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Design and Implementation of a Controller for a Recirculating Aquaponics System using IoT

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***Abstract* –** This paper details the automation of the Aquaponics system, where the required parameters needed for the growth of plants are controlled, and are monitored using IoT. By utilizing this system, we achieve a symbiotic relationship between the plants and the fish. The IoT part of this system helps in monitoring the parameters from anywhere by connecting to the 'ThingSpeak' server.

***Keywords* – RAS (Recirculating Aquaponics System), IoT, Controlled environment, Symbiosis.**

I. INTRODUCTION

In our current way of life, healthy, natural food is a luxury only a few can afford. The increased demand for food supply has made companies across the globe to turn to chemical means, to increase food production, which results in crops being contaminated by unwanted pesticides and other chemical growth substances. These means for an increase in production rates, has also reduced the nutrition values of the food. In the future, the increase in population, demand for the ground water level will severely affect food production, and result in a drastic reduction of the nutritional level of the food. To overcome these problems researchers and innovators worldwide, have introduced vertical farming, which can turn out to be a viable solution. In vertical farming, there are so many methods like Hydroponics, Aeroponics and Aquaponics. Among all other methods the most sustainable method of growing food is Aquaponics. This was an ancient method used in the eastern and southern parts of the world, and it is now modified and re-introduced as a modern method of agriculture.

This aquaponics is the combination of hydroponics and aquaculture, where in Hydroponics, plants are grown by using the artificial nutrients which are given directly to the roots by a stream of water, without using soil. Many engineering techniques like NFT, Raft system, Stacks, grow beds are used to cover the absence of soil. In a conventional hydroponic system, the major drawback is the water coming out of the system, as it is harmful to the environment and cannot be used again. Aquaculture is farming of fish in a separate area like tanks, ponds, raceways and in cages for increase in fish production, but in this method, the water coming out of the system is wasted and cannot be used again without using a proper filtration system. Upon careful consideration of the drawbacks of both, hydroponics and aquaculture, aquaponics was introduced. In this system, the waste generated from the fish is converted into plant nutrients by using bacteria present in the water and then sent to plants to grow hydroponically. Hence the whole system is in recirculation and this is called the Recirculating Aquaponics System (RAS).

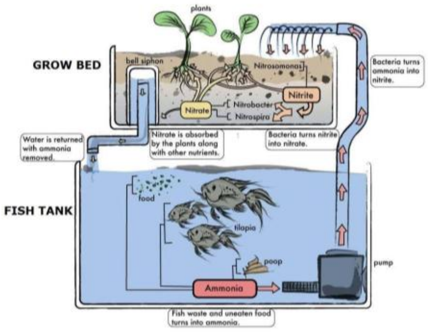

Fig. 1. The basic diagram of an aquaponics system

The above figure represents the basic structural design of an aquaponics system. In this design the Grow bed is filled with Grow medium which can be clay balls, coco peat, gravel, rock wool, peat moss. In the bottom of the Grow bed, a proper drainage system is fixed. Under the Grow bed, there is a fish tank which is filled with water and fish. An aerator is fixed to the fish tank for giving oxygen to the fish. A pump is attached to the fish tank to the Grow bed, for pumping the water into the Grow medium. The water contains ammonia produced by the fish waste, this ammonia is converted in to nitrates by using bacteria. These nitrates are useful for plant growth. The excess water is filtered in grow medium and sent back to the fish tank. In this way the water is recirculated through the system.

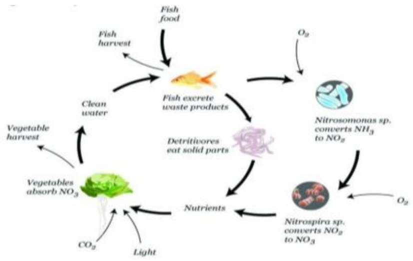

Fig. 2. Cycle of aquaponics.

Fig.2. represents the cycle of aquaponics, where the fish food is consumed by the fish and the waste as ammonia (NH_3), is reacted with oxygen in the presence of Nitrosomonas bacteria, (NH_3) is converted into Nitrites (NO_2^-). Then these Nitrites again reacting with oxygen in the presence of Nitrobacter bacteria, (NO_2^-) is converted into Nitrates (NO_3^-). These nitrates are useful for plant growth. Water from the Grow bed is filtered and sent back to the fish to survive. So, this is called a symbiotic relationship between the plants and the fish. The bacteria are automatically generated in the water and that growth rate of the bacteria totally depends on the surface area of the water in the fish tank.

II. CONSTRUCTION

In every aquaponics system, the first step is to establish a cycle in the system. So, for the formation of bacteria in the grow medium, the fish waste is circulated through the grow bed and from the grow bed the water is filtered and sent back to the tank. In a 7-day period the bacteria required to convert ammonia into the nitrate is formed. Then the plantation is started. In this project spinach is taken as a test plant, and aquarium sharks as the fishes. Whole grow medium is closed with a temperature and light transitive resistant material, for controlling the temperature & humidity inside a closed chamber W1209 (temperature controller) is used, and it is connected to Peltier module (thermoelectric cooler) in a separate loop. An LED is used maintaining the light inside the closed chamber. For maintaining and controlling of moisture in grow medium and duration of the light, Node MCU is used. For sensing the moisture in the Grow bed, Soil moisture sensor is used. For sensing the temperature and humidity DHT11 is used, these sensors are connected to a Node MCU's analog and digital pins, the output from the controller is connected to 4 channel relay-module. This relay module controls the state of LED according to the photoperiod given, and controls the state of pump whenever the moisture reduces bellow the limit (500 R).

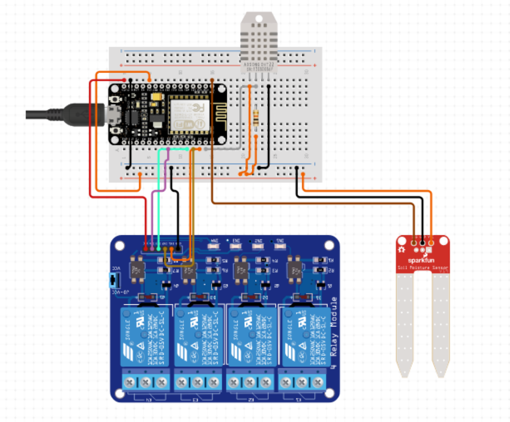

Fig. 3. Main loop circuit diagram

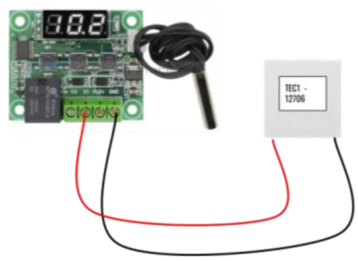

Fig. 4. Temperature control loop diagram

III. TEST CASE

The test cases contain all the data required for testing the parameters. The major components present in the test cases are, type of plant, growth parameters needed for the plant to grow and type of Fish and the requirements of Fish. By changing the test cases, this project can be implemented anywhere. The test cases are given in the bellow table.

Table I. Test subjects

Plant	Spinach	**Fish**	Aquarium Sharks
Moisture	30 – 50%	**Quantity**	10
Growth Duration	30 days	**Fish feed**	Food balls
Temperature	25 - 30	**Feed rate**	Twice a day
Photoperiod	8hrs	**Aeration**	09:00 – 17:00
PPFD	140 umol/m2/s	**Water change**	2 weeks once

The above test subject table gives the test subjects used in this project. Spinach is taken as the test plant, because it is easy and comes to harvest in only 30 days. The temperature needed for this plant to grow is 25 – 30 degrees centigrade. The root moisture needed for the plant is in between 30 – 50%. The usual light intensity needed for the spinach to grow is above 140umol/m2/s, this is provided by using the LED's as grow lights. The Light duration (Photoperiod) in which the photosynthesis rate is high is 8 hrs. In this duration the production of new leaves and utilization of energy produced by the plant happens.

For the supply of nutrients, the fish waste is used; we used aquarium sharks as the fish. These fishes produce a lot of waste that is enough for the bacteria to generate required amount of nitrate for the spinach grow. Aeration (supply of oxygen) is must for the fish as well as plants, studies states that, oxygen is produced more in daytime than in night time. The aeration is given only in fixed hours (0900 – 1700). The change in water in the fish tank for every 14 days is necessary, due to so much of solid accumulation in the fish tank. By controlling the feed rates for the fish, the ammonia levels in the water can be reduced. So, these fishes get the feed for every 6 hrs.

IV. WORKING

In any type of Aquaponics system, the cycling of the water is necessary. The first thing before planting the seeds, the system needs to start cycling with the fish waste ammonia water. This water after reaching the grow bed, the ammonia in the water is converted in to the nitrate by the beneficial bacteria in the grow bed. After a week of time the plantation is started. With the plantation, the parameters for the spinach plant are loaded in the Node MCU board. This controller will maintain the moisture in the grow bed by comparing the sensor data with the predefined limit (500 R), turning on or off of the pump for every ½ hr interval. Photoperiod for the light inside the closed chamber is turned on and off every 8hrs of time period as spinach needs 140 umol/m2/s for 16 hrs duration. Along with this, another loop consisting of, W1209 temperature controller where the temperature for spinach (25 degrees) limit is set, and that controller will turn on or off the peltier device thus controlling the temperature inside the closed chamber.

All the data from soil moisture sensor, temperature and humidity from DHT11 sensor and LED on or off state is uploaded to the thingspeak cloud server for further monitoring and testing.

Fig. 5. Cycling of system

Fig. 6 Sensor and device setup

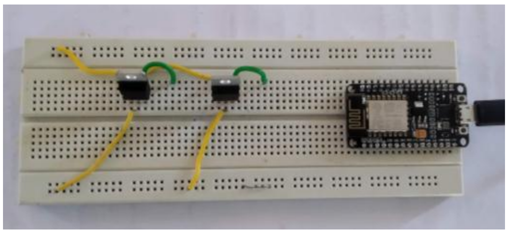

Fig. 7. Controller setup

V. OUTPUT

For the testing of this project, spinach was planted in the grow medium and the different parameters necessary for its growth was monitored during a 2-week period. At the end of 2-weeks, the seeds had sprouted, and the plant had a growth of four inches.

Fig. 8 Shooting of seeds

Fig. 9. Data from Thingspeak

VI. CONCLUSION

Aquaponics has the capabilities of becoming a viable means of farming and agriculture in the future, with small aquaponics systems sprouting in most colonies and households for satellite farming systems. This paper is one attempt of many to detail the various operating parameters that have to established to ensure the successful operation of an Aquaponic system.

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