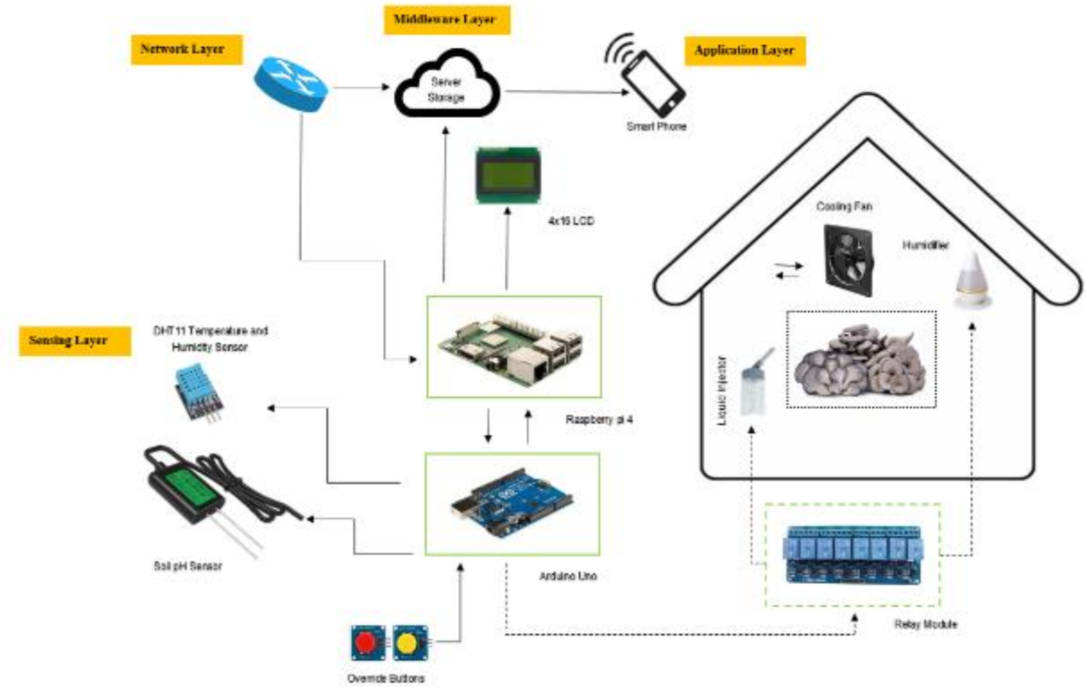

Fig. 2. System Block Diagram

Figure 2 depicts the study's overall system design. The system is divided into four major tiers. Sensing, network, middleware, and application are the layers. The sensor layer is primarily responsible for gathering real-time temperature, humidity, and pH levels from the grow beds. Essentially, the monitoring site is the farmer's mushroom production area. The second layer is the network layer, which is in charge of fundamental data and information transfer as well as the interaction of systems and cloud platforms. The third tier is the middleware layer, which is a collection of sublayers in the cloud that manage data, web servers, and cloud storage and is located between the network layer and the application layer. Finally, the application layer includes capabilities that allow users to access data in real-time via mobile devices.

The sensor readings were recorded to a set of parameters required by the microcontroller via analog or digital input connections, and this information data will be passed to the WiFi module via serial communication. The system was configured to connect to accessible WIFI with internet connection situated in the field area and control the data base of the system. Raspberry pi 4 and Arduino Uno obliges as the bridge to the sensors, it receives sensor data, and communicate sensor data to the database over the appropriate channel. Moreover, the system automates the process of adjusting pH levels in the grow beds. When the pH level of the grow beds drops below 5, the system will automatically inject liquid lime to regulate the pH level and stops when it reaches to the ideal level of 6.

On the other hand, the temperature and humidity of the indoor environment is monitored using DHT11 temperature sensor. The humidifier and cooling fan will automatically turn ON when the temperature rises 28˚C above and switch OFF when the temperature falls below 28˚C. This will reduce the temperature of the cultivation area which is essential for mushroom development.

Furthermore, the farmer can monitor the data such as pH level and temperature via internet using PC or smartphones. Likewise, the system has LCD installed that shows the current pH level of the grow beds as well as the temperature and humidity of the cultivation area. The farmer can also override the control of the liquid pump, cooling fan and the humidifier.

The study conducted an experimental method in which the factors has been observed in the controlled environment using the developed system and the uncontrolled environment. This experimental procedure was done in two weeks' time, or until harvesting time. The outcome of the comparison determined the yielding effect of the mushroom using the system. Environmental factors considered in the study were temperature and humidity of the area and the pH level of the grow beds. The system employed a soil pH level sensor to monitor the current pH level in the grow beds and DHT11 for temperature and humidity.

Furthermore, the system was set up to connect to an accessible WIFI network with an internet connection located in the field area and operate the system's data base. The Raspberry Pi 4 and Arduino Uno act as a bridge between the sensors, receiving sensor data and communicating it to the database via the appropriate channel. The technology also automates the process of regulating pH levels in grow beds. When the pH of the grow beds falls below 5, the system will automatically inject liquid lime to adjust the pH level and will stop when the pH level reaches the optimal level of 6.

The temperature and humidity of the inside environment, on the other hand, are monitored using a DHT11 temperature sensor. It is capable of measuring relative humidity between 20 and 90% RH within the operating temperature range of 0 to 50°C with an accuracy of ±5% RH. Temperature is also measured in the range of 0 to 50°C with an accuracy of ±2°C. Both values are returned with 8-bit resolution (W Gay, 2018). The humidifier and cooling fan will turn ON automatically when the temperature goes over 28˚C and turned OFF when the temperature falls below 28˚ C. This will lower the temperature of the culture area, which is necessary for mushroom growth.

In this method of oyster mushroom cultivation, various physicochemical parameters required for oyster mushroom cultivation are continuously monitored and are automatically adjusted to the required conditions. Farmers can also view these parameters in mobile phone or the PC System with internet connectivity. The temperature will be controlled by the cooling fan and humidifier. By this technique, required cooling is obtained than conventional method of cooling. Similarly, the optimum pH level of the grow beds can be maintained using the automation on adjusting the pH level in the grow beds. With this, it is easy to maintain the physicochemical parameters at an optimal level round the clock with a minimal effort and cost. By adopting this technique in mushroom cultivation, it is possible to obtain oyster mushrooms in high quantity than the conventional methods and this makes more profit for the cultivator rather than following conventional methods.

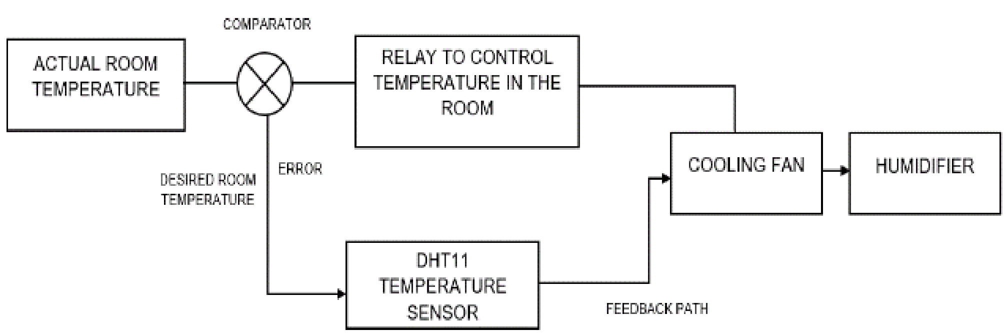

Fig. 3. Block diagram of the temperature and humidity control system

Figure 3 shows the block diagram of the temperature and humidity control system. The microcontroller measures the temperature from the Digital Integrated Circuit (DIC) DHT11 sensor, which senses the humidity and temperature from the surrounding. This sensor can measure a temperature range from 0°C to 50°C and humidity range from 20% to 90% with an accuracy of ±1°C and ±1%. The DHT11 sensor module gives the measured value of the temperature in degree Celsius. When the temperature hits 28°C or above, the humidifier and the cooling fan will automatically switch ON to decrease the heat.

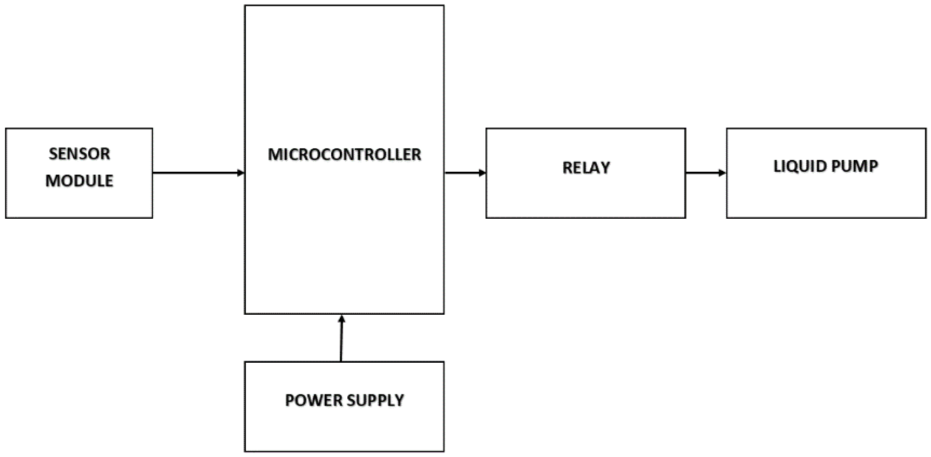

Fig. 4. Block diagram of the pH level automation

Figure 4 shows block diagram of the pH level automation. The incorporation of Raspberry Pi 4 and Arduino Uno were utilized to automate the process of regulating the pH level in grow beds. The pH level of the grow beds will be measured using a soil pH sensor. When the pH level of the grow beds dips below 5, liquid lime was automatically pumped into the grow beds to restore the pH required for oyster mushroom development. All of this information can be accessed via cell phone.

System Requirements

Table 1. Hardware and Software Requirements

Hardware	Software
1. Raspberry pi 4	1. Windows 10
2. Arduino Uno	2. Python
3. Soil pH Sensor	3. PHP
4. DHT11 Temp. Hum. Sensor	
5. RS485 Mudbus	
6. 4 Channel Relay Module	
7. Cooling Fan	
8. Humidifier	
9. DC 5V Water Pump	

Results and Discussion

This chapter presents the results of the study, focusing on the growth and development of oyster mushrooms *(Pleurotus spp.)* through the implementation of an IoT-based automation system.

Design and development of an IOT-based system

The developed system was implemented at SNSU-Mainit Campus Mushroom Production Area and was duly authorized by the school campus director with approved letter request. The suggested technology was tested using a closed cabinet replica.

Fig. 5. System Setup

A closed cabinet replica was used to test the proposed system shown in figure 5. The upper section is for the controlled environment, while the lower section is for the uncontrolled environment.

Fig. 6. The controller and socket outlet

Figure 6 shows the controller and socket outlet of the system and the main circuitry of the system. All hardware components are mounted on this panel box.

Fig. 7. Real-time Data

Figure 7 illustrated the system that has a liquid crystal display (LCD) installed to monitor the actual status of the environment in real-time including the pH level of the substrate. The buttons are also used in overriding the controls of the system.

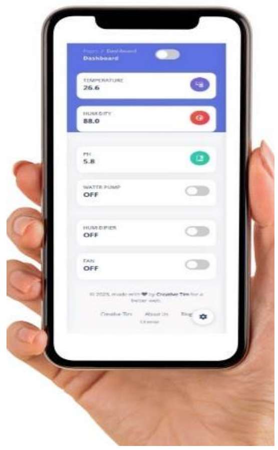

Fig. 8. Web Application

With IoT integration, the system can also be controlled and monitored over the internet. The system has the capability to override the controls and monitor actual environment condition using PC or mobile devices with access to the internet. The application was developed using PHP with assimilation of Laravel as framework, see Figure 8.

The actual data of the physicochemical parameters such as temperature, humidity and pH level can be acquired directly from the database of the system. The data can be downloaded as comma-separated values file (Figure 9).

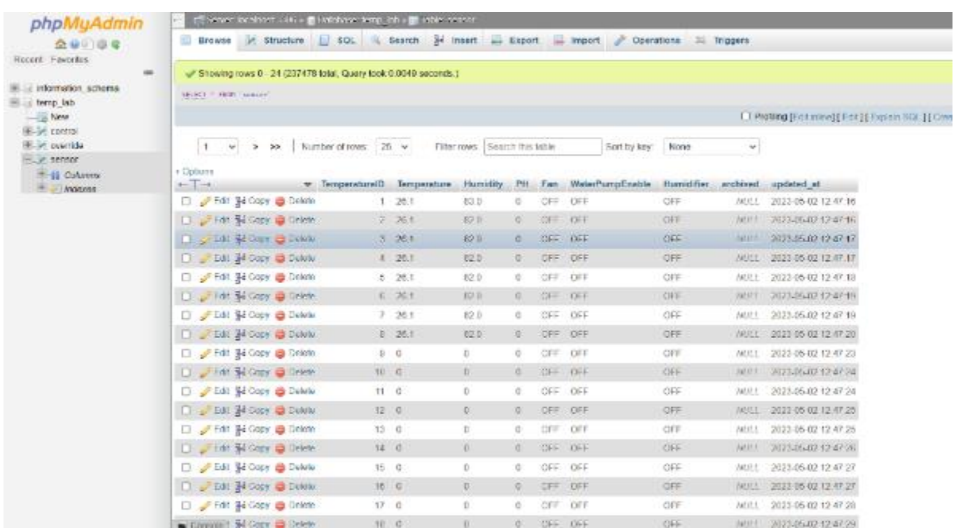

Fig. 9. Actual data from the database.

Figure 9 shows the actual data from the database. The data can be downloaded as .csv file. The data also shows the status of the device.

1	Temperat	ph	Humidity	updated_at	date
2	26.5	5.9	73	12:00:00 AM	6-Jun-23
3	26.5	5.9	73	12:00:00 AM	6-Jun-23
4	26.5	5.9	73	12:00:00 AM	6-Jun-23
5	26.5	5.9	73	12:00:00 AM	6-Jun-23
6	26.5	5.9	73	12:00:00 AM	6-Jun-23
7	26.5	5.9	73	12:00:00 AM	6-Jun-23
8	26.5	5.9	73	12:00:00 AM	6-Jun-23
9	26.5	5.9	73	12:00:00 AM	6-Jun-23
10	26.5	5.9	73	12:00:00 AM	6-Jun-23
11	26.5	5.9	73	12:00:00 AM	6-Jun-23
12	26.5	5.9	73	12:00:00 AM	6-Jun-23
13	26.5	5.9	73	12:00:00 AM	6-Jun-23
14	26.5	5.9	73	12:00:00 AM	6-Jun-23
15	26.5	5.9	73	12:00:00 AM	6-Jun-23
16	26.5	5.9	73	12:00:00 AM	6-Jun-23
17	26.5	5.9	73	12:00:00 AM	6-Jun-23
18	26.5	5.9	73	12:00:00 AM	6-Jun-23
19	26.5	5.9	73	12:00:00 AM	6-Jun-23
20	26.5	5.9	73	12:00:00 AM	6-Jun-23
21	26.5	5.9	73	12:00:00 AM	6-Jun-23
22	26.5	5.9	73	12:00:00 AM	6-Jun-23
23	26.5	5.9	73	12:00:00 AM	6-Jun-23
24	26.5	5.9	73	12:00:00 AM	6-Jun-23
25	26.5	5.9	73	12:00:00 AM	6-Jun-23
26	26.5	5.9	73	12:00:00 AM	6-Jun-23
27	26.5	5.9	73	12:00:00 AM	6-Jun-23
28	26.5	5.9	73	12:00:00 AM	6-Jun-23
29	26.5	5.9	73	12:00:00 AM	6-Jun-23
30	26.5	5.9	73	12:00:00 AM	6-Jun-23
31	26.5	5.9	73	12:00:00 AM	6-Jun-23
32	26.5	5.9	73	12:00:00 AM	6-Jun-23
33	26.5	5.9	73	12:00:00 AM	6-Jun-23
34	26.5	5.9	73	12:00:00 AM	6-Jun-23
35	26.5	5.9	73	12:00:00 AM	6-Jun-23
36	26.5	5.9	73	12:00:00 AM	6-Jun-23

June-6

1	Temperat	ph	Humidity	updated_at	date
2	26.8	6.1	89	5:18:00 AM	5-Jun-23
3	26.9	6.1	89	5:18:00 AM	5-Jun-23
4	26.5	7.4	89	5:18:00 AM	5-Jun-23
5	26.8	7.4	89	5:18:00 AM	5-Jun-23
6	26.8	7.4	89	5:18:00 AM	5-Jun-23
7	26.7	7.4	89	5:18:00 AM	5-Jun-23
8	27.5	7.4	89	5:18:00 AM	5-Jun-23
9	27.5	7.4	89	5:18:00 AM	5-Jun-23
10	27.9	7.4	89	5:18:00 AM	5-Jun-23
11	26.6	6.1	89	5:18:00 AM	5-Jun-23
12	26.6	6.1	89	5:19:00 AM	5-Jun-23
13	26.6	6.1	89	5:19:00 AM	5-Jun-23
14	26.6	6.1	89	5:19:00 AM	5-Jun-23
15	26.8	6.1	89	5:19:00 AM	5-Jun-23
16	26.9	6.1	89	5:19:00 AM	5-Jun-23
17	26.5	6.1	89	5:19:00 AM	5-Jun-23
18	26.8	3	89	5:19:00 AM	5-Jun-23
19	26.8	3	89	5:19:00 AM	5-Jun-23
20	26.7	3	89	5:19:00 AM	5-Jun-23
21	27.5	3	89	5:19:00 AM	5-Jun-23
22	27.5	3	89	5:19:00 AM	5-Jun-23
23	27.9	3	89	5:19:00 AM	5-Jun-23
24	26.6	5.3	89	5:19:00 AM	5-Jun-23
25	26.6	5.3	89	5:19:00 AM	5-Jun-23
26	26.6	5.3	89	5:19:00 AM	5-Jun-23
27	26.6	5.3	89	5:19:00 AM	5-Jun-23
28	26.8	4.3	89	5:19:00 AM	5-Jun-23
29	26.9	4.3	89	5:19:00 AM	5-Jun-23
30	26.5	4.3	89	5:19:00 AM	5-Jun-23
31	26.8	4.3	89	5:19:00 AM	5-Jun-23
32	26.8	3.4	89	5:19:00 AM	5-Jun-23
33	26.7	3.4	89	5:19:00 AM	5-Jun-23
34	27.5	3.4	89	5:19:00 AM	5-Jun-23
35	27.5	3.4	89	5:19:00 AM	5-Jun-23
36	27.9	3.4	89	5:19:00 AM	5-Jun-23

June-5

Fig. 10. Downloaded csv file.

Fig. 11. Controlled Environment

The photos of the controlled environment are shown in Figure 11. It is evident that with the use of the system the required temperature and pH level for oyster mushroom growth have acquired resulting to its faster growth. It can be observed that in a short period of time for five days the mushroom pins begin to develop in the grow beds.

Fig. 12. Uncontrolled Environment

Figure 12 displays the grow beds in uncontrolled environment. The mushroom grows at a slower rate in this type of environment during the same time period. This will result in a poor yield of mushroom.

RATING	MEAN RANGE	VERBAL INTERPRETATION
5	4.21 – 5.00	Excellent
4	3.31 – 4.20	Very Good
3	2.61 – 3.30	Satisfactory
2	1.81 – 2.60	Fair
1	1.00 – 1.80	Poor

Result and Discussion

Research Instrument

The system was tested and assessed by the respondents using a questionnaire with a 5-point Likert scale that scored the following qualities modeled after ISO 25010 standards for evaluating standard software development:

(1) Functionality - the system can effectively and efficiently adapt to different types of hardware, software, and other operational or usage environments;

(2) Reliability - the system reliably facilitates the accomplishment of specified tasks and objectives in every module or panel;

(3) Portability - the system can adapt to different hardware, software, or other operational specifications;

(4) Usability - the system allows users greater control due to its wide range of capabilities;

(5) Performance - the system has good response, processing, and throughput when performing its functions but depends on less resources;

(6) Security – the system ensures that data are accessible only to authorized users;

(7) Compatibility - the system can perform the required functions effectively while sharing a common environment and resources with other products without impacting the usage of resources; and

(8) Maintainability - the system enables the user to modify the system's settings without producing any defect or degrading its quality.

Table 2 shows the corresponding verbal interpretation of the Likert score

Table 2. Likert scale for system evaluation

Instructions on how to complete the assessment form were supplied in the questionnaire. Furthermore, the researcher informed the respondents about the study's goal and explained how to complete the Likert scales by ticking the box corresponding to the rating for each performance indicator based on the ISO standards. The questions on the system assessment survey were prepared in both English and Tagalog to enable comprehension of the significance of each indication.

RESPONDENTS	N	PERCENTAGE
Expert	1	7%
Students	14	93%
Total	**15**	**100%**

Table 3. Distribution of respondents

Table 3 shows the number of respondents. Fifteen (15) persons evaluated the system including one (1) expert in the field of mushroom farming as well as in-charge of the cultivation area and fourteen (14) students who are considered as the farmers respectively.

Table 4. Result of system evaluation

MEASURE	WEIGHTED MEAN	DESCRIPTIVE RATING
Functional Suitability	4.77	Excellent
Reliability	4.63	Excellent
Portability	4.65	Excellent
Usability	4.55	Excellent
Performance Efficiency	4.66	Excellent
Security	4.66	Excellent
Compatibility	4.6	Excellent
Maintainability	4.64	Excellent
Grand Mean	**4.64**	**Excellent**

Table 4 presents the comprehensive evaluation results of the system based on ISO 25010 standards, encompassing various key components such as functional appropriateness, dependability, portability, usability, performance efficiency, security, compatibility, and maintainability. The overall rating of the system was 4.64, reflecting an "excellent" score. This indicates that the system excelled in meeting the specified evaluation criteria and demonstrates its capability to effectively contribute to the optimal growth of the oyster mushroom. The excellent rating across multiple dimensions underscores the system's robustness, reliability, user-friendliness, efficiency, security, compatibility, and maintainability. The system's high evaluation score highlights its effectiveness in managing and maintaining the required environmental conditions for oyster mushroom cultivation, leading to enhanced growth and productivity.

Conclusion

The implementation of the automated system for controlling the oyster mushroom environment proved to be highly successful. The system effectively regulated the temperature and humidity in the growing area while maintaining the desired pH level of the substrate. The experimental results revealed that optimal growth of Oyster Mushroom *Pleurotus spp*. was achieved when cultivated in a controlled environment with a temperature of 26˚C and a substrate pH level of 5.8 with average humidity at 89.67%, resulting in a remarkable mycelial growth rate of 0.8 cm per day. Moreover, the evaluation of the system based on ISO 25010 standards criteria demonstrated its excellent performance in meeting the required functionalities. The findings highlight the significant potential of the system to enhance mushroom farming productivity. By providing efficient monitoring and environmental control for indoor cultivation of oyster mushrooms, the developed IoT-based system offers a promising solution for increasing mushroom yield. With the successful establishment of this monitoring system, it is evident that IoT technology can play a vital role in optimizing mushroom production.

References

[1] April Firman Daru, Susanto, Whisnumurti Adhiwibowo and Alauddin Maulana Hirzan. (2020). Internet of Thing Based Automatic Temperature and Humidity Regulation Model for Oyster Mushroom Cultivation.

[2] DOST Harmonized National Research and Development Agenda 2022-2028.

[3] Khalid Bin Muhammad, Tariq Rahim Soomro, Jamshed Butt, Hussain Saleem, Muhammad Asghar Khan, Samina Saleem. (2022). IoT and Cloud based Smart Agriculture Framework to Improve Crop Yield meeting World's Food Needs.

[4] IJCSNS International Journal of Computer Science and Network

[5] Nisha Aggarwal and Dinesh Singh 2022. A Review on Usage of Internet of Things (IoT) Technologies in Mushroom Cultivation. Nisha Aggarwal and Dinesh Singh 2022 ECS Trans. 107 9739

[6] P Sihombing, T P Astuti, Herriyance and D Sitompul. 2017.*" Microcontroller based automatic temperature control for oyster mushroom plants"*.

[7] Rebaka Sultana, Ismail Hossain MD, Saifullah MD, Ruhul Amin, and Rajesh Chakraborty. 2018. "Influence of Substrate pH and watering frequency on the growth of Oyster Mushroom".

[8] Warren Gay. (2022). DHT11 Sensor.

[9] Gay, W. (2018). DHT11 Sensor. In: Advanced Raspberry Pi. Apress, Berkeley, CA. https://doi.org/10.1007/978-1-4842-3948-3_22