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Research paper

Design and Development of Intelligent Aquaponics System

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Abstract

The aquaponics system is actually the integration system of two waste product. The aquaponics system can be ranged from the simple which is the fish tank is just below the plant bed to the more contemporary one where it using multiple of fish tanks and advance technology to maintain the water level, quality and pH of water and the interval time for the motor pump to be operated. To reduce the electrical energy consumption, the project carries out from the solar energy to make it more economical and safe. Furthermore, the system has many benefits. First, the crops are chemical-free as the nutrients from the fish acts as the fertilizer for the growing plant. The pH value of the water in fish tank will always persistent because of the circulating process. It also can be developed anywhere because it only requires a small space of area. Farmers can save the budget to spend on utility bills at the end of the month because the system applies renewable sources to generate energy. Lastly, aquaponics used minimal labor because man does not need to look after their grown crops for fertilizing, weeding or watering the plants.

Keywords: *aquaponics system; pH value.*

1. Introduction

Aquaponics system is actually combination of fish and plant production using aquaculture refers to any system that combines conventional aquaculture or aquatic animals such as snails, fish, crayfish or prawns in tanks with hydroponics which is cultivating plants with water in a symbiotic environment [1]. In normal aquaculture, excretions from raising aquatic animals can accumulate the increase of toxicity. Then, water from an aquaculture system is fed to a hydroponic system where the byproducts are broken down by nitrification bacteria into nitrates and nitrites which are utilized by the plants as nutrients and the water is then recirculated back to the aquaculture system [2]. Usually, aquaponics systems vary in size from small indoor or outdoor units to large commercial units, using the same technology as shown in Figure 1. In addition, as existing hydroponic and aquaculture farming techniques form the basis for all aquaponics systems, the size, complexity and types of foods grown in an aquaponics system can vary as much as any system found in either distinct farming discipline.



Fig. 1: The existing Aquaponics Systems

2. Aquaponics Systems

Aquaponics consists of two main parts with the aquaculture part of raising aquatic animals and the hydroponics part of growing plants. The bio-filter and hydroponic components can be combined by using plant support media such as gravel or sand that also functions as bio-filter media. However, aquaponics system nowadays normally uses electrical energy and it's somewhat hard to assemble. Thus, this project tackles the problem by developing an aquaponics system that is powered by solar energy and it's easy to assemble. This aquaponics system consists of an electrical water valve, a water pump and a solar energy supply.

In Malaysia, the majority of energy source is from oil. Since the world is consuming the energy sources, a precautionary step to protect the

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environment must be proceeded. A renewable energy is a good replacement for current energy source. Malaysia is suitable for generating energy through solar panel because it is located near the equator, which received average of 12 hours a day and night throughout the year. Thus, the solar panel is the ideal green energy for powering the aquaponics control pump because of the project location. However, the main objectives are to powering the water pump and air pump using green energy via solar panels. Water pump required AC voltage, therefore the inverter is used for this application. This project focuses on using an inverter, instead of replacing the AC water pump with DC water pump.

Table 1: Benchmarking on Competitive Product [1].

Characteristic	Conventional Aquaponics	Aquaponics with AC Supply	Aquaponics with Solar Energy
Capability	• Almost no maintenance • Only can plant water based plant because no soil needed. • Basic hydroponic technique • 1 level deck farming • Plant get nutrient direct from water.	• Water pump can operate 24 hours a day using AC supply. • Multilevel deck for green plant farming and aquaculture. • Can use soil as based for farming.	• Use solar energy to generate power to pump waste water. • Multilevel deck farming and aquaculture.
Performance	• Using basic hydroponic equipment • No movement of water • Plant get mineral directly from water • Less complex	• Continuous power supply • Save space • Plant separate from water tank • Need water pump to push water/nutrients upwards	• Use battery as power bank • Easy to install • Easy to manage and maintain. • Alternative for electricity supply • Self-contained based
Cost	• Less cost • No electrical usage • Only maintain on aquaponics/hydroponics equipment.	• Slightly more expensive due to electrical usage. • Need water pump and water filter • Multilevel deck and more wire	• Solar panel, controller, less wire • Water pump • Less expensive than using AC supply aquaponics technique
Reliability	• Aquatic life lives in same plant growth equipment • Only can plant water based plant • Need large space • May cause damage to plant product	• Depend on AC supply • Does not portable due to wiring problem • If problem with power supply, major shut-down will happen for repair purposes.	• Need sunlight to charge battery • Longer battery lifespan • Stand-alone system • Does not affect other tank if doing maintenance • Does not damage the plant product due to separate farming and aquaculture
Greatest Potential to Improve	• Continuous mineral supply • Supply continuous oxygen water for aquatic life.	• Need to be stand-alone system for maintenance proses.	• Longer battery lifespan • Heavy duty • Water resistance.

Table 2: Opportunities for Competitive Advantage [2].

product	Best features	Why
Conventional Aquaponics	Less maintenance	-does not use electricity and electric component
Aquaponics with AC supply	Continues power supply	-Got 24-hours power supply to start up pump for water sprinkling. -much power pump
Aquaponics with solar energy	Green technology	-Use solar energy to produce electricity

Some advantages of aquaponics system such as [3]:

1. Allowing green technology for lifestyle.
2. Decrease pollution percentage for using green technology equipment.
3. More advance technique for green-technology implement by others and
4. Less awareness on save-earth campaign by using green technology.
5. The perception that there is not a difference in quality between this product and the other existing products.

While in the process of developing this hydroponic system, there are several things that we take into account. The variables such as pressure, voltage, power, rate of volume flow is the most vital part in developing this system. To make sure our hydroponic system run smoothly, so have made a few calculations for the variables mentioned.

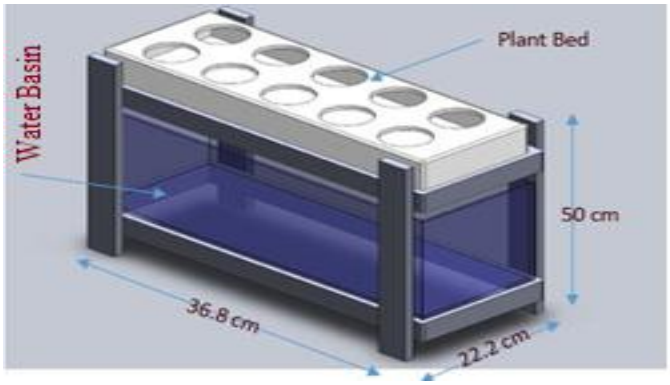


Fig. 2: Our Aquaponics Design using Solidworks.

3. Results and Discussion

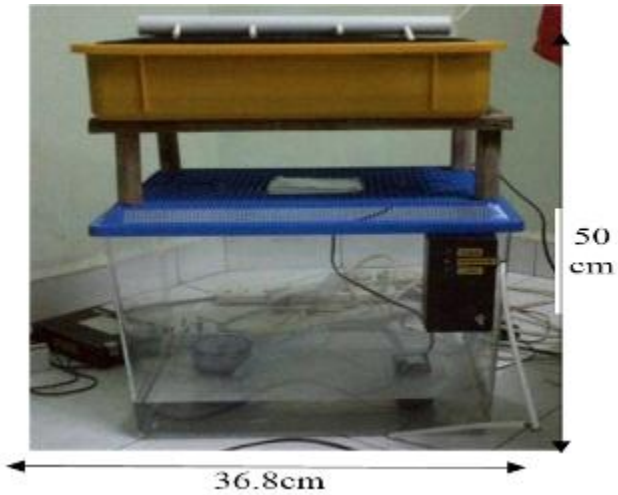


Fig. 3: Our Aquaponics Design.

For the pressure, P:

P = ρgh
P = (1) (9.81) (0.5m)
= 4.91 Pa

On the calculation above, we identified the pressure needed to pump the water upward. So, the pump that we used must be at least has pressure about 4.91 Pa. The calculation of the Power, P. The current value taken is based on the Amp of the solar. The value is ±500 mA.

P = IV
P = (0.5) (12)
= 6 W

For the flow rate, we identified that the suitable flow rate of the water is at least 350 LPH (litre per hour). We estimated the maximum flow rate for the pump is about 1000 LPH. This flow rate is depending on the type of the pump that we are going to use as long as it is suitable for the system. For the voltage, the voltage supplied by the solar panel is at least 12 volts. The reason for the system need to be supply by 12 volts is because the water pump that we used need 12 v of voltage in order for it to work.

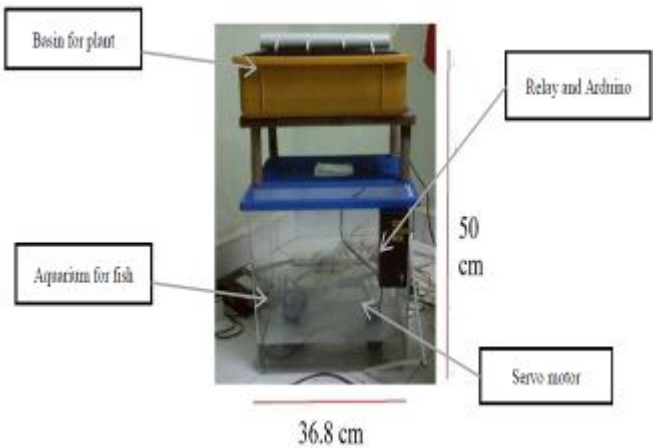


Fig. 4: Aquaponics Design with components

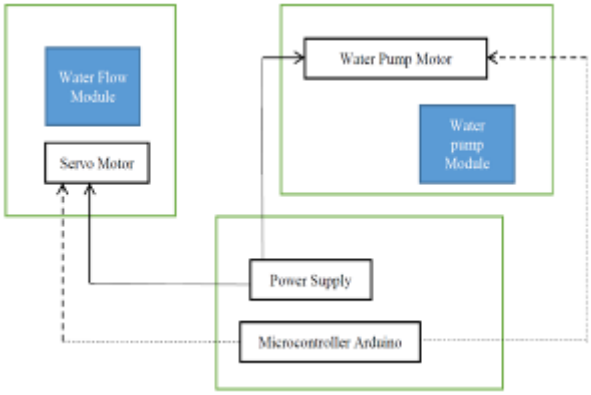


Fig. 5: block diagram of aquaponics system

Basically, aquaponics system that have been made as Figure 4 is the combination of aquaculture and hydroponic basin. This system is can be standalone because it used the solar panel system to generate the power supply to the battery. Apart of that, to operate well this aquaponics system consist of Arduino, motor pump, relay, servo motor and also 12V battery. Arduino is the main component to operate the system flow, when microcontroller Arduino sending the signal which to light ON the blue LED as the indicator for the water motor pumps to works. This aquaponics system also consists of relay in order to enable the water pump to operate which to pump all the water in and out from the hydroponics basin. Arduino also acts to sending the signal for the red LED to turn on as indicator for the servo motor to operate in the next process. While, the servo motor function is to enable the outlet water flow from hydroponic and sends back the clean water into the aquarium tank.

The system operated when microcontroller Arduino sending the signal, which to light ON the blue LED as the indicator for the water motor pumps to works. Before that, the relay is used to enable the water pump to operate which to pump all the water which contains waste from the aquarium tank. After that, the water that been pump out below from the tank been send into the top of aquaponics container. Therefore, this water which contained the waste from the fish tank will be used as fertilizer and also to absorb the nutrient from the waste fish to make the aquaponics plant more fertile. Moreover, at the same time the water will be filter at the aquaponics container in order to make the water is clean again. Next, the process continues with Arduino sending the signal for the red LED to turn on as indicator for the servo motor to operate in the next process. Thus, the servo motor is activated by enable the outlet water flow from aquaponics container and sends back the clean water into the aquarium tank. This process will be in standby condition which is indicates when actuator, the motor pump and servo motor is deactivated. Hence, this process will be repeated again.



Fig. 6: Aquaponics system testing

The aquaponics system has been test by using the green mustard as the plants and catfish as the aquaculture. Besides that, the operation of the system also has been test and all of the component were functional well. The system leaves by a few days in order to gain the result based on the circulation of the system. After testing period complete, positive result come out with the green mustard growth well and all the components also successful operated.

For future works, to provide a good framework and high efficiency of the system, the solar panel must be moved as the sun moves. The sun's energy must be captured by tracking the sun position. It is because, the output energy of solar power is being regard on the sun angle towards the solar panel and the daily weather. The system cannot be operated smoothly if there is no enough energy stored to supply to the system. Other than that, high technology battery can be used to power up the pump. High technology battery doesn't drain easily and provides higher battery life performance to generate the power system. Presently, the battery shortly runs out because of high energy usage to supply to the system. To run a truly profitable system, the ratio number of plants and fishes must be optimized in order to maximize a quality output and food harvest. Number of aquatic animals must be enough to supply the nutrient to the plants. Too much fishes but least plants can cause high percentage of the nitrogen compound and pollutes the water. The design specifications of grow bed and fish tank also can be set meticulously to minimize the power needed to circulate the water. This can save the energy consumed. Not just that, additional design and sensor can be added to improve the parameters of the water quality. Thereby, the fish growth and crop yields are positively preserves.

4. Conclusion

In brief, the design of the aquaponics system generated by the solar power was successfully developed using Arduino technology, solar power bank, battery, inverter and control pump. The main objectives of this project has been achieved successfully. This project indicates a pace towards green energy technology despite not using common electrical energy to generate the working system. An inverter is used to convert the DC to AC voltage and step up the voltage to 110V or 240V because solar [5] panel produces average 12V of DC voltage to the system. It challenges the common aquaponics system that already connects to the normal power of 240V AC. The focused is given more to the inverter as it acts as a power grid to power up the control pump. Most notably, the replacement of the water pump with an air pump that has capabilities to aerate the fish tank water, plant's grow bed and circulate the water throughout the system. Besides that, this projects also encounters with the challenges to find the suitable air pump that operate in DC voltage. Recently, most of the aquarium shops sold normal AC voltage of air pump and portable battery of air pump. Thus, some minor changes need to be done to make the system able to be operated. Amount of food production poses a very real and serious threat to human life today. With the problem cause from nature and human, it cannot be denying that this aquaponics system is a potential solution to address the issues of resource conservation and access to a safe and quality food sources. The simplicity, efficiency and reliability that offered by aquaponics system makes the system accessible and user friendly especially to the people with no agriculture background. In addition, the product also can be commercialized to our country as it can be a profitable endeavor to the community, especially to the fish/vegetable production company as it requires less maintenance and minimal labor for the grown living (as example, fishes and vegetables). Aquaponics system also can be built both in indoor and outdoor area although the available area spaces is small.

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