Bulgarian Journal of Agricultural Science, 26 (No 1) 2020, 243–247

The cleaning capacity and productivity of LECA® and Floating raft aquaponic filters in an integrated recirculation system

Ivaylo Sirakov

Trakia University, Faculty of Agriculture, Department of Biology and Aquaculture, 6014 Stara Zagora, Bulgaria
E-mail: ivailo_sir@abv.bg

Abstract

Sirakov, I. (2020). The cleaning capacity and productivity of LECA® and Floating raft aquaponic filters in an integrated recirculation system. *Bulg. J. Agric. Sci., 26 (1)* 243–247

The aim of current study was to investigate the effect of periodically flooded LECA® and Floating raft aquaponic filters with water from an integrated recirculation system on its cleaning capacity and productivity of a common carp (*Cyprinus carpio* L.) and lettuce (*Lactuca sativa*). The aquaponic system contained two types' hydroponic sub-systems (media bed and deep water culture). The water flow rate in them was maintained at 0.5 $l.min^{-1}$ and periodically was stopped (every 4 h) for one hour. The influence of pointed flooding regime in both filters on average weight of cultivated carps, water cleaning capacity, as well as lettuce productivity was tested.

The periodically flooded with water filters did not affect negatively the cultivated fish in current study. Better cleaning capacity of ammonium nitrogen, nitrate nitrogen and orthophosphate phosphorus in tested water regime was found for LECA® filter and they were lower respectively with 69.2%, 2.77% and 18.7% compared with the average values in these parameters found for floating raft aquaponics filter. The better yield of cultivated lettuce in tested flooding regime was found for LECA® filter and it was higher with 1.3% compared with this found for floating raft system.

Keywords: aquaponics; common carp; lettuce; flooding regime

Introduction

Aquaponic system is innovative recirculation system where fish cultivation is integrated with the production of plants. The water from water tanks, rich in nutrients is used for plants for their growth, from the other side they are playing a role as biofilter for cleaning the water from aquaculture section (Rakocy et al., 2006). The aquaponic filter are predominantly used for the treatment of nitrates and phospahtes in recirculation system (RAS) and nutrient removal by plants improves water quality and enchance hydrobionts production (Endut et al., 2010).

This new and sustainable technology is an object of numerous studies recently – testing different fish (Rakocy et al., 2003; Graber and Junge, 2009; Dediu et al., 2012) and plant species (Hu et al., 2015; Hundley et al., 2018), different media (Roosta & Afsharipoor, 2012; Sirakov et al., 2017), economic efficiency (Blidariu & Grozea, 2011; Palm et al., 2014; Greenfeld et al., 2018), etc. The productivity and cleaning capacity of aquaponic filter in these integrated systems is highly dependent from water treatment strategy i.e. ratios between fish and plant sections (Endut et al., 2010; Buzby and Lin, 2014), flow rates (Endut et al., 2009; Afsharipoor and Roosta, 2010), hydroponic sub-systems (Lennard & Leonard, 2006; Sirakov et al., 2017).

One important question object of studies recently is how the flooded regimes in plant section affect cleaning capacity and productivity in different hydroponic systems. The studies exploring this topic are highly restricted (Lennard & Leonard, 2014) to the present moment.

The aim of current study was to investigate the effect of periodically flooded LECA® and Floating raft aquaponic filters with water from an integrated recirculation system on its cleaning capacity and productivity of a common carp (*Cyprinus carpio* L.) and lettuce (*Lactuca sativa*).

Material and Methods

Aquaponic system

The integrated recirculation system is situated at the Experimental aquaculture base in Trakia University, Stara Zagora, Bulgaria. It consists from fish tanks, mechanical filter (settling tank) and biofilter (moving bed biofilter), plastic tank (120 l) and aquaponic section (Figure 1). The system had four fish tanks with the water volume of 2 m^3. During the experiment only one of them was used for cultivation of experimental fish. The water from this tank passed subsequently thoughout settling section and moving bed biofilter with the the total volume of 4 m^3. The water from the filters was pumped into fish tank and aquaponics sections. After cleaning process the water from the filter compartment was pumped back into the fish tank used for carp cultivation. A water flow rate of 3 l. min^{-1} was assured to fish tank. Every day the bottom of fish tank and filter was cleaned by siphoning. The water lost during the cleaning process and evaporation was compensated by adding of fresh water (up to 10% of recirculation aquaponics system' volume per day).

The compartment used for cultivation of plants was consisted from two types hydroponic sub-systems (media bed and deep water culture) (Figure 1). The first hydroponic sub-system was filled with lightweight expanded clay aggregate (LECA®) and the second one used polystyrene sheet with 5 mm thickness which floated on the surface of water. For the needs of current trial 1 m^2 surface from each of the hydroponic sections was used. Four specielized plant growing lights (18W, Osram Fluorescent Fluora Tubular Linear Lamp) was used in relation to favorable light condition (12-h light/12-h dark) for cultivated lettuce to be assured.

The water from fish tank (3 m^3) was pumped with submersible pump throughout plastic tank with volume used as settling tank for aquaponic section. Afterwards with two valves the water was moved in both hydroponic sub systems. It consisted from tanks with volume of 0.5 m^3. The water flow rate in hydroponic sections was maintained at 0.5 $l.min^{-1}$ and periodicaly was stopped for one hour (every 4 h).

Experimental common carp

The common carp (*Cyprinus carpio* L.) with an average weight of 625 ± 127.2g in good health were adapted for one week to the condition of the aquaponic system. The used

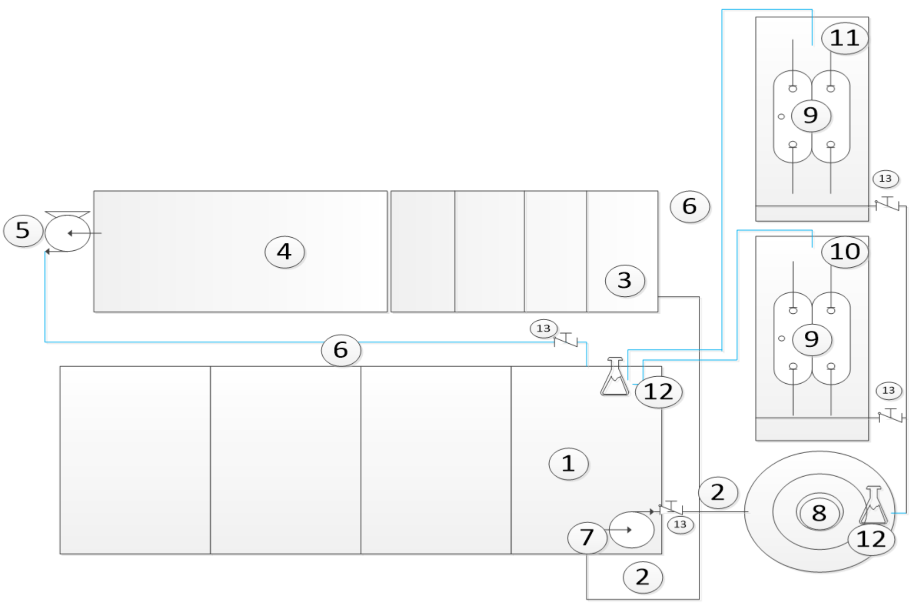

Fig. 1. Aquaponic system used during the trial:
***1*) fish tank; *2*) outlet water; *3*) mechanical filter (settling tank); *4*) moving bed biofilter; *5*) pump; *6*) inlet water; *7*) submersible pump; *8*)plastic tank (settling tank); *9*) plant growing lights; *10*) Lightweight expanded clay aggregate (LECA) filter; *11*) Floating raft filter; *12*) sample points; 13) valves**

stocking density was 1.25 kg.m^{-3}. The fish were fed three times per day. The daily feed ration was adjustted to 2% from carp's biomass.

Experimental plants

For the trial 32 lettuce seedlings (10 day old *Lactuca sativa* variety "Gentelina") were chosen and transported from greenhouse situated in Plovdiv to the Experimental aquaculture base at Trakia University. The plants were transferred to rock wool (Grodan®) substrates and afterwards all plants were placed in hydroponic pots. Sixteen lettuce seedlings were planted in the hydroponic sub-system filled with lightweight expanded clay aggregate (LECA®) and the other ones were planted in the floating raft hydroponic section. A possible deficit of microelements in experimental lettuces was avoided by foliar spraying of B-essentials® once per week according producer's requirement.

Investigated parameters

The experiment was carried out during July-August 2017 for 50 days. The mortality of experimental fish was registered daily. The weight of the common carp was measured at the start and at the end ot trial at technical scale with accuracy of 0.01 g.

The cleaning capacity of different hydroponic sections was investigated by measurement of hydrochemical parameters in plastic tank before aquaponic section and after floating raft and LECA® hydroponic compartments (Figure 1). Dynamics of nitrogen (ammonium and nitrate) and phosphorus (ortho-phosphate-phosphorus) compounds were measured spectrophotometrically with the DR 2800 (Hach Lange®) every week with cuvette tests (Table 1).

Table 1. Methods and range of cuvette tests used for monitoring the hydrochemical parameters

Quality parameters	Determination method	Measuring range (mg L^{-1})
Ammonium-nitrogen	Indophenol blue	0.015-2
Nitrate - nitrogen	2.6 dimethylphenol	5-35
Phosporus (ortho + total)	Phosphormolybdenum blue	0.05-1.5 mg L^{-1} PO_4-P 0.15-4.5 mg L^{-1} PO_4

At the end of the trial the fresh weight of lettuce was measured on technical scale with accuracy of 0.01 g. The length of roots in experimental plants (cm), cultivated at two hydroponic sub-systems was also measured.

Statistical analysis of data

The data received from the trial were statistically analysed with ANOVA single factor (MS Office, 2010).

Results and Discussion

Growth parameters in common carp (*C. carpio* L.) cultivated in recirculation system with aquaponic filters

The average weight of common carp cultivated during the trial increased by 30.7% (Figure 2). The calculated specific growth rate (SGR) was 0.53 %body.wt. gain.day^{-1}. The received SGR was lower than this found from Shete et al. (2016) for this species cultivated in aquaponic system in integration with mint (*Mentha arvensis*), but the fish cultivated in its study were with lower initial weight. How Alyshbaev, 2013 stated the specific growth rate in fish depends on different factors such as species, age, water temperature, quality and quantity of food. The younger ones are capable of doubling their weight in a much shorter time than when they are older due to fast growth rate. The raised fish did not experienced from negative effect of periodically interrupted water flow because continous flow rate in this moment was assured from water coming from biological filter (Figure 1).

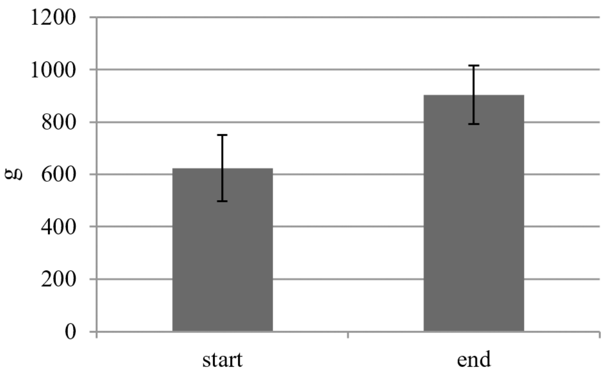

Fig. 2. Average weight of common carp cultivated during the trial

Hydrochemical parameters in LECA® and Floating raft filters

It could be hypothesized that increasing the time which water spent in a filter will improve its quality and assimilation of nutrients from plant cultivated in hydroponic sub-section. The better effect in hydrochemical parameters of chosen flooded regime was found for LECA® filter (Figure 3). The ammonium nitrogen removal in LECA® and floating raft filters were respectively 84.8% and 50.6% and the difference in the concentration of ammonium nitrogen after both filters was 69.2% in favour of LECA® filter but it was not significant (p≥0.05) (Figure 3). The nitrate nitrogen removal in the above discussed filters were respectively

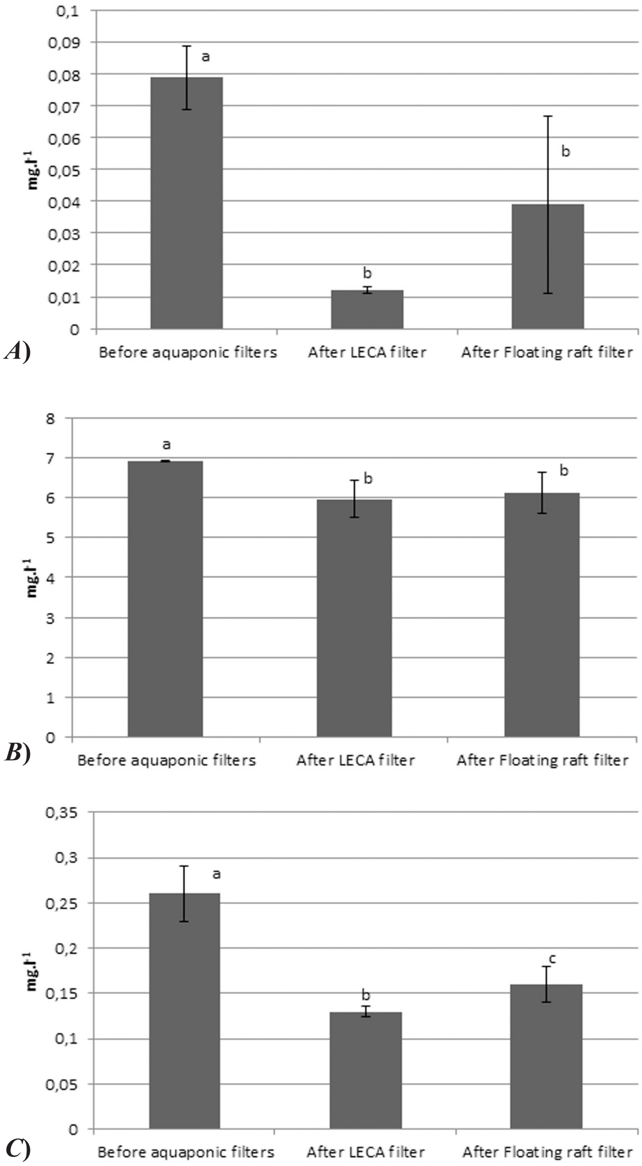

Fig. 3. Hydrochemical parameters during the trial: *A*) Ammonium nitrogen, *B*) Nitrate nitrogen, *C*) Orthophosphate phosphorus

13.9% and 11.5%, respectively and the difference in concentration of nitrate nitrogen after both filters was 2.77% in favour of LECA filter but it was not significant ($p \geq 0.05$) (Figure 3). The phosphate removal in LECA® and floating raft filters were respectively 50% and 38.4% and difference in concentration of orthophosphate phosphorus after both filters was 18.7% in favour of LECA® filter and it was significant ($p < 0.05$) (Figure 3). Better removal rate of nutrients was found for the LECA® filter. Seawright et al. (1998) stated that gravel systems may remove the requirement for the separate biofilter as the substrate also acts as a medium for nitrifying bacteria. That was also confirmed from the current trial. Shete et al., 2016 found similar tendency in NO_3-N and phosphate removal when removal capacity of crushed stone medium and the floating raft system were compared. The lower cleaning capacity of tested filters compared with the data received from the study made from Shete et al. (2016) is probably due to the presence of biofilter in current aquaponic system which additionaly removed nutrients from the water.

Growth parameters in lettuce (*Lactuca sativa*) cultivated in LECA® and Raft filters

The better yield in lettuce (*L. sativa*) from periodically flooded filters was found for LECA® one and it was 1.3% higher when compared with the productivity of plants from floating raft system but the difference was not significant ($p \geq 0.05$) (Figure 4). The higher average root's length in lettuce (*L. sativa*) from periodically flooded filters was found for floating raft filter and it was 18.5% higher when compared with the one from plants from floating raft system and the difference was significant ($p < 0.05$) (Figure 4). The bet-

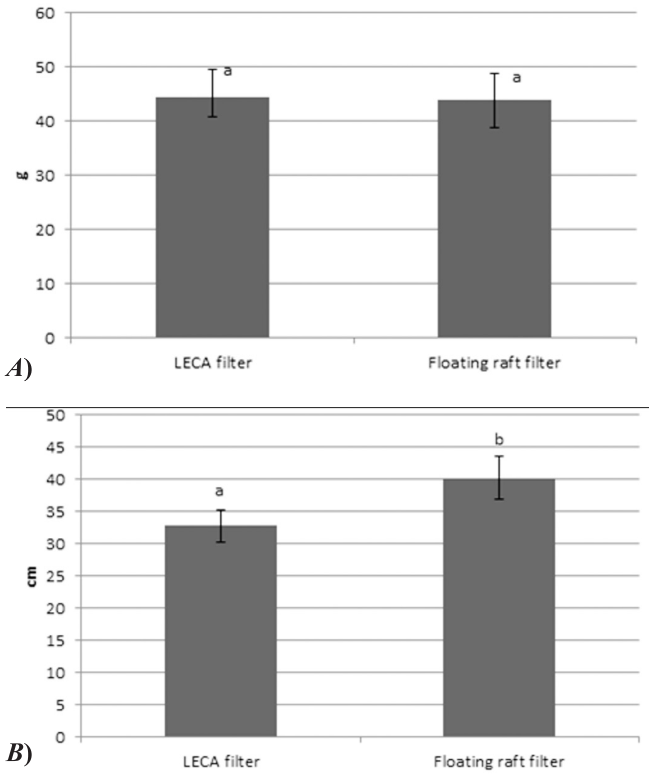

Fig. 4. Average yield (*A*) and root's length (*B*) in lettuce (*Lactuca sativa*)

ter yield in lettuce (*L. sativa*) from LECA® filter compared with this found for floating raft system could be explayed with higher nutritional absorbtion from plants cultivated in LECA® filter due to nutrients availability in this section. The lower nutrional possibility in floating raft system leads also to the higher root's length of plants. Speculatively other possible reason for higher yield in lettuce from LECA® filter could be due to the symbiotic relations between plant's root and nitrification bacteria present in the system. This is why the future study of rhizosphere of plant's cultivated in different aquaponic filters will be highly valuable.

Conclusions

The tested flooded regime (running of water in the system every 4h and stopped for one hour) in aquaponics filters did not affect negatively the cultivated common carp in current study. Better cleaning capacity of ammonium nitrogen, nitrate nitrogen and orthophosphate phosphorus in tested water regime was found for LECA® filter and they were lower respectively with 69.2%, 2.77% and 18.7% compared with the average values in these parameters found for floating raft aquaponics filter. The better yield of cultivated lettuce in tested flooding regime was found for LECA® filter and it was higher with 1.3% compared with this found for floating raft system.

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Received: December, 28, 2018; *Accepted:* January, 17, 2019; *Published:* February, 29, 2020