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COMPARISON BETWEEN TWO PRODUCTION TECHNOLOGIES AND TWO TYPES OF SUBSTRATES IN AN EXPERIMENTAL AQUAPONIC RECIRCULATION SYSTEM

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Abstract

Two of the main parameters, which defined the cleaning capacity of cultivated plants and productivity of aquaponic systems, are the type of hydroponic compartment and plant's growing media. The aim of current research was to compare the cleaning capacity and plant's productivity of media bed and raft hydroponic sections as a part of a model aquaponic recirculation system. The impact of different plant growing mediums (cotton wool and rockwool) on lettuce yields was also retraced. For the purpose of this research two types of hydroponic sections (media bed and deep water sections) were constructed and integrated into an existing recirculation aquaculture system. For the trial 36 lettuce seedlings were used. Half of the plants were transferred to cotton wool and the other half of the lettuce plants were transferred to rockwool (Grodan®) substrates and afterwards all plants were placed in hydroponic pots. Eighteen lettuce seedlings (half planted on cotton wool and the other half on rockwool (Grodan®) substrate) were planted on the hydroponic section filled with lightweight expanded clay aggregate (LECA) and the other eighteen plants (half planted on cotton wool and the other half on rockwool (Grodan®) substrate) were planted on the floating raft hydroponic section.The hydrochemical parameters were measured during the trial. At the end and middle of the trial the fresh weight of lettuce plants was measured.A better removal capacity in ammonium, nitrate and ortho-phospahte were observed in the LECA section compared with the cleaning capacity in the raft section as a part of experimental aquaponic system. The raft technology showed better plant productivity compared with the one found for the LECA bed technology. The productivity of lettuce plants is highly dependent on the type of plant growing medium, when they are cultivated in the floating raft technology.

Key words: *aquaponic, deep water technology, media bed technology, plant growing substrates*

INTRODUCTION

Aquaponics is a sustainable aquaculture technology (Nelson, 2007; Graber and Junge, 2009; Diver and Rinehart, 2010), where the hydrobionts and vegetables are cultivated in the same recirculation system (Rakocy et al, 2006; Timmons et al., 2002; Rakocy et al, 2006; Karimanzira et al., 2016).
The interest of the aquaculture sector in Bulgaria on this particular production technology is continuously increasing in the last few years. Some aquaponics projects were already accepted for financing from "Programme for Maritime Affairs and fisheries /2014-2020/". Although studies connected to the development of aquaponic technology in Bulgaria will be highly appreciated by the aquaculture branch, such studies are still missingup to now.
As an innovative technology the efforts of many researchers are connected to the optimization of aquaponics.
Two of the main parameters, which defined the cleaning capacity of cultivated plants and productivity of aquaponics systems, are the type of hydroponic compartment and plant's growing media. Limited studies are connected with these topics (Lennard and Leonard, 2006; Roosta and Afsharipoor, 2012; Schmautz et al., 2016), and many research questions still remain open.
The aim of current research was to compare the cleaning capacity and plant's productivity of media bed and raft hydroponic sections as a part of a model aquaponic recirculation system. The impact of different plant growing mediums (cotton wool and rock wool) on lettuce yields was also retraced.

MATERIALS AND METHODS

Model aquaponic system

For the purpose of this research two types of hydroponic sections (media bed and deep water sections) were constructed and integrated into an existing recirculation aquaculture system situated at the Experimental aquaculture base in Trakia University, Stara Zagora, Bulgaria (Figure 1).

The volume of the fish tank was 2 m^3. The total volume of the settling tank and biofilter was 5 m^3. The water from the filters was pumped into fish tank and aquaponics sections. The valve split the water between fish tank and hydroponic sections. The water flow rate in hydroponic sections was maintained at 0.5l min^{-1}. A water flow rate of 3.l min^{-1} was assured to fish tank. The light for each of the hydroponic compartments were assured from 2 plant growing lights (Osram Fluorescent Fluora Tubular Linear Lamp).

Once per week the bottom of settling and fish tanks were syphoned and the sediments were removed. 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 week).

For the needs of current trial 0.7 m^2 surface from each of the hydroponic sections was used. The first hydroponic section was filled with lightweight expanded clay aggregate (LECA) and the second hydroponic section used polystyrene sheet with 5 mm thickness which floated on the surface of water (Figure 1).

Experimental fish

Twelve specimens from the fish species common carps (*Cyprinus carpio* L.) with an average weight of 563.08 ± 51.5rp.in good health condition were adapted for one week to the condition of the newly built aquaponic system. The used stocking density was 3.3 kg.m^{-3}. The fish were fed manually three times per day. The daily feed ration was adjustted to 2% from carp's biomass. The mortality of experimental fish was registered daily.

Experimental plants

For the trial 36 lettuce seedlings (15 day old *Lactuca sativa* variety "Jyltakrasavica") were chosen and transported from greenhouse situated in Plovdiv to the Experimental aquaculture base at Trakia University. Half of the plants were transferred to cotton wool and the other half of the lettuce plants were transferred to rock wool (Grodan®) substrates and afterwards all plants were placed in hydroponic pots. Eighteen lettuce seedlings (half planted on cotton wool and the other half on rock wool (Grodan®) substrate) were planted on the hydroponic section filled with lightweight expanded clay aggregate (LECA) and the other eighteen plants (half planted on cotton wool and the other half on rock wool (Grodan®) substrate) were planted on 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.

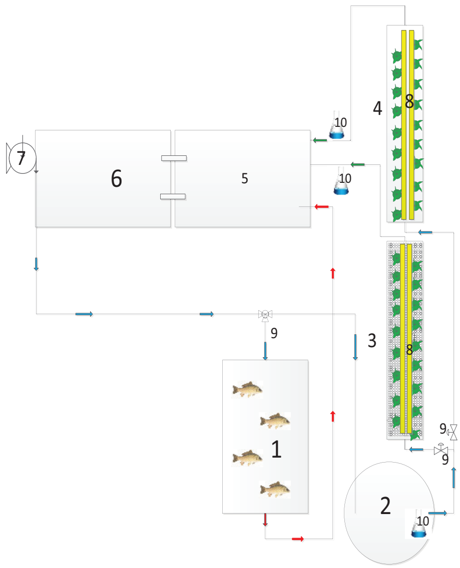

Figure 1. The model aquaponics system used in current trial: 1) fish tank; 2) sump; 3) light weight expanded clay aggregate (LECA) section; 4) raft aquaponics section; 5) sedimentation tank; 6) biological filter; 7) pump; 8) plant growing lights; 9) valves; 10) sample points for hydrochemical analysis

Studied parameters

The duration of experiment was 30 days.The biomass of the experimental carp was calculated at the start, middle and end of experiment. The percentage weight gain (PWG) in experimental fish was calculated according following equation:

$$PWG = \frac{(W2 - W1)}{W1} x100$$

where:

- W1-initial weight of carp;
- W2- final weight of carp at the end of trial.

The survival of fish during the trial was also registered.

The cleaning capacity of different hydroponic sections was investigated by measurement of hydrochemical parameters in sump and after raft and LECA bed hydroponic compartments (Figure 1). The oxygen content, pH and electrical conductivity were measured daily with a portable meter (HQ30D) accordingly with LDO, pH (liquid) and conductivity electrodes. Dynamics of nitrogen (ammonium and nitrate) and phosphorus (ortho-phosphate-phosphorus) compounds were measured spectrophotometrically with the DR 2800 (Hach Lange) every 10 days with appropriate tests for the aim (Hach Lange, 2007).

At the end and middle of the trial the fresh weight of lettuce plants was measured on technical balance with 0.01g accuracy. The length of roots in experimental plant cultivated at a two production technology 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 DISCUSSIONS

The current study presents the results from the first experiment in aquaponics ever made in Bulgaria. The general view from used hydroponic sections could be seen on Figure 2.

Figure 2. View from a model aquaponic system

Experimental fish

There was not observed mortality in experimental fish during the trial. At the middle and end of the experimental period the biomass in carp increased accordingly with 9.21% and 11.97% compared with its initial value. It was found that percentage weight gain (PWG) of carp was 10.14% in the middle of the experiment and 13.6% at end (Figure 3).

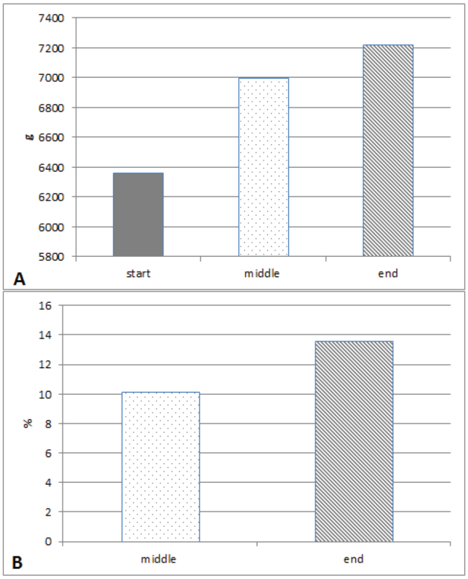

Figure 3. Growth parameters in common carp *(C. carpio)* cultivated in aquaponics mesocosmos system: A) Biomass of experimental carp; B) Percentage weight gain (PWG) during the trial.

Hydrochemical parameters

A hydroponic section could serve as a biofilter in the aquaponic recirculation system (Endut et al., 2009), decreasing the quantity of metabolites excreted from fish and toxicological compounds which are released in water from faeces and uneaten feed.

Comparing the level of pH in both experimental hydroponic sections, its level was much closer to neutral pH in the LECA section compared with its value in the raft section, but the difference was not statistically proven (Table 1). The quantity of oxygen in the raft and LECA sections was higher accordingly with 16.05% and 10.8% compared with its value in sump before the hydroponic sections

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and differences were significance ($P \leq 0.05$) (Table 1). The quantity of ammonium nitrogen, nitrate nitrogen and ortho-phosphate-phosphorus significantly decreased after the experimental hydroponic sections (Table 1). The quantity of ammonium nitrogen was with 36.2% higher after raft section compared with its quantity in water after LECA section (Table 1). The concentration of nitrate was higher with 11% in the section used deep water technology compared with its value in the LECA section, but differences were not proved statistically ($P \geq 0.05$) (Table 1). The lower concentration of ortho-phosphate phosphorus was observed also in the LECA section in comparison with the concentration of this compound measured in the raft section (with 46.8% higher value) (Table1).
The received results from the current study are in line with the data received from Lenard and Leonard, 2006, according to which the gravel bed and floating hydroponic section are suitable for integration with recirculation aquaculture system. Lenard and Leonard, 2006, found that oxygen concentration and nitrate removal was higher in the raft system but phosphate removal was higher in the gravel bed section.

Table 1. Hydrochemical parameters in mesocosmos aquaponics system

Parameters	Before aquaponics section +Sx	After RAFT aquaponics section +Sx	After LECA aquaponics section +Sx
pH	7,23±0,23[a]	7,79±0,50[a]	7,42±0,41[a]
Oxygen ($mg.l^{-1}$)	6,17±0,36[a]	7,35±0,33[b]	6,92±0,45[c]
Conductivity ($\mu S.cm^{-3}$)	269,22±1,09[a]	269,22±1,39[a]	264,44±0,89[b]
Ammonium nitrogen ($mg.l^{-1}$)	0,55±0,08[a]	0,309±0,09[b]	0,197±0,06[c]
Nitrate nitrogen ($mg.l^{-1}$)	1,57±0,21[a]	1,15±0,33[b]	1,02±0,27[b]
Ortho-phosphate-phosphorus ($mg.l^{-1}$)	0,42±0,23[a]	0,25±0,14[b]	0,133±0,07

[a,b,c]-values in the same row with different superscript letters are significantly different ($P < 0.05$)

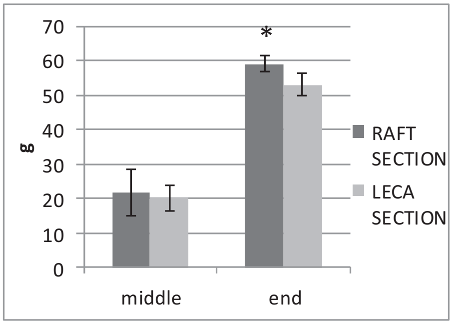

Figure 4. The average weight of lettuce plants cultivated in raft and LECA section; Asterisk (*) denotes a significant different at $P < 0.05$

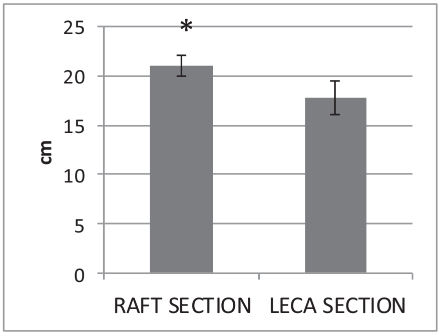

Figure 5. The average length of root in lettuce cultivated in Raft and LECA section. Asterisk (*) denotes a significant different at $P < 0.05$

The results in the current study showed a better removal capacity in ammonium, nitrate and ortho-phosphate in the LECA section compared with the cleaning capacity in the raft section. The differences in volume of the gravel bed and floating hydroponic sections in the study made from Lenard and Leonard, 2006 was a possible reason for slight differences in the received results between the current research and the cited study.
The average weight of lettuce plants cultivated in the raft section was higher with 7.65% at the middle and 10.32% at the end of the current trial in comparison with the received values for this parameter in the experimental plants in LECA compartment (Figure 4).
At the end of the trial the average length of the roots in lettuce cultivated in the raft section was higher with 16.1% compared with the average length of the roots in the experimental plants

cultivated in the LECA section and the difference was significant (Figure 5).

The received results connected with growth of the cultivated plants are in contradiction with the data received in the study made from Lenard and Leonard, 2006, which stated that biomass gain and yield in lettuce, followed the relationship gravel bed > floating raft technology.

According to Graber and Junge, 2009, LECA is a type of clay, which is super-fired to create a porous medium. By our opinion this porous structure of LECA made it much preferable ecological niche for attachment of different types of bacteria than the condition available in the floating raft technology. The bacteria probably compete for nutrient compounds with cultivated lettuces in the current trial, which decrease the accessibility of nutrients for plants in the LECA section.

The mediums we used in our trial (rock wool and cotton wool) did not affect the plant's weight, when lettuces were cultivated in the LECA section (Figure 6). The measurement made at the middle and the end of trial in the raft section showed that lettuces planted in rock wool medium had accordingly with 27.6% and 17.6%higher average weight in comparison with this found for experimental lettuces planted in cotton wool (Figure 6).

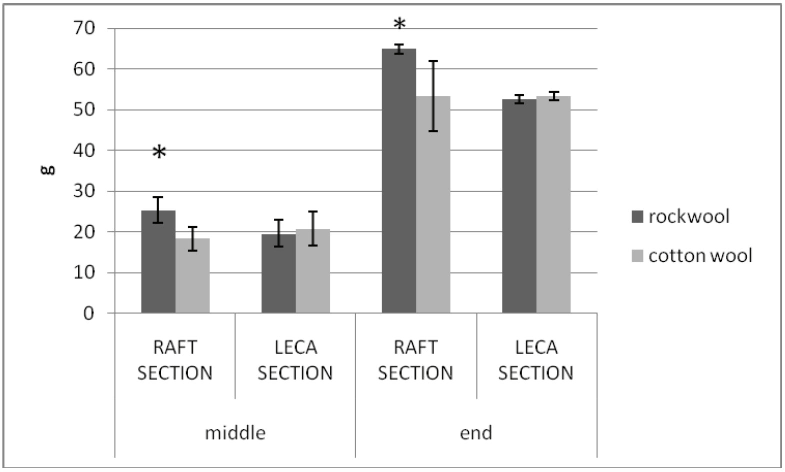

Figure 6. The average weight of lettuce plants cultivated in cotton wool and rockwool (Grodan®) mediums. Asterisk (*) denotes a significant different at P < 0.05

CONCLUSIONS

The LECA bed and floating hydroponic sub system are suitable for integration with the recirculation aquaculture system. A better removal capacity in ammonium, nitrate and ortho-phosphate were observed in the LECA section compared with the cleaning capacity in the raft section as a part of experimental aquaponics system. The raft technology showed better plant productivity compared with the one found for the LECA bed technology. The productivity of lettuce plants is highly dependent on the type of plant growing medium, when they are cultivated in the floating raft technology.

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