Automated Indoor Aquaponic Cultivation Technique

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Abstract— **Aquaponic has become an interesting model for private sector, aquaculture and environmental scientist because of many advantages that can be obtained. The word 'Aquaponic' refer to the integration of 'hydroponic' (growing plant/vegetable production without soil) with aquaculture (fish farming). The growth performance of comet goldfish (aquatic) against a hydroponic plant of Ipomoea aquatic (water spinach), *Spinacia oleracea* (spinach) type of leafy vegetable and water plant were evaluated in recirculation of this Aquaponic system towards temperature, light and fish waste effectiveness. The fish were feed with commercial pelleted feeds containing 30% crude protein which can provide almost all nutrients required for the plant growth. Auto feeder place in this system used to maintain the growth and survival rates. Filter systems used to remove the amount of waste materials and breakdown products from the water. In this project, a set point is the desired value that needed by the user. The set point will be the desired water level, the monitored temperature in fish tank, the monitored temperature at plant area and the desired amount of food. While Arduino (Mega) function as a brain that used to receive the information from the sensor and come out with an instruction in term of response (action) as the feedback. Then the action will be based on the actuator that was reacted towards the act received. Therefore, this closed system was completed the project development system.**

Index Terms—**Aquaponic, hydroponic, Adruino, automated controller, aquaculture**

I. INTRODUCTION

Recently, the incorporation of recirculated fish with a vegetable hydroponic production called Aquaponic has become an interesting model for private sector, aquaculture and environmental scientist because of many advantages that can be obtained. Now almost 50% of the world's food fish and is perceived as having the greatest potential to meet the growing demand for aquatic food. At least additional of 40 million tonnes of aquatic food were estimated will be required by 2030 in order to maintain the current per capita consumption [1]. The word 'Aquaponic' refer to the integration of 'hydroponic' (growing plant/vegetable production without soil) with aquaculture (fish farming) [2].

The growth performance of comet goldfish (aquatic) against a hydroponic plant of Ipomoea aquatic (water spinach), Spinacia oleracea (spinach) type of leafy vegetable and water plant were evaluated in recirculation of this Aquaponic system towards temperature, light and fish waste effectiveness. Using the technique of stem cuttings to conduct this study for water spinach (Ipomoea aquatic) and technique plant through seed for spinach (Spinacia oleracea). The accumulation of waste nutrients from fish culture is controlled by hydroponic [3, 4] which may lower overall consumption of water [5] and produce additional, saleable crops [3]. During cultured of fish, a few portions of the feed are converted (20-35%) to useable energy [1].

The fish were feed with commercial pelleted feeds containing 30% crude protein which can provide almost all nutrients required for the plant growth. This nutrient rich Comet Goldfish effluent provides an opportunity to use it as fertilizer supplement in agriculture. The balance of nutrient is excreted in form of solid and dissolved fractions [1]. Controlling the schedule of feed rate and proper amount of feed towards fish in this system can overcome problems regarding overfeeding that can cause health problems due to high ammonia and nitrites, low oxygen levels, low pH levels, fin rot, fatty liver and improper digestion. Proper filtration can solved the problem of cloudy water.

Filter systems used to remove the amount of waste materials and breakdown products from the water. In this case, the grown hydroponic plants in this system are used as the bio filters that help in water regeneration of uneaten food and waste materials that collect by the filters [6].

This nutrient rich Comet Goldfish effluent provides an opportunity to use it as a fertilizer supplement in agriculture [7]. Removals nutrient by the plants improve on the quality of effluent and may enhance the fish production. The amount of nitrate produce in a fish culture system is directly proportional into two factors: the amount of density of fish in the system and amount and protein content of the food, as different fish species require different protein content in their respective diets [1]. In indoor system, capture of solid waste and conversion of ammonia to nitrate to nitrification are usually the main treatment, steps within the recirculation loop [8].

Way to reduce water usage and improves the waste management and nutrient recycling is by providing the recirculation aquaculture system [9]. Clearly, the production of organic matter, nitrogen and phosphorus is directly linked to the food conversion ratio and differs with different diets, temperatures, fish species, fish sizes and culture systems [8,9]. Besides that, plants also required light to grow and yield well.

The total quantity of light that plants receive during illumination directly involved in the process of photosynthesis. There are various types of light that can be used to determine the effectiveness of plant growth such as incandescent, luminescent lighting systems, light-emitting and light-light [12,

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13]. However, tissue cultured plants are almost always chosen to be planted under the fluorescent lighting with high output, where the blue and red areas [11]. The increase in temperature can affect the flow of organisms and maintenance of fish populations by affecting their distribution, survival and growth. These may change by size and age, as the Comet goldfish prefer to be in a stable environment of 24°C-30°C. Maintaining an independent body temperature is most fish lack means of. Lethal and sub lethal temperature can alter metabolism, growth, and competitiveness interactions by increased the water temperature [14].

II. System Descriptions

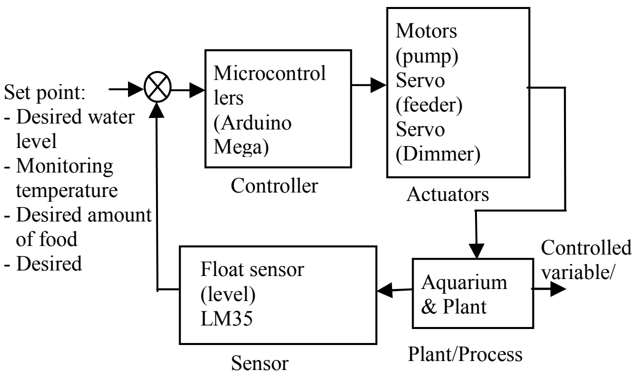

Fig. 1. Automated Indoor Aquaponic Technique Descriptions

Figure 1 shows the overall block diagram of an Aquaponic system. Set point is the desired value that needed by the user. The set point will be the desired water level, the monitored temperature in fish tank, the monitored temperature at plant area and the desired amount of food. While Arduino (Mega) is the brain that used to received the information from the analyzation of the sensor and comeout with an instruction in term of respons (action) as the feedback. Then the action will be based on the actuator that will react towards the act received. Therefore, this closed system will completed the project development system.

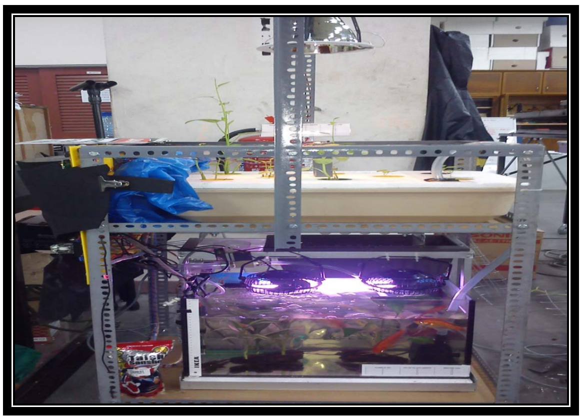

Fig. 2. Front View of Automated Indoor Aquaponic Cultivation

III. Project Methodology

The development of an Automatic Indoor Aquaponic System were consists of two important fractions which was hardware development and software development. Methodology to be implemented in this project contains of six stages. Process flow methodology starts from the description of work to be done, the brainchild of new or previous working reference right up to the stage of analyzing the data that was collected as shown in Figure 3.

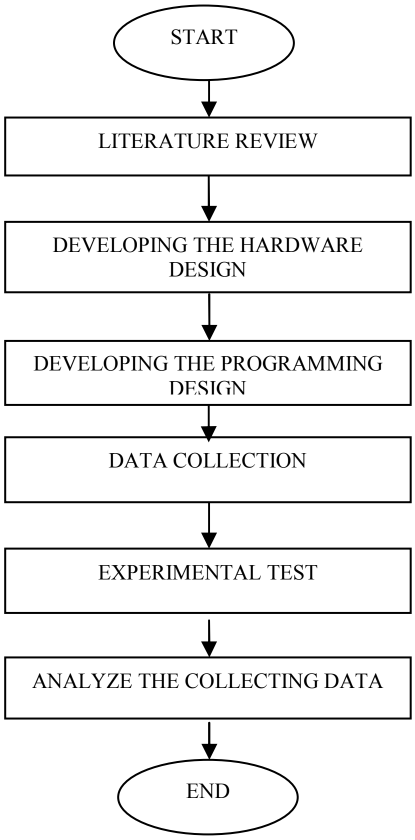

Fig. 3. Methodology Flowchart

A. Literature Review

This section provides an overview of some of the earlier Aquaponic system and all the components that might be used in this development. In the end, a brief discussion of the evaluation in terms of the advantages and disadvantages of each method are described.

B. Hardware Development

Hardware is the physical components that have been merged together in order to build and form a "micro-based Indoor Aquaponic System".

1. *Fish parameter details*

Fish species Comet goldfish suitable to be in a temperature of 24-30°C. Comet goldfish with an initial mean weight of 30-50g were stocked at a density of 25.5L in a glass aquarium, length 46cm, width 30cm, height 31cm in size with water depth of 21 cm. Commercial pelleted feed “Taisho sanshoku” contain protein 27%, fat 2%, fibre 5% and ash 9% was used in this study. Fish were feed twice per day at 11am and 9pm based on RTC1302 at a rate of 5g. Small size pellets were used for the experimental duration.

2. Hydroponic Component

Four samples of Water spinach (Ipomoea aquatica) and four samples of Spinach (Spinacia oleracea were placed in a Hydroponic tray (length 55cm, width 42cm, height 15cm) that constructed 10.8cm above the fish tank surface. The hydroponic tray was filled with fish waste water with a depth of 10cm and 7.5L. Hydroponic units were irrigated daily at each 30 minutes based on real time clock (RTC1302). This system is using an unfiltered fresh water supply of 3L per irrigation. Irrigated water were retained in the hydroponic unit until it reaches the 11cm from the bottom tray level and drained back into the fish tank through a 15mm PVC pipe by gravity. All of the plant will grow in the medium basket while the plants root immersed in the water.

3. Light for Plant Growing

Artificial light supplied to the plants was practically a daylight bulb with a rating of 100 watts (normal light). The cost is cheaper compare to the special grow light put up for sale in the market. The usage of this light is affordable to be bought to replace the actual grow light. ON and OFF conditions of the light was depends on the timer that had been set. For this system, the time the light operates is at 10:00 am until 2:00pm and 7:00 pm to11:00pm per day.

4. Temperature Sensor (DS18B20 and LM35)

Theoretical the fish require to be in a temperature between 24°C to 30°C to keep it growth and live well. The heat is supplied by the application of heater. To monitor the temperature of the water in the fish tank that the heater produce, temperature sensor, DS18B20 was used. It is a one wire temperature sensor and give a reading in digital value. This temperature sensor DS18B20 was immersed in the fish tank in this system.

Theoretical the plant require to be in a temperature between 25°C to 30°C to keep it growth healthier and yield well. The heat were supplied by the application of artificial light. To monitor the temperature at the plant area which produce by the light, temperature sensor LM35 was used.

5. Float Sensor

Float sensor was used to control the water level in the fish tank to constantly maintain at it set point required. The float sensor used to detect a minimum and maximum level of water in the tank. The float sensor act as a switch to be either in active high or in a active low that indicate discrete level measurement 1 or 0. It used to indicate the sufficient water level and insufficient water level in the tank as to avoid insufficient water level for the pump to operate.

6. LCD Display

This system used LCD type of 4x20 to display the data of the system that consists of water level status, the current date and time status, the measured temperature of LM35 and DS18B20 status and also the speed of fan and the brightness of light status [15].

C. Programming Development

Software is one of the most important part of implementing a system or device to interface with hardware in order to ensure the functionality of the system. Since Mega 2560 is used as the controller of the system, therefore Arduino 1.0.1 was used to develop the programming.

D. Data Collection

Trials of the prototype could be implemented only after the completion of the prototype design end and when the successful hardware and software interface with each other to generate the data system [16]. Data from the experimental tests were recorded and collected repeatedly to get results that can be referred to at a later date. Data around the aquarium water temperature is measured using a sensor DS18B20. While the temperature data at the plant area was taken into account by the measured reading of LM35. The collected data were stored on the SD card based on the data logger technique. Furthermore, the data with respect to how the amounts of food affect the fish growth will also be taken into account. This data were used to prove whether these fish are really getting the requirements needed from the system for it to remain healthy. This data is very important to obtain reasonable assurance that the system is very helpful towards the fish and plants grow and stay healthy.

IV. EXPERIMENTAL TEST

1. Test for Float Sensor Functionality

Float sensor was placed in a fish tank in accordance with the standards set for the input data. This sensor was used to detect the absence of water in the tank. This experimental test was done to verify the functionality of the sensor towards this system to control a water level. This sensor was as an enhancer on the system to provide an optimal space for the fish to live and also to maintain the inconsistency water that may affect the water temperature variation. If the sensor detects floating High (1), the sensors act as a switch to let the valve to activate and to be open automatically as a result of receiving input from the sensor and thus to let the new incoming water to fill the space in the fish tank. Table I represents the data that was recorded.

TABLE I. FLOAT SENSOR FUNCTIONALITY

No. Of Test	Water Absent	Level Indicator	Functionality
1	0	1	YES
2	0	1	YES
3	0	1	YES
4	0	1	YES
5	0	1	YES
6	0	1	YES
7	0	1	YES
8	0	1	YES
9	0	1	YES
10	0	1	YES

Float sensor was placed in the aquarium at a desired set point. As the water level reach minimum volume, the float sensor detected 1. Hence, the valve that connected with pipe will turn ON and new water flowed in through the pipe into the tank. The float sensor was set to be active low and normally closed. The float sensor applied in this system was able to provide an optimal space for the fish and to avoid from inconsistency of water. The recorded data proved that the float sensor has been functioned well since the float sensor able to monitored and also set the desired water level. The developed system were able to perceive good control performance on the level control by maintained the desired water level.

2. Test for Temperature Sensor (DS18B20) Functionality for Water Temperature

The heater applied in the system is set to be in a temperature of 30°C which is nearer to the room temperature. The heater used to warm and to maintain the water temperature in the tank from fluctuate. Besides that, manual thermometer is placed near to the DS18B20 to check whether the measured heat obtained is similar. Data of water temperature in the aquarium is measured by using DS18B20 which is immersed in the water of an aquarium. The objective of this test is to prove the functionality of DS18B20 that applied in this system. Then the data will be recorded using data logger technique. From this data, the owner can analyze and take an action if the heater is not working or the temperature sensor is damaged by replacing it with new equipment. Table II is presented the recorded reading of DS18B20.

TABLE II. DS18B20 READING FOR WATER TEMPERATURE

SET POINT (°C)	TEMPERATURE DS18B20 (°C)
30	29.50
30	29.56
30	29.56
30	29.25
30	29.31
30	29.37
30	29.37
30	29.43
30	29.43
30	29.43
Average	**29.42**

The transformation of measured data was changed linearly to the set point of temperature which has been set 30°C. Throughout this experimental test, the minimum data sample of temperature gained was 29.25°C and the maximum data sample of temperature was 29.56°C. The average water temperature read by the sensor was 29.42°C which was different only about 0.58°C compare to set point temperature. This mean that the sensor DS18B20 has an accuracy about 98%. This results achieve due to the influence heat of the heater against the water in the aquarium. This temperature sensor were able to monitored the temperature variation of water in the aquarium and also let the user analyze and take an action if the heater was not function or the temperature sensor was damaged during the operation. Therefore, the temperature sensor DS18B20 has responds to the water temperature and proved that DS18B20 was relevant to monitor the temperature for this system. Consequently the cost of developing the system can be reduced since the temperature sensor availability were easily found in the market.

3. Test for Temperature Sensor (LM35) Functionality for Water Temperature

Heaters used in the study were determined to be in a temperature of 30° C where the temperature is close to the room temperature. Manual thermometer is placed near the sensor LM35 to test the accuracy of the sensor readings. Data of the water temperature in the aquarium is measured using the LM35 that submerged in the water. Then the data will be recorded using a data logger technique. From this data, the user can analyze and take an action if the heater does not work nor may cause by the temperature sensor itself have been damaged. Thus the user can easily detect and replace it with new equipment. Table III shows the reading of the LM35 data.

TABLE III. LM35 READING FOR WATER TEMPERATURE

SET POINT (°C)	TEMPERATURE DS1B20 (°C)
30	25.80
30	25.90
30	26.00
30	26.10
30	26.20
30	26.30
30	26.40
30	26.50
30	26.70
30	26.70
Average	**26.26**

Based on this data sample, the minimum temperature gained was 25.80 °C and the maximum temperature was 26.70°C. The average water temperature read by the sensor was 26.26°C which was different only about 3.74°C compare to set point temperature. This mean that the sensor LM35 has an accuracy about 87.5% only. This data fluctuate due to the influence of heat of the heater in the water or inefficiently temperature sensor to be used under the water. This sensor manage to monitor the temperature variation of water in the aquarium and let the user to analyze and take an action if the heater was not operated or the temperature sensor was damaged by replaced it with new equipment. During this experimental test, the LM35 was defective. The defectiveness was detected towards the data that kept in the SD card by the used of data logger technique. As for conclusion, the temperature sensor LM35 does not efficiently responds to the water temperature and proved that LM35 was not relevant to measure water temperature because the accuracy was lower than DS18B20 and the functionality was easily defective.

V. Conclusion

As a conclusion, the Automated Indoor Aquaponic Cultivation Tecnique was able to perceive a good control performance. The overall integration of controller, actuators and sensors effectively create a closed-loop control system.

The temperature sensor DS18B20 was able to monitored the water temperature variation in the aquarium and let the user analyse and take an action if the heater is not worked or the temperature sensor was damaged during the operation. Therefore, based on data acquire the temperature sensor DS18B20 was responded to the water temperature and proved that DS18B20 was suitable for this system. Throughout the data that kept in the SD card by using data logger technique to record the temperature as a database for monitor by the user. Additionally, from the experimental test proven that the LM35 were not very accurate compare with DS18BB20.

Moreover the water level can be determined by the developed system and able to perceive good control performance on the level control. The float sensor applied in this system are able to show the functionality and does provide an optimal space for the fish and avoid from the inconsistency of water that might ruin the pump. From this research, the development of this Automated Indoor Aquaponic Cultivation Technique show that the functionality of auto feeder and volume of fish waste assisted to the development of fish growth and plants progression. In additional, it can be proved that this system was significant to be used as there were no fish were death and the plants had been successfully growing.

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