



Aquaponic Ecosystem Monitoring with IOT Application

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ABSTRACT

Aquaculture is an agricultural technology that combines aquaculture (fish farming activities) with hydroponic activities (planting crops without soil media) in one circulation. The most important element in aquaculture is the existence of fish, plants, and bacteria. These three elements form a mutually beneficial relationship or symbiotic mutualism. The main purpose of the aquaculture system is to maintain water quality and reduce ammonia levels from the water so that it can be utilized by other organisms. In addition, aquaculture can also save space and can produce two types of human food simultaneously, plants and livestock. Agricultural technology design with Aquaculture also uses the concept of Internet of Things (IoT) as information from sensors and sensors of value generator is accessible through applications installed on smartphones from anywhere with an Internet connection. Development of monitoring of aquaponic ecosystems with IoT systems was developed using a program using micro-controls to control temperature, humidity, pH levels and water pumps. There are some improvements made to this project.

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 favourable for the place where there is no fertile soil, or lack of water or even lack of free land/soil [1-8].

Nowadays, rapid development of country provides associate impact to agriculture because of land of agriculture was destroyed to form new building and residential district. Vertical hydroponics provides associate intelligent resolution to gardeners that have restricted horizontal house and for gardeners that wish to maximize their yield. They are largely suited there to don't grow terribly tall,

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and can be used effectively on walls, fences, balconies, and for higher density growth in small yards. The usage of chemical pesticide will be dangerous for the people [9-12]. It possibly avoided once we tend to follow aquaponic system. The advantages of this methodology of farming will be more exploited by massive scale production of crops. The controlled growing conditions will scale back the use of chemical.

Aquaponics fundamentals dictate that fish are fed and then waste is produced, which is an ideal nutrient source for plants. Fish require the optimal growth of high-quality feed and water. Solid waste must be removed and dissolved waste in the form of ammonia excreted by the fish is toxic to them, even at low concentrations. In fact, water can be crystal-clear, yet highly toxic. Furthermore, fish need plenty of oxygen, especially at a high storage rate, and the oxygen content in the water is largely a function of the surface area [13,14].

Figure 1 shows how aquaponic system works. For the first part, Fish are nourished with food and produce waste rich in ammonia. Too much waste is fish toxic, but they can withstand high nitrates levels. Next the bacteria, cultivated both in the growing beds and in the fish tank, this ammonia breaks down into nitrites and then into nitrates. Then, plants take converted nitrates as nutrients. The nutrients are a fertilizer that feeds the plants. Also, plant roots help filter the fish's water. Besides that, water in the system is filtered through the growing medium in the growing beds. The water also contains all the fish nutrients. Finally, oxygen enters the system via an air pump and during dry periods. This oxygen is essential for plant growth and the survival of fish [12].

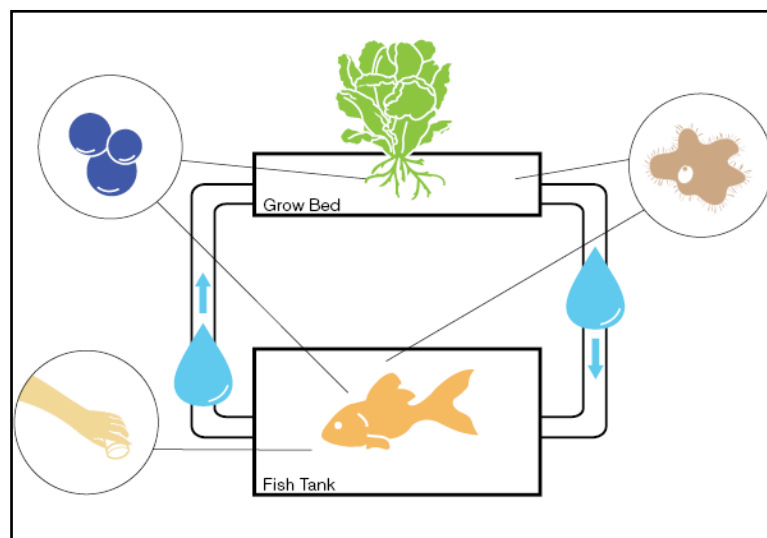


Fig. 1. Aquaponics System Cycle

2. System Overview

The main objective of this system is to develop an Internet of Things based aquaponics monitoring system which measures and displays parameters like pH level, soil moisture, humidity & temperature, on continuously to the user. Real time observations of the water inside the aquarium tank can be done for the favorable growth and survival of the fishes as well as the plants related to the complete system. Figure 2 shows the Block diagram of the system.

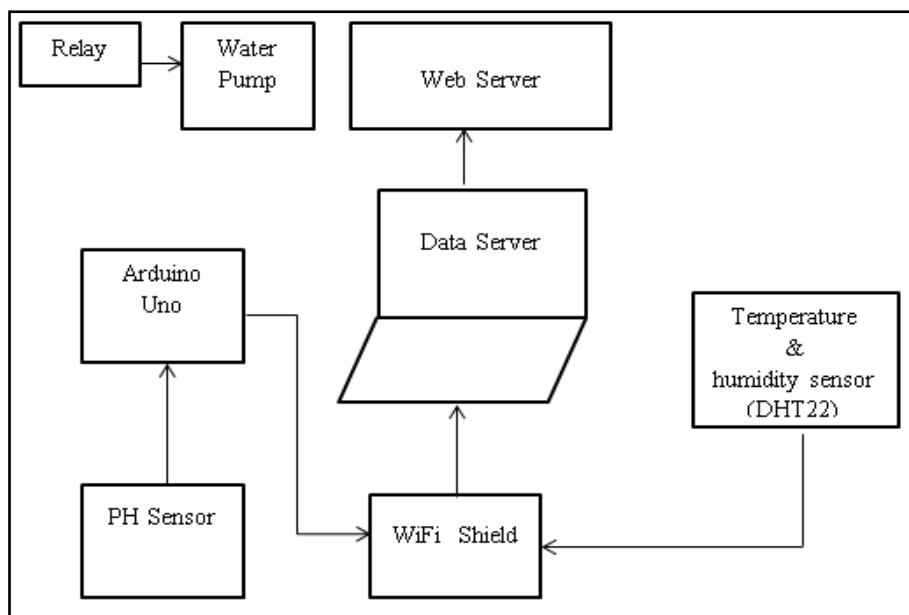


Fig. 2. Block Diagram of the System

2.1 Aquaponics System Hardware

The aquarium tank required for the system was built of dimension (44cm length x 30cm wide x 24cm height) with minimal cost and expenses. After that preparation of frame out of the PVC pipes to create a space for the plants to grow into the system. The water was filled, and the tank was left as it is for some days. When the cycle got ready, 2 pairs of puyu fishes were kept into the tank for a few weeks. The water was circulated throughout the frame and then back to the tank. 4 more pairs of the same fish were added into the tank for better results. Then, the germinated seeds of mustard were kept inside the holding cups which had grown bed within them. The observations were done for a couple of weeks without introducing the system to the electronics part. Figure 3 shows the aquarium setup of the system.

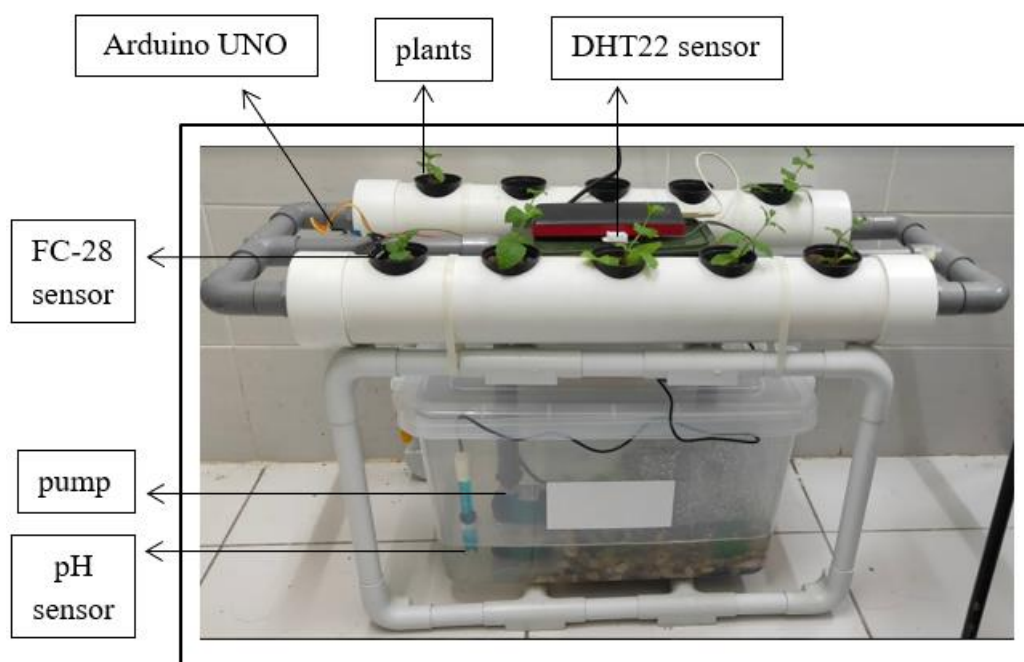


Fig. 3. Aquarium setup of the system

2.2 Design and System Architecture

The basic architecture of the aquaponic indoor system is an integrated user access with a graphical user interface by monitoring and controlling applications installed on a smartphone. The system architecture is grouped into three main points, namely client1 (user), server, and client2 (internal module), which can communicate with server via different media, as shown in Figure 4. The user will operate the experimental model remotely through the server. The server will forward the command to the hardware module. Microcontroller output data returned via server to the user.

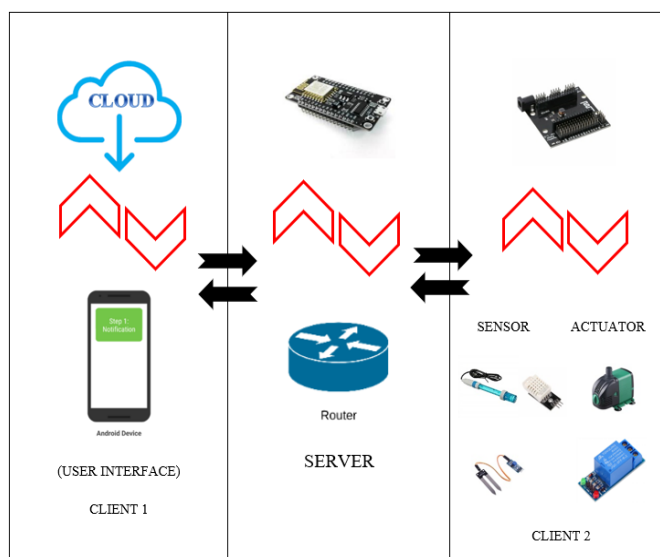


Fig. 4. Block System architecture diagram

2.3 Application Software Design

Smart Aquaponic application design created on the Android platform using model-based programming Block (Software Block-Base Programming Tool) App Inventor, this is a software development process programming system model using logic blocks that configure the interface screen created by App Inventor, a web-based software that is directly accessible via a web browser developed by the Massachusetts Institute of Technology (MIT) and Figure 5 shows the App Inventor Interface and Figure 5 shows the application design diagram. The application and program process also made directly on the web browser, and these can be tried with the emulator or mobile device.

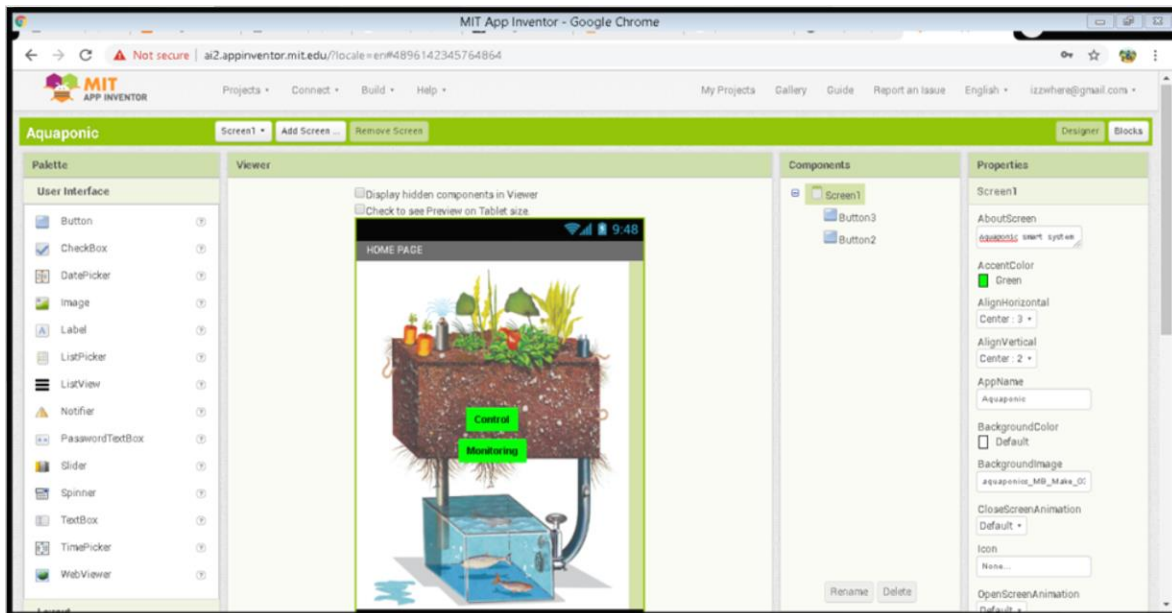


Fig. 5. App Inventor Interface

Based on Figure 6, for the first block explains the plan to create an app using the MIT App Inventor. In the plan, information related to block programming, android operating systems, Wi-Fi transmissions and om-server requests are required. The second block explains the necessary analysis of hardware and software requirements. Subsequently, the third and fourth blocks describe the design to make control of the navigation structure buttons and the design interface page. The fifth block describes the implementation of the program and the test program. Lastly, the results and tests obtained from all devices.

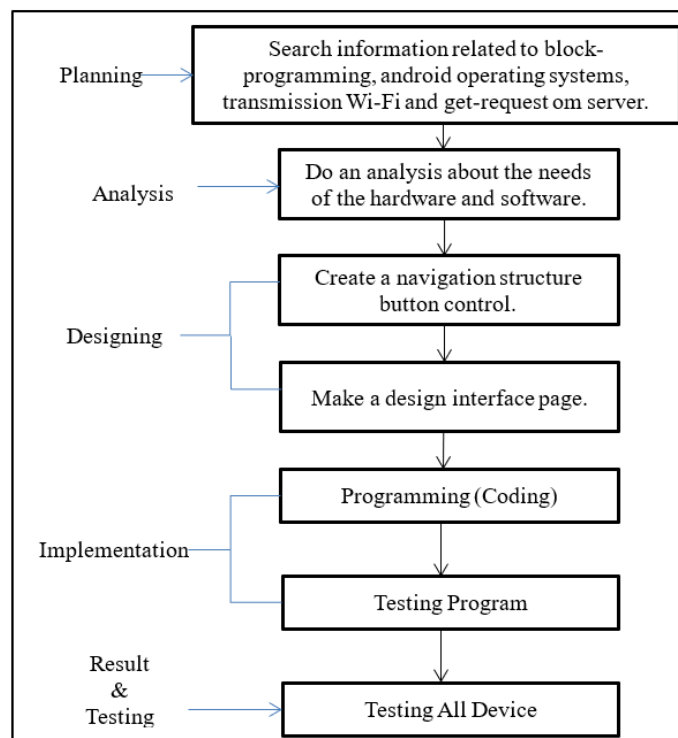


Fig. 6. Application Design Diagrams

2.4 Block Editor Part

Block editor that sets the app's behavior based on the developer's wishes. This part when the developer uses drag and drop the logic block tool to create an app to start coding. The language's primitive structures allow the app developer to easily manipulate the functionalities of these touch-enabled, portable, and sensing devices. Figure 7 shows the MIT app inventor block editor part.

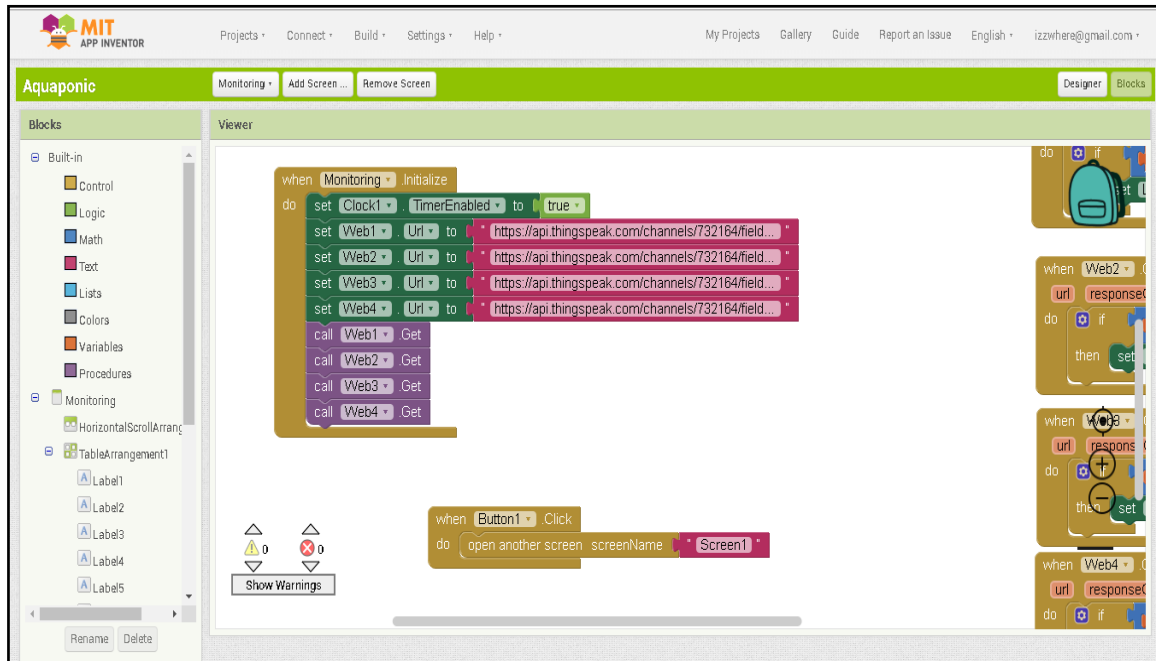


Fig. 7. MIT Inventor Block Editor

2.5 Method of Cultivation

Mustard greens suitable to be planted on various types of soil with moderate humidity. The most suitable temperature between 25°C and 35°C [13]. Limits are sprayed and added with compost and organic fertilizer. Lubricate the soil before planting. For starters, seed nursery method is done. Then, after 3 days the seedlings have germinated and leafy the perfect plant. Furthermore, the seedlings can be removed from a closed place and placed in a shady place. Do perfect watering to keep the soil moist. Figure 8 shows the growth of mustard greens plants at first day until day 8.



Fig. 8. Growth of mustard greens plants at first day until day 8

After that, the ready-to-grow seeds should have 2 new leaves. Usually, the size of the stem becomes length up to 5 cm or more. To pick up seedlings at seedbeds, the seedlings should be watered to facilitate seed separation without seed root damage. Make a hole in the planting medium on a polybag with a width of 2 cm, depth of 5 - 7 cm. Insert the stem of the tree into the hole until it leaves the main leaf on the top, close the hole, flush with water slowly until all wet soil parts. Figure 9 shows the growth of mustard greens plants at day 11 until day 18 and Figure 10 shows the growth of mustard greens plants at day 21.



Fig. 9. Growth of mustard plants at day 11 until day 18



Fig. 10. Growth of mustard plants at day 21

2.6 Nutrient Film Technique Planting

To plant in the grow pipes, the seedling needs to be supported with a short pipe or net cup containing 3–4 cm of gravel or other growing media in Figure 10. The rest of the net cup should be filled with a mixture of gravel and a moisture-retaining medium such as compost or coco fibre. The medium helps retain moisture because the young plant roots only barely touch the water flow inside the grow pipe. If coco fibre or compost is unavailable, then any standard medium will suffice. After one week, the roots should have extended out through the net up and into the grow pipe with full access to water flowing along the bottom of the pipe. In addition, wicks can be extended from the bottom of the net cup into the stream of water, if necessary.

For planting, follow what is shown in the following Figure 11. Make sure the plant cup has enough holes to allow the root system to grow out into the pipe but also to prevent the growing medium from falling out. A plant cup made from a net cup and 10 cm of PVC pipe (50 mm).

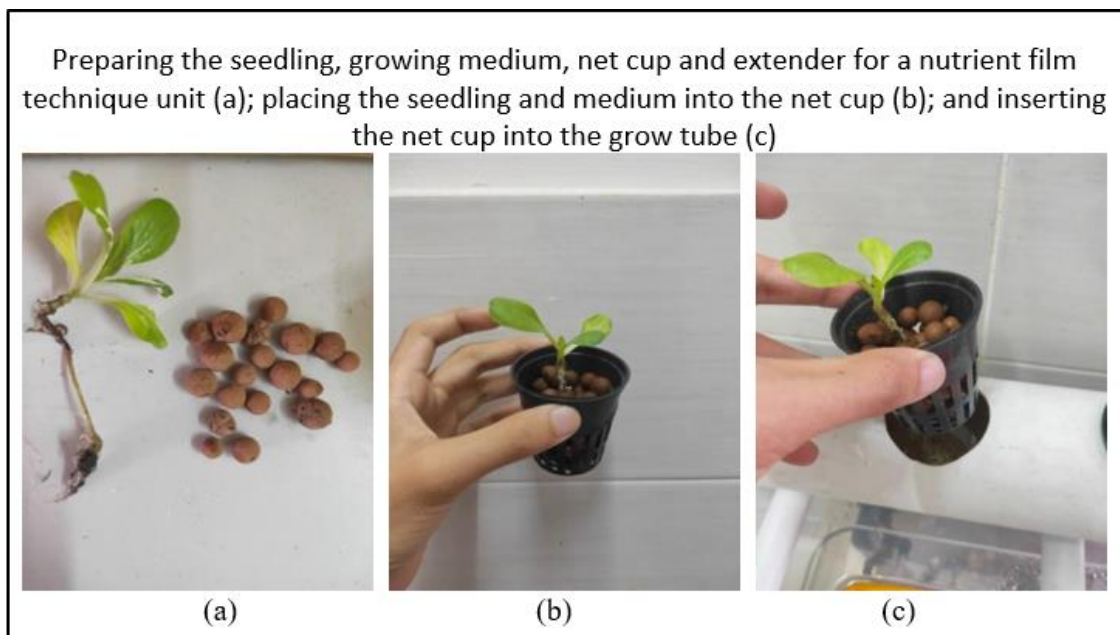


Fig. 11. Nutrient Film Technique planting

2.7 Acclimatizing Fish

Acclimatizing fish into new tanks can be a highly stressful process for fish, particularly the actual transport from one location to another in bags or small tanks in Figure 12. It is important to try to remove as many stressful factors as possible that can cause fatality in new fish. There are two main factors that cause stress when acclimatizing fish: changes in temperature and pH between the original water and new water; these must be kept to a minimum.

The pH of the culture water and transport water should ideally be tested. If the pH values are more than 0.5 different, then the fish will need at least 24 hours to adjust. Keep the fish in a small, aerated tank of their original water and slowly add water from the new tank over the course of a day. Even if the pH values of the two environments are close, the fish still need to acclimatize. The best method to do this is to slowly allow the temperature to equilibrate by floating the sealed transportation bags containing the fish in the culture water. This should be done for at least 15 minutes. At this time small amounts of water should be added from the culture water to the transport water with the fish. Again, this should take at least 15 minutes to slowly acclimatize the fish. Finally, the fish can be added to the new tank.

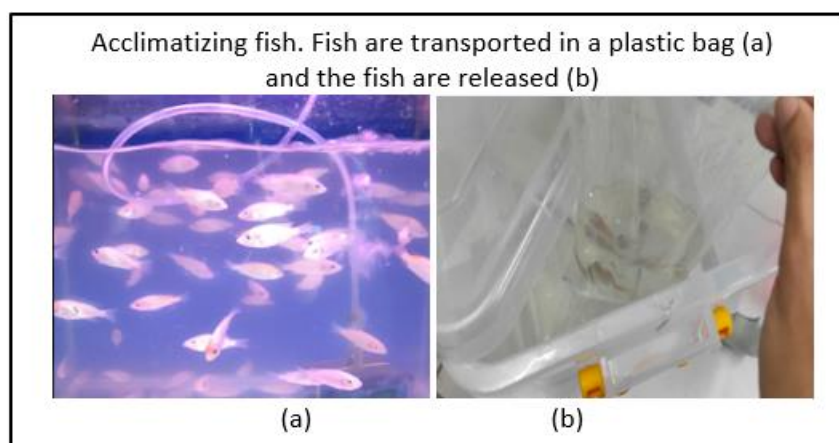


Fig. 12. Acclimatizing Fish

3. Results and Discussion

3.1 Testing Automatic Mode

Automatic testing could be done by accessing router hotspot from the user's smartphone, so the system device is in the same network with a smartphone and information exchange goes through the internet. After that, user can open the application interface and access the IP router with an IP address. When the user has accessed the router's IP address, the user can connect to the user interface to capture the information given to the interface pages. Automatic mode can be done to see that the system device can monitor and control the actuator on parameters specified without user instructions. The test result obtained that sensor can also perform measurements of air temperature, humidity, soil moisture and pH level, Ethernet shield can act as a server that can receive and send data, and relay as a switch for various actuators. From the information the sensor DHT22 reads the temperature value were ideal conditions ranging from 27°C-30°C and air humidity at the ideal range of 65 percent-80 percent and soil moisture is in ideal conditions ranging from 601-950 which means that it is moist and relay that is integrated on the sensor will be off. Table 1 shows the ideal condition and actuator condition of device FC-28.

Table 1
 System Ideal Condition and Actuator Condition on Device FC-28

FC-28	DHT 22		PH0-14	RELAY	ACTUATOR
SOIL	HUM	TEMP	PH LEVEL	DRIVER 1	WATER PUMP
<=501 (WET)	<=65%	>30°C	OFF	OFF	OFF
>501 && <=950 (MOIST)	>65%	>27°C && <=30°C	OFF	OFF	OFF
>950 (DRY)	>=80%	<27°C	ON	ON	ON

3.2 Manual Measurements of Plant Height

The proposed smart aquaponics system has been continuously tested for 21 days. All sensor values were acquired for humidity, temperature, pH, and soil. Furthermore, manual plant height measurements were performed for data mining and analysis. The plants are pak coy, also known as mustard greens. Linear regression models were designed and their respective R2 value (goodness-of-fit measure) was calculated. As shown in Figure 13, where yp is the plant height (cm) and x is the number of days, the linear regression model of $yp = 0.8814x + 5.8796$ with R2 value of 0.9732 was formulated over time for plant height. The model can describe the growth of the plant over time.

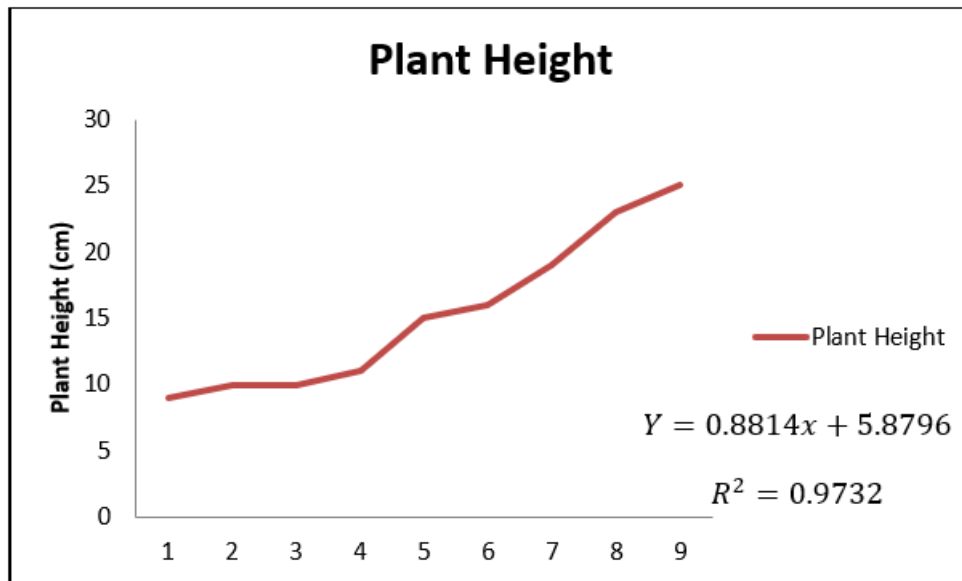


Fig. 13. Graph from measurements of plant height

3.3 Monitoring Section of the System

The monitoring section have been designed and developed in order to detect and measure the system parameters of the aquaponics system. The technologies used to develop this section has made things easier to percept about the favourable conditions required for the fishes and plants to grow within a same combined system. Different sensors have showed different types of readings when compared for a week, the data that has been acquired through the used sensors have been showed below.

The suitable range of temperature for the growth and survival of plants and fishes inside the system is in between (20-30) degree Celsius. The readings were taken for a week and the system was seen very favourable in the development of a healthy system [14-16].

The suitable humidity for the growth and survival of plants and fishes inside the system is in between (40-95) %. The readings were taken for a week and the system was seen very favourable in the development of a healthy system [17-19]. Figure 14 and Figure 15 serial monitor for sensor humidity and temperature.

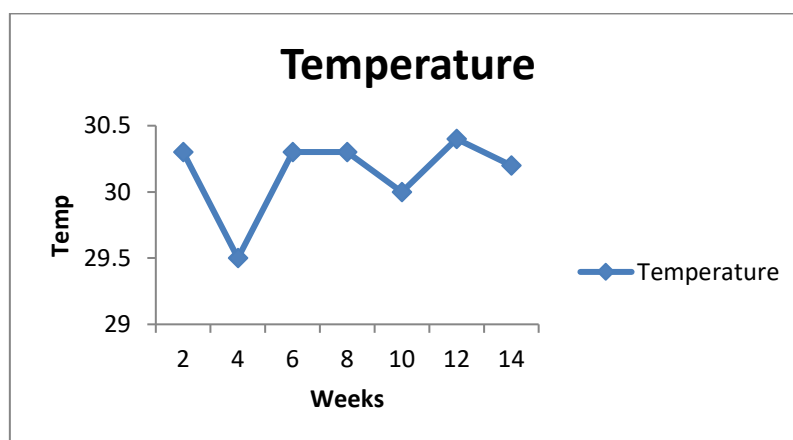


Fig. 14. Graph showing Temperature of the system

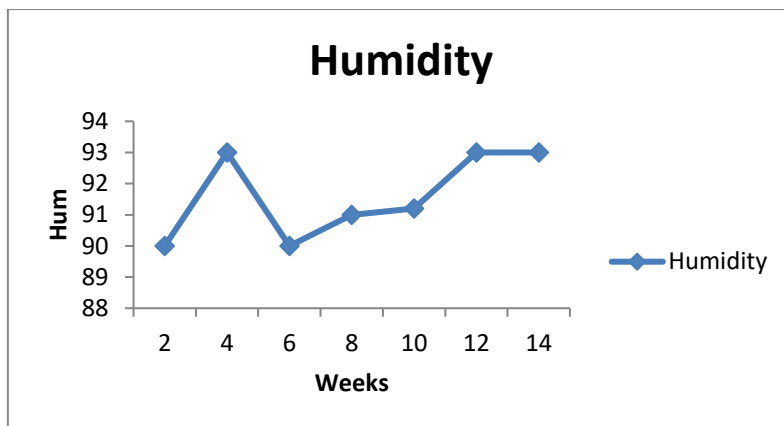


Fig. 15. Graph showing Humidity of the system

The suitable soil moisture range for the growth and survival of plants and fishes inside the system is in between (350-700). The readings were taken for a week (Figure 16) and the system was made favourable in the development of a healthy system [20-23].

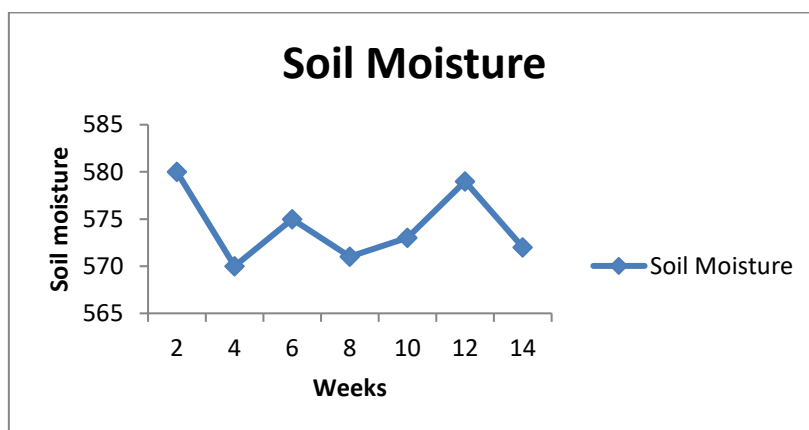


Fig. 16. Graph showing Soil Moisture Values

The suitable pH range for the growth and survival of plants and fishes inside the system is in between (6.5-8). The readings were taken for a week (Figure 17) and the system was made favourable in the development of a healthy system [20-23].

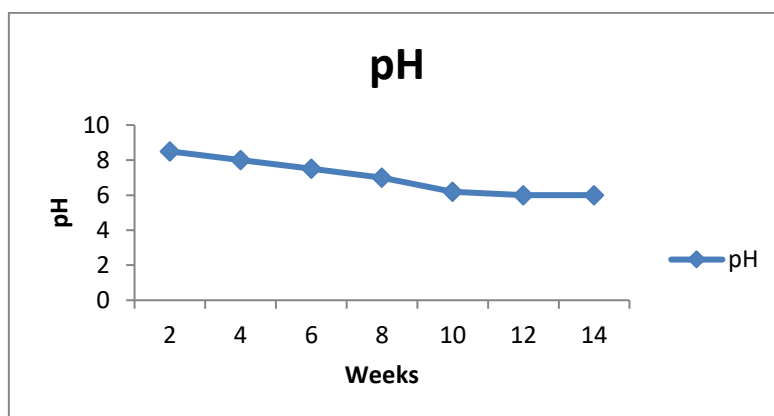


Fig. 17. Graph showing pH Values

4. Conclusions

The result of laboratory experiments is that aquaponic devices with monitoring system and internet control can monitor temperature, humidity and soil moisture on internet hardware platforms. A low-cost aquaponics system using NodeMCU microcontroller is successfully designed. The program of NodeMCU is developed to monitor and control the water parameters. The system developed is capable of detecting pH value, temperature, humidity, soil moisture and using ESP8266 to send data to Thingspeak. The aquaponics system using NodeMCU microcontroller has been successfully developed to monitor the water parameters and a portable aquaponic system can be deployed anywhere.

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