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NUTRIENTS DYNIMIC IN AN AQUAPONIC RECIRCULATING SYSTEM FOR STURGEON AND LETTUCE (*LACTUCA SATIVA*) PRODUCTION

DINAMICA NUTRIENTILOR INTR-UN SISTEM RECIRCULANT ACVAPONIC PENTRU PRODUCEREA STURIONILOR SI A SALATEI DE CULTURA (*LACTUCA SATIVA*)

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Aquaponics are modern production systems, which integrate the aquaculture technology with hydroponic systems (vegetable production without soil) with a goal of fructification of residual nutrients resulted from metabolic activity of fish biomass as high quality vegetable biomass sealable as ecological products. In the present study, as a first step in aquaponic recirculating systems evaluation, the authors aim to compare two types of recirculating systems: classical (hereby noted with RAS) and integrated/aquaponic (RAS_A) regarding water quality parameters generally, and TAN (total ammonia nitrogen) production and transformation, particularly.
Key words: recirculating system, aquaponics, sturgeons, water quality.

Introduction

Aquaponics are defined as integration of hydroponic plant production into recirculating aquaculture systems (RAS) and has been proposed as a method to control the accumulation of waste nutrients from fish culture (Rakocy and Hargreaves 1993) in a way that consumes less water and produces additional, saleable crops (Rakocy and Hargreaves 1993).

Plants cultured hydroponically (without soil) absorb nutrients, which are excreted directly by the fish or generated by the microbial breakdown of organic wastes. Fish feed provides most of the nutrients required for plant growth. As the aquaculture effluent flows through the hydroponic component of the recirculating system, fish waste metabolites are removed by nitrification and direct uptake by the plants, thereby treating the water, which flows back to the fish-rearing component for reuse. Aquaponics has several advantages over classical recirculating aquaculture systems. One of the main advantages, suggested in the present paper, is represented by the control of water quality parameters through uptake of nutrients by vegetable biomass.

Materials and Methods

A 8-weeks experiment was conducted in an experimental recirculating aquaculture system placed in a laboratory of the “Aquaculture, Environment Science and Cadastre” department of “Dunarea de Jos” University, Galati (the system was described in detail in a various of papers: Sfetcu L. et all., 2005; Cristea V. et all., 2005).

The principal attention in running of the experiment was daily control of water quality parameters to maintain optimal ranges for fish and for plants development. For the present experiment, the water samples were collected from different points of the system in order to have a clear view of the nutrients cycle throughout the system. Thus, for the integrated recirculating system the sampling points were represented by sedimentation tank (outlet of fish rearing units), inlet of biological filter, inlet of aquaponic modules, outlet of aquaponic modules (inlet of rearing units); for classical system the sampling points were similar excepting the hydroponic modules which were disabled (fig. 1).

The following equipment was used to measure the water quality: oxygen concentration and percentage saturation were measured with the WTW Oxi 315 i, pH was measured with the pH meter WTW, model pH 340 and NH_3, NH_4^+, NO_2^- and NO_3^- concentrations were measured by using the Lovibond Photometer PC 22.

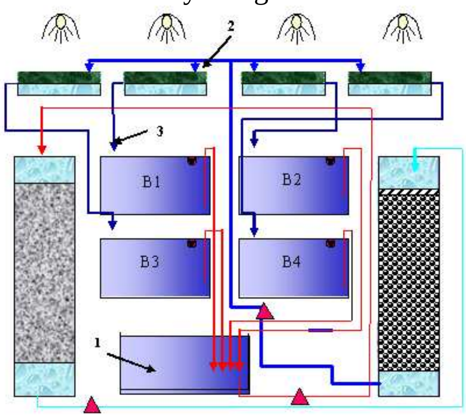

Figure 1. Aquaponic recirculating system – sampling points for water parameters measurements (1-aquarium outlet; 2 – hydroponic modules inlet; 3 – hydroponic modules outlet/ aquarium inlet)

The experiments were conducted in two consecutive periods, one month each, representing two distinct experimental variants (V1/RAS – experiment regarding nutrients dynamic in classical recirculation system and V2/RAS_A – experiment regarding nutrients dynamic in aquaponic recirculation system). In both cases we have used the same species, bester (a hybrid obtained from crossbreeding of *Huso huso* female and *Acipenser ruthenus* male), the same stocking density (5,04 kg/m^3), the same feed inlet (1,7% BW daily ratio) and the same feed pellets, 3mm, containing 46% protein. In recirculating systems, generation of total ammonia nitrogen (TAN) is a result of metabolism of protein provided by daily feed inlet. In conclusion, the ammonia production rate is directly depended on feeding rate, protein content of feed and proteic nitrogen quantity excreted by fish biomass as total ammonia nitrogen (TAN).

The ammonia removal rate from the classical recirculating system (RAS) was calculated with the following formula:

$TAN_{removal} = (Q/V * (C_{in}-C_{out})-C_{out}/dt)$

The amount of TAN retained in lettuce biomass in aquaponic recirculating system was calculated with the following formula:

$TAN_{retinut} = (Q/V * (C_{in}-C_{out}) - dC_{out}/dt)*d$

Where, Q=the flow rate (m^3/day), V= system volume (m^3), C=concentration of TAN (mg/m^3), d= aquarium depth (m), t=time (d)

Results and Discussions

The results presented in this paper represent a chapter from a complete assessment of integrated recirculating system efficiency from productive as well as technological and operational management perspective.

Temperature. Water temperature evolution can be seen in table 1. In the classical recirculating system the water temperature variate between 18,80°C (min) and 26.30°C (max), the average was 23,07±2,74 °C, while in the aquaponic recirculating system the water temperature reached values comprised between 16,93 °C and 19,80°C; the average for the all experimental period is 18,29 ± 0,67°C. Regarding differences registered for temperature, for both experimental periods, the T Student test emphasized significant differences ($P < 0.05$) for all sampling points reveled in table 1.

pH. In RAS, the pH varied between 6,90 (min) and 7,72 (max), with the average of 7,25±0,31 over experimental period, while in RAS_A the pH registered values comprised between 6,98 and 7,28, with the average for the experimental period of 7,18 ± 0,76 (Table 1). From a statistical point of view there weren't significant differences between the two recirculating systems regarding pH values ($p>0,05$), although significant differences were observed among the three sampling points of RAS_A ($p<0,05$).

Oxygen. In RAS the dissolved oxygen (DO) concentration varied between 4,60 mg/l (min) and 5,53 mg/l (max), with average of 5,03±0,30 mg/l, while DO in RAS_A registered values comprised between 5,90 and 6,53 mg/l, the average for entire experimental period was 6,19 ± 0,15 mg/l (Table 1). Regarding the dynamic of dissolved oxygen concentration from both experimental periods, the T Student test emphasized significant differences ($p< 0.05$) between the averages registered for the two recirculating systems: classical and aquaponic. Likewise, significant differences ($p< 0.05$) were recorded for the three sampling points of aquaponic recirculating system. The highest DO concentration was registered for outlet of technological water from hydroponic modules, respectively aquaria inlet.

Table 1.
Oxygen concentration, pH and temperature (± standard deviation- STD) for both systems and all sampling points

Water parameters	Sampling point	RAS		RAS_A		P*
		Media	STD	Media	STD	
Oxygen(mg/l O_2)						
	Aquaria inlet/hydroponic outlet	5,10	0,17	6,67**	0,17	0,000 *
	Aquaria outlet	4,90	0,24	5,58**	0,23	0,000*
	Hydroponic modules			6,32**	0,20	
	AVERAGE	5,03	0,30	6,19	0,15	0,005 *
pH						
	Aquaria inlet/hydroponic outlet	7,29	0,27	7,20**	0,70	0,21
	Aquaria outlet	7,21	0,28	7,17**	0,07	0,34
	Hydroponic modules			7,17**	0,85	
	AVERAGE	7,25	0,31	7,18	0,07	0,32
Temperature(^{0}C)						
	Aquaria inlet/hydroponic outlet	23,26	2,03	18,29	0,66	0,005 *
	Aquaria outlet	22,90	2,71	18,16	0,65	0,005 *
	Hydroponic modules			18,47	0,58	
	AVERAGE	23,08	2,74	18,29	0,67	0,005 *

*Significant differences for comparison between systems ($P < 0.05$).
** Significant difference for comparison between sampling points of the same system (($P < 0.05$).

Total ammonia nitrogen. In first the experimental week, in RAS, a rapidly decreasing of TAN was observed, while in the following weeks, the ammonia concentration stabilized and the system reached the stable state (fig. 2).

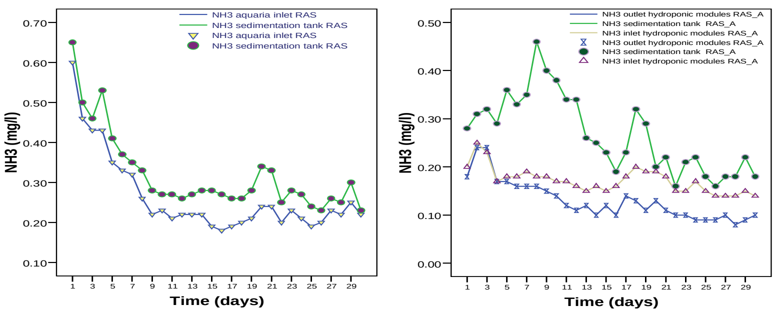

Figure 2. Ammonia variation in RAS (sedimentation tank, inlet aquaria) – left; ammonia variation in RAS_A (sedimentation tank, inlet hydroponic modules, inlet aquaria) – right.

The ammonia concentration maintained in the range of 0,21-0,29 mg/l, excepting the first days when values exceeded the technological limits (the highest concentration was 0,63 mg/l) and a higher refreshing rate was applied. The average concentration of ammonia measured in sedimentation tank was 0,31±0,09 mg/l, while the average ammonia concentration for fish aquaria inlet was 0,26 ±0,09 mg/l. From a statistical point of view, the difference between means of the two paired variables was found to be significant ($p<0.05$, df=29). In the second experimental stage (after integration of hydroponic modules) the ammonia concentration registered a slightly decreasing slope till the minimal value of 0,13 mg/l (average 0,18 ± 0,04 mg/l). Regarding the difference between mean ammonia of the two recirculating systems (classical and aquaponic), this was found to be statistically significant ($p<0.05$, df=29). For RAS_A, the average concentration calculated for values measured in fish sedimentation tank was 0,26±0,79 mg/l, while the values registered at fish tank inlet was 0,13 ±0,04 mg/l. Regarding the ammonia average concentration calculated for values measured at hydroponic modules inlet was 0,17±0,26 mg/l. The comparison tests regarding the mean differences between concentration measured in three distinct sampling points showed significant differences among all tested variables ($p<0.05$, df=29).

Regarding total ammonia nitrogen (TAN), the average concentration for RAS was 0.25±0,28 mg/l while for RAS_A the TAN concentration was 0,15±0,07mg/l. TAN removal rate varied between 0.64 mg/l/day and 3.98 mg/l/day (2.28 mg/l/day±0.83) for classical recirculating system, and between 2,60 mg/l/day and 12.05 mg/l/day (5.61 mg/l/zi±2.57) for integrated recirculating system. From entire TAN quantity introduced daily in the system with fodder (5,46 mg/l/day in RAS and 6,74mg/l/ day in RAS_A) approximately 29,52% was oxidized in biological filter in classical recirculating system and 45,43% was at the same time oxidized in biological trickling filter and retained in hydroponic modules in integrated recirculating system .

Nitrite. Nitrite, in RAS, registered an average concentration of 0,09±0,12 mg/l while, in RAS_A, the average concentration was 0,01±0,01 mg/l. The measurements performed in the three sampling points of integrated recirculating system emphasized differences in the first days of experiment and almost the same concentration for the rest of experiment (0,01 mg/l) (fig.3).

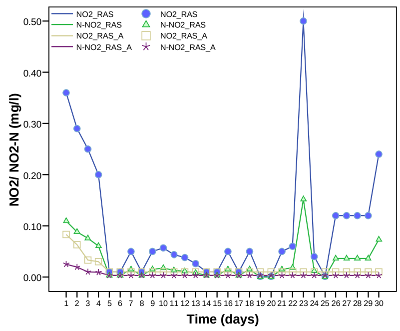

Figure 3. Nitrite concentration in RAS and RAS_A

Nitrate. The nitrate concentration, in classical recirculating system (RAS), showed an ascending line to the maximum concentration of 118 mg/l NO_3^- (29,12 mg/l NO_3-N) reached in the last days of experiment. In integrated recirculating system the nitrates were consumed, thus the concentration drop from 116,43 mg/l to 50,63 mg/l in the end of experiment (fig.4, left).

In the aquaponic recirculating system the highest values of nitrate concentration were registered to the inlet of hydroponic modules and the smallest concentration to the outlet of hydroponic modules (fig.4, right).

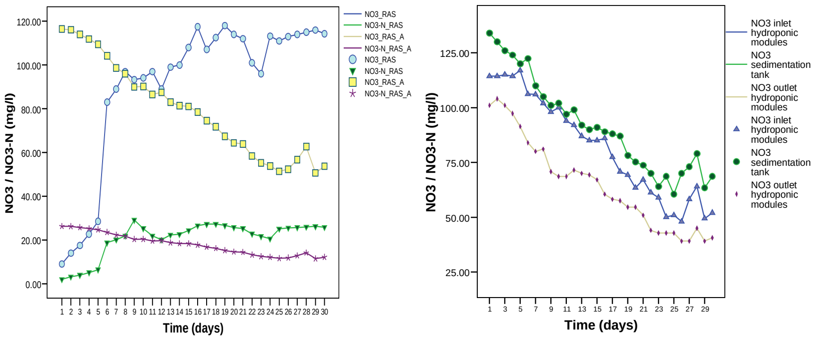

Figure 4. Nitrate concentration in RAS and RAS_A –left; nitrate concentration variation for the sampling points of RAS_A) - right.

As it can be seen in figure above, the average concentration of nitrates in RAS was 90,52 ± 6,26 mg/l comparing with aquaponic recirculating system where the average of nitrate concentration was 79,39 ± 3,96 mg/l. The means of the two variables were significantly different ($p<0.05$). Also, significant differences were registered when the means of the nitrate concentration measurements for each sampling point were compared. Thus, the average concentration of nitrates measured in sedimentation tank (21,88 ±3,99 mg/l) was lower than nitrate average concentration calculated for inlet hydroponic modules sampling point (23,28 ±4,25 mg/l) and higher than average concentration measured for outlet hydroponic modules sampling point (20,60 ±3,76 mg/l)

In a classical recirculating systems, the nitrates are not considered toxic products as long as does not accumulate to the alarming concentrations of 100 -200 mg/l. Over a production cycle period the nitrate concentration evolution tendency is to accumulate and rise above mentioned values; the only possibility to control nitrates in this case is represented by water replacement/refreshing rate. In aquaponic recirculating systems, the nitrates represents the main source of nutrients for plants development and, for this reason, the accumulation rate is very small or even null, when an appropriate operational management is applied.

Conductivity .For the present experiment conductivity represents a measure of total dissolved solids from technological recirculating water [(TDS)ppm = Conductivity µS/cm x 0.67]. In conventional recirculating system (RAS) the conductivity varied in the range of 112÷464, 60 µS/cm (55, 66 ÷230, 91ppm TDS), the average for all experimental period was 279, 33±106, 17 µS/cm or 138,82± 52,76 ppm TDS. In integrated recirculating system (RAS_A) conductivity varied in the range of 358,67÷476, 00 µS/cm (178,26÷236, 57 ppm TDS), the average for all experimental period registering 412, 11±36, 99 µS/cm or 204, 81± 18, 38 ppm TDS. Rakocy J., 2006 recommends, for plant optimal growth and high removal efficiency of nutrients, a TDS concentration ranging between 200-400ppm. In our experiment, the general trend of TDS concentration was to decrease due to a quicker uptake of nutrients by plants than waste production of fish biomass.

Conclusions

The parameters of water quality were maintained in optimal limits for bester rearing, over all experimental period; when these parameters exceeded optimal range (especially during first experimental period), an exchange of 5-10% from the total water volume of the system was applied.

Comparing with high amount of nitrogen input entered equally in the systems through feed, total ammonia nitrogen concentration was maintained at lower values in RAS_A in comparison with RAS, this confirming efficiency of hydroponic biofiltration units.

The dissolved oxygen concentration and pH measured at the outlet of the hydroponic units were slightly higher than those registered to the inlet of the hydroponic units. The difference shows that the hydroponic units may play an important role in oxygenation of technological water and as a buffer in maintaining the pH in neutral range.

Concentration of nitrates during the second experimental period (after the integration of the modules) was significantly lower than in the first period. This fact certify the hypothesis according to the aquaponic systems contribute to maintaining of technological water quality what has as effect the diminution of residual water amount.

The combination of fish rearing and vegetable production in the same recirculation system leads to an increase of nutrients retention from the culture system. Aquaponic systems require less water quality monitoring than classical recirculating aquaculture systems.

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