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Towards urban farming: internet of things indoor based rice planting with SMS alert notifications

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ABSTRACT

The purpose of this study is to "achieve an environment indoors where the researchers can cultivate rice and tilapia in one system – aquaponics system." Aquaponics is a combination between aquaculture (farming of fish) and hydroponics (growing plants without soil), being a technique to grow plants with aquaculture effluent. Tilapia fish will provide nutrients for the rice plants, and the rice will consume the fish excreted waste. The study consists the Internet of Things (IoT) Aquaponics system consists of five (5) sensing device – pH sensor, room temperature and humidity sensors, water temperature sensor, water flow sensor, and non-contact liquid sensor. The sensor readings would be sent to the Thing Speak acquiring of real time data which is the database of the system for information utilization. If the acquired data is not within the threshold range, a SMS (Short Message Service) operated by Twilio will be sent to the end user for alert notification. The Twilio is an Android Package Kit (APK) for the android phone. It was created using Massachusetts Institute of Technology (MIT) App Inventor to display the stored sensor readings in the database and to be able to give suggestions to the user as it monitor the parameters of the system.

KEYWORDS: *Android, Aquaponics, Fish, IoT, Monitoring, pH sensor, rice plant, Temperature sensor, ThingSpeak, Twilio, water level, and flow sensor*

1 INTRODUCTION

Aquaponics refers to the system that supports the dual combination of the aquaculture (fish rearing) and the hydroponics (production of the plants without soil). The excretions of the fish containing ammonia are converted by the nitrifying bacteria into nitrites and then to nitrates which can be used as nutrients for the plants. As compared to the traditional methods of farming, aquaponics is favorable for the place where there is no fertile soil, or lack of water or even lack of free land/soil (Nichols and Savidov, 2012; Junge et al., 2017).

In the Philippines, Aquaponics is a sustainable method of producing food, according to a Department of Science and Technology (DOST) webinar presented during National Science and Technology Week. Because the water is recycled in the tank, it consumes 90% less water than conventional farming. An aquaponics system also requires less area. Because nutrient-rich water is given straight to the roots of the plants, vegetables may be planted closer together.

The principal purpose of the study is to develop an "Internet of Things Indoor-Based Aquaponic Rice Planting", an indoor-based aquaponics system for the combination of rice crop and tilapia. This study consumes low water usage, no deployment of synthetic fertilizers, and low susceptibility to pests.

The chosen fish and type of rice plant embedded in the system were Nile Tilapia as it grows fast, can reach a weigh exceeding 5kg, tastes good, and is known to thrive (Food and Agriculture Organization) and the National Seed Industry Council (NSIC) recommended RC160 (Tubigan 14) because it only takes 107 days to mature after seeding.

Internet of Things (IoT) is an emerging trend within precision agriculture with a primary objective to improve the utilization of resource inputs, accelerate vegetable growth, and reduce human intervention. IoT could enable semi and fully automated processes with real-time monitoring via sensors (Yanes, 2020). IoT embedded process control can automatically manipulate such environmental factors using heating, air-conditioning, air flow and ventilation, light intensity and spectrum adjustments, and fogging. Aquaponic−bioponic systems at the management level would benefit greatly from IoT because of its merits in enhancing the classical automation model.

2 MATERIALS AND METHODS

Preparation and Scope of the Study

The study is capable and bounded to perform tasks such as:

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- Monitoring the water temperature ranges from 27 to 32 degree Celsius (Benzie, et al, 2020).
- Monitoring the air humidity and air temperature level by using a "temperature and humidity sensor" for rice to assist the user in maintaining 60&-80% humidity level and 25-35 degrees Celsius.
- Monitoring the pH level using pH sensor to assist the user in maintaining 5.6 to 6.8 pH level which is within the ideal range for both rice and tilapia.
- Sending Shot Message Service (SMS) error alerts to the user using the ThingSpeak and Twilio application whenever an error is detected.
- Displaying the information needed by the users that are based on the data that were gathered by the sensors using the Massachusetts Institute of Technology (MIT) application, and providing suggestions to the user.
- Monitoring the continuous water flow in the system using a water flow sensor and a water level using non-contact liquid sensor.

The ideal pH level, humidity level, and temperature level were based on research and suggestions of the Bureau of Fisheries and Aquatic Resources (BFAR) and Philippine Rice Institute (PhilRice).

Data Gathering

Using ESP32 as microcontroller to collect the data that are being read by the sensors. Daily management is mandatory since the system is not made to automatically fix the encountered problem. The parameters in the project are set for Nile Tilapia and also for the NSIC RC160 rice variant. The parameters of the sensors should be manually adjusted by the user if the user chooses to grow a different variant of fish, or a different variant of plant, or both.

Rice plants were observed weekly to monitor their development. The following data were obtained; (a) percent survival - this accounted as the number of germinated seeds per treatment (b) plant height - three sample plants were randomly selected per treatment per replication from which the parameter will be measured.

The fish must be introduced first in the system so that the nutrients could be formed before adding the plants. The seedlings could be planted after a week or more because, by that time, the nutrients from fishes are ready to serve as their natural fertilizer (Crop-King, 2012). The number of fishes that should be put in the tank has a limit and must depend on the ideal number per gallon of water. A pound of tilapia needs 3 gallons of water (Yamuna, 2021). The farmer must avoid overpopulation because it can cause glass breaking and fish health issues.

Project Design

The hardware requirements of the study are as follows: ESP32 microcontroller, real-time clock, non-contact liquid level sensor, humidity and temperature sensor, pH level sensor, water pump, air pump, water flow sensor, grow light, relay, solar panel, solar charge controller battery, inverter, an automatic transfer switch. And for the software requirements, Arduino Integrated Development Environment (IDE) is used to program the microcontroller, ThingSpeak as database, MIT App Inventor to create an Android Package Kit (APK). To properly achieve this study, knowledge and integration are needed in using Arduino IDE, MIT App Inventor, database, electronic circuitry, system troubleshooting and planning.

Hardware Prototype Block Diagram

The alternating current (AC) power supply will energize the whole system and the battery will be used when the outage occurs. If the battery would be subjected to charging, thru the use of solar panel and solar charge controller the battery would be charged and monitor the input and output voltage of the battery, The Direct Current (DC) output voltage of the battery was converted to Alternating Current (AC) voltage supply using an inverter. The Automatic Transfer Switch (ATS) will automatically change the main power supply of the proposed project study to battery; to keep the system and output devices running. The pH sensor, room temperature, and humidity sensor, water temperature sensor, water flow sensor, the non-contact liquid sensor will be connected to the microcontroller. The microcontroller will control the main operation of the project. The real-time clock and microcontroller together with a relay module will control the automatic on and off in the grow light with respect to time.

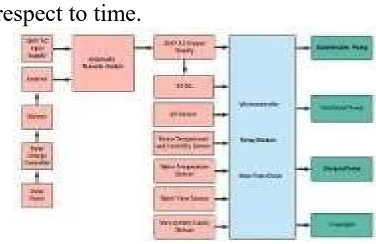

Figure 1 shows the hardware process flow of the system.

Block Diagram of Data Flow

Using the Internet of Things (IoT), the Android Packet Kit (APK) will display the value of the pH level, air temperature & humidity, water temperature, and water flow. The Short Message Service (SMS) is used to send alerts if there is a problem in the system. The data measured will be analyzed to extract useful information to give insights. By using the related studies as a reference for the parameters, the system can help the user with the next best move to overcome a specific problem in the aquaponics system.

Figure 2 shows that the ESP32 microcontroller will be processing all the measurements and data.

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3 RESULTS AND DISCUSSION

Figure 3 shows the outcome design of created aquaponics system – its embedded sensors, and grow light.

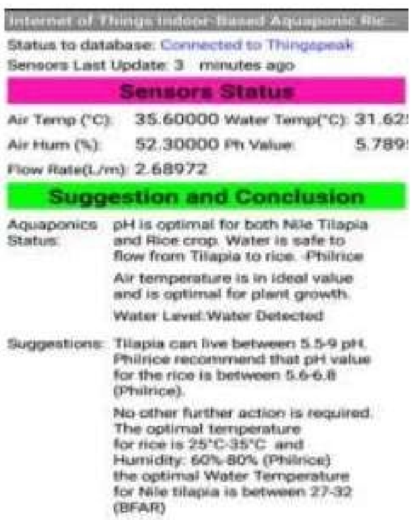

Figure 5 shows the actual display of the developed application. The displayed image consists of the acquired real-time data from the sensors and their corresponding statuses and suggestions for the user.

Sensor Parameters Tetsing

The standard parameters for the IoT based Indoor Aquaponics Rice Planting are in accordance on the functionality of the system, and some other research literatures.

Table 1(a) shows the optimal parameter ranges for the aquaponics system and table 1(b) shows the parameter reading that the system should have to avoid the overflow of water and to determine if the overhead pump is still working.

Table 1(a): Standard Parameters Baseline Value

pH	Water Temperature	Air temperature & Humidity
5.6-6.8	27 °C -32°C	25 ºC -35 ºC 60%-80%

Table 1(b): Standard Parameters Baseline Value

Water flow	Non-contact Liquid Sensor
>0	1

The data testing was accomplished up to Day 25, but as shown in table 1, only sampling of gathered data from day 0 to day 5 was presented to validate the functionality of the developed aquaponics system. Table 2: Sampling Gathered Data from Day 0 to Day 5

Gathered Data Day 0 to Day 5							
The system works 24 hours. Every 10 minutes, it sends data unless there is no internet connection. The list below is just sample data from each day.							
Date	Day Number	Air Temperature (°C)	Humidity (%)	Water Flow Rate (L/m)	Water Temperature (°C)	pH	Water level (using non-contact liquid sensor)
16-Jun	Day 0	34.5	59.3	1.897	31.18	6.715	1
Interpretation		The system is not encountering any error and the measured parameters is within the range beside of humidity for the optimal growth of Nile tilapia and rice.					
17-Jun	Day 1	33.6	60.7	1.78	31.43	6.89	1
Interpretation		The pH was not at an ideal level. It was caused by the planting of rice since some of the soil flowed to the aquarium. On day 4, the pH is already stabilized.					
19-Jun	Day 3	32.3	71.2	1.649	31.12	6.848	1
Interpretation		The pH was not at an ideal level. It was caused by the planting of rice since some of the soil flowed to the aquarium. On day 4, the pH is already stabilized.					
20-Jun	Day 4	32.7	62.4	1.599	31.18	6.785	1
Interpretation		The pH was not at an ideal level. It was caused by the planting of rice since some of the soil flowed to the aquarium. On day 4, the pH is already stabilized.					
21-Jun	Day 5	30.3	73.9	1.426	30	6.623	1
Interpretation		The system is not encountering any error and the measured parameters is within the range for the optimal growth of Nile tilapia and rice					

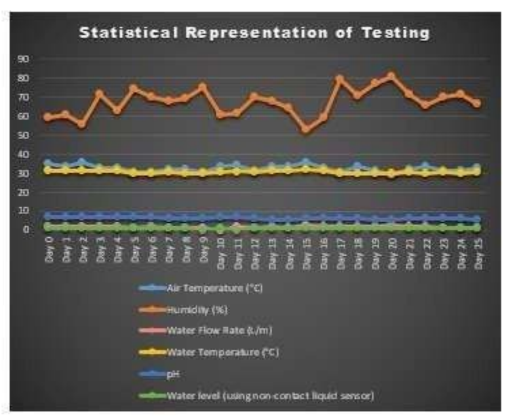

Figure 6 shows the statistical representation of the gathered data from Day 0 to Day 25.

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The gathered data shows that the system is useful in helping the user achieve, fix, and maintain the good condition of the aquaponics system with the use of the Aquaponics Rice Monitoring Application and Short Message Service (SMS) alert. The gathered data were bounded in the control limits pf parameter ranges.

Short Message Service (SMS) Notification

Figure 7 shows the received text messages of the researchers during the testing procedure that helped them to immediately take action in correcting the encountered problem.

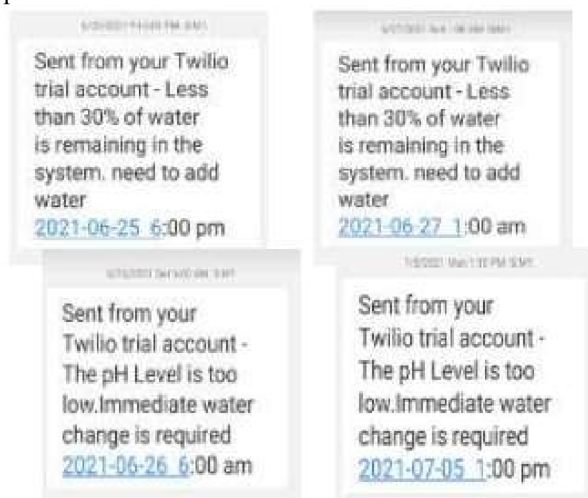

Figure 7. Short Message (SMS) Notification

Figure 8 shows the received text messages which were disregarded and/or intentionally neglected by the researchers since they were delivered during maintenance and calibration of the system.

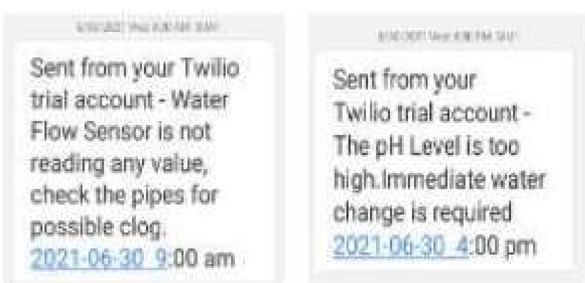

Table 3 shows the alert details that would be received by the user through SMS for the system's notification and Table 4 shows the information being displayed by the Aquaponics Rice Monitoring application that depends on the situation.

Rice Plant and Tilapia Fish Growth

Figure 9 shows the rice plants that were planted in two different locations. The one on the left side was placed outside the system, and the plant on the right side was planted on the aquaponics system.

Table 3: Set Parameters for SMS Alert

Sensors	Set Value	Short Message Service (SMS) Content
Non-contact liquid sensor	0	Less than 30% of water is remaining in the system. need to add water
	1	N/A
Water Flow Sensor	0	Water Flow Sensor is not reading any value, check the pipes for possible clog.
	>0	N/A
pH Sensor	<=5.5	The pH Level is too low. Immediate water change is required
	>=9	The pH Level is too high. Immediate water change is required

Table 4: Aquaponics Rice Monitoring Set Parameters

Aquaponics Rice Monitoring(APK)			
Sensor	**Set Value**	**Status/Conclusion**	**Suggestion**
Non-contact liquid sensor	0		Water Level: Low water level. Add water
	1		Water Level: Water Detected
pH Sensor	5.6-6.8	pH is optimal for both Nile Tilapia and Rice crop. Water is safe to flow from Tilapia to rice. (PhilRice)	PhilRice recommend that pH value for the rice is between 5.6-6.8 (PhilRice).
	else	pH is not in ideal level. The ideal level is between 5.6 to 6.8 for Rice-Tilapia Aquaponics.	Change water to avoid fish kill. Chlorinated water must be stored for 24 hours first before use (BFAR). PH adjuster liquid can also be used to adjust the pH level of the new water.(PhilRice)
Temperature and Humidity sensor	25°C-35°C 60%-80%	Air temperature is in ideal value and is optimal for plant growth.	No other further action is required. Just maintain the value of Air temperature is 25°C-35°C and Humidity: 60%-80% (PhilRice) the optimal water temperature for Nile tilapia is between 25°C-35°C (BFAR)
	else	Air temperature or/and humidity is not in ideal value. The ideal value of Air temperature is 27°C-32°C and Humidity: 60%-80%	Adjust the available ventilation system until the value of Air Temperature is 27°C-32°C and Humidity: 60%-80%

Figure 9. Rice Plant and Tilapia Fish Growth

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Table 5 presents the height of the rice plants on day 25. It also shows the average height of two plants planted in different system.

Table 5: Tabulated Rice Plant Height

Indoor Aquaponics Rice Plant				Outdoor			
Height (in mm) after 25 days				Height (in mm) after 25 days			
Cup Number	Plant Number			Plant Number			
	1	2	3	1	2	3	4
1	210	190	200	279.4	284.48	297.18	276.86
2	255	255	100	Average Height		284.48	
3	225	233	215				
4	190	183	195				
5	215	225	215				
6	172	222	224				
7	216	210	170				
8	215	242	240				
9	225	210	220				
10	186	174	190				
11	225	190	175				
12	211	191	120				
Average Height	203.7222222						

Table 6 shows the survival rate of the Nile tilapia when the system was used by the researchers.

Table 6: Tabulated Count of Nile Tilapia

Testing	Nile Tilapia	
	Adult	Fingerlings
Start	18	60
End	13	45
Survival rate	72%	75%

Correlations of Data

The correlation of data is done by applying a scatter plot diagram to Table 2 in order to graphically represent the relationship between two variables for a set of data.

Figure 9 shows the correlations of variables between air temperature and humidity. As the humidity decreases the air temperature will increase.

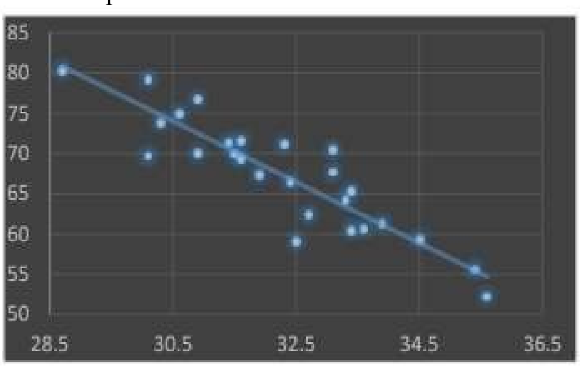

Figure 9. Variables between air temperature and humidity.

Figure 10 shows the relationship between pH and temperature value in which the increase in pH leads to the increase in temperature.

Figure 10 is the correlations of variability between humidity and pH sensor. The relationship between the two variables are inversely proportional to each other.

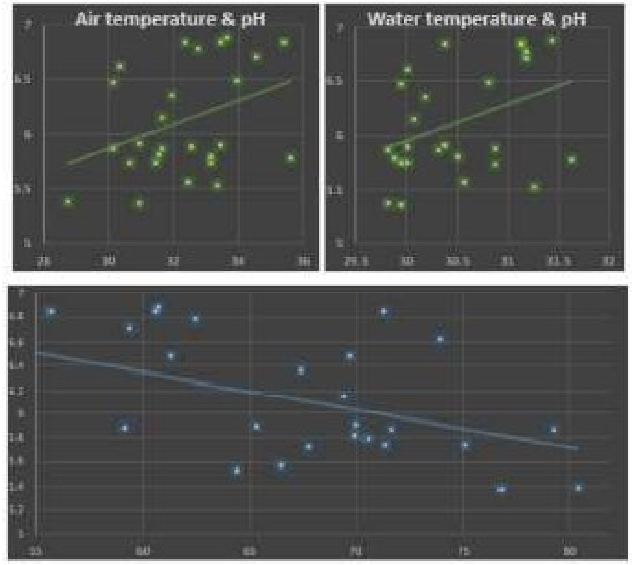

Figure 10. Relationship between pH and temperature value

As for the basis of testing the developed system in other different weather conditions, presented in table 7 is the test and the collection data conducted during rainy days, the southwest monsoon is one of the reason of having Relative Humidity (RH) greater than the recommended parameters.

Table 7: Gathered Data from Day 0 to Day 7 during Rainy Days

The test and the collection of data is conducted during rainy days, the southwest monsoone is reason of having Relative humidity greater than the recommended parameters							
Date	Day Number	Air Temperature	Relative Humidity	Flow rate	Water Temperature	pH	Non Contact liquid sensor
19-Jun	Day 0	30.1	78.5	1.92141	29.1875	5.83691	1
	Interpretation	The system is not encountering any error and the measured parameters is Within the range for the optimal growth of Nile tilapia and Rice.					
20-Jun	Day 1	30.4	82.3	1.14045	29.5	6.62956	0
	Interpretation	Due to the slow waterflow to cycle the water of the system the noncontact liquid sensor detected a 0 value which means the tank for the fingerlings is having a low water level. The increase in pH level is due to the performed water change since Tagged Nile tilapia died					
21-Jun	Day 2	29.9	80.7	2.23131	29.4375	6.68555	1
	Interpretation	The proponents performed a waterchange due to the dead tagged Nile tilapia at day 2 causing the pH reading to increase slightly.					
22-Jun	Day 3	28.4	86.3	3.33523	28.125	6.49127	1
	Interpretation	The parameters beside of the air humidity is in optimal range. The decrease in pH is normal in aquaponics since the microbial in the system tends to lower the pH.					
23-Jun	Day 4	28	88.2	3.63843	28.25	6.11214	1
	Interpretation	The parameters beside of the air humidity is in optimal range. The decrease in pH is normal in aquaponics since the microbial in the system tends to lower the pH.					
24-Jun	Day 5	28.3	88	3.33713	28.1875	6.06841	1
	Interpretation	The parameters beside of the air humidity is in optimal range. The decrease in pH is normal in aquaponics since the microbial in the system tends to lower the pH.					
25-Jun	Day 6	27.9	86.9	3.12381	28	6.00196	1
	Interpretation	The parameters beside of the air humidity is in optimal range. The decrease in pH is normal in aquaponics since the microbial in the system tends to lower the pH.					
26-Jun	Day 7	28	86.9	3.03203	28	5.97869	1
	Interpretation	The parameters beside of the air humidity is in optimal range. The decrease in pH is normal in aquaponics since the microbial in the system tends to lower the pH.					

Legend

Non Contact liquid Sensor	
1	Water Detected
0	No water Detected

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$$Relative\ Humidity = \frac{Actual\ Amount\ of\ water\ vapour\ in\ the\ air\left(\frac{g}{m^3}\right)}{Maximum\ Amount\ of\ water\ vapour\ the\ air\ can\ hold\ \left(\frac{g}{m^3}\right)} x100$$

4 CONCLUSIONS

The aquaponics system was able to cultivate Tilapia and rice in a location wherein the indoor agricultural method is suitable. The study utilized Internet of Things (IoT) as the system database that can acquire real-time data for information utilization of the user. The Short Message Service (SMS) notification of the prototype provides an alert to immediately respond on the problem encountered by the system such as clogged pipes, clogged filter, and a pH value which is critical to the environment of the Nile Tilapia and Rice.

There are series of troubleshooting, calibration, and debugging of programs encountered and/or performed during the project implementation. The results gathered in the testing procedure from day 0 to day 25 were measured based on the functionality of the proposed project. Its functionality was evaluated in accordance with its accuracy, reliability, acceptability, and aesthetics. In general development, project conceptualization was acceptable. Although there are technical circumstances and the calibration is only done by the proponents, and so accuracy does not come across 100 % perfectly, hence it implies improvement and modification for the system.

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