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Comparison of the technological background of aquaponic systems

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SUMMARY

Aquaponics is the combined culture of fish and plants in recirculating aquaculture systems, an ecologically sustainable horticultural production technique with long traditions.

The objective of this study is to compare flood-and- drain, and the water crossflow system and examine the differences in the water quality, fish yield and plant growth parameters for Common carp (Cyprinus carpio) and basil (Ocimum basilicum). During the study, water quality parameters of two treatments were compared in temperatures, pH, EC and NO_3^-N *were significantly different (p<0.05). Leaf area of the basil plants grew to an average of 20.37 cm*^{2} *(±9.02 cm*^{2}*). The plants' biomass production was significantly different (p<0.05) in the two systems. The biomass production showed lower yield, 458.22 g (±214.59 g) in the constant flow system that in the flood- and- drain system 692.9 g (±175.82 g). Fish Growth parameters were better in constant flow system (FCR 5.48 g/g ± 0.19). However, the specific growth rate (SGR) demonstrated that fish grew faster in flood- and- drain system 1.38 %/day (±0.29).*

Keywords: *Aquaponics, common carp, basil, flood- and- drain system, constant flow systems*

INTRODUCTION

Aquaponics is an ecological horticultural production technique that is integrating aquaculture and hydroponic systems, which is a sustainable food production method. Diver (2006) believed that in aquaponics, the production of plants in a soilless medium, where all of the nutrients supplied to the crop are dissolved in water. These water soluble nutrients are nitrogen forms which derived from ammonia nitrogen excreted by fish, provides nitrogen source for plants growth (Rakocy et al., 2006). The nitrogen is essential in aquaponic systems for plants.

Fish excrete ammonia (NH_3^+) through their gills as a nitrogenous waste. If ammonia levels are to build up too high, they become toxic to the fish, therefore is very important that during Nitrification the nitrifying bacteria transform NH_4^+ to NO_3^- in the presence of oxygen (Hu et al., 2015). The two genera of chemoautotrophic nitrifying bacteria are *Nitrosomonas sp*, which oxidise ammonia (NH_3^+) to nitrite (NO_2^-), and *Nitrobacter sp* that further oxidise nitrites (NO_2^-) to nitrates (NO_3^-) that are the usable for plants (Rakocy, 2007; Graber and Junge, 2009; Endut et al., 2014).

There are three types of most commonly used aquaponics systems classified by the types of growing media, namely nutrient film technique (NFT), media-filled (flood and drain) and floating-raft (deep water culture) (Engle, 2015; Wongkiew et al., 2017). In the flood and drain system is a type of auto siphon that exploits a few physical laws of hydrodynamics and allows the media bed to flood and drain automatically, periodically, without a timer or any complicated device. Water flows into each grow bed at a constant flow rate. As the water fills the grow bed it reaches the top of the standpipe, and begins to drive through the standpipe back to the sump tank (Shete et al., 2016). Without the bell, the bell siphon would create a constant water level which has already been used at other aquaponics systems, e.g. the Floating Raft Aquaponics. Here the plants' roots are in a constant water level (Nuwansi et al., 2018).

Somerville et al., 2014 believed that media beds are either designed for constant flow systems, or as to flood- and- drain (*Figure 1*). In these systems the media (e.g., pumice stones, sand, gravel or expanded clay pebbles) has a number of functions, such support to the plant roots as well as substrate for mechanical and biological filtration (Zou et al., 2016). In constant flow systems, water flows through the bed, and for the plants are provided for constant water output. (Love et al., 2014; Zou et al., 2016). In flood-and- drain systems, plant roots are temporarily exposed to a static nutrient solution before the solution is drained away through a bell siphon. (Somerville et al., 2014).

The objective of this study was to compare flood-and- drain system, and the constant flow system and examine the differences in the water quality, fish yield and plant growth parameters for Common carp (*Cyprinus carpio*) and basil (*Ocimum basilicum*).

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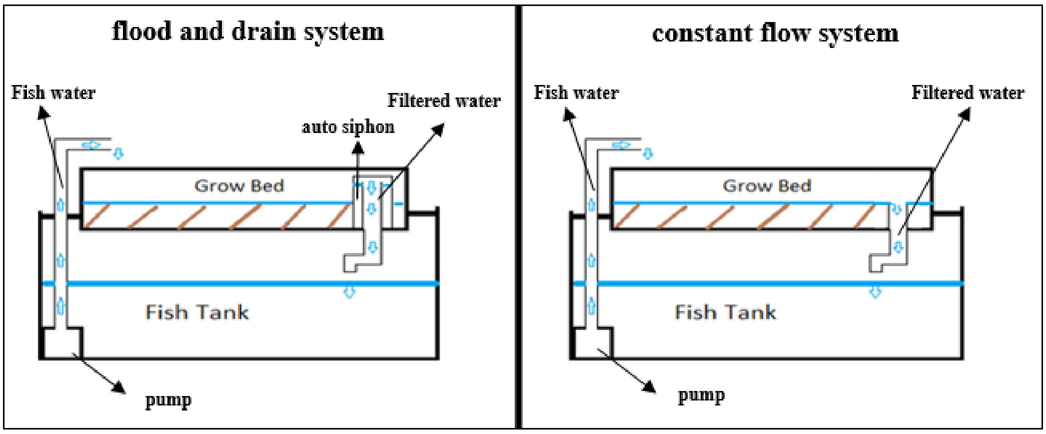
Figure 1: **The flood- and- drain and constant flow systems**



MATERIALS AND METHODS

Experimental aquaponics system

The experiment was conducted for a period of 6 weeks in the Fish biology Laboratory of University of Debrecen Faculty of Agricultural and Food Sciences and Environmental Management. There were three replicates for each treatment. The system was operated in double sheet plastic tunnel greenhouse under shade cloth. One aquaponics unit consisted of 2 tanks namely fish tank and hydroponics tank (for plants). The water of fish tank was aerated using an air pump (Air pump 400, Eheim, Germany) for ensuring a correct level of dissolved oxygen. Six independent (not connected to each other) aquaponics units were maintained in this experiment, two treatments, three replicates in each treatment. The aquaponics were flood and drain systems with auto siphon in one treatment. and constant flow in the other. The capacity of fish tank and hydroponics tank were 225 litres and 32 litres, respectively. Water flow of hydroponics tank was maintained from fish tank with a submersible water pump (capacity 1650 l/h). Crushed stones were used as the gravel bed in the hydroponics tanks, it was 25 cm in height and with the grow bed surface area of 41 cm x 72 cm (*Figure 2*).

The double sheet plastic tunnel greenhouse environmental characteristics

The indoor environmental factors were measured during the experiment. Light intensity was measured with a digital luxmeter (PKT-5065 Luxmeter, spectral, range: 0.1–100.000 Lux; 0.1 Lux; ±4%) close above the water surface. The measured surface lux values after shading was ranged between 7305.15 Lux and 9039.34 Lux respect to the weather conditions. There was the air humidity (PCE-THB 40 Thermo Hygrometer Barometer) in the greenhouse, were 65.82% on average and temperature of air 30.63 °C on average.

Water quality measurements

Water parameters were measured daily inside the fish tanks: pH (HANNA combo HI 98120), (EC) electrical conductivity (Adwa AD332, Romania), redox potential (ORP) (HMdigital ORP-200) temperature, dissolved oxygen (DO) and oxygen saturation (Hach-Lange HQ40D, Germany). Other parameters such the ammonia nitrogen (NH4-N) nitrite-nitrogen (NO_2-N) and nitrate-nitrogen (NO_3-N) were analysed with a spectral photometer (Hach Lange DR 3900, Germany) once a week (*Figure 3*).

Fish Cultivation

Common carp (*Cyprinus carpio*) were procured from a commercial fish farm, Hajdúszoboszló, Hungary. They were acclimated in our wet laboratory facility for another 7 days before the experiment. Initial mean body weight was 140.51 g and a stocking density of 8.43 kg/m^3. Fish were fed with sinking carp feed pellets (BioMar- EFICO Alpha 756 Crude protein: 40%, Crude fat: 23%, Crude fibre: 3.9%) 5 g/fish tank twice a day at 8.00 am and 4.00 pm. Feed conversion ratio (FCR)= F/ (Wt –W0) (g/g) the specific growth rate (SGR) = (lnWf – lnWi x 100)/t; were calculated after the end of the experiment.

Hydroponics

Basil (*Ocimum basilicum,* Genovese F1) plants were chosen for the experiment because of their fast growth, notable nutrient uptake (Kurd et al., 2017; Mostafavi et al., 2019) The basil seeds were planted in universal potting soil. After growing for 14 days, the plantlets were transplanted into the aquaponics system. The plants were planted in the grow bed, beforehand the basils' initial weight was measured, because we intended to calculate the plants biomass production too. Harvesting was done once, at the end of the experiment. The leaf area of basil, (nine basil leaf for each treatment) was measured once a week during the experiment. The leaf area was calculated after Mousavi et al., 2011 with the formula: [LA = 0.209 (L^2 + W^2) + 0.25], where LA= is individual leaf area (cm^2), L= is the leaf length (cm) and W= is leaf width (cm).

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Figure 2: **The experimental aquaponics units**

Statistical Analyses

The data were subjected to analysis using statistical package SPSS version 22 in which two-sample t-test were performed at significance level of ($p<0.05$) to determine the difference between the treatments for the different parameters.

RESULTS AND DISCUSSION

Water quality

Water quality parameters, oxygen and redox potential were not significantly different ($p>0.05$) in both systems throughout the entire experiment. The redox potential (ORP) is strongly affects biological and chemical processes. Wang et al., (2015) demonstrated ORP is related to the decrease of dissolved oxygen (DO). The stability of the nitrification determines optimal operation of an aquaponics system. DO level of the aquaculture suggested to be 5 mg L^{-1}. (Boyd, 1982) The nitrifying bacteria have an optimal range of DO (4–8 mg L^{-1}) which is suitable to promote nitrification (Tyson et al., 2008). The EC, pH and temperature showed significant differences ($p<0.05$) between the treatments. The electrical conductivity (EC) varied over the experiment, but it was mainly between 538 and 1222 mS. The electrical conductivity (EC) in aquaponics is typically between 0.3 and 1.1 dS m^{-1} (Graber and Junge, 2009; Lennard and Leonard, 2006; Pantanella et al., 2012; Roosta and Hamidpour, 2011). This depend on the aquaponics system Hashida et al., (2014) believed the ideal electrical conductivity (EC) in a hydroponic water is typically between 1 and 3 dS m^{-1}. The pH-value were between 7.6 and 9.1 (*Table 1*). The experiment of Silva et al., (2017) resulted in pH variation when measured in the aquaponics to be between 8.35 to 8.81. Water temperature varied within a narrow range, it is one of the important factors responsible for optimum fish growth, plant growth, and the performance of nitrifying bacteria in biofilter (Shete et al., 2016). Nitrification is optimal when the temperature is between 25 and 30 °C, (Antoniou et al., 1990), this temperature is the optimal for the growth of common carp too (Svåsand et al., 2007).

Table 1

Water quality parameters

System	DO (mg L^{-1})	O_2 (%)	pH	Temperature (°C)	EC (µS cm^{-1})	ORP (mv)
flood- and- drain	6.30 ± 1.04	76.29 ± 11.06	8.38* ± 0.31	24.20* ± 2.11	839.76* ± 204.05	110.45 ± 50.68
constant flow	6.49 ± 1.24	76.87 ± 13.17	8.54* ± 0.31	23.41* ± 2.23	789.50* ± 122.51	119.73 ± 55.16

Note: Mean values ± SEM of water quality parameters, * significance ($p < 0.05$)

Nitrite-N (NO_2-N) and ammonia (NH_3-N) parameters of the water did not show any significant ($p>0.05$) variation throughout the experimental period. The flood- and- drain system showed significantly ($p<0.05$) lower Nitrate-N (NO_3-N) concentration than constant flow system (*Table 2*). In aquaponics systems, total ammonium nitrogen (TAN) needs to be oxidized to NO_3-N because this is to fish is only high concentrations toxic (200 mg L^{-1}) (Akinwole, and Faturoti, 2007, Graber and Junge, 2009; Hu et al., 2014). NO_2-N parameters have to be maintained at low levels (Buzby and Lin, 2014; Liang and Chien, 2013). NO_2^-N level of in a well-operated aquaponics systems is between 1 to 3 mg L^{-1} (Akinwole, and Faturoti, 2007, Rakocy et al., 2003).

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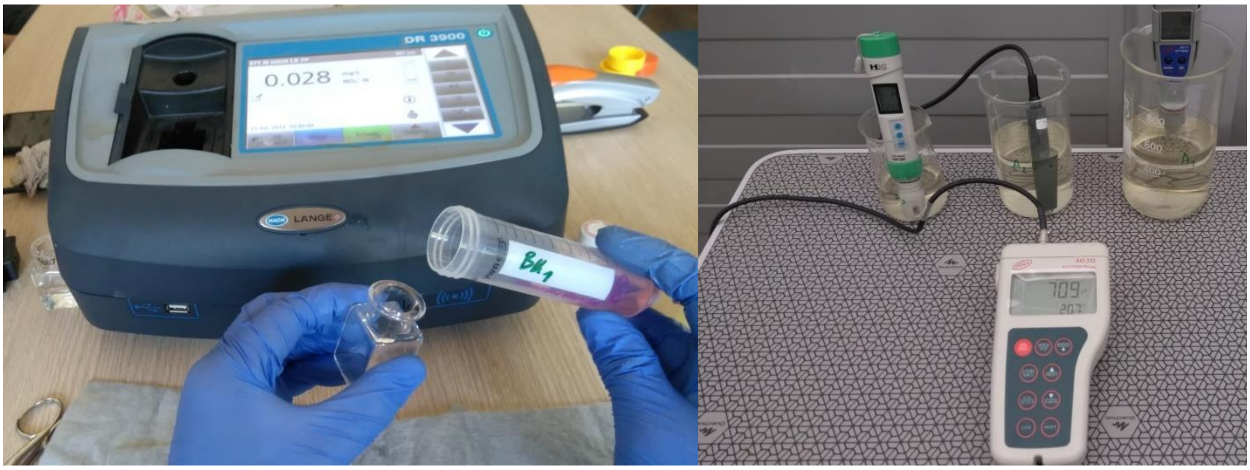
Table 2

Parameters of nitrogen forms in the water

System	NO_2-N (mg L^{-1})	NO_3-N (mg L^{-1})	NH_3-N (mg L^{-1})
flood- and- drain	0.04 ± 0.05	3.45* ± 0.9	1.01 ± 0.85
constant flow	0.09 ± 0.11	4.91* ± 1.7	0.74 ± 0.48

Note: Mean values ± SEM of water quality parameters, * significance ($p < 0.05$)

Figure 3: **Measurement of water quality parameters**

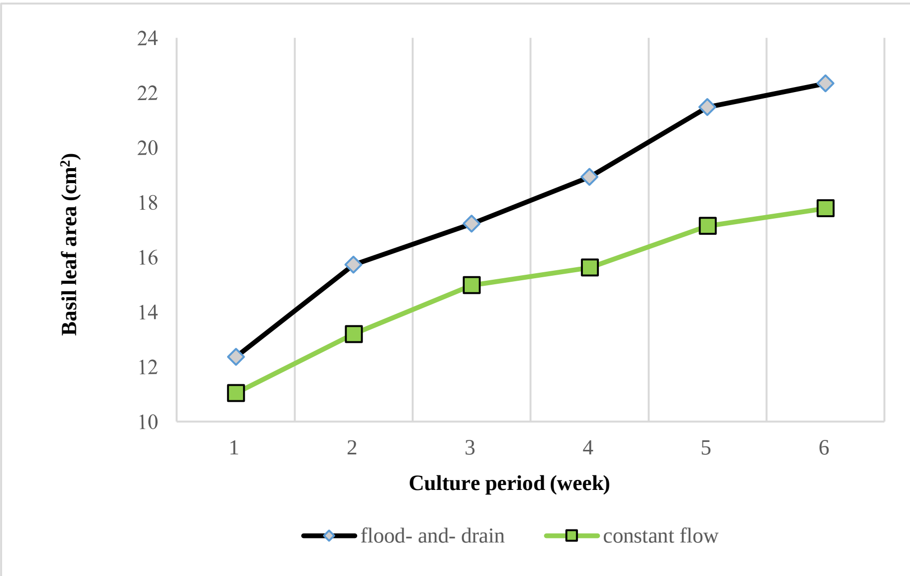


Plant Growth parameters

The plants performed well considering that not extra fertilizer was added throughout the experiment. During the experiment, leaf area of the basil plants grew to an average of 20.37 cm^2 (±9.02 cm^2) (*Figure 4*).

The plants biomass production were significantly different ($p<0.05$) in the systems. The biomass production was lower 458.22 g (±214.59 g) in the constant flow system that in the flood- and- drain system 692.9 g (±175.82 g). The nutrient supply from the fish husbandry units was enough to produce 8.61 kg/1.77 m^2 the basil total biomass production. Different results have been reported by Rakocy et al., (2004) in tilapia and basil combination in aquaponics system where the basil biomass was 2.1 kg/m^2.

Figure 4: **The leaf area of basil plants**



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Fish Growth parameters

No fish mortality was observed during the experiment. The growth performance of the carp did not show any significant variation (p>0.05) in the aquaponics systems during experimental period.

The *Table 3* shown the calculated FCR, SGR and the growth data. The most interesting observation in the present study is that better FCR (food conversion ratio) was obtained in constant flow system, (indicating higher feed efficiency) under cooler water temperatures. Similar results have been reported (Zou et al., 2016) that lower FCR was obtained in summer because the temperature was higher. However, the specific growth rate (SGR) demonstrated that fish growth rate was faster in warmer water.

Table 3

Performance of the Common carp in the experimental systems

System	Initial Weight (g/Fish)	Final Weight (g/Fish)	SGR (%/day)	FCR (g/g)
flood- and- drain	140.57 ± 30.23	198.71 ± 64.13	1.38 ± 0.29	7.48 ± 1.79
constant flow	140.43 ± 31.25	217.17 ± 52.00	1.83 ± 0.06	5.48 ± 0.19

CONCLUSIONS

The water parameters were favourable not only for the fish but also for the activity of nitrification bacteria what provide optimal operation of the aquaponics systems. Basil produced large biomass with no plant protection problems. Fish production parameters did not show favourable values in any of the systems due to the hot summer (Zou et al., 2016). Considering overall water parameters fish growth, plant growth, and other water quality parameters, the experiment revealed that the flood- and- drain and constant flow systems are equally suitable in the carp and basil cultivation.

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