Evolution in Electrical and Electronic Engineering Vol. 3 No. 2 (2022) 879-887

EEEE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/eeee
e-ISSN : 2756-8458

Development of Indoor Aquaponic System with Monitoring Mechanism for Tilapia and Pak Choy

N. M. A. Amri[1], S. Suhaila[1]*, A. Yusoff[2], N. S. A. M Taujuddin[1], R. Hazli[3], N. Ibrahim[1], S. Z. M. Muji[1]

[1]Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

[2]Faculty of Electrical and Electronic Engineering,
Universiti Pendidikan Sultan Idris (UPSI), Tanjung Malim, 35900, MALAYSIA

[3]Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, Pagoh, 84600, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/eeee.2022.03.02.103
Received 27 June 2022; Accepted 03 October 2022; Available online 30 October 2022

Abstract: This study aimed to create a smart aquaponics system that could manage and monitor PH, total dissolved solids (TDS), turbidity, water level, oxygen (ORP), and temperature levels. The quality of the water is checked throughout the day with this system, and the user will change the water or add the water depending on the changes. Each of the sensors has its role in order to stabilize the water condition. For example, Tilapia can survive below the PH value of 5.5 and Pak Choy is suitable for a PH value of 6.5. There are 3 objectives in these studies, which are to develop an aquaponic system for the indoor environment specifically for Tilapia and Pak Choy, to develop a monitoring mechanism for the aquaponic system and to analyse the performance of the developed system. The proposed aquaponic system has 8 different results which are the weight of the fish, plant growth and the 6 sensors reading that enables the user to find the relationship of each reading. From the reading, the FCR reading is 1.5949 where the value of FCR has been reached which is more than 1. Growth recording rate reaches 4.62, survival and condition factor reach 100% for survival rate and condition factor is 32.73, mortality rate stays 0 and length gain of tilapia is 2.5cm and Pak Choy is 3.5cm after taking the reading of 9 weeks. All of this reading proves that the project has finally succeeded in all aspects.

Keywords: Aquaponic, PH, TDS, ORP, water level, ORP, turbidity, FCR, monitoring

Corresponding author: suhailas@uthm.edu.my

1. Introduction

Malaysia has evolved into a nation with fast urbanization and population growth. Malaysia's population grew from 32.6 million in 2020 to 32.7 million in 2021, according to the Malaysian Department of Statistics (2021) [1]. As a result, the food supply has become a vital way to ensure food security as cities and populations develop, particularly in urban areas. This is due to a lack of agricultural operations in urban areas capable of producing adequate food for self-sufficiency. Unfortunately, compared to other countries such as Taiwan and Singapore, Malaysians still having less aware of urban farming [2]. This is because urban farming is constrained by a lack of land and water, agricultural waste, the use of chemical residues, and pollutants that are harmful to the environment [3]. The aquaponics system continuously monitors and analyses the conditions of the fish and plants, taking automated corrective actions to balance out the aberrations based on data, and qualitatively deferring from the collected data to improve the conditions for operations, risk reduction, and manual intervention for fish setup [4]. The solution provides a real-time overview of the many metrics gathered from the system, such as temperature, PH, water level, turbidity, TDS, ORP sensor, and its developed system.

2. Literature Review

Aquaponics is a food production system that combines aquaculture (raising aquatic animals such as fish, crayfish, snails, or prawns in tanks) and hydroponics (growing plants in water), in which nutrient-rich aquaculture water is fed to hydroponically grown plants, where nitrifying bacteria convert ammonia to nitrates. Because all aquaponic systems are based on current hydroponic and aquaculture farming methods, the size, complexity, and kinds of foods cultivated in an aquaponic system may vary as much as any system found in any unique agricultural discipline. The comparison between indoor and outdoor aquaponic systems is shown in Table 1.

Table 1: Indoor vs outdoor aquaponic system

	Indoor Aquaponic System	Outdoor Aquaponic System
Pros.	Can produce food continuously in any climate and is more productive. The water is recycled and recirculates from a fish tank to grow the bed over and over again. Plants and fish in the aquaponics system will reward with maximum productivity due to the controlled environment. Outdoor pests will not be eating or destroying the plants and fish in an indoor aquaponic system.	The aquaponics can be in large scale or unlimited space compared to indoor aquaponic systems.
Cons.	Artificial lighting systems, heat lamps or any customization such as pump drain uses a lot of money at the beginning of the project.	Climates play an important factor. For example, if in colder climates, the system will be shut down. Therefore, the fish will not reach a harvestable size. If using an outdoor greenhouse, the conditions become unsuitable for certain fish when the water temperature becomes too warm. There would be more pests destroying the plants and fish in an outdoor aquaponic system.

The comparison types of aquaponic systems of [5]-[7] are shown in Table 2.

Table 2: Summary of types of an aquaponic system

Ref.	Types of Aquaponic	Description	Advantages	Disadvantages
[5]	Development of aquaponic using solar-powered control pump.	-The project objectives are to power water and air pump using green energy via solar panels. - Water pump required AC voltage and an inverter is used for this application. - The project focuses on using an inverter to replace the water pump with a DC water pump because when replacing grid power with solar panel energy.	-The aquaponics project is cheap and suitable for small scale. -The aquaponics project is easy to design and produce. -The electricity consumption is low and it always replenishes due to solar-powered projects.	-Lack of sensors and monitoring system. -Can be easily damaged due to cheap PCB board. -The battery can be easily worn out due to recycled power intake and outage.
[6]	Aquadroid: An app for aquaponics control and monitoring.	-The water circulates from the aeromal filter, grow bed, sump tank, and to the fish tank. -The project uses a glass PH sensor electrode, temperature sensor and soil moisture sensor. -It detects and monitors PH and temperature parameter values of water using the sensors within the 100 L sump tank. -The project uses app inventor blocks to generate the Aquadroid app to control the whole process of the project.	-The aquaponics project is cheap and suitable for a small to medium scale. -Aquaponics is advanced compared to other projects available on the market.	-Very complex coding due to Aerator. -The total price for the project is expensive. -The power consumption is too high.
[7]	IoT-based aquaponics monitoring system.	-The project uses Raspberry pi 3 to provide an extra port to the project as well as connect to the data server. -The project uses Arduino nano and Raspberry pi 3 for the microcontroller. -The project uses ultrasonic, temperature, PH and humidity sensors. -The project detects any reading of PH, humidity, temperature and water levels	-The aquaponics project uses ultrasonic, temperature, PH and humidity sensors. -It shows a graph and real-time reading of the project for the temperature and humidity.	-The project is expensive because it uses Raspberry pi 3. -The circuit is complex and easily can be damaged. -The plants for the aquaponic are barely minimum.

	and displays it on the LCD screen.	-The project is suitable for small-scale aquaponic.

3. Materials and Methods

A project management framework consists of the procedures, activities, and tools that are used to complete a project from the beginning until the finish. It encompasses all the key components required for planning, managing, and governing projects. The general workflow of the project is shown in Figure 1.

It is important to maintain PH at levels that are acceptable to both fish and plants. Tilapia, for example, require PH to be in the range of 5.0 to 10.0. Plants, on the other hand, grow best when PH levels are below 6.5. Nitrifying bacteria perform optimally at PH levels greater than 7.5 and stop working when PH levels fall below 6. The compromise that is optimal for all three components of an aquaponics system fish, plants, and nitrifying bacteria is a PH of 6.8 to 7.0. However, maintaining PH within such a narrow window can be difficult and may lead to unnecessary adjusting and tweaking. As long as the PH is maintained between 6.4 and 7.4 it will be tolerable to all three components of the system. Therefore, the PH monitoring levels are set to be 6.5 to 8 for this project. For the water level, it is to make sure that it does have enough water to supply the plants as well as the fish itself. Mostly the water level will decrease from evaporation itself, through water droplets as well as the exposure to heat. Therefore, the height of the water threshold is set to any desired amount for the project. For the temperature reading, it is important to stay between 15 and 30 Celsius. This is because when the water temperature is high, the tilapia will become active and consume a lot of food which makes them produce more ammonia in the water and when the water temperature is low, the tilapia will become inactive and consume less food which makes them produce less ammonia in the water. This problem can relate to the FCR of the fish, especially when the fish are inactive when the temperature is low. Therefore, the water temperature threshold is set between 15 °C to 35 °C Celsius. The oxygen levels are needs to be more than 0.8mg to cultivate 5 red tilapias in the water and make it enough to consume oxygen when the fish are in an active state. Therefore, the oxygen threshold is set to be more than 0.8 mg. The TDS sensor reading needs to be 50ppm to 1000ppm. The value of the TDS is suitable for drinking water and suitable for Tilapia fish to thrive in the water. The reading of TDS varies when the water starts to have harmful contaminants and needed to be treated. The Turbidity sensor reading must be below 1. These are the normal value for the turbidity. The turbidity sensor measures the cloudiness of the water. The cloudiness of the water creates a lot of problems such as algae which are common problems when taking care of a fish that produces a lot of waste produced in the water.

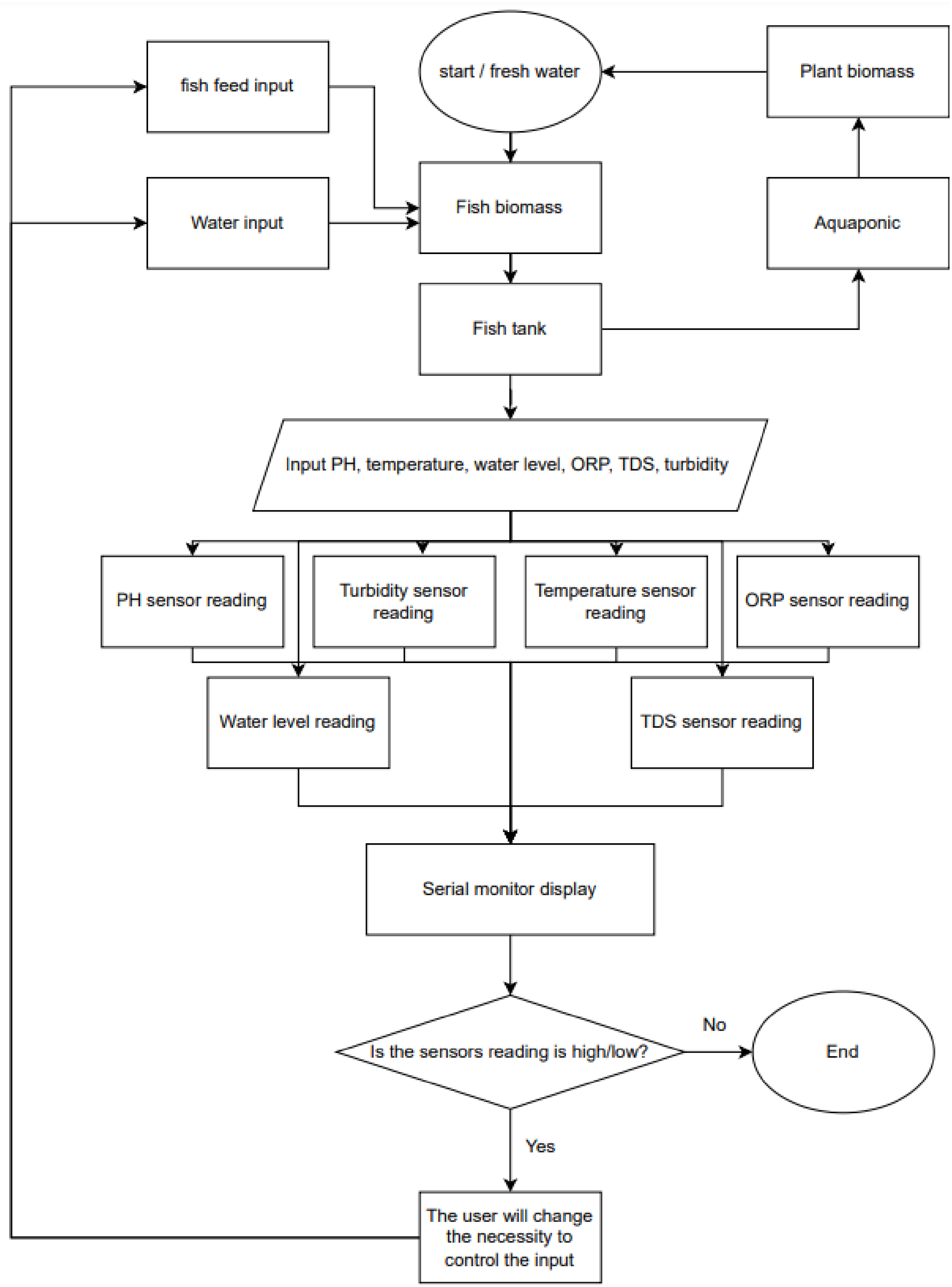

Figure 1: Applications Flowchart

4. Results and Discussion

4.1 Development of an aquaponic system

The aquaponics system was mostly made of plastic PVC for household products. For instance, the PVC plastic that holds the plants were made of 9 holes for each row and it is consist of 4 rows of plants, which totals up to 36 plants. The indoor aquaponic monitoring display system has a length of 118cm with 120 cm and 56 cm in width respectively. The project only uses 10 pots considering the project uses 5 Tilapia fish for the experiment. This is to balance out the nutrients that the plants needed in the project. Figure 2 and Figure 3 show the growth bed and system setup, respectively.

Figure 2: Plant growth bed

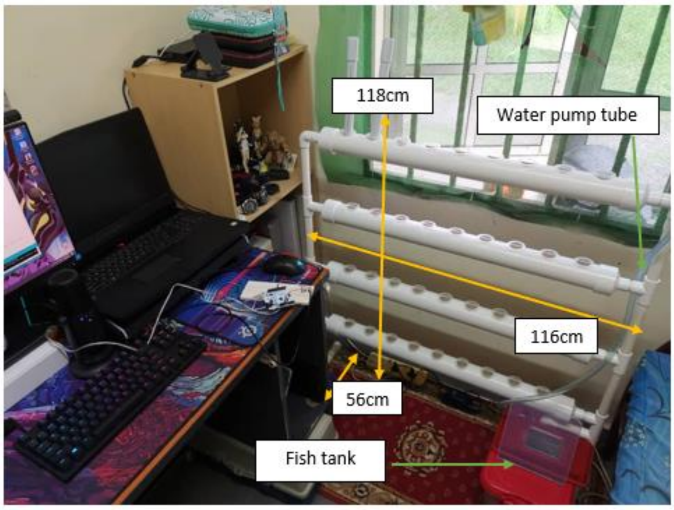

Figure 3: Aquaponic system setup

The growth lights are specifically intended to replace natural sunshine, promoting photosynthesis and delivering the appropriate colour spectrum for the plant to develop and thrive. During cloudy days, the LED growth lights were used on the Pak Choy for a minimum of 6 hours during the day if the sunlight were absent. Figures 4 and 5 show the difference between LED growth lights and without LED growth lights in the indoor room.

Figure 4: Without LED growth lights

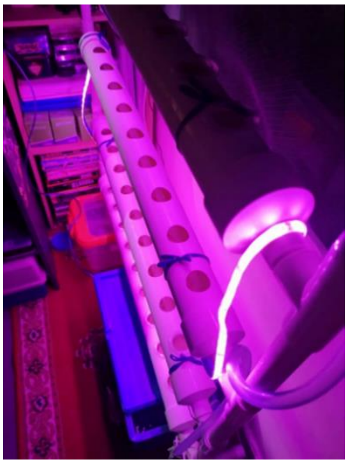

Figure 5: With LED growth lights

Starting from week 7, the plants were grown from 0cm to 4cm and this can be shown in Figure 5. The Red Tilapia managed to survive during the full 9 weeks of the project and it grows from 1 g to 1.80 g and 3cm to 5.5 cm in 9 weeks this can be shown in Figures 6-8.

Figure 6: Pak Choy 4 cm

Figure 7: 1.80 g of Tilapia

Figure 8: 5.5 cm Tilapia

4.2 Result of sensors, growth of Tilapia fish and Pak Choy

The result of sensors, growth of Tilapia fish and Pak Choy of 9 weeks are presented in Table 3. The full table has been simplified into 3 dates which are the 11, 18 and 30 of May. Table 3 shows each of the values of fish weight, plant height, PH value, turbidity value, water level value, TDS, temperature value and ORP value.

Table 3: Reading of aquaponic system and the 6 sensors

Parameters	Days & Date		
	Wednesday 11.5.2022 (Week 7)	Wednesday 18.5.2022 (Week 8)	Monday 30.5.2022 (Week 9)
Weather	Day	Day	Day
Fish weight (g)	1.76	1.76	1.80
Plants height (cm)	0.00	0.60	3.50
PH value	7.0	6.6	7.0
Turbidity value (NTU)	1.0	1.1	1.4
Water level value(mm)	550	538	520
TDS value (ppm)	50	50	65
Temp. value (C)	32	30	30
ORP value (mV)	527	500	520
Fish condition	Healthy	Healthy	Healthy
Plants condition	Healthy	Healthy	Healthy
Weight of fish food (g)	0.01	0.01	0.01

The aquaponics system can improve water quality so that fish survival can be increased compared to conventional fish farming. The recorded temperature data showed that with an average of 30 ºC there is no difference in temperature in the fish tank. The fish tank or container is located close to the windows and is affected by nearly the same environmental conditions. The fish weight starts at 1g and it grows to 1.8 g. In the first month, the fish fry starts to increase their weight and after the first month, the growth starts to be slower than the first month. This is because the fish feed is 0.02 g (for a day) and has not been increasing for the 9 weeks of the project. The main reason for the fish feed of 0.02 g is because the fish pellet was fed to the fried one by one until it reaches 0.02 g and when the fish stops eating, that is how to calculate the fish feed by grams. The plant height starts from 0 cm to 0.8 cm on week 1 until 6. This is a too slow growth for the plants and most of them are small and fragile. This is because there is not enough sunlight in the room and most of this time is either cloudy or rainy season and that is why after week 6, all the plants were dead because of insufficient sunlight provided. To counter this problem, the growth LED light (blue and red lights combined), helps with the plant's growth and imitates sunlight. Most of the plants needed a minimum of 6 hours of full sunlight to help them grow into healthy plants, therefore during the rainy or cloudy season, the growth LED light was turned on up to maximum of 6 hours a day (depending on sunlight). The turbidity value in Table 3 is mostly stable in value until it reaches 2.0. This tells the reading that during that time, most of the fish tanks has algae inside it. The reason for the algae is because the temperature reading of the particular day was low which is 27 ºC and the Tilapia fish were not very active therefore the algae was produced. The TDS value shows that when the turbidity sensor reading reaches 2.0, the reading of the TDS value has also increased. The water level losses from the first week which is 550 are lost to 540. Therefore, the water loss is around 10 during each week and the water loss is decreased gradually by 10 each week based on Table 3. The ORP and PH value is mostly the same throughout the week. However, the readings of the ORP and PH were slightly different during the morning and at midnight. This can be seen in Table 3 where the ORP and PH readings are high during the day and were 2 ºC or 3 ºC. This can be examined by looking at the ORP value as less during the day because the Tilapia fish were active during the daytime and their PH was low as well during the daytime compared to midnight.

4.3 The findings and the calculation of the Feed Conversion Ratio (FCR)

To calculate the FCR, the total weight of fish and the total weight of feed is needed. The calculation is shown as follows:

Total weight of feed =

0.01g X 2 = 0.02g for a day

7 X 9 = 63 total days

0.02g X 63 = 1.26

Total weight of feed = 1.26

Total weight gain of fish = Final weight – initial weight

1.80g – 1.01 = 0.79g

FCR was calculated daily. The formula for FCR:

$$FCR = \frac{\text{Total weight of feed}}{\text{Total weight gain of fish}} \qquad \textit{Eq.1}$$

FCR = 1.26/0.79 = 1.5949

The FCR is merely how much feed is required to develop one kilogram of fish. For instance, the FCR would be two if it takes two kilograms of feed to grow one kilogram of fish. The FCR for Tilapia fry is 1.59. The best FCR value is from 1.0 to 2.4. Therefore, the FCR of the experiment has been concluded. The FCR value has been reached.

5. Conclusion

The project has been completed according to the flow chart and as planned in the Gantt chart. The objectives of developing an aquaponic system for an indoor environment specifically for Tilapia and Pak Choy have been achieved. The indoor aquaponic system is designed to be suitable for the Tilapia and Pak Choy to be together and thus it creates one full cycle where the Tilapia gets the clean water from the Pak Choy and the Pak Choy gets the nutrients from the fish. More on that, developing a monitoring mechanism for the aquaponic system by using sensors and data display tools has also been achieved. This is vital in this project since each of the sensors, including PH, TDS, ORP, temperature, water level, and turbidity sensors, will fluctuate depending on the time of fish feeding, the intensity of sunshine or light in the room, and the fish's behaviour. The sensor reading may be verified using the water quality tester to see whether or not our reading is correct. The multipurpose sensors in the sensor reading may test the PH, ORP, turbidity, and TDS sensor. Finally, analysing the performance of the developed system in term of water quality as well as plant and fish growth have been accomplished. Each of the sensors gave different readings with 2 separate readings of day and night. From there, the reading can be shown and to learn the effects and behavioural of the fish and the waters which will eventually affect the plants if there is a slight change in the readings. There is no variation in temperature in the fish tank, according to the collected temperature data, with an average of 30C. The fish tank or container is near the windows and is subjected to similar environmental conditions. The observation began on March 30, 2022, during a transition time from rainy to overcast season, with cold temperatures in the morning and hot temperatures in the afternoon. As a result, even though the measurement was taken at 12:00 PM, the temperature was 30 °C at the start of the observation. After 8 PM., the temperature begins to drop by 2 or 3 degrees Celsius. Although the water temperature varied greatly from day to day, it remained within the ideal range for Tilapia development.

Acknowledgement

The authors would also like to thank the Faculty of Electrical and Electronic Engineering, University Tun Hussein Onn Malaysia (UTHM) for the support to complete this project.

References

[1] Current Population Estimates, Malaysia, 2021. Department of Statistics Malaysia Official Portal. (n.d.). Retrieved December 13, 2021, from https://www.dosm.gov.my/v1/index

[2] The potential of urban farming technology in Malaysia: Policy intervention. FFTC Agricultural Policy Platform (FFTC-AP). (2020, July 16). Retrieved November 30, 2021, from https://ap.fftc.org.tw/article/965.

[3] Chatterjee, A., Debnath, S., & Pal, H. (2020, February 25). The implication of urban agriculture and vertical farming for future sustainability. IntechOpen. Retrieved November 30, 2021, fromhttps://www.intechopen.com/chapters/71024

[4] Blog, monday. (2021, November 29). A guide to project monitoring and evaluation. monday.com Blog. Retrieved November 30, 2021, from https://monday.com/blog/project-management/project-monitoring-and-evaluation/.

[5] Vernandhes, W., Salahuddin, N. S., Kowanda, A., & Sari, S. P. (2017, November). Smart aquaponic with monitoring and control system based on IoT. In 2017 second international conference on informatics and computing (ICIC) (pp. 1-6). IEEE.

[6] DS18B20 (Digital Temperature Sensor) and Arduino. Arduino Project Hub. (n.d.). RetrievedDecember27,2021,fromhttps://create.arduino.cc/projecthub/TheGadgetBoy/ds18b20-digital-temperature-sensor-and-arduino-9cc806

[7] Pasha, A. K., Mulyana, E., Hidayat, C., Ramdhani, M. A., Kurahman, O. T., & Adhipradana, M. (2018, July). System design of controlling and monitoring on aquaponic based on Internet of Things. In 2018 4th International Conference on Wireless and Telematics (ICWT) (pp. 1-5). IEEE.