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Development of Solar Powered Portable Mini NFT Aquaponics Educational Kits

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Abstract: Aquaponics has been introduced as a subject as a subtopic in *Rekabentuk Dan Teknologi* (RBT) to expand the usage of aquaponics in the community. However, the lack of learning material is an issue since there is no hands-on experience for the students. From this issue, it has to come out with one of the innovations to develop mini NFT aquaponics educational kits. This project aims to develop a prototype of a mini aquaponics system that can be used as a proper learning material to fulfill the student's needs. This aquaponics system was powered by using solar photovoltaics and batteries, which could avoid use on the grid power supply. This could save bills since the system should be run for 24 hours non-stop. The solar-powered NFT aquaponics system could not only introduce aquaponics system, but also renewable energy to the students

Keywords: Aquaponics, NFT, Solar-Powered

1. Introduction

Aquaponics is a combination of aquaculture, which is growing fish (aquaculture) and other aquatic animals, and hydroponics which is growing plants without soil. Aquaponics combines the two in a symbiotic relationship in which plants are fed by the discharge or waste of aquatic animals. In exchange, the plants help to clean the water that is returned to the fish. Aquaponics food production is highly efficient because it re-uses the nutrients in fish feed and feces to grow crop plants in an ecological cycle [1]. Its potential to improve sustainability is discussed in terms of food security and as an alternative to intensive fisheries or aquaculture, by effectively managing the food-water-energy nexus [1].

There are various benefits of using the aquaponics system as compared to the conventional plant growing mechanism [2]. Some benefits are, it has a faster-growing process, does not require soil, can grow in any area, and takes up less room, seasonal changes have no effect on plant growth, there is little or no need for herbicides and pesticides, and plants are protected against many illnesses.

Aquaponics system primarily has three different types of system design and one of them is the Nutrient Film Technique (NFT). NFT is a system that uses horizontal pipes or gutters for growing plants [3]. It is popular because of its space efficiency and lower labor cost, making it popular in the commercial market.

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There is a subtopic in *Rekabentuk Teknologi* (RBT) for form two students which covered the aquaponics system. However, there is still no learning material for experiments on aquaponics. This study can help to fulfill the need for learning material for this subtopic. This study aims to develop a solar-powered portable mini NFT aquaponics educational kit for students especially form 2 secondary school students for the subject *Rekabentuk dan Teknologi* (RBT) to act as learning material

2. Methodology

The more detail about the process used, including the components involved:

2.1 Project Equipment

(a) Fish Tank

In this research, an acrylic fish tank was used since it is durable and easier to move because it is so lightweight.

(b) DC Water Pump and tub

DC water pump was used in the system since it is easy to be operated and controlled. It is also more efficient compared to an AC water pump. An inverter was not included in the system due to the DC water pump. To maximise the ability of the water pump, a water tube has been added to let water flow into grow bed. Table 1 shows the parameter for a water pump.

Table 1: Parameter for water pump

Voltage (V)	Power (W)
3.5 – 9 V	1– 3 W

(i) Aquaponics Pipe and Pots

The system needs a grow bed and an aquaponics pipe will act as a grow tray in a Nutrient Film Technique (NFT) system. The water will flow through the pipe which will also go through the roots where nitrification will occur while pots act as houses for the plant in the grow tray.

(ii) PVC Water Pipe and Pipe Fitting

PVC pipe will be used as a stand for aquaponics pipe since it is easy to connect. This stand also needs a pipe fitting such as L-junction (elbow), 3-junction (tee) and 4-junction (cross).

(iii) Battery and Solar Charge Controller

In this system, the 12V DC 7.2Ah size of the battery has been chosen to store the energy produced by the solar system since the rating of the connected load is not too high. A solar charge controller is required to control and protect the battery from overcharging, monitor the battery voltage and when it is minimum, cut off the supply to the load switch to remove the load connection. Table 2 shows the specification of the energy story of the battery.

Table 2: Specification of the battery.

Model	Voltage (V)	Capacity (Ah)	Dimension (mm)			Weight (kg)
			Length	Width	Height	
MSL 12-7.5	12	7.2	150	63	94	1.80

(iv) Solar Panel and Stand

In this system, poly-crystalline cells have been chosen as the solar due to their low cost compared to mono-crystalline and thin film cells. Apart from that, the moderate lifespan is also the reason to be applied to the system. To maximise the capability of solar panels, a stand has been used to able hold solar at a good angle to acquire sunlight. Table 3 shows the specifications of 10W polycrystalline solar photovoltaic.

Table 3: The specifications of 10W polycrystalline solar photovoltaic

Maximum Power (W)	10
Tolerance (%)	+-3
Maximum Current (A)	0.55
Maximum power Voltage (V)	18.00
Short Circuit Current (A)	0.60
Open Circuit Voltage (V)	22.6
Dimension (mm)	340 x 231 x 15
Power Specification at STC	1000w/m^2, AM1.5, 25°C

2.2 Project Block Diagram

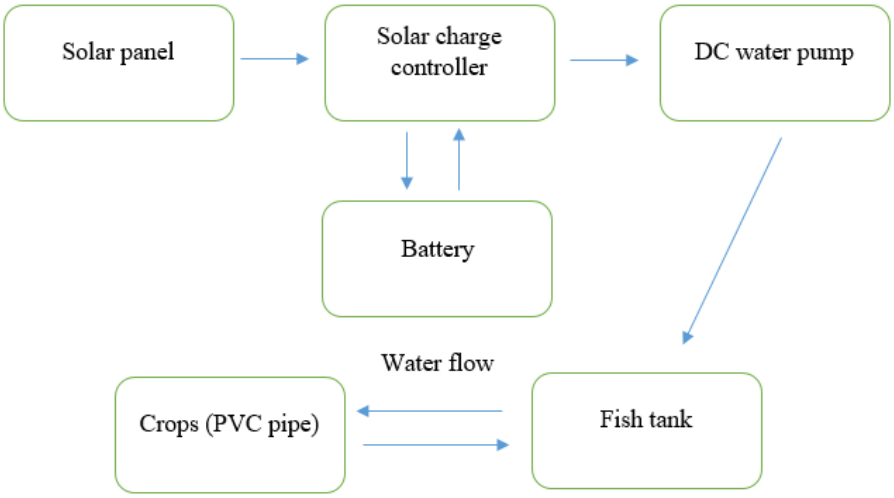

Figure 2: Block diagram of the project

A solar panel, solar charge controller, DC water pump and battery, fish tank, and PVC pipes are all part of a solar-powered portable mini NFT aquaponics educational kit system project. A solar panel is the electric source of the system which will be connected to the solar charge controller and battery. DC water pump then connects with a solar charge controller to power it up to create a water flow between the PVC pipe and fish tank.

2.2 Project Development

The details and information about the aquaponics system have been studied through past research. Information about aquaponics such as types of fish and types of plants that are suitable for aquaponics systems has been obtained from past papers. After the information was gathered, then proceed to another part which is to design the mini NFT aquaponics system. The design was modeled by using SketchUp software since a 3-dimensional sketch is required for this stage of the project. After the design satisfies and fulfills the objective, the workflow proceeds to the next step, which is designing the sizing for the solar PV panel, battery, inverter, solar charger controller, and water pump needed for the system. To obtain this objective, the calculation for the load of the system power of the solar panel, water pump, and battery was crucial. This is crucial since the solar PV system will be integrated into the aquaponics system where solar PV will power up the water pump. Then proceed to obtain the result before analysing and doing the discussion before finishing the report writing.

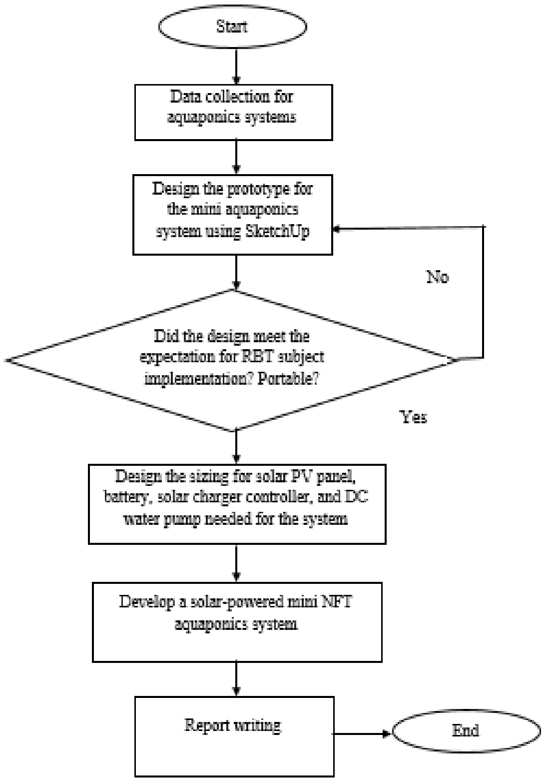

Figure 3: Flowchart of the software development

3. Results and Discussion

3.1 DC Water Pump for Proposed System

The volume of the tank can be calculated:

Volume of tank
= 27cm × 15cm × 15cm
=6075cm

Flow rate equations are:
Q = 10L × 60 / 100
Q = 6

Total dynamic head equations are:
HV = 0.56ft
Hf : (f × total pipe length) + (f × Le) f = 0.007 [22], Le = total no. of elbow × coefficient = 6 × 2 = 12ft
Total pipe length = 0.89m ≈ 2.92ft
Hf = 0.1044ft
TDH = (0.56ft) + (0.1044ft)
TDH = 0.6644 ft ≈ 0.7ft

The horsepower of the water pump is:

hp = (0.7 ×6×1)/3960
hp = 0.001 hp
Assuming the efficiency of the water pump is 50%, the horsepower value of the water pump is:
Actual power required, = hp / pump efficiency, η =0.001 hp / 0.5 =0.002 hp

To convert the value of power to Watt, the formula that can be used are:
Power (W) = hp × 746
= 0.002 hp × 746
= 1.492 W ≈ 1.5W

At the market, the minimum power rating for a water pump of 3W of the water pump. Hence 3W water pump will be chosen for this project.

3.2 Solar Panel for Proposed System

For daily operation, the power consumption of the water pump can be figured by using the formula:
Esp = 1.5 W × 24 hrs = 36 W/h
Assuming the peak sun hour are around 8 – 3 clock (7 hours)
PSP = 36/4h =9 W

Assume we use a 10W solar panel, to obtain the required solar panel are:
Nospv =9/10 =0.9

This means at least 1 solar panel is necessary. However, 2 solar panels were used in this design.

Battery for Proposed System
Assuming the battery of 12V 7Ah is going to be used, the size of the battery can be obtained by using Et = 12V × 7Ah = 84Wh

Then we assume the depth of discharge (DOD) is 60%, so the discharged time of the battery is:

Bdt = (84 × 0.6)/ 0.9 = 56 hours
Meaning that when using a 12 V 7 Ah battery it will run for 56 hours

Time taken for the battery to be fully charged is calculated with the equations:
Bct = 7Ah / 1.12 A =6.25 hours ≈ 6 hours 30 min

3.3 Battery for Proposed System

To test whether the solar PV could run the system, the voltage shown at the solar charge controller has been taken for two weeks starting from 29th May until 11th Jun.

Table 4: Value of the voltage, current and power at 8.00 am for two weeks

Days	Voltage (V) at 8.00 am	Current (mA) at 8.00 am	Power (W) at 8.00 am
1	14.4 V	105.30 mA	1.516 W
2	12.6 V	92.14 mA	1.161 W
3	12.7 V	92.87 mA	1.179 W
4	11.6 V	84.83 mA	0.984 W

5	11.2 V	81.90 mA	0.917 W
6	11.5 V	84.09 mA	0.967 W
7	11.1 V	81.17 mA	0.901 W
8	12.4 V	90.68 mA	1.124 W
9	12.5 V	91.41 mA	1.143 W
10	12.6 V	92.14 mA	1.161 W
11	12.6 V	92.14 mA	1.161 W
12	11.6 V	84.83 mA	0.984 W
13	11.6 V	84.83 mA	0.984 W
14	12.9 V	94.33 mA	1.217 W

Table 5: Value of the voltage, current and power at 12.00 pm for two weeks

Days	**Voltage (V) at 12pm**	**Current (mA) at 12pm**	**Power (W) at 12pm**
1	14.4 V	105.30 mA	1.516 W
2	14.2 V	103.84 mA	1.475 W
3	13.5 V	98.72 mA	1.333 W
4	12.9 V	94.33 mA	1.217 W
5	13.6 V	99.45 mA	1.353 W
6	12.9 V	94.33 mA	1.217 W
7	14.4 V	105.30 mA	1.516 W
8	14.4 V	105.30 mA	1.516 W
9	14.3 V	104.57 mA	1.495 W
10	14.4 V	105.30 mA	1.516 W
11	13.7 V	100.18 mA	1.372 W
12	12.8 V	93.60 mA	1.198 W
13	13.2 V	96.53 mA	1.274 W
14	14.2 V	103.84 mA	1.475 W

Table 6: Value of the voltage, current and power at 8.00 pm for two weeks

Days	Voltage (V) at 8.00 pm	Current (mA) at 8.00 pm	Power (W) at 8.00 pm
1	13.7 V	100.18 mA	1.372 W
2	13.9 V	101.64 mA	1.413 W
3	12.5 V	91.42 mA	1.143 W
4	12.2 V	89.21 mA	1.088 W
5	12.7 V	92.97 mA	1.181 W
6	12.0 V	87.75 mA	1.053 W
7	13.6 V	99.45 mA	1.353 W

8	13.5 V	98.72 mA	1.333 W
9	13.7 V	100.18 mA	1.372 W
10	13.6 V	99.45 mA	1.353 W
11	12.4 V	90.68 mA	1.124 W
12	12.5 V	91.42 mA	1.143 W
13	13.5 V	98.72 mA	1.333 W
14	13.9 V	101.64 mA	1.413 W

The highest power consumption during 8.00 am was on the first day which is 1.516W. The lowest value was during the 7th day which is 0.901 W but still able to power the DC pump. Although the power is a bit low, it still can operate DC pumps in the system which are crucial for the aquaponics system to sustain. This low value of power is due to the night time when there is no sunlight, at 8.00 am the sun starts to light the solar panel to charge the battery. It is predicted to have low power consumption at this time.

The power at 12.00 pm is high since this is the peak sun hour to shine at the brightest. A solar panel can obtain maximum sunlight to charge up the battery even on a rainy day. On a sunny day, the battery would not be overcharged due to the solar charge controller that will cut off the current even though the load is still ON.

The discharge has been set to stop at the value of 10.7 V since it could not power the water pump properly. Based on the results, this shows the system can sustain 24 hours for two weeks even if there is a cloudy day which is on days 4, 6, 11, and 12. The system can run non-stop and the aquaponics system would not be disturbed.

4. Conclusion

The design of a portable mini NFT aquaponics kit should be done one step at a time, starting with the calculation of the load size, rechargeable battery size, and solar panel size. Since the load is a DC water pump, the water pressure and flow must also be considered in the calculation. The portable mini NFT aquaponics kit is then sketched in three dimensions using SketchUp software. When all of the equipment was ready, the hardware development began. The DC water pump was tested to see if it could run for the needed period using the solar panel. The secondary purpose was to integrate solar PV with the portable mini aquaponics educational kit. The aquaponics component was developed and then integrated with solar PV to evaluate the water flow. Finally, the final objective was to test the effectiveness of a solar-powered portable mini NFT aquaponics educational kit. The solar system for the DC water pump successfully runs for 24 hours non-stop.

This project was carried out as planned and proved to be possible, and the result demonstrated that this technology is practical and usable. Even though there is always room for improvement. The Solar Powered Portable Mini NFT aquaponics Educational Kit proved that it can be used in school sessions.

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