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Evaluation of condition and technological performance of hybrid bester reared in standard and aquaponic system

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Abstract. Bester sturgeon is considered a hybrid (cross between beluga *Huso huso* (Linnaeus, 1758) female and sterlet *Acipenser ruthenus* Linnaeus, 1758 male) with great potential for intensive aquaculture technology due to its quality caviar and meat production. Apart from Russia, first promising experiments on sturgeon culture have been carried out in several European countries (Germany, Hungary, France) and Japan as well as the U.S.A. Yet, in the field of bester sturgeon nutrition many authors consider that further investigation is desirable. In this context, the present experiment has as main goal the evaluation of bester capability for nutrients utilization and feed conversion under different feeding rates and environmental conditions. The trails were conducted in an experimental recirculating system and an aquaponic system in different development stages. For both experiments "Troco supreme" fodder with 46% protein content was used. The feeding efficiency was assessed through technological indicators. The fish condition (allometric factor) and growth performance was assessed for both rearing systems: standard RAS and aquaponic RAS.

Key Words: hybrid bester, recirculating aquaculture, intensive rearing, aquaponics.

Introduction. Producing fish in conventional RAS (recirculating aquaculture system), in which a large volume of water is refreshed and a limited number of water treatments units are used (essentially mechanical waste removal and biofiltration) has a smaller environmental impact than flow-through systems (Martins et al 2010). Nevertheless, in the last decade many efforts have been paid to limit the impact of aquaculture on aquatic environments. Integrating into the recirculating system's configuration of denitrification reactors, sludge thickening technologies and ozone treatments led to a further decrease in water use, waste discharge and energy use in RAS (David et al 2009). The new technologies, although highly efficient, are however expensive and difficult to manage. In this context, the approach of integrated recirculating aquaculture tends to balance the efficiency of high-tech RAS and add value to aquaculture waste (Gal et al 2010).

Nowadays, consumer demand for safer food products is very much on the increase. Aquaculture production systems must consider animal well-being and health in order to obtain high quality outcomes (Sammouth et al 2009). Those factors depend on proper control on water parameters and good husbandry practices which eliminate the risks for poor technological performance or flesh quality.

A method of improving effluent water quality characterized by high nutrient concentrations, especially nitrate, is to use hydroponic culture. Merging the two disciplines, wastewater treatment and crop production, requires moving the focus from optimizing the degradation, nitrification, denitrification and absorption rates to maximizing the recycling rates of phosphorus and nitrogen and to fulfilling the quality requirements of the resulting products such as plant biomass, fish and effluent water (Graber & Junge 2009).

In this study we considered the potential of two sustainable recirculation systems, with the goal of assessing whether the rearing in RAS and RAS-A (recirculating aquaponic system) conditions led to any differences in fish production. In this study we assessed: (1) fish growth performances; (2) water quality parameter dynamics; (3) fish condition.

Material and Method. The trials were conducted in the laboratory of the Aquaculture, Environmental Sciences and Cadastre Department of the University Dunarea de Jos, Galati. The experiments have been carried out in two experimental rearing systems: a recirculation aquaculture system (RAS, total volume 1.5 m^3) and a RAS connected to 4 modules for hydroponic production (RAS-A, total volume 1.8 m^3).

The recirculated treatment loop of the RAS consisted of 4 fish rearing units and water treatment units while the RAS-A configuration includes additional hydroponic modules (Figure 1).

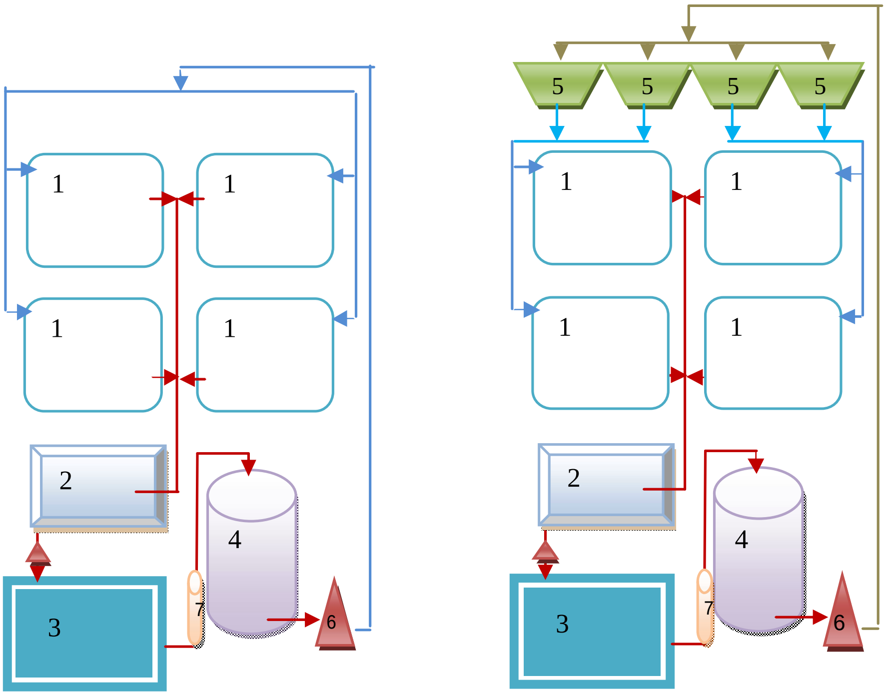

Fig. 1. Schematic representation of recirculation aquaculture systems (RAS) and aquaponic system (RAS-A); 1:Rearing tank; 2:Water distribution storage tank; 3:Sand filter;4: Biofilter; 5: Hydroponic units; 6: Pump; 7: UV reactor.

Rearing modules unit – are represented by 4 rectangle aquariums with a volume of 300 litters/aquarium. Water conditioning unit has the mission to control and maintain in optimal range the main water quality parameters such as: oxygen concentration, ammonia nitrogen concentration, total suspended solids concentration, pH and carbon dioxide. Thus, for the TSS (total suspended solids) and settable solids control the recirculating system has been provided with a submerged sand filter. The mechanical filter has a foot plate with tronconic items of hard plastic material where a number of long gaps are realized; through those gaps the filtrated water is passing without involving the filtration material represented by the quartz sand. For the biological filtration have been used a trickling filter. The sterilization and disinfection process is realized with a UV installation mounted on the principal supply flow of the rearing units. The technical characteristics of the UV lamp, TERA POND, Type UV-C 35000 is the power -36Watt, that assures the right amount of gamma radiation with optimal length wave for the technological flow. For oxygen concentration supply dictated by the stocking intensification degree, the recirculation system was provided also with an oxygenation unit formed by one compressor Resun Air-Pump, Model: ACO-018A with a flow of 260L/min. Water distribution installation consists in three pumps, Grundfos, type UPbasic 25-6 180, max.10bar, which assures the technological flow necessary for each rearing unit. The flow rate was maintained to 12 L/min for both systems. Before starting up the experiment the biofilter was activated for developing a healthy population of nitrifying bacteria capable for removing the ammonium and nitrite.

Water of both systems was sampled twice a week at 9:00 am. For RAS, 50 mL of water were collected at the inlet of the biofilter (considered as the outlet of the mechanical filter), from water distribution storage tank (considered as the outlet of the fish rearing tanks and mechanical filter inlet) and at the outlet of biofilter (considered inlet of the fish tank), for the assessment of the biofilter nitrification activity. For RAS-A, besides sampling points mentioned above, 50 mL of water were collected at the outlet of the hydroponic modules (considered as the inlet of the fish tanks) for the assessment of plant filter activity (Cristea 2002).

The following water quality parameters were controlled every day within the system: pH; temperature; dissolved oxygen concentration. Every two days ammonium, nitrite and nitrate concentrations were checked and if those parameters exceeded the critical levels, the water was exchanged (but not more than 10% daily) in order to maintain the values within the experimental range.

The following equipment was used to measure the water quality parameters: 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 conductivity was measured with Cond 740 WTW.

Determination of NH_4^-, NO_2^-, NO_3^- and PO_4^{3-} was carried out using the photometric method. The biochemical analyses were performed using Kjeldahl method for proteins and Soxhlet method for fats.

For the first experiment, recirculating system (RAS) was populated with a total biomass of 4442g randomly distributed in the four tanks as follows: 1104 g to B1, 1114 g to B2, 1106 g to B3 and 1118 g to B4 unit. In the second experiment, recirculating aquaponic system (RAS-A) was populated with a total biomass of 5038 g, biomass distributed differently in the four tanks as follows: 1263 g to B1, 1257 g to B2, 1238g to B3 and 1280g to B4. The mean individual initial and final weight and length measurements are given in Table 1.

Table 1

Initial biometric data for the sturgeons populated in the classical and aquaponic systems

	System	*RAS*		*RAS-A*	
Rearing unit		Mean	Std. Deviation	Mean	Std. Deviation
B1	Initial weight (g)	92.00	21.30	251.33	45.49
	Initial length (cm)	28.62	2.03	40.66	1.40
B2	Initial weight (g)	92.83	11.81	253.83	28.29
	Initial length (cm)	28.41	1.90	39.91	1.24
B3	Initial weight (g)	127.81	24.76	241.25	33.97
	Initial length (cm)	32.22	1.70	39.75	1.25
B4	Initial weight (g)	128.90	29.99	260.50	37.75
	Initial length (cm)	31.59	2.36	41.25	2.02

For both systems (RAS and RAS-A), the feeding ratio used was 1% BW/day in the first two tanks (B1 and B2) and 2% BW/day in the last two rearing units (B3 and B4). On the first day of the experiment, to be gradually accustomed to food, fish were fed with 25% from calculated ratio on the first day, 50, 75 and finally 100% in the fourth day. The daily feeding rate was administered in four meals that were distributed every three hours, starting at 9.30 am. Fish were fed pellets of 3mm with a protein content of 46% (Table 2).

Table 2

Biochemical composition of feed Troco supreme (3 mm)

Composition	*Wet weight (%)*
Protein	46%
Fat	16%
Fibre	1.5%
Ash	9.5%
Phosphorus	13%
Calcium	1.9%
Lizin	3.1%
Metionin	1.1%
Vitamin A	15000 UI/kg
Vitamin D_3	2000 UI/kg
Vitamin E	200 mg/kg
Vitamin C	280 mg/kg

In the end of the experiment the fish were weighed and the growth performance of the fish assessed using the following equations: Weight Gain (W) = Final Weight (Wt) - Initial Weight (W0) (g); Food Conversion Ratio (FCR) = Total feed (F) / Total weight gain (W) (g/g); Specific Growth Rate (SGR) = 100 x (ln Wt - ln W0) / t (% BW/d); Relative Growth Rate (RGR) = (Wt -W0)/ t /BW) (g/ kg/d); Protein efficiency ratio (PER) = Total weight gain (W) / amount of protein fed (g);Relative Weight Gain (RWG%) = (Wt – W0) x 100 / Wt; Condition factor (CF)=100xW/$(L_{fish})^n$, where n is the allometric factor calculated by linear regression.

Statistical analysis was performed using the SPSS 15.0 for Windows. Statistical differences between variables were tested using t test or Anova ($\alpha = 0.05$) after a normality test (Kolmogorov-Smirnov) and an equal variance test for homoscedasticity (Fisher test). The coefficient of variation (CV) was calculated as the ratio of the standard deviation to the mean.

Results and Discussion

Water quality parameters. In the present experiment, the dissolved oxygen concentration (DO) in the standard recirculating system ranged between 4.60 mg L^{-1} (min) and 5.53 mg L^{-1} (max), the average for the overall period was 5.03±0.30 mg L^{-1}, while DO concentration in aquaponic system showed a narrow range comprised between 5.90 and 6.53 mg L^{-1}, with a mean of 6.19 ± 0.15 mg L^{-1}.

The statistical analysis emphasized significant differences (t-test, $p<0.05$) between the systems and within the aquaponic system's different sampling points (Anova, $p<0.05$). Thus, post-hoc analysis showed that mean DO value registered at the outlet of hydroponic modules was significantly higher than those measured at fish thank outlet or biofilter inlet.

The concentrations of TAN, NO_2–N, NO_3–N and TDS (total dissolved solids) in the rearing water are shown in Table 3. The nutrients concentrations in RAS-A were low because of their continuous removal by plants. There were not statistically significant differences in TAN concentrations between the two recirculating systems. Nitrite and nitrate concentrations were statistically lower in the RAS-A compared with the RAS (t test, $p<0.005$).

Table 3

Mean (±SD) values for the main water quality parameters in standard and aquaponic recirculating system

Rearing system	*TAN (mg L^{-1})*	*N–NO_2^- (mg L^{-1})*	*N–NO_3^- (mg L^{-1})*	*O_2 (mg L^{-1})*	*TDS (mg L^{-1})*	*pH*	*T^0C*
RAS	0.43±0.26	0.003±0.03	20.83±8.00*	5.03±0.30*	204.81±18.38*	7.25±0.31*	23.07±2.74*
RAS-A	0.40±0.19	0.002±0.01	17.92±4.89*	6.19±0.15*	138.82±52.76*	7.18±0.07*	18.29±0.67*

*Statistically significant difference ($p<0.05$) between RAS and RAS-A.

Compared to flow-through or ponds, reuse systems typically have significantly reduced make-up flows that can result in the build-up of some compounds (Colt 2006). In the present experiment the higher refreshing rate in RAS system (3 times higher than in RAS-A) allowed the control of toxic compounds through dilution, which was not the case of aquaponic system where the residual nutrients were assimilated by lettuce.

Fish performances. In the first experiment, the average individual weight of bester was 110.38 ± 21.96 g and the total length 30.21 ± 1.99 cm, while at the harvest mean individual weight recorded 123.83±31.79 g and total length 43.64 ± 5.10 cm. In the second experiment, the average individual weight was 251.72 ± 36.37 g and the total length 40.39 ± 1.47 cm while at the harvest, individual weights recorded an average of 397.60 ± 45.05 g and total length 45.05 ± 2.57 cm. The mean and standard deviation values for the weight (g) and the length (cm) of the bester from the four rearing units are detailed in Table 4.

Table 4

Initial biometric data for the sturgeons populated in the classical and aquaponic systems

Rearing unit	*System*	*RAS*		*RAS-A*	
		Mean	Std. Deviation	Mean	Std. Deviation
B1	Final weight (g)	102.91	26.34	364.83	117.19
	Final length (cm)	55.370	7.67	44.50	2.94
B2	Final weight (g)	102.33	15.07	331.83	46.66
	Final length (cm)	30.75	1.85	43.33	1.69
B3	Final weight (g)	144.45	39.48	445.75	98.71
	Final length (cm)	32.27	3.28	45.62	2.09
B4	Final weight (g)	145.63	46.28	448.00	156.93
	Final length (cm)	56.18	7.62	46.75	3.57

There was no difference in weight gain among the fish in the two replicate tanks for each rearing system. The results in terms of growth efficiency showed better records for the fish fed with 1%BW/day comparing with those receiving 2%BW/d in both trials (Table 5). However, in the second experiment the FCR and PER differences amongst basins were negligible comparing with gained biomass which was evidently higher for the B3 and B4 basins.

Comparative analysis of the two systems reveled a better performance of fish reared in aquaponic recirculating system: FCR mean value for RAS was 1.66 comparing with 1.15 obtained for RAS-A; SGR mean value for RAS-A was 1.29 versus 0.72 in RAS; RGR in RAS was only 0.83, with 4.96 times lower than RAS-A.

Table 5

Technological indices of the fish sampled at the end of the first (RAS) and second (RAS-A) trial

Production system	*Rearing unit*	*SGR (% BW/d)*	*DGR (g/kg/d)*	*FCR*	*PER*
RAS	B1	0.60	0.60	1.53	1.42
	B2	0.52	0.52	1.77	1.22
	B3	0.66	0.93	2.76	0.79
	B4	0.66	0.93	2.76	0.79
RAS-S	B1	1.09	3.30	0.79	2.75
	B2	0.97	2.87	0.90	2.41
	B3	1.53	4.93	1.04	2.10
	B4	1.59	5.37	0.98	2.21

The differences between the two recirculating systems reveled by comparison of the main technological performance indicators could be explained due to interference of some influence factors. The mean individual weight of the fish populating the RAS-A system was higher comparing with mean weight of the fish from RAS system and, although we expected to slower growth rate associated with older fish the results showed contrarily a better performance. This is due, first of all, to the water quality parameters, among which temperature plays an important role (Docan et al 2011).

Thus, in order to perform a comparative analysis for the fish maintained in different thermal conditions is recommended to use a proper coefficient that will cancel the differences and will estimated a growth curve based on the performance registered in the given conditions. This coefficient, experimented by Kleiber in 1775 on mammals and adapted for fish by Cho (1992), can be used to predict a biomass gained in different thermal conditions then those experimented:

$$TGC = [FBW\ (g)^{1/3} - IBW\ (g)^{1/3}] \ / \ \Sigma\ [Temp(^{0}C) \times Time\ (days)]$$
$$EFBW = [IBW\ (g)^{1/3} + \Sigma\ [TGC \times Temp(0C) \times Time\ (days)]^{3};$$

Where: TGC - thermal growth coefficient; FBW – final body weight; IBW – initial body weigt, EFBW – estimated final body weight.

Considering that there were found significant differences (t test, $p<0.05$) between temperature of the two systems and that this could be an important influence factor for the growth performance, the final weight for the RAS-A system have been estimated based on TGC calculated for the first system. Thus, mean value for the TGC calculated for the individuals maintained in RAS conditions was 19.8×10^{-4}, and the predicted final biomass of the fish reared in the second system (RAS-A), based on the TGC obtained for the biomass held in RAS, was 6347.78g comparing with 7755g, the real final biomass. On the other hand, the predicted final biomass for RAS system on the base of TGC calculated for RAS-A system (49×10^{-4}) was 6959g instead of 5650.32g that were obtained.

This result shows that the average temperature of 23.07 ^{0}C at which RAS system operated exceed the optimal range for sturgeons.

In our experiments the associated factors of lower temperature and better water quality parameters conducted to better results in the second experiment in spite of the larger individual weight normally associated with a lower specific growth rate.

Fish condition. Length-weight regression analysis performed for the both experimental stages revealed a higher determination coefficient (r^2 = 0.85) for fish used to populate classical recirculating system (homogeneous population) compared with those who inhabited aquaponic recirculating system (r^2 = 0.75). At the end of the second experiment, length-weight regression analysis performed on exemplars taken from the two recirculating systems, classical and aquaponic, emphasized a lower determination coefficient value in the first case (r^2 = 0.65), dispersion being evident (high variability) compared with the integrated system, where homogeneity was recovered and reflected in a high determination coefficient (r^2 = 0.87).

The coefficient of variation is the measure of dispersion and is calculated by dividing the mean to standard deviation. In this case, the CV increased from 25% to 35% for classical recirculating system, RAS and a slight decreased from 20% to 13% for aquaponic recirculating system (Figure 2). These values confirm the above regression analysis, although statistically it is considered as a coefficient of variance <35% reflects a series with a high degree of uniformity.

In aquaculture water's physical and chemical properties (herein referred to as water quality) are strongly influenced by the technological approach and indirectly by the fish wastes, flow or exchange rate. Fishes may incur additional energetic costs associated with stress responses from physical and chemical fluctuations in aquatic systems (Barton & Iwama 1991). Poor water quality, as determined by each species, can prompt the reallocation of energy from secondary (non-essential) physiological processes (e.g., growth, reproduction) towards primary (essential) processes (e.g., metabolism, immune function). Thus, adequate, or preferably ‘‘optimal’’, water quality is essential for holding fish in an environment that will neither activate their stress responses nor alter their normal energy budget (Portz et al 2006).

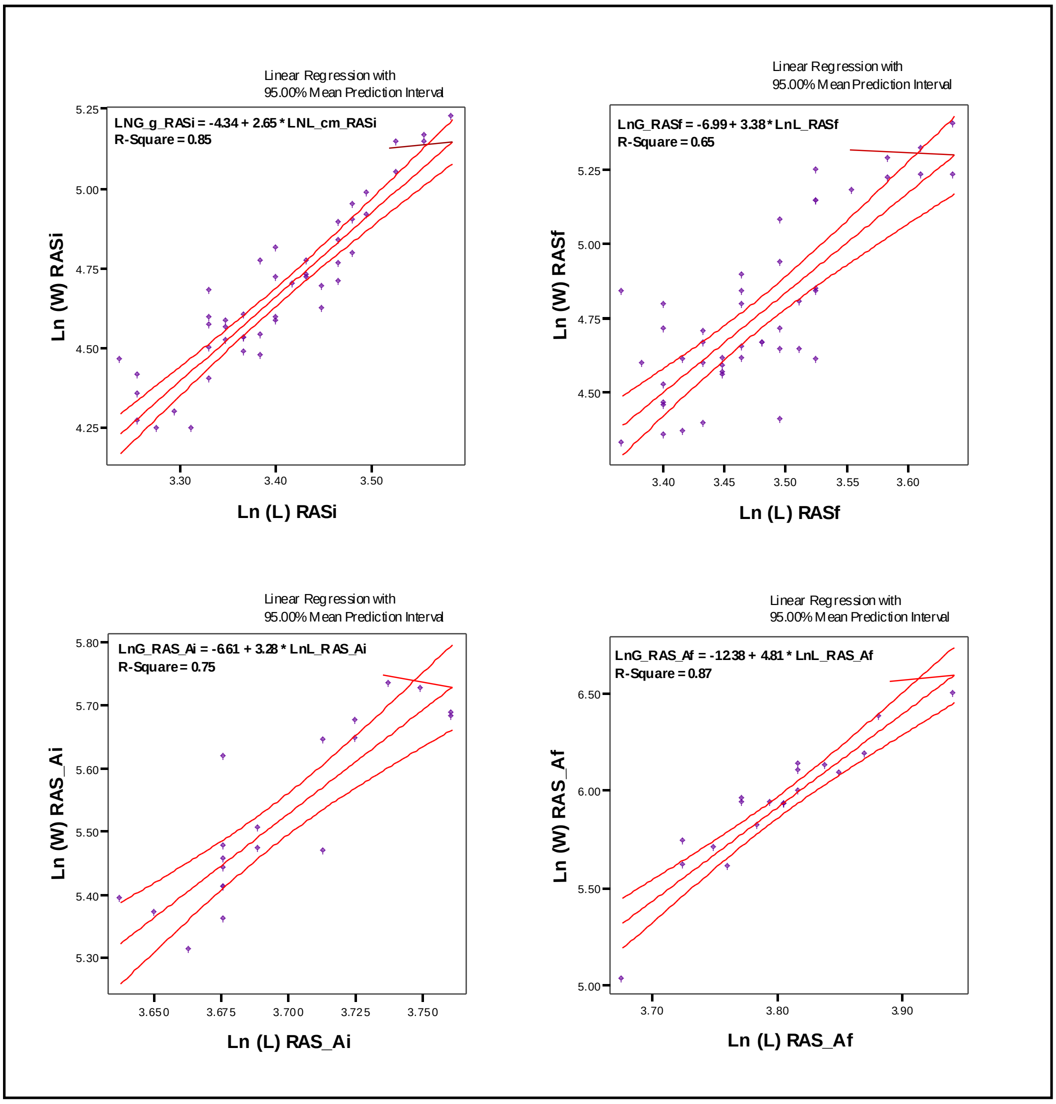

Figure 2. Length-weight relationship in populated and harvested bester for both classic and integrated recirculating systems.

In order to investigate the fish condition exposed to different water quality parameters we have used a simple and effective tool represented by allometric condition factor.

The basic assumption underlying the use of condition factors is that fish in better “condition” (nutritional and health status) are more full-bodied and therefore heavier at a given length. Traditionally, in aquaculture is used Fulton’s condition factor. Braga (1986) stated that Fulton’s condition is only adequate for comparison of fish of the same size, while the allometric condition factor allows studies of different length ranges.

In the present experiment, the allometric condition factor for bester sturgeon reared in RAS, was significantly ($p<0.05$; t-test) lower in the end of the trial comparing with the initial measurements, while for RAS-A, allometric factor significantly improved during the trial ($p<0.05$; t-test). Have not been registered significant differences (ANOVA; $p>0.05$) among rearing units for neither of the systems. The mean values for allometric condition factor calculated in the beginning and the end of the both trials are synthesized in Table 6.

Table 6

Allometric condition factor for bester sturgeon calculated in the beginning and in the end of experiments

Rearing system	*Statistical parameters*	*Rearing units*			
		B1	B2	B3	B4
RASi	MEAN	*0.39*	*0.41*	*0.38*	*0.40*
	STD	*0.05*	*0.05*	*0.03*	*0.03*
RASf	MEAN	*0.30*	*0.36*	*0.46*	*0.35*
	STD	*0.16*	*0.08*	*0.21*	*0.19*
RAS-Ai	MEAN	*0.37*	*0.40*	*0.38*	*0.37*
	STD	*0.04*	*0.03*	*0.02*	*0.01*
RAS-Af	MEAN	*0.39*	*0.42*	*0.44*	*0.43*
	STD	0.08	0.03	0.06	0.06

Conclusions. Bester growth rates were compared in the two rearing systems: recirculating aquaculture system (RAS) and aquaponic system with reuse of the waste water after treatment in hydroponic modules. The reuse hydroponic treated water increased fish growth over a month period. It also had a positive effect on fish conditions, reduced variability and improved feeding efficiency. This slower growth in the RAS cannot be only explained by the concentration levels of the rearing parameters but also by higher temperature which exceeded the optimal range for bester.

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