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Arduino Based Auto Monitoring and Controlling System with GSM Module Integration for the Optimal Growth of Mushroom *(Pleurotus djamor)*

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Abstract

This research project aimed to develop an arduino based auto monitoring and controlling system with GSM module integration for the optimal growth of mushroom *(Pleurotus djamor)*, that could simultaneously control and monitor the conditions of the environment inside the greenhouse system. The project automatically monitored the current state of the environment, showed the current conditions, and remotely sent the data to the researchers. The integration of the GSM module in the system enabled researchers to remotely communicate to the microcontroller that controls and adjusts the desired state of the environment based on the parameters set inside the greenhouse system. To ensure the accuracy of the design, series of laboratory trials, and careful analysis of the results were made. Thus, findings revealed that the optimal growth of mushroom *(Pleurotus djamor)* is potentially achieved when exposed to the greenhouse system compared to that of the conventional way of cultivating mushroom.

Keywords: *Arduino, GSM module, monitoring and controlling system, mushroom, and greenhouse*

1. Introduction

Mushroom farming plays a major impact in poverty alleviation, out of the 7.7 billion world's population, 700 million people experienced food scarcity and almost 2 billion from it are malnourished. Inevitable deterioration of the living environment pushed the world leaders all over the globe to plan for sustainable solutions in addressing this primary concern of humankind [1]. Mushroom farming is a way for challenging tasks due to common factors that need to be considered such as the environmental conditions of a particular location or area where mushroom cultivation will be done. Successful cultivation of edible mushrooms depends on some external factors, in most regions, successful cultivation most likely observed because of short intervals between harvests, fewer requirements for production, minimal land requirements, and the abundance of agricultural biomass [2]. Different key stages are affecting the growth of mushroom, some of which are spawned inoculation and climate or environmental control, when treated carefully, this contributes to the successful mushroom growth; in modern cultivation, this can be enhanced through the aid of technology [3].

In the United States and Europe, the use of thermodynamics engineered systems to control temperature, pressure, and relative humidity levels have been the practice for modern high resource setting in mushroom cultivation, advanced facilities were utilized for mushroom growers to maximize the production [2]. Mushroom growers from low and middle-income countries are struggling for successful production, regulation and manipulation of mushroom growth factors like sterilization and climate or environmental control requires expensive technologies and intensive energy to do the task, inefficient means of environmental control such as temperature and humidity during the mushroom cultivation has greatly affected the production [2].

In the Philippines, typical mushroom growers depend on the natural environment as wild mushrooms grow in their natural environment. Farmers in certain areas grow mushrooms for commercial and personal use relying only on the natural growth of fungus that can be found on their farm or sometimes in their backyards. Agricultural production processes such as food storage facilities and greenhouse for growing plants commonly measure and control temperature and humidity. Traditional monitoring systems consumed a lot of time because the collection of data for the determination of temperature and humidity will be done within acceptable limits. In recent years, many systems have been proposed. Control of temperature and

humidity monitoring system using the AT89S52 as a microcontroller and TC36i wireless communication module for temperature and humidity measures [4], it is also made possible to control greenhouses gasses through GSM-based system [5]. The mushroom cultivation is carried out to certain parameters in the extent of a controlled environment. The utilization of the IQ3 Trend Controller had been introduced for automatic environment control, most likely for high resource setting that allows every stage of mushroom growth to maximize the yield [2]. Robotics application has become the center of innovation for some researchers around the globe to effectively design a system for effective mushroom cultivation.
The control system interface is constantly improving to design more strategic system location and operating conditions for ideal installations and to adjust the needs of mushroom plants [6]. In 2015, real-time tracking of data on quarantine plants had been developed to transfer data over wireless communication [7]. Business producers have been working on controlling the ecosystem of the mushroom growth, this is done through building a greenhouse environment that enables the mushroom grower to manipulate its environmental conditions and maximize the yield of mushroom production [8]. Embedded system has become the trends of innovation in measuring parameters from the sensors to obtain particular data, this approach opens another way of collecting data and monitor environmental progress that the plants have to receive in the greenhouse, the ability to monitor parameters set inside the greenhouse that includes state of the soil, temperature and humidity level contributes a lot to the yields in the cultivation of mushroom [9]. Also, online image analysis of the plants inside the greenhouse had been developed to constantly observe and investigate the growth of the plants [10]. Automation has become popular in robotics research, almost everything can be automated, it is now possible to control water system precisely using wireless sensor inside the greenhouse. In some regions, most of the concern is the cost of building the system, the high-class country could be able to set up high resource setting for this system using high-class sensors and the like, but for the low and middle country, this is a primary concern. However, innovation never stops, low cost sensors are recorded effectively in measuring plant temperature and can be used instead of high-cost industrial sensors to accurately measure the desired data [11]. In the same year, the additional device for measuring soil moisture, air moisture, and the temperature had developed with low-cost automation implemented in the field [12].
This opens an opportunity to keep on innovating and continuously developing a practical design to address this issue. Robotics applications nowadays are beneficial in the agriculture sector particularly when climatic parameters needed for particular crops like a mushroom can be controlled and monitored easily. Applying automation to agriculture create several advancements like increasing productivity and quality of mushroom while saving money and time.
This matter pushed the interest of the researchers to develop a low-cost research project known as Arduino based auto monitoring and controlling system with GSM module integration for the optimal growth of mushroom (*Pleurotus djamor*). Generally, this research project aimed to create a low cost automated monitoring and controlling system which is highly reliable and useful for optimal growth of *Pleurotus djamor* commonly known as Pink Oyster mushroom. Specifically, this research project aimed to a) build an arduino based auto monitoring and controlling system with GSM module integration for the optimal growth of *Pleurotus djamor*, b) Provide and maintain the optimum environment of the mushroom *(Pleurotus djamor)* growth in terms of automated monitoring and controlling system of temperature, humidity level, and soil moisture wirelessly through the integration of GSM module, and c) Compare the growth of the mushroom *(Pleurotus djamor)* cultured using the developed low-cost greenhouse system and the *Pleurotus djamor* cultured without the aid of greenhouse system in terms of its chemical and physical changes.

2. Materials and Methods

2.1 Materials

The hardware components used in the development of this low-cost project design were Arduino Uno Atmega328, 92mmx92mmx25mm mini fan, water pump, light bulbs, humidity and temperature sensor (DHT 11 basic), 3/8 in diameter pipe, jumper wires, breadboard, relays, GSM module 900, and 16x2 LCD, mobile phone and touch mobile Philippine sim card. All the other materials in building a small greenhouse were obtained from recycled materials in the backyards. Pink Oyster Mushroom species were obtained from the department of agriculture.

2.2 Methods

2.2.1 System Design

The proposed system required three (3) sensors namely, temperature sensor, humidity sensor, and soil moisture sensor. There are 12 components namely, Arduino Uno, Mini Fan 92mm×92mm×25mm, Water pump, Light bulb, Light bulb holder, Pipe 3/8-inch diameter, Jumper wires, Breadboard, IRF530N Relay, GSM Module 900, and 16 x 2 LCD. In this system, Arduino is the heart of the whole system which takes control over the process. When sensors sense any changes in the environment, Arduino comes into action and process the required operation. Whatever environmental changes occur inside the greenhouse, the robot will process information and update the researcher. The researcher will then command the robot respectively depending on the action needed for the particular state. In this system, the LCD is used for displaying the status for all operations like temperature, humidity, and soil moisture state at closer monitoring, but it can be monitored remotely via SMS through the help of GSM module 900 attached to the Arduino. The LCD's data pins are connected in 4-bit mode. The relay is operated using ULN2003 connected to digital pins and controlled via SMS command. Humidity and temperature are connected to the analog pins; soil moisture is connected to digital pins of Arduino, while GSM module 900 signals obtained via Rx and Tx pins of the Arduino and the module. The mini Fan, light bulb, and water pump are directly connected to the relays and controlled via SMS command. Series of lines of codes and algorithms were developed and encoded to the microcontroller to set desired parameters in the project design.

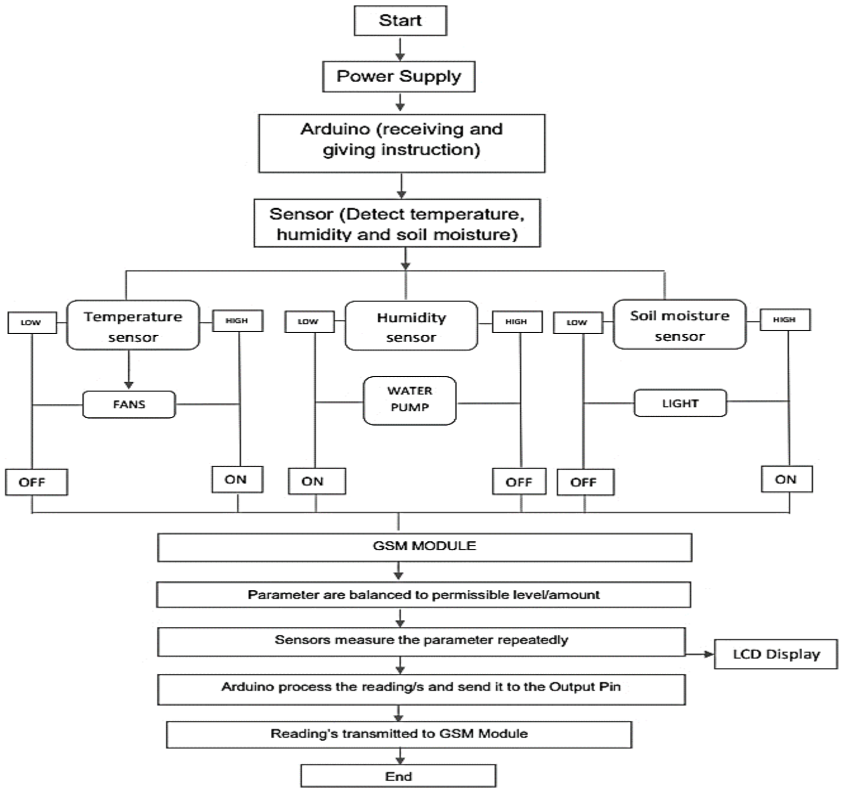

Fig. 1 Conceptual design of the project.

2.2.2 Block Diagram

Below is the block diagram of the design which shows the bird's eye view of the whole system.

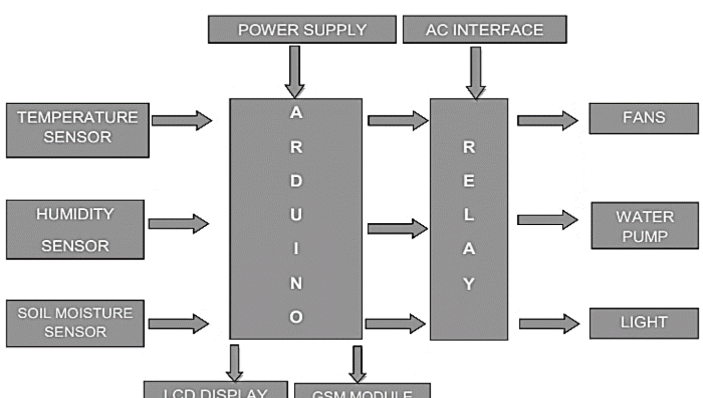

Fig. 2 Block diagram of the project.

2.2.3 Nurturing and Monitoring of Mushroom (*Pleurotus djamor)* Growth

Nurturing of mushroom is done separately, the experimental group is nurtured inside the greenhouse system without any human intervention and relied only on the parameters set and encoded on the robot. While the control group was nurtured in the designated open space in the backyard and relied on the natural process or natural environmental conditions with human intervention if needed throughout the study. One (1) month is allotted to nurture the mushroom started from September 1, 2019 to September 30, 2019. The monitoring is done weekly, all the necessary data in connection to the development of the mushroom from both experimental and control group were recorded, and photos were taken to ensure that all the observations needed were accurately recorded.

2.2.4 Statistical Analysis

All results obtained during the conduct of the study were carefully treated and used to support the results of the project. The project was built and tested for accuracy from June 24, 2019 to August 02, 2019. Descriptive statistics were used to analyze the accuracy of parameters set and encoded variables inside the greenhouse system. To describe the developmental growth of the mushroom every week, qualitative data through series of observations were utilized.

3. Results and Discussion

3.1 Accuracy test for temperature

As presented in Table 1, a series of trials were done to test the temperature control inside the greenhouse for monitoring and controlling the system of the designed project. For the first trial, 2 minutes and 8 seconds time intervals were obtained to raise the temperature from 20.0℃ to 27.0℃. In the second trial, it took 2 minutes and 13 seconds to raise it to 27.0 ℃ temperature and 1 minute and 23 seconds for the third trial to raise it from 20.0 ℃ to 27.0 ℃, and 1 minute and 48 seconds for the fourth trial. Lastly, 2 minutes and 2 seconds time interval were recorded to reach the temperature value of 27.0 ℃ gaining a mean value of 2 minutes and 19 seconds to raise the temperature from 20.0 ℃ to 27.0 ℃. The results showed that it took a short period of time to increase the temperature needed by the mushroom for the temperature ranging from 20.0 ℃ to 27.0 ℃ in order to meet this temperature state. To test the time interval needed to cool down the greenhouse environment from higher temperature to lower temperature, the researcher set the ideal temperature range of greenhouse environment from 35.0℃ to 30.0℃, 1 minute and 45 seconds were observed in the first trial, 2 minutes and 17 seconds in the second trial, 2 minutes and 45 seconds in the third trial, 2 minutes and 35 seconds in the fourth trial and 2 minutes and 31 seconds in the fifth trial were recorded to change the temperature state from 35.0℃ to 30.0℃. These results indicated that it took a short period of time to reduce the temperature from higher to lower as justified by the mean value of 2 minutes and 15 seconds intervals. The results showed that temperature requirements in growing mushroom (*Pleurotus djamor*) for optimal care were made possible as the results revealed in this table. The results affirmed by the previous study conducted which stated that the ability to control the temperature environment contributed a lot to the rapid development of mushroom (*Pleurotus djamor*) since it prefers mostly in the tropical and subtropical regions [13]. Temperature ranges from 20.0℃ to 35℃ is ideal for optimal growth of mushroom for spawn running and spawn production [14].

Table 1: Test of temperature control over a period of time

Temperature (℃) Range	Trial 1 (min)	Trial 2 (min)	Trial 3 (mins)	Trial 4 (min)	Trial 5 (min)	Mean
20.0℃ - 27.0℃	2:08	2:13	1:23	1:48	2:02	**2:19**
35.0℃ - 30.0℃	1:45	2:17	2:45	2:35	2:31	**2:15**

3.2 Accuracy test for humidity

As can be gleaned in Table 2, humidity control was tested and verified in order to maintain the full monitoring and controlling system of the greenhouse's humidity level inside the designed project. In order to control the humidity, the use of automated water mist, mini-fan, and light bulb installed in the system was utilized and controlled remotely via SMS command. In the first trial, the humidity environment was set to a low condition; the results obtained 48 seconds to control and change its normal humidity environment or the desired environmental state. For the second trial, it took 41 seconds to normalize the humidity level and 53 seconds were gained in the third trial. During the fourth trial, 44 seconds were obtained to normalize the environment and 47 seconds were observed in the last trial. The results showed that humidity monitoring and controlling system inside the greenhouse were made possible. Hence, the desired humidity level from 80% to 90% needed to nurture the mushroom can be adjusted in a short period of time as justified by the mean value of 46.6 seconds; the ability to control and achieved this desirable humidity level will contribute a lot to the optimal growth of the mushroom, these findings affirmed by the previous study conducted for humidity level control of mushroom which stated that optimal humidity value for the fungus to grow is within the optimal humidity value ranging from 80% to 90% rate [15]. The ability to control the temperature range inside the greenhouse helped a lot to achieve the desired humidity level [14], it is indeed possible to grow the mushroom plant inside the greenhouse with a desirable environmental condition for optimal growth of mushroom (*Pleurotus djamor*).

Table 2: Test of humidity control over a period of time

Humidity Range	**Trial 1 (sec)**	**Trial 2 (sec)**	**Trial 3 (sec)**	**Trial 4 (sec0**	**Trial 5 (sec)**	**Mean**
Low to Normal (80%-90%)	48	41	53	44	47	**46.6**

3.3 Accuracy test for soil moisture

As revealed in Table 3, soil moisture control was tested inside the greenhouse, in order to control the soil moisture, the automated watering system through the use of a water pump was utilized, this is controlled remotely via SMS command. For the first trial, the results obtained a time interval of 10 minutes and 46 seconds, while 11 minutes and 1 second for the second trial, for the third trial, 10 minutes and 50 seconds time interval were obtained, 11 minutes and 13 seconds for the fourth trial and 10 minutes and 37 seconds in the fifth and final trial. Based on the results, it showed that it took a considerable period of time to dry up the soil inside the greenhouse as justified by the mean results of 11 minutes and 9 seconds. Hence, in watering the mushroom, careful procedures must be taken into consideration since the drying of soil took a bit of time. Low moisture content resulted in the death of the fruiting body, while rapidly increasing soil moisture content substantially affect the growth of mushrooms. The optimum moisture content for growth and substrate utilization depends upon the organism and the substrate used for cultivation. Increasing moisture level is believed to reduce the porosity of the substrate, thus limiting oxygen transfer. For this reason, the use of high moisture content limits the growth within the whole substrate, resulting in surface growth [16]. The findings implied that soil moisture content should be monitored and controlled carefully to maintain the desired moisture content suitable for mushroom growth, it can be done easily through this project design.

Table 3: Test of soil moisture control over a period of time

Soil Moisture Indicator	**Trial 1 (min)**	**Trial 2 (min)**	**Trial 3 (min)**	**Trial 4 (min)**	**Trial 5 (min)**	**Mean**
High to Low	10:46	11:01	10:50	11:13	10:37	**11:09**

3.4 Growth of mushroom *(Pleurotus djamor)* inside the greenhouse system

As revealed in Table 4, the mushroom (*Pleurotus djamor*) fruiting bag is placed inside the greenhouse design for the cultivation process of the tissue, the development of the mushroom (*Pleurotus djamor*) fruiting intensively observed and recorded by the researchers. As the table revealed, the chemical and physical changes were used as the basis for qualitative data to be gathered during the cultivation process inside the greenhouse system for four weeks (1 month). For the first week of observation, there were no changes observed in both chemical and physical aspects of the mushroom (*Pleurotus djamor*). On the second week, there were still no observable changes in the chemical state of the tissue. However, in the physical state, the formation of rhizomorphs in the tissue started to spread and be observed. During the third and fourth week of mushroom (*Pleurotus djamor*) inside the greenhouse system, a lot of visible changes happened like the mushroom's color appeared as color pink and its tissue started to grow. When *Pleurotus djamor* grows and reached its maximum size, its color started to fade, this means that *Pleurotus djamor* is ready for harvest. The results showed that the research project design installed inside the greenhouse system is effective in controlling and monitoring the environmental state of the greenhouse needed for the growth of mushroom (*Pleurotus djamor*) since it can accurately control parameters which were required by the *Pleurotus djamor* to grow while monitoring the condition at the same time.

Table 4: Mushroom *(Pleurotus djamor)* growth cultivated using Arduino based auto monitoring and controlling system with GSM module integration installed in the greenhouse system.

State of changes based on intensive observations	**1st week**	**2nd week**	**3rd week**	**4th week**
Chemical Change	No changes observed	No changes observed	Change of color is observed, the pink color started to appear in the body of gradually growing mushroom (*Pleurotus djamor).*	Pink color gradually disappeared and started to fade in its full grown size.
Physical Change	No changes observed	Rhizomorphs started to spread.	The mushroom (*Pleurotus djamor)* tissue started to grow.	The mushroom (*Pleurotus djamor)* was grown and reaches a considerable size of full grown mushroom.

3.5 Growth of mushroom *(Pleurotus djamor)* outside the greenhouse system

As can be gleaned in Table 5, another set of mushroom (*Pleurotus djamor*) fruiting bag nurtured and cultivated without the aid of the greenhouse system and its growth solely dependent on nature or natural environmental condition. The researchers intensively observed the development of tissue and recorded the observations. This table shows the chemical and physical changes that occurred during the cultivation process for four weeks. There were no changes observed in both the chemical and physical aspects of *Pleurotus djamor* spawns during its first week. On the second week, there's still no changes observed in the physical state. However, in the chemical state of the tissue, the fruiting bags started to moist. During the third week of the mushroom, its chemical phase altered. Its color became dark, dark spots and green mold also appeared. The fourth week of *Pleurotus djamor* spawn outside the greenhouse system became black and contaminated. The environment outside the greenhouse system has greatly affected the growth of *Pleurotus djamor* because of losing temperature control as well as the humid environment invites bacteria to grow, and bacteria will push out the mushroom crop leading to contamination, insufficient moisture also affected the growth of *Pleurotus djamor* which stopped the growth and development while direct sunlight affects the mold growth of *Pleurotus djamor* leading to the contamination of the sample. The result implied that the lack of environmental conditions control needed for mushrooms substantially affected the growth.

Table 5: Mushroom (*Pleurotus djamor)* growth cultivated without the aid of Arduino based auto monitoring and controlling system with GSM module integration installed in the greenhouse system.

State of changes based on intensive observations	**1st week**	**2nd week**	**3rd week**	**4th week**
Chemical Change	No changes observed	No changes observed	The mushroom (*Pleurotus djamor)* spawn became dark.	The mushroom (*Pleurotus djamor)* spawn changed color into black.
Physical Change	No changes observed	The fruiting bags started to moist	Dark spots and green molds started to appear.	The mushroom (*Pleurotus djamor)* fruiting bag was totally contaminated

4. Conclusions

The arduino based auto monitoring and controlling system with GSM module integration seems to have accurate results and capability features as it's worked properly according to the codes and system designed. Based on the series of tests and experimental results, it can be concluded that a low-cost project design known as arduino based auto monitoring and controlling system with GSM module integration is indeed an effective system for the optimal growth of the mushroom (*Pleurotus djamor*).

Appendices

Appendix A: The finished project design of greenhouse system

Fig. 3 The greenhouse system.

Fig. 4 Humidity control test.

Fig. 5 Temperature control test.

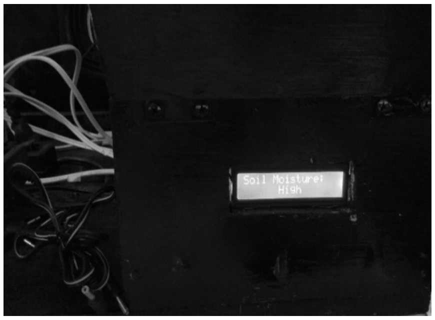

Fig. 6 Soil moisture control test.

Appendix B: Sample SMS command and communication to the greenhouse system

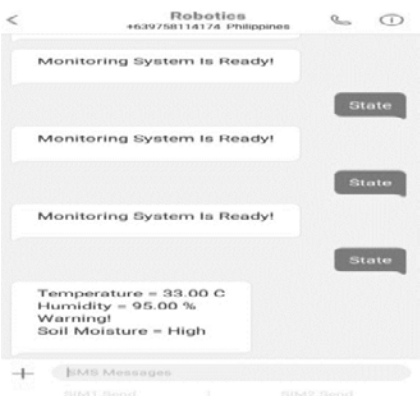

Fig. 7 Monitoring the state of greenhouse.

Fig. 8 Sending SMS command to the greenhouse.

Appendix C: Weekly recorded growth of Mushroom *(Pleurotus djamor)* inside the greenhouse as observed

Fig. 9 First week of cultivation.

Fig. 10 Second week of cultivation.

Fig. 11 Third week of cultivation.

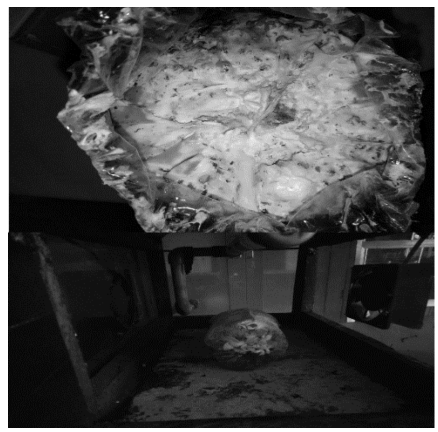

Fig. 12 Fourth week of cultivation.

Fig. 13 Ready for Harvest.

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