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LOW-TECH AQUAPONIC SYSTEM BASED ON AN ORNAMENTAL AQUARIUM

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Abstract

The goal of the aquaponic system was to establish a self-sustaining herbs production in an applied research environment based on a home ornamental aquarium as a nutrient source for the plants. The study was conducted in two different stages. The first stage was to set up an aquarium with ornamental fish. This stage was conducted over a 40 days period (including water cycling). On this stage a 400 liters aquarium was set up then populated with Goldfish (Carassius auratus auratus) and Bronze Corydoras (Corydoras aeneus). During the time needed to set up the aquarium, basil, oregano and parsley seedlings were prepared aside. Upon completing this stage, the seedlings were moved into the grow bed and an aquaponic system was established. Thus, the NO_3^- *rich water from the fish tank was directed to the grow bed. The working paper will present the steps to establish an ornamental aquarium, and how to turn it afterwards into a natural nutrients factory for a self-sustainable plant crop.*

Key words*: aquaponics, biotechnologies, sustainable food system.*

INTRODUCTION

Basically, the aquaponic systems (or "aquaponics", or "aquaponic agriculture", depending on the system's scale) are food production units, based on a combination of aquaculture and hydroponics, tailored to provide healthy food productions (fish and plants). Aquaponics were borned in 1984 through the article published by Watten and Busch (Connolly and Trebic, 2010). Today, this new innovative agriculture technology is widely adopted in countries in America and Australia. Unfortunately, in Europe, the number of aquaponic implementations is still scarce.

In brief, an aquaponic system is a symbiotic closed-loop recycling fresh water system between fish and plants, where the wastes generated by fish (such as urine and ammonia) are converted by nitrifying bacteria into forms that plants can accept in their nourishment processes, thus acting as biofilters and cleaning the water before being sent back to fish (Figure 1). The most common cultivated plants are green leafy plants such as lettuce, basil, parsley and mint.

There also have been cultivated tomatoes, cucumbers, cabbage, kale, celery, eggplant and okra but the income obtained from the herbs is much higher and therefore those are preferred (Rakocy et al., 2006; Connolly and Trebic, 2010).

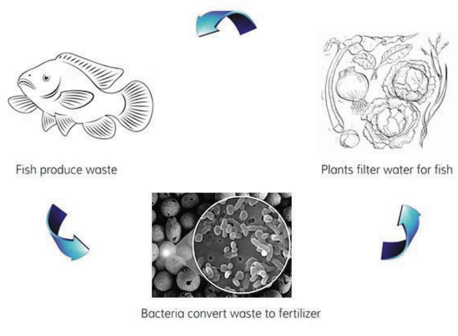

Figure 1. How aquaponic systems work?

Regarding the fish, the most common grown species is tilapia *(Oreochromis niloticus)*. However, any species of fresh water fish can be

suitable for an aquaponic system as long as a proper fish tank is prepared (dimension wise) and the required environmental conditions are met (Elia et al., 2014).
In this context, the paper present the steps to build an ornamental aquarium and to turn it afterwards into a fully fledged *reversed* aquaponic system used to grow healthy plants for consumption or use and also to reduce aquarium maintenance.

MATERIALS AND METHODS

The project required not only to turn an existing aquarium into an aquaponic system, but to build the aquarium also. *Not any aquarium, but an ornamental aquarium intended to be shown in public, placed one meter above the floor*.
This latter requirement hindered a "regular" implementation of an aquaponic system due to the fact that, in case of a "regular" implementation, the grow bed will be suspended out of reach, two meters above the floor. This has led to the emergence of novelty in implementation of such a system, which ultimately had to be configured with the grow bed placed *below* the level of the fish tank. This model of build is known as *reversed* aquaponic system.
To assess the water parameters, the following indicators were used: water temperature, pH value and nitrogen concentration (ammonia, nitrites and nitrates) (Nicolae, 2007). While water temperature was determined by direct observation (using a thermometer), nitrogen concentrations were determined using spectrophotometric analysis of water probes. pH value was assessed by using a commercial test kit. The water assessment was carried out between December 2014 - January 2015.
The aquarium was built out of tampered glass, using silicone to harden and seal the joints. A sturdy aquarium stand was also built out of metal bars to withstand a total weight of about 500 kg.

RESULTS AND DISCUSSIONS

The aquarium

To build the aquarium (Figure 2) were necessary: four 10 mm thick tempered glass sheets for the side walls; one 12 mm thick tempered glass sheet for the bottom; four 12 mm thick 50 mm wide tempered glass stripes for reinforcements and lid support; painter's tape; scissors and scraper; aquarium silicone and silicone gun. The thickness of the glass chosen for the build was based on the physical parameters of the glass.

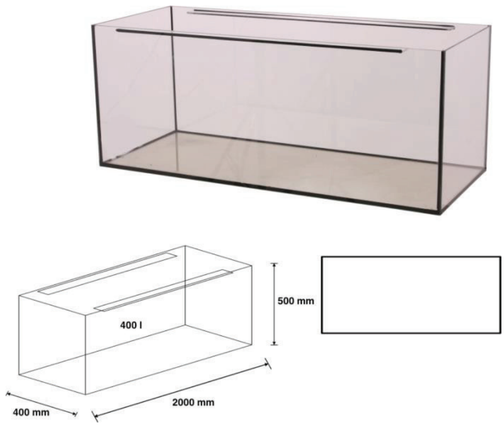

Figure 2. Aquarium blueprints

Based on the thickness and the dimensions, the weight of an empty aquarium can be calculated (Table 1). *This is a very important factor to be taken into account when designing the aquarium stand.*

Table 1. Physical parameters of tampered glass

Glass thickness (mm)	6	8	10	12	15
Weight (kg/m^2)	**15**	**20**	**25**	**30**	**37,5**
Light transmission (%)	88	87	86	84	82
Light reflection (%)	8	8	7	7	7
UV absorption (%)	38	43	46	52	56
Shadow reduction (%)	0,88	0,82	0,80	0,74	0,70

In order to build the aquarium, the aquarium elements were first lined out and checked one against the others, to make sure that every glass element was cut according to the blueprints.
Then, the edges of the aquarium sides were covered on both sides with painter's tape to prevent soiling with silicone.
The sides of the bottom were also covered with painter's tape except for the surfaces to be jointed with the sides. One by one, the ends of the bottom and the corresponding edges of the

side elements were covered with silicone and put together in position. The reinforcements were also covered with silicone and placed in position.
After all the edges of the side elements and the bottom were aligned and the silicone in excess removed, the painter's tape was removed. The silicone was left to cure for three days.
Meanwhile, the aquarium stand was placed in position and levelled so as the table surface to be perfectly horizontal. The spot where the aquarium stand was positioned was chosen according to the following rules:
- to be away from direct bright light in order to prevent excessive algae growth;
- to preserve a constant temperature;
- taking into consideration the ability of the floor to support the weight of the full loaded aquarium and grow beds (the stand should be as close as possible to floor crossbeams);
- close to a power outlet.
Prior to place the aquarium on its stand a shock absorbent 5 mm thick polystyrene sheet was placed and fixed to the table surface. Finally, the aquarium was filled with water in order to make sure the quantity of gluing was good and that there are no water leaks. The aquarium was then emptied and cleaned.
The next step was to install the power filter, water heating system and air pump. While the heating system and the air pump were placed into their final designated position (taken into consideration the future aquaponic system), the power filter role was only to hasten the Nitrogen cycling process. Later on the power filter was replaced by an experimental biofilter to deliver both mechanical and active water filtration. None of the electrical devices were turned on yet.
Chemically inert artificial gravel was chosen as substrate.
The gravel was rinsed in warm tap water before adding it to the aquarium (the less dust in the water, the faster it will clear when the filter is started up).
The substrate was slightly sloped upward toward the back of the aquarium. Some artificial plants and decorations were added also, and then the aquarium was filled with tap water (Figure 3).
Before that, a plate was placed on the substrate to prevent its dispersion when the water is added.

Figure 3. The aquarium build

Water dechlorinator was added to the water in order to remove the chlorine and chloramines.
According to the best practices on any aquarium build some facts are necessary to be taken into account:
- regarding the size of an aquarium, the rule "bigger is better" always apply. A bigger aquarium is easier to maintain due to its high inertia: thermal shocks and water imbalances are much less likely to occur;
- the heaters are to be plugged in only after the aquarium is filled with water and after the thermostat in the heater has adjusted to the water temperature;
- the *effective* water volume is not the geometric volume of the aquarium. It only represents the *real* volume of the water contained in the aquarium.
The number and adult size of the fish to live in the aquarium will always dictate the dimensions of the aquarium. A simple calculation model (based on the length of an adult fish) will show the needs in term of water of *one* adult fish. Knowing the total number of fishes meant to be in the aquarium in the production stage, the *effective* water volume may be calculated (Table 2).

Table 2. The needs in term of water of an adult fish

Fish length (cm)	**< 5**	**5 - 9**	**9 - 13**	**> 14**
Litres of water / cm	1,5	2	3	4

For example, based of the above formula, a 4 cm neon tetra (*Paracheirodon innesi)* will need 6 liters of water, while a 15 cm hoplo catfish (*Hoplosternum thoracatum)* will need 60 liters of water.

System cycling - *a process common to all aquarium setups*
After the water was allowed to sit for a few days in order to remove the Chlorine and to reach optimum temperature the aquarium was populated with only a few Goldfish *(Carassius auratus auratus)* and Bronze Corydoras *(Corydoras aeneus)*.
The fish, as a result of their respiratory and digestive processes, started to produce ammonia (NH_3), a Nitrogen based compound toxic to the fish. Some food in excess was also provided, in order to *increase* the ammonia level in the fish tank while decomposing.
Once ammonia was present in the system, the first nitrifying bacteria (*Nitrosomonas*) was lured into the system and started to colonize. As a result of its presence, ammonia started to be converted to nitrites (NO_2^-), also a Nitrogen based compound, even more toxic for the fish than NH_3. *This point is the critical point in terms of fish welfare, when in the water are found high levels of both NH_3 and NO_2^-.* Fortunately, the presence of NO_2^- in the water lured the second nitrifying bacteria to the system (*Nitrobacter*), which converts the nitrites to nitrates (NO_3^-), a Nitrogen based compound harmless to fish *and* an excellent food supply for plants (Hodoșan, 2012).
The process of biological oxidation from ammonia to nitrates, carried out by autotrophic bacteria, is known as *nitrification* and can be identified by assessing the values of water parameters obtained during system cycling (Figure 4).
Nitrification is also the process that drives the aquaponic systems.

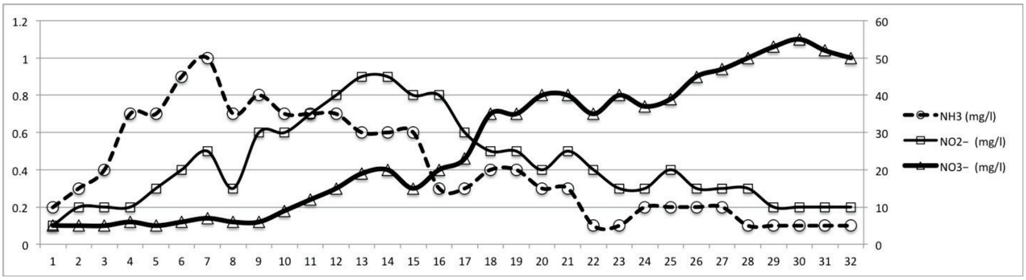

Figure 4. The nitrification process

System cycling is concluded once the levels of NH_3 and NO_2^- are below 0,3 mg/l, while NO_3^- is in excess of 30 mg/l. *At this point any fresh water aquarium can be turned into an aquaponic system*.
Thereby, along with the production of plants, the required periodical removal of a part of the water from the aquarium with the addition of clean water will no more be necessary: instead, the plants will do the cleaning of the water.

System conversion
In order to turn the aquarium into an aquaponic system were made some preparations:
- at the same time with system cycling process we started some basil and parsley seeds in perlite;
- a small grow bed was established, in order to support some seedlings to clear the water while cycling the system;
- a piping system was set up between the fish tank and the grow bed, and between the collector tank back to the fish tank;
- for basil we made sure that the plugs are not too wet, as the seed will rot;
- an experimental new biofilter was added to the system, aiming to replace later the actual power filter;
- a lightning system was also added to the grow bed.

The grow bed
Normally, the grow bed sits *above* the fish tank, and the water showers back to the fish tank, also providing natural aeration through water surface movement (Figure 5).
In addition, no additional pump is needed (apart from the pump which lift the water from the fish tank to the grow bed).

Figure 5. The grow bed

In our setup, the grow bed was placed on a table *below* the level of the fish tank. To make the system work, we provided the grow bed with an overflow (Figure 6) leading to a collector tank placed below the level of the grow bed.

Figure 6. The overflow

A 10 cm thick layer of Hydrotone was added at the bottom of the grow bed, followed by a 20 cm thick layer of aquarium gravel. For this stage, a germination tray was placed on top of the gravel.

How the system works?
The water is pumped from the aquarium to the biofilter (flood and drain system) (Figure 7). At this stage, the filter retains all suspended particles (Hodoșan, 2014).
Also, most of the nitrifying process occurs within the filter. Coming out from the filter water begins to fill the grow bed till the overflow level is reached. The water in excess flows into the collector tank.

Figure 7. The aquaponic system

When the water reaches a certain "High" level, a "smart" pump starts to move the water from the collector tank back to the aquarium. The drain pump only stops when a preset "Low" level is reached.

The plants
Parsley (*Petroselinum crispum*) is a common herb rich in calcium, iron and vitamins A and C. It also has a high market value. Even it can resist to 0°C temperatures, the minimum temperature for growth is 8°C. It enjoys sun for up to eight hours a day.
While in the first year the plant produce only leaves, in the second year the plant will begin sending up flowers for seed production. Harvesting begins when the individual stalks are 15 cm long.
Basil (*Ocimum basilicum*) has a high value and high demand in urban zones. Its seeds need a high and stable temperature (around 22°C) to germinate. It grows in warm conditions with full exposure to the sun. When temperatures above 27°C are reached, shading is needed.
Harvesting begins when the plant is 15 cm high and continues for the next 30 - 50 days. A few variations are also available: Italian Genovese basil (sweet basil), lemon basil and purple passion basil.

CONCLUSIONS

Any existing ornamental aquarium can be easily transformed into a self-sustaining herb production unit.

The costs of such a system are very low and no special skills or tools are required. Moreover, even an aquarium can be made out of low cost components. It is not required special skills and tools also.

This is a way for urban people to get closer to the nature, to enjoy the peaceful view of some beautiful fish, and, with virtually no production costs, to have in their kitchen fresh herbs straight from the grow bed all year round.

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