Aquaponic System

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Abstract - Over recent years the research and development for Aquaponics has received increased attention due to its possibilities in helping reduce strain on resources within 1st and 3rd world countries. Aquaponics is the combination of Hydroponics and Aquaculture and mimics a natural environment in order to successfully apply and enhance the understanding of natural cycles within an indoor process. By using this knowledge of natural cycles it is possible to create a system with the capabilities similar to that of a natural environment with the benefits of electronic adaptions to enhance the overall efficiency of the system. This paper covers our solution to this opportunity involving overall design, the technology involved and what benefits it could bring to the current market.

Keywords: Aquaponics; Natural Environment; Efficiency.

I. Introduction

Aquaponics is based on a productive system that can be found in nature. It can be described as the combination of Aquaculture and Hydroponics and this is where the name comes from: Aqua-ponics. It uses the nutrient rich water from the tank for the growth of the plants that sit in the grow bed. The now clean water is then slowly removed back to the tank. A simple flood and drain system is what we will operate so the plants are able to receive oxygen and small breaks from the water to reduce the chance of root-rot.

We were tasked with designing and building an Aquaponics system that supports both fish and plant culture without the use of soil and supported by water recirculation. The system must be as sustainable as possible. From this, our idea's focussed on the sustainability of the system. The main objective of the project is to create a working system as to support both fish and plant culture. The system must be able to be monitored so that optimum conditions are in place. This would mean using sensors to check temperature and other parameters. The overall budget for the prototype was 250€.

From the stated problem our idea's focussed on the sustainability of the system. We decided to target the household market as a small system would be easier to control and keep sustainable compared to a large (small farm) sized system. This system would also allow us to create an aesthetic product that would sit within the home. The smaller system would allow easier control over the environment within and would require a smaller electronic system. Even though there are many Aquaponics systems in use at a large scale there are not many for use within the home and this is why our market was targeted towards this area. With the recent increase in both sustainable products and the purchase of organic foods there is a large market share available for a quality Aquaponics System.

Through sustainable manufacturing and the use of recycled materials (glass, plastic, etc.) we could create a product with little impact on the environment. This footprint would be continuously kept low by the correct use of the system which would need up to 90% less water than traditional farming and the only real input would be the energy to power the electronic system.

Our design is focussed on creating an aesthetic and attractive look for a modern indoor Aquaponics system. There were no restraints on the physical look of the product so we were able to be creative. Through the use of LED lighting we put a spotlight on the tank itself drawing attention away from the other features. [1][2]

The paper is structured into six sections overall. These six sections include: Introduction which discusses the problem and proposal; State of the Art which covers related work and method/technologies within the product; Project Development including overall architecture and components; Conclusions which discusses the final thoughts; Achievements and finally Future Development.

II. State of the Art

Related Work

Currently on the market it is possible to find many Aquaponics systems. However if we are more specific to our intended market of Indoor Aquaponics then the market shrinks vastly. Also this market can again be reduced by adding the term 'Designer' to our Aquaponics system as many consumers do not want to decorate their home with objects that are unpleasing to look at. Overall there is only one real competitor in the household Aquaponics market which can be seen in Figure 1.

Figure 1: Aquafarm [3]

The Aquafarm is a simple set-up product that enables the consumer to have a small Aquaponics system within their home. The design is basic and simple to manufacture, however it is prone to failing after a short period of time due to its design. The difference between our system and the Aquafarm is that we will be able to monitor parameters within the water to ensure the fish's safety and our design is similar to traditional aquariums with a simple LED system to enhance the viewing of the tank whereas the Aquafarms' design is bland and uninteresting.

Methods and Technologies

In order to build our prototype to a high quality standard we initially had to research in deoth Aquaponics as a whole. The following list presents the most accurate methods and technologies for the product that we are developing:

Nitrogen Cycle

The nitrogen cycle is the process by which microorganisms convert the nitrogen in the air and organic compounds (such as within soil) into a usable form. This is an invisible process that is essential for Aquaponic systems to work. It is responsible for the conversion of fish waste into nutrients for the plants. Without this process, the water quality would deteriorate rapidly and become toxic to both the fish and plants in the system. The water therefore in Aquaponics does not need to be treated chemically to make it 'safe', nor does it have to be replaced. In Aquaponics, a system is said to have 'cycled' when there are sufficient quantities of bacteria to convert all the ammonia into an accessible form of nitrogen for the plants. The bacteria will arrive naturally to a system and colonize the water column and biofilter (clay pebbles in our case).

The bacteria convert the ammonia into nitrite and then the bacterium converts the nitrite into nitrate (NO_3). Nitrate is a very accessible nutrient source for plants. Fish will also tolerate a much higher level of nitrate than they will ammonia or nitrite. When all these bacteria are found in sufficient numbers in order to convert all of the ammonia and nitrite being produced in a system, it is said to have 'cycled' [4]

Types of Aquaponic Systems

During our research we have learned that there are three most commonly used types of Aquaponic systems.

1) Media filled beds are the simplest form of Aquaponics. They use containers filled with media of expanded clay or similar. Water from a fish tank is pumped over the media filled beds, and plants grow in the media. This style of system can be run two different ways, with a continuous flow of water over the rocks,

or by flooding and draining the grow bed, in a flood and drain or ebb and flow cycle.

2) Nutrient Film Technique (NFT) is a commonly used hydroponic method, but is not as common in Aquaponics. NFT is only really suitable for certain types of plants, generally leafy green vegetables as larger plants will often have root systems that are too big and invasive.

3) Deep Water Culture (DWC), works on the idea of floating plants on top of the water allowing the roots to hang down into the water. This method is one of the more commonly practiced commercial methods

Since the media based system has been found to be the most reliable and the simplest method of Aquaponics, our prototype is built in this way. Additionally, this kind of set-up requires the least maintenance in comparison to the types presented above. [5]

Fish tank

Any water-tight, food-safe and fish-safe container can be used. Its size depends on how many fish will be kept inside and on the size of the grow bed.

To build our prototype we used 28 litre tank made of Acrylic glass which is more commonly known as Plexiglass.

Grow beds and growing medium

An Aquaponics media filled grow bed is simply a suitable container that is filled with a growing media such as gravel, hydroton (expanded clay) or lava rock. It performs four separate functions; Firstly, it provides support for the plants and provides somewhere for the roots to take hold. Additionally, the media is responsible for mechanical filtration, mineralization and biological filtration.

A grow bed can be made out of a wide variety of materials but care should be taken to make sure it fulfils certain criteria. A grow bed should be safe to use first and foremost, and should be made of a materials that will not leak unwanted chemicals into the water, or that will affect the pH of the water. [6]

Figure 2: Growbed with clay pebbles [6]

We decided to build our grow bed from the most commonly used material which is 5mm acrylic and fill it with small plant pots that would hold the expanded clay pebbles as they are the lightest and the cheapest media available .(Figure 2)

Pump

A water pump is needed to circulate the water from the fish tank through the grow bed and back to the tank.

For our system we have been provided with the Syncra Silent 0.5 Multifunction Pump. (Figure 3)

Figure 3: Syncra Silent Multifunction Pump [8]

Tubing

Tubing is needed to carry the air and water through the system. Water pumps generally use half inch tubing while air pumps are set up for quarter inch tubing. Plastic tubing is available in both clear and black; black tubing deters algae from growing and clogging the tube.

Plants

There have been over 300 different Aquaponic plants that have been tested that will be happy in an Aquaponic system. The major group that will not grow are root vegetables. [7]

Since our Aquaponic system is described as a small kitchen garden we recommend growing common herbs such as basil, thyme or rosemary.

Fish

What is wanted out of the system, climate and available supplies are the major factors that need to be considered before choosing the type of fish for any Aquaponic system.

The fish and plants selected for the aquaponic system should have similar needs as far as temperature and pH. There will always be some compromise to the needs of the fish and plants but, the closer they match, the more success you will have. [10]

The number of fish in the system is a constant subject of debate among people who practice Aquaponics. To ensure safety of fish and plants the parameters of the water should be frequently controlled and level of fish stock should be adjusted to the tests results.

Figure 4: Convict cichlids [9]

Our tank will be stocked with Convict cichlids (*Amatitlania nigrofasciata*) (Figure 4) since they don't need a lot of space and are easy to take care of.

III. Project Development

In this Chapter we will cover the Aquaponics System as a physical object, mechanical system and an electrical system.

Design

Our initial design was aiming to be sleek and simple so that it wouldn't be intrusive to have within the kitchen or home. This is where the cylindrical shape came into the design. However, the development of our main idea came quickly through the research stage of our project. We found out that the cuboid tank would offer more water due to its corners whereas the cylinder did not have these. This also improved the well-being of any fish kept within the tank as fish prefer a large body of water to swim freely. The change of shape provided a stronger base for the tank but produced weak spots at the corners. This would be tackled by metal supports hidden behind the veneer/plastic strips that would wrap around the base and top. The design would incorporate the LED strips around the underside of the Grow Bed for aesthetic appeal.

Figure 5: Design of our system

The Grow Bed design now follows the shape of the cuboid tank apart from an area taken out the back middle section. This was to allow the pump to sit in the middle of the tank and to allow feeding of the fish with ease. This area will often be covered from view by the plants growing within the Grow bed and does not take anything away from the physical appearance of the tank itself. (Figure 5)

Architecture

Bell siphon

To ensure even flow of water throughout grow bed we decided to use simple method inspired by the bell siphon (Figure 6). This method simply involved a tube with a much smaller diameter than the pump tube so that the grow bed could fill with water as the smaller tube could not expel the rising water as quickly as it was being pumped into the grow bed. This small tube would be surrounded by a similar guard/filter to stop any waste/dirt.

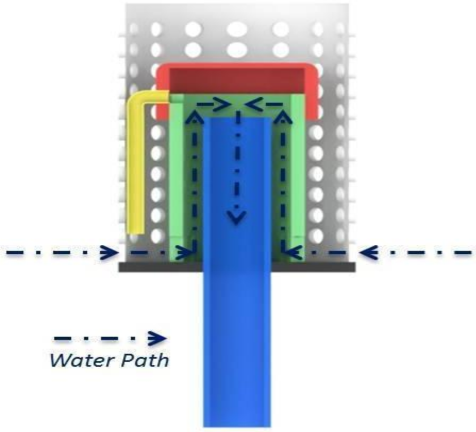

Figure 6: Bell siphon water path [11]

Fail safe development

Originally we planned and designed to have small cut outs where the pipe entered the grow bed as fail safes in-case the bell siphon/stand pipe failed. We found that these cut outs would not direct the water directly back to the tank and this could lead to splashes over the side of the tank. The development of this was to use a single pipe at a pre-set safety level.

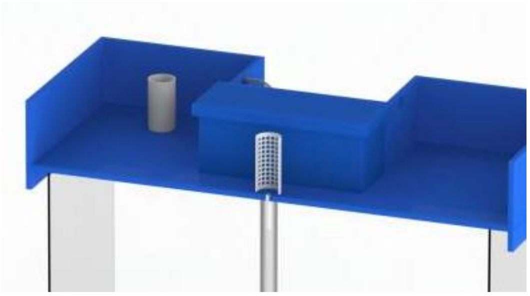

Figure 7: The fail safe stand pipe

The pipe itself would be larger than the pump pipe so that it could remove the water quicker than it was coming in to the grow bed so that it would not spill over the side or reach the height of the electronics casing. The fail safe stand pipe can be seen in Figure 7 and clearly shows its large size to easily remove the water.

Grow bed

The Grow Bed (Figure 8) itself was developed a large amount during the development phase to fit with the changing electronic and design demands.

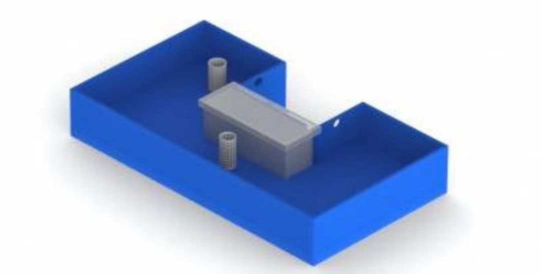

Figure 8: Final grow bed design

- Cut outs were added to the bed to allow the pump tubing to go straight into the bed instead of sitting atop a side. (Figure 9)

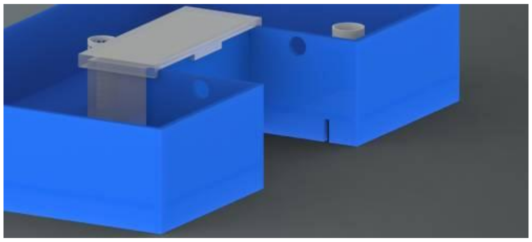

Figure 9: Cut outs in the grow bed

- The sides of the bed were increased by 10mm to allow extra space for water.
- Holes were added for the stand pipes.(Figure 10)

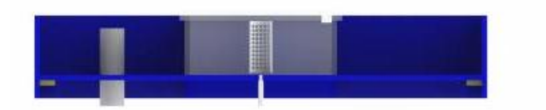

Figure 10: Grow bed cross-section

- Stabilizing features were added to keep the bed in place. (Figure 10)

Electronic housing

The placement of the electronics was an area which required a large amount of time due to the safety risk between electronics and water. We decided to create a small space within the Grow Bed for the electronics (Figure 11). This small area would come with a lid for easy removal of the electronics while also keeping them safe from water splashes.

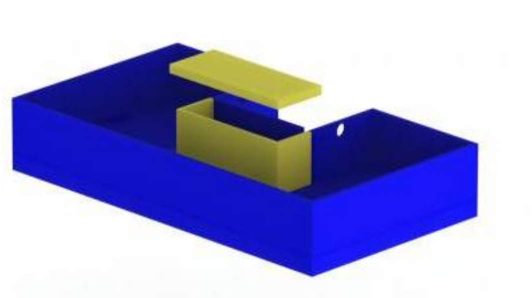

Figure 11: Electronic housing

Also the housing would include a small cut out from the back where the wires could pass through so that the lid could stay secure

Electronics [12]

If we want to be successful with the aquaponic system we have to frequently check the water temperature and pH level. Therefore, we need an electronic system which is composed with the following components:

Motherboard

The motherboard we chose is Arduino Duemilanove ARDU-004 as it is programmable with free Arduino software. It has 14 digital pins operating at 5 V that can be used as an input or output. Additionally, Duemilanove has 6 analog inputs

LCD Screen

We chose a basic small LCD module (Figure 12) as it was cheap and sufficient for our prototype. It will be connected to the power supply (5V) and to Arduino motherboard.

Figure 12: LCD Module 16x2

Temperature Sensor

Temperature Sensor with the reference DS18B20 is the best option because it is waterproof and the temperature range that it checks is great enough. The sensor will be powered by data line to the Phidget Interface Kit 8/8/8 Model: PHD-1018_2.

pH Sensor and pH Adapter

We decided to buy ASP2000 pH sensor that will measure the pH level from 0 to 14. To connect it to the motherboard it is necessary to use pH/ORP adapter (*PHD-1130)*.

Relay

The relay works as a switch that can connect and disconnect the water pump.

Current driver

The water pump works with direct current (DC) while the rest of components use an alternating current (AC). Due to that we need the current driver to convert DC into AC.

Power supply

The components we chose need 5V power supply. We selected the INM-0761 power supply as it has 2,5 A which is sufficient for our system.

Functionalities

Our Aquaponic system will work via the following steps:

1. The water from the fish tank is pumped in the grow bed by the water pump. The pump is controlled by the Arduino, manipulated by the relay and programmed to switch on and switch off at certain intervals.
2. When water in the grow bed reaches specified level the pump is turned off by a pre-set timer. At this moment plants are provided with necessary nutrients and then water flows back to the fish tank through a small pipe.
3. Sensors within the tank send information to the Arduino which is then displayed on the LCD screen.

If for an unknown reason the water pump is kept running and the stand pipe cannot handle the flow then the water will rise to a set level where we have installed a fail-safe stand pipe so the water will quickly drain back to the fish tank. This larger pipe is included so the water does not overflow out of the grow bed.

Tests and Results

The tests that we undertook were to ensure that all components would be safe within our electronic system. Fortunately it is now possible to do this by using an online software instead of physically creating several circuits manually. Figure 13 shows the test setup and the connections between the components.

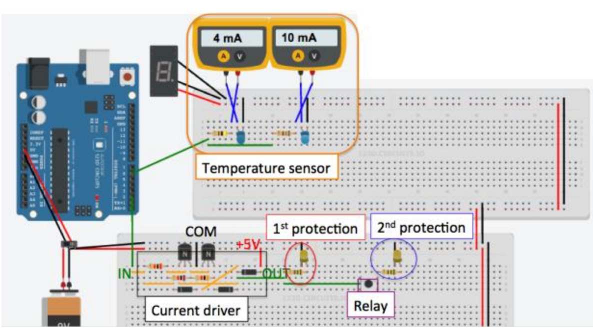

Figure 13: Test setup

The tests that were completed were to check three different areas of our electronics:

- Relay
- Current Driver
- Sensors

Relay Test

In purple in Figure 13 you can see the relay. After initializing the Arduino motherboard and connecting onto the digital PIN 2, the first yellow LED circled in red turns on and the second yellow LED circled in blue turns on as well. The relay works correctly as a switch because we can see with a set code through the Arduino that the LED's turn on and off at set times.

Current Driver

In black in Figure 13 you can see the current driver. After initializing the Arduino motherboard and connecting onto the digital PIN 2, the first yellow LED circled in red turns on. This means that the current driver works.

Sensors

Our temperature sensor reacts to changes in temperature by changing resistance. For this test, we used two different resistances to illustrate two different temperatures. On the multimeter we can see 4mA and 10mA (Figure 13), this is the current after each resistances and this means we just need to send these signals to the Arduino to show them as temperatures on the LCD screen.

IV. Conclusions

Our main objective was to create a working system that supported both fish and plant cultures and through long research and development phases we believe that we have created a system that can complete the required objective and be aesthetically pleasing. Due to the electronics put in place within our system and the necessary tests conducted, we are able to monitor the system and ensure optimum conditions at all times. In order to be sustainable we believed the project should run at 15-30 minute intervals. This would save power compared to a continuous system and provides plants extra oxygen in order for quicker growth. Overall in our own opinions we have completed the requirements and also expanded so that the system will be successful within the intended target market due to an aesthetic design and simple functionality.

V. Future development

Regarding future development we would possibly look towards creating a much cheaper product that can be made from entirely recycled materials to be shipped/manufactured within third world countries. The benefits of an Aquaponics system within these countries would be immediately felt due to the increase in both food and water resources.

VI. Acknowledgements

Firstly we would like to thank Instituto Superior de Engenharia do Porto for this opportunity to do this program and project. We would also like to thank our client, Abel Duarte, and all supervisors and teachers that have supported us throughout the project, enabling us to create work finished to a high quality.

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