AACL BIOFLUX

Aquaculture, Aquarium, Conservation & Legislation
International Journal of the Bioflux Society

The influence of stocking density on the growth of common carp, *Cyprinus carpio,* in a recirculating aquaculture system

Ionica Enache, Victor Cristea, Tudor Ionescu, and Săndita Ion

„Dunărea de Jos" University of Galaţi, Faculty of Food Science and Engineering, Galați, Romania, European Union. Corresponding author: I. Enache, enaoana@yahoo.com

Abstract. The paper presents some aspects regarding the influence of stocking density on the breeding of the common carp in a recirculating aquaculture system (RAS). The experiment covered a 30 day-period. It was conducted in four aquaculture tanks, 500 L/tank, in the recirculating aquaculture pilot system of "Dunarea de Jos" University of Galați. Two kind of stocking density variants were compared: 64 kg/m^3 in V1 (B1, B3) and 32 kg/m^3 in V2 (B2, B4). The stocking density was: 491 fish in B1, average weight - 65 g/ fish; 245 fish in B2, average weight - 66 g/ fish; 211 fish in B3, average weight - 152 g/fish; 107 fish in B4, average weight - 150 g/fish. The technological indicators obtained revealed the following: the specific growth rate (SGR), calculated as a mean value on the two repetitions, was 1.28%/day in V1 and 1.49 %/day in V2, indicating better growth in V2; the food conversion ratio (FCR), calculated as the mean value of the two repetitions, was 1.28 in V1 and 1.06 in V2, expressing a higher efficiency in capitalization of food in V2. The mean biomass gain in V1 was 30.46 kg/m^3 as compared to 18.55 kg/m^3 in V2, almost perfectly correlated with the stocking density. The daily growth rate (DGR) varied in a similar way, from 494.57 to 520.90 g/day in V1 and 302.4 to 315.9 g/day in V2. The experiment demonstrated a remarkable technological plasticity in both experimental variants, whereas, in terms of technological performance indicators, it was found that the application of lower stocking densities lead to higher crop biomass. The high stocking density means, therefore, large amounts of metabolic waste, removed from the breeding units through their effluent, the recirculating flow of which is 4m^3/h, enough to ensure the whole volume of water in a growth tank to be changed every half hour.

Keywords: common carp, RAS, stocking.

Rezumat. Lucrarea prezintă aspecte privind influenţa densităţii de populare asupra crapului, crescut într-un sistem recirculant de acvacultură (RAS). Experimentul s-a desfăşurat pe o perioadă de 30 de zile. S-au folosit patru unităţi de creştere, cu o capacitate de 500 L/unitate, în cadrul sistemului recirculant pilot al Universităţii "Dunărea de Jos" din Galaţi. Au fost comparate doua variante de densitate: în V1 (B1, B3) s-au introdus 64 kg/m^3 iar in V2 (B2, B4) 32 kg/m^3. In B1 densitatea de stocare este de 491 exemplare cu masa medie de 65 g/exemplar, în B2 de 245 exemplare cu masa medie de 66 g/exemplar, în B3 de 211 exemplare cu masa medie de 152 g/exemplar iar în B4 de 107 exemplare cu masa medie de 150 g/exemplar. Indicatorii tehnologici obţinuţi se prezintă astfel: rata specifică de creştere (SGR) calculată ca medie a celor doua repetiţii a fost 1,295 %/zi în V1, respectiv 1,515 %/zi in V2, ceea ce indică o creştere mai buna în varianta V2; rata de conversie a hranei (FCR), calculată ca medie a celor două repetiţii a fost 1,28 în V1 şi 1,06 în V2; aceasta exprimând un randament superior de valorificare a hranei în V2. Sporul de creştere în V1 a fost de 30,46 kg/m^3 în timp ce în V2 a fost de 18,55 kg/m^3. Acest indicator se corelează aproape perfect cu densitatea de stocare. Rata zilnică de creştere (DGR) a variat într-un mod similar, de la 494,57 la 520,90 g / zi în V1, respectiv de la 302,4 la 315,9 g / zi în V2. Experimentul a demonstrat o plasticitate tehnologică remarcabilă în ambele variante experimentale, însă sub aspectul indicatorilor de performanţă tehnologică s-a constatat că aplicarea densităţilor de populare mai scăzute conduce la obţinerea unor sporuri de biomasă de cultură mai mari. Densităţile ridicate de stocare presupun, implicit, cantităţi însemnate de reziduri metabolice care sunt eliminate din unităţile de creştere prin efluentul acestora, al cărui debit de recirculare este de 4m^3/h, acesta asigurând preschimbarea întregului volum de apă, dintr-un bazin de creştere, la fiecare jumatăte de oră.

Cuvinte cheie: crap, RAS, densitate.

Introduction. Raised in China for over 3000 years as a food source, the common carp has become over time the most popular farmed fish. The specific, omnivorous, way of feeding, the relatively small requirements if compared to the quality of environmental conditions and high one of the meat, are some of the arguments justifying why the carp (*Cyprinus carpio*, Linnaeus 1758) is the main species of culture farms in Romania and not only. It is raised in ponds in Israel, Europe and Asia, while in North America and Australia, according to some specialists, it is regarded as a harmful species because it destroys the vegetation and defiles the water (Berra 2007).

The remarcable ecotehnological plasticity of the carp has led, in recent years, to conducting a set of experiments on its intensive in controlled production systems of recirculating type. The design, technology and operational management of intensive aquaculture recirculating systems it is known to be overwhelmingly dependent on its bearing capacity, also defined by the stocking density. Therefore, high density stocking requires the removal of large amounts of metabolic waste Therefore, high density stocking requires large amounts of metabolic waste removal (Bhakta et al 2009). Under these circumstances, the water quality in intensive aquaculture recirculating systems becomes paramount. The economic performance of a recirculating production system largely depends on the cost of the equipment in the water treatment unit. All recirculating aquaculture systems remove waste solids, oxidize ammonia and nitrites, remove carbon dioxide and aerate or oxygenate the water before its return to the culture tank. In the case of systems with a high degree of production intensity or when the crop species is most sensitive to environmental conditions, the water requires further treatment consisting in removal of fine solids and dissolved organic matter and the application of certain procedures of disinfection (Cristea et al 2002). Stocking density is a key factor in determining productivity and profitability of aquaculture systems production (North et al 2006).

Material and Method. The material base for the experimental measurements was the pilot recirculating system of the Department of Fisheries and Aquaculture, "Dunarea de Jos" University of Galați. Experiments were conducted for a period of 30 days, between August and September 2010, in four rearing units with a capacity of 500 L/unit.

The configuration of the pilot recirculating system for carp intensive growth (see Figure 1) was designed and realized so as to integrate water treatment equipment (mechanical, chemical and biological filters) and breeding units, sized according to specific technology (Cristea 2008).

Conditioned by the role played in RAS, the integrated components of the pilot in Figure 1 are grouped into two categories:

- essential components including: breeding tanks, mechanical filter, biological filter, disease control equipment, pumps, components for the management of dissolved gases (oxygen and carbon dioxide), air conditioning equipment, independent electrical generator;
- secondary components: technological space, monitoring equipment for water quality, food distribution system, raw material storage facilities, facilities for administrative activities.

The recirculating system consists of four octagonal breeding tanks, the geometry and hydraulic technology of which meet the technological requirements in terms of efficiency to remove solids. The effluent of the 4 breeding units is collected and transported by a mechanical filter (drum filter), retaining solid particles and removing them regularly. The process of solids removal continues in the next stage of mechanical filtration by means of a sand filter and an ACLM 05 - ROMET Buzau type of charcoal (10 m^3/h - maximum filtering speed). The circuit of the water between the mechanical and the biological filters is ensured by a recirculation pump P_1, the water reaching the top of the biological filter (medium volume filter: 1.3 m^3). The collecting of water is gravitational in the tank at the bottom of the biofilter. From this point on, the water is taken by pump P_2 to the denitrifying filter (work pressure: 2.0 to 6.0 bar) and a UV filter (wavelength: 254 nm), then it is transferred into the breeding units.

The recirculating system is equipped with a sensor system that ensures monitorization of the following parameters: level, temperature and dissolved oxygen concentration in all four breeding units, input and output flows in each unit, ammonia concentration measured in two points - before and after the biofilter, nitrite and nitrate concentration, dissolved oxygen concentration measured after the biological treatment of water, the pH in the drainage basin of the mechanical filter, and the pH in the output flow. The system is equipped with a control module for the following variables: dissolved oxygen concentration and water level in each basin, pH in the filter tank driver. The level in the pools controlled by an automatic valve, placed after the mechanical filter, meant to ensure water supply. The recirculation flow is controlled by an on/off option in pumps P_1 and P_2, respectively. The objective of the control system is to keep within prescribed limits the values of key parameters in water quality: dissolved oxygen, ammonia, nitrite and nitrate concentration.

The components of the recirculating system are sized depending on recirculation flow and is 4m³/h, ensuring the changing of the entire volume of water in a breeding pool every half hour.

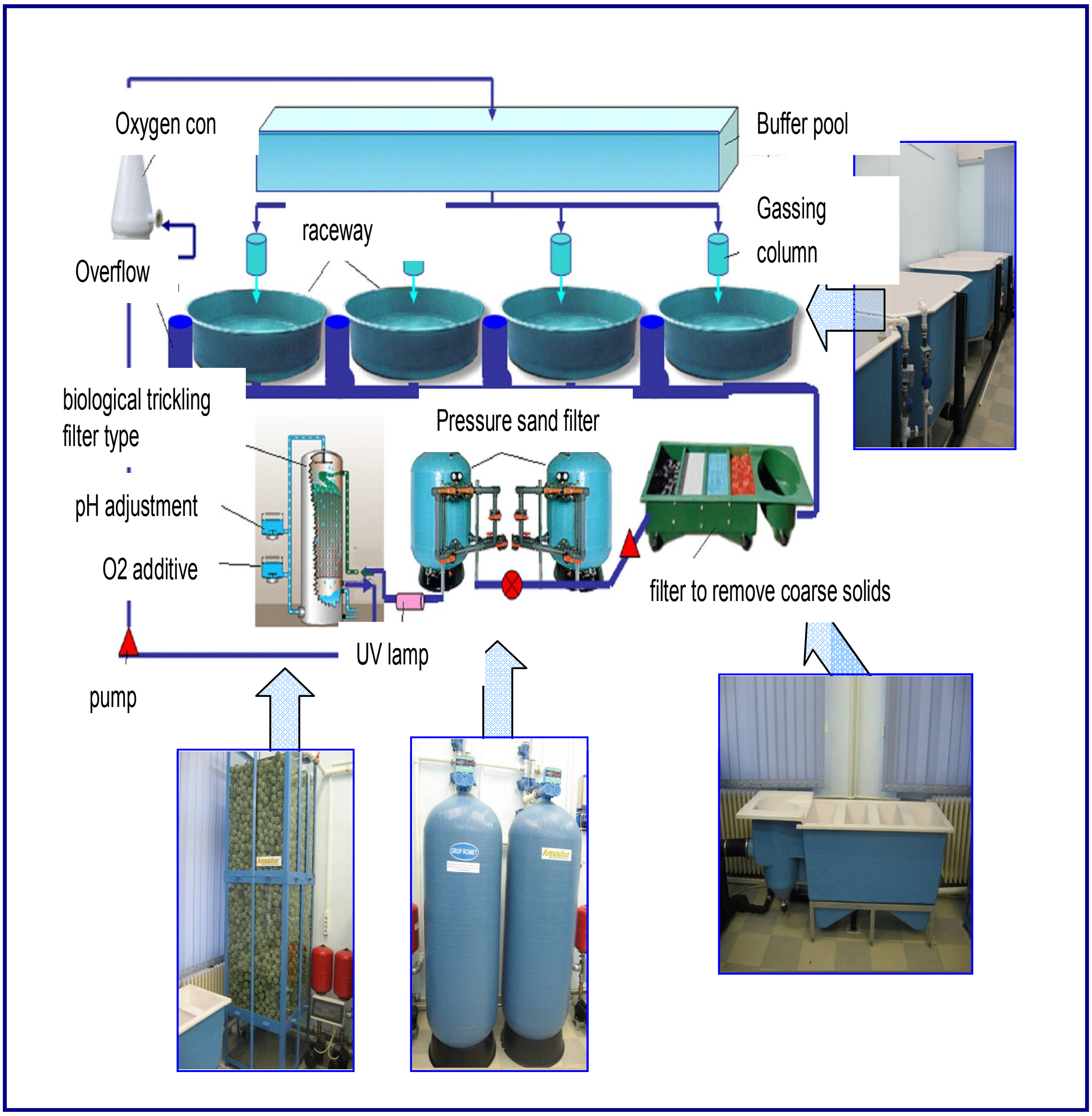

Figure 1. Recirculating system layout (Cristea 2008).

The biological material used in the experiment is represented by carp sapling, aged 15 months, provided by the Research Institute of Aquatic Ecology and Development, Fisheries and Aquaculture, Galati, from the Brates breeding station. We have experimented two types of density:

• Experimental version 1:
B1-64 kg/m^3-491 specimens, 65 g/sample average weight,
B3-64 kg/m^3-211 specimens, 152 g/sample average weight.
• Experimental version 2:
B2-32 kg/m^3-245 specimens, 66 g/ sample average weight,
B4-32 kg/m^3-107 specimens, 150 g/ sample average weight.

Somatic measurements were made on 20 samples from each tank, at the beginning and at the end of the experiment, determining total length (TL), standard length (LS), head length (HL), body depth (Hc), body weight (W) (see Tables 2 and 3).

The food used for the biomass culture was type MASTER Aller pellets, 4mm grain, 35% protein content (see Table 1 for biochemical composition). The ratio used was 1.7% for body weight. The pellets were automatically distributed by a tape dispenser with a capacity of 5 kg (see Figure 2). Being administered continuously in the breeding units, from 9 a.m. to 9 p.m., the food provided equal opportunities for all fish in the tanks.

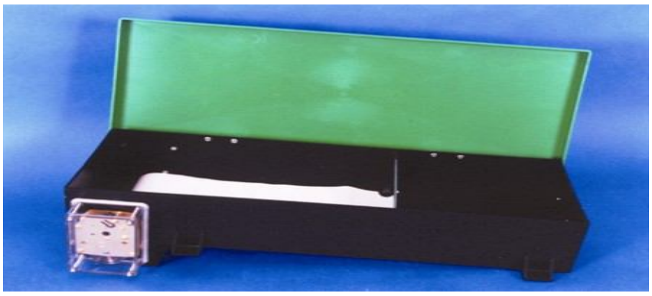

Figure 2. Tape dispenser

Table 1

Chemical composition of ALLER MASTER 4mm pellets

Nutrients	*Quantity*
Crude protein	35%
Crude fat	9%
NFE	36%
Ash	7.8%
Fibres	4.2%
Gross energy	4476/18.7 Kcal/MJ
Convertible energy	3485/14.6 Kcal/MJ
N in dry matter	6.1%
P in dry matter	1.3%
Energy in dry matter	4865/20.3 Kcal/MJ
Vitamin A	2500 (IE)
Vitamin D3	500 (IE)
Vitamin E	150 (mg)

Generally, in common carp feeding, the protein necessary varies between 35% and 45% for larves, between 30% and 40% for saplings, and between 20% to 30% for consumption fish in summer II and III (Oprea & Georgescu 2000). ALER MASTER has a high energy content and is recommended for intensive carp production. Its composition is as follows: fish flour, soy, pea protein, flour, rapeseed, wheat, fish oil, vegetable oil, minerals and vitamins.

Results and Discussion. The objective of this study was to determine the effect of stocking density on performance indicators, for *C. carpio*, in an industrial recirculating aquaculture system. The main somatic measurements of fish at the start and at the end of experiment are given in the Table 2 and Table 3.

Table 2

Initial somatic measurements (at stocking)

Parameter/ Variant	*TL (cm)*	*SL (cm)*	*HL (cm)*	*Hc (cm)*	*W (g)*
B1	15.2-19.2	12.1-14.9	3.3-3.9	3.7-4.2	42-92
B2	16.3-19.2	12.9-14.9	3.4-4.4	3.9-4.5	56-103
B3	19.1-25.4	14.8-20.2	3.8-5.1	4.4-5.3	93-260
B4	18.8-27.9	14.7-21.9	4.7-6	4.8-6.1	94-270

Table 3

Final somatic measurements (at harvesting)

Parameter/ Variant	*TL (cm)*	*SL (cm)*	*HL (cm)*	*Hc (cm)*	*W (g)*
B1	16.6-22.4	12.4-19.9	3.3-4.4	4.2-6.1	68-150
B2	16.2-22.7	12.6-17.7	3.5-4.4	4.4-5.9	64-166
B3	20-28.6	15.1-23.1	4.1-6.1	5.5-7.9	124-346
B4	21-29.2	14.9-23.3	4.3-6.2	4.9-7.9	110-364

Regarding water quality, during the experiment the following parameters were monitored daily: temperature ranged from 18 to 26°C (optimal for breeding), oxygen from 3 to 6.8 mg/L (lower values were recorded in the double-density tanks), nitrates between 7.9 and 14.4 (lower values occurring in low density tanks), ammonium between 0.4 to 2.2 and pH between 7.1 and 7.8.

If compared with the preoccupation for the intensity of terrestrial animal production, stocking densities applied in fish breeding are a major, general concern. This study evaluated the way density influences growth performance: final weight, specific growth rate (SGR), food conversion ratio (FCR). Intensive growth inevitably involves increasing the stocking density much more than in natural habitats. This is even more valid for the densities used in recirculating aquaculture systems. For this reason, public, scientific and governmental attention has focused on stocking density, considered as a key factor that may affect the pathological condition of fish in intensive farming systems (Van de Nieuwegiessen 2009).

In both experimental variants, V1 (tanks B1, B3) and V2 (tanks B2, B4), significant growth gains were achieved, under the circumstances of a 98-100% survival rate. In variant V2, where the stocking density was lower than in V1, the growth gain increased. The analyses of the average values of each variant showed an increase of fish biomass of 30.46kg/m^3 in V1 and 18.55 kg/m^3 in V2. The daily growth rate (DGR) the technological indicator showing a theoretically linear growth of fish, ranged from 494.57 to 520.90 g/day in V1 and 302.43 to 315.97 g/day in V2.

Growth technological indicators for *C. carpio* sapling are summarized in Table 4 and graphically represented in Figures 3 and 4. Both the table and the chart indicate a better growth of crop biomass in version V2 (tanks B2, B4).

Table 4

Technological indicators for common carp growth

Experimental variant *Indicators*	*V1* *B1*	*V2* *B2*	*V1* *B3*	*V2* *B4*
Initial biomass (kg)	32.10	16.23	32.14	16.03
Initial biomass (kg/m^3)	64.21	32.48	64.29	32.06
Final biomass (kg)	46.94	25.31	47.77	25.51
Final biomass (kg/m^3)	93.88	50.62	95.54	51.02
Biomass gain (kg)	14.83	9.07	15.62	9.47

Biomass gain (kg/m^3)	29.67	18.15	31.25	18.96
Initial number of fish	491	245	211	107
Final number of fish	482	239	210	106
Survival (%)	98	98	100	99
Initial fish weight (g/fish)	65	66	152	150
Final fish weight (g/fish)	97	106	227	241
Days of growth (days)	30	30	30	30
GR (Growth rate) (g/day)	494.57	302.43	520.90	315.97
SGR(Specific growth rate) (%/day)	1.24	1.45	1.32	1.53
Individual weight gain (g)	14	15	75	91
Food gived (g)	19500	9900	19500	9900
FCR Feed conversion ratio (g /g)	1.31	1.09	1.25	1.04
Feeding level (g/kg gr.met.)	650	325	650	325
Feeding level (% biomass)	1.7	1.7	1.7	1.7
Crude protein (PB %)	35.0	35.0	35.0	35.0

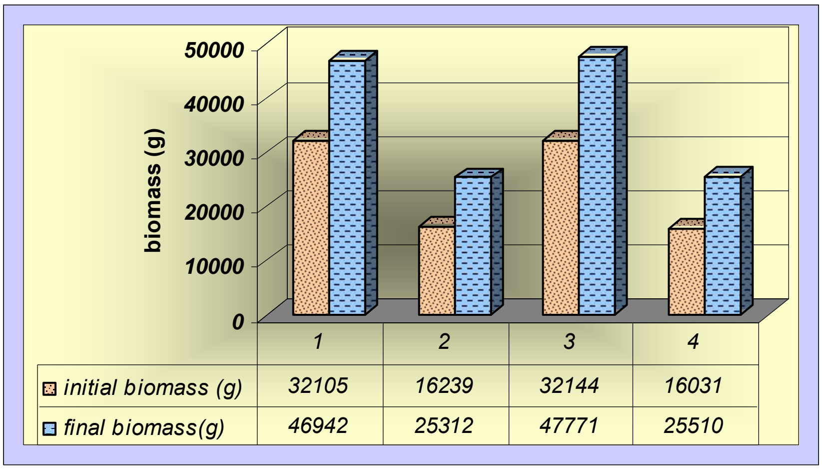

Figure 3. Dynamics of fish growth.

Figure 3 shows the evolution of fish growth in all four units. What is to be noticed are the very close values between the repetitions of variant V1 (tanks B1, B3) (the results being similar); the same is true for variant V2 (tanks B2, B4). Among the most significant technological indicators are the specific growth rate (SGR) and the food conversion ratio (FCR).

The food conversion ratio was calculated using the following formula: FCR = F/(Bf-Bi) (F - amount of food administered; (Bf-Bi) – growth gain; Bf, Bi - final and initial biomass).

The specific growth rate was calculated using the following formula: SGR = [(Bf ln - ln Bi)/T]*100 (Bf - final biomass; Bi - initial biomass; T - time interval (days)).

Both indicators were better in version V2. Consequently, in V2 a SGR value of 1.51 g%/day was obtained, and a FCR of 1.065 g food/g growth gain, while in V1, a SGR value of 1.29 g%/day and a FCR of 1.28 g food/g growth gain.

Figure 4 shows the inverted correlation between the evolution of SGR and FCR: a low FCR is always got when the SGR increases.

The average weight of the samples in the four experimental variants showed similar values throughout the experimental period except for pool B4, which showed slightly higher values for average weight (Figure 5), as can be seen in the somatic measurements of 20 samples from each tank.

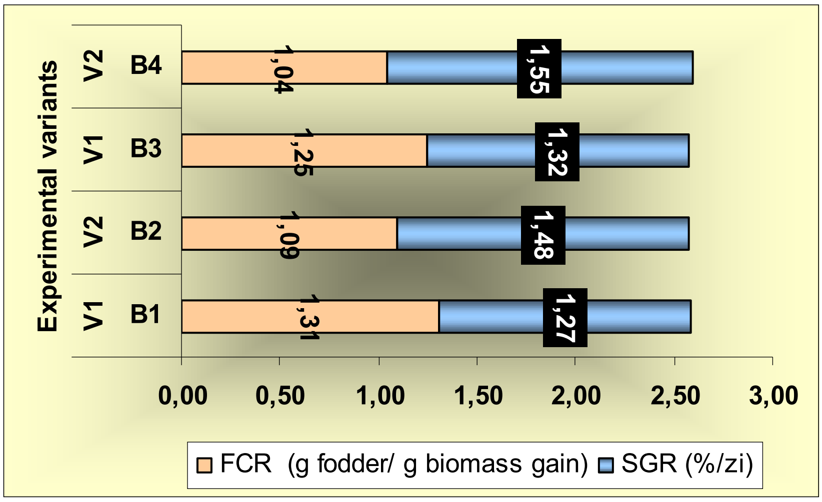

Figure 4. The variation of feed conversion ratio (FCR) and specific growth rate (SGR).

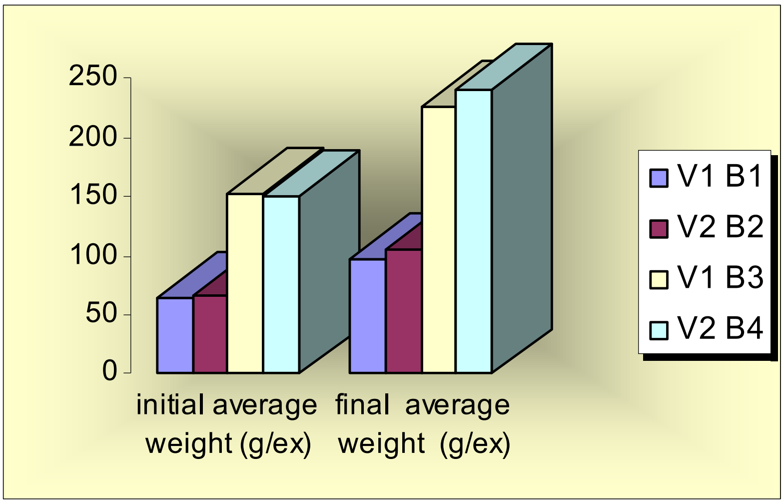

Figure 5. Evolution of average mass for the two experimental variants.

The carp samples in the two experimental variants were iniatally weighing between 65-152 g/sample in variant V1, and 66-150 g/sample in variant V2. The initial stocking density was 64 kg/m^3 in V1 and 32 kg/m^3 in V2. At the end of the experiment, the stocking density was 95 kg/m^3 in V1 and 51 kg/m^3 in V2, this indicating a biomass increase of 48.43% in V1 and 59.37% in V2, and a 10.94% increase if we compare V1 with V2.

Conclusions. The objective of this experiment was to determine a suitable carp stocking density in recirculating systems so that the ratio between the growth rate and the efficiency of food production to lead to profit. In some countries, fish are grown primarily in recirculating aquaculture systems (RAS).

Intensive recirculating systems allow fish growth in every region, provides full control over the growing medium and also allows a large percentage of water re-use, by means of the three types of filtration: mechanical, biological and chemical (Van de Nieuwegiessen 2009).

The experiment demonstrated a remarkable technological plasticity in both experimental variants; nevertheless, in terms of technological performance indicators it was found that application of lower population densities lead to higher crop biomass gain (Sharma & Chakrabarti 1998).

In both experimental variants, V1 (tanks B1, B3) and V2 (tanks B2, B4), significant growth gains were achieved in terms of survival rate (98-100%). In variant V2, where the stocking density was lower than in V1, the growth gain increased. The analyses of the average values of each variant showed an increase in biomass by 30.46 kg/m^3 in V1 and 18.55 kg/m^3 in V2. The growth rate (GR) technological indicator shows linear growth, virtually constant, ranging from 494.57 to 520.90 g/day (V1) and 302.43 to 315.97 g/day (V2).

The results confirm what other authors have also claimed: that the stocking density influences the growth rate, the fish size and farm productivity (Cruz 1991).

Farmers are interested in increasing fish densities as this reduces production costs. However, it was demonstrated that the stocking density influences the health of farm fish farmed (Bakeer & Tharwat 2006).

Nevertheless, to better argument the optimal stocking density of carp species, *C. carpio*, more investigations are necessary.

Aknowledgements. The research was conducted in the framework of the POSDRU project, "Efficiency of PhD Students Activity in Doctoral Schools no. 61445 - EFFICIENT", funded by the European Union and the Romanian Government. The authors want to thank to the management staff of the project for their support.

Conflict of Interests. The authors declared no conflict of interests exists in the case of team and research presented here.

References

Bakeer M. N., Tharwat A. A., 2006 Effect of stocking density and manuring rate on silver carp (*Hypophthalmichthys molitrix*) reared in earthen ponds. Journal of the Arabian Aquaculture Society **1**(2):57-68.

Berra M., 2007 Fresh water fish distribution, Printed in United States of America. Library of Congress Cataloging-in-Publication Data.

Bhakta J. N., Biswas J. K., Bhakta P., Munekage Y., Jana B. B., 2009 Fish stocking density induced growth responses of some biogeochemical cycling bacterial population. Braz J Aquat Sci Technol **13**(2):45-50.

Cristea V., Grecu I., Ceapă C., 2002 [Recirculating systems engineering]. Editura Didactică şi Pedagogică, Bucharest. [In Romanian]

Cristea V., 2008 [Scientific partnerships to develop a pilot recirculating system for the promotion and implementation of innovative technologies for superintensive aquaculture]. Granted by: Ministry of Education and Research, National Authority for Scientific Research, Program CEEX, Module I, AGRAL. [In Romanian]

Cruz E., 1991 Production of common carp (*Cyprinus carpio)* with supplemental feeding in ricefields in North Sumatra, Indonesia. Asian Fisheries Science **4**:31-39.

North B. P., Ellis T., Turnbull J. F., Davis J., Bromage N. R., 2006 Stocking density practices of commercial UK rainbow trout farms. Aquaculture **259**:260–267.

Oprea L., Georgescu A., 2000 [Nutrition and fish feed]. Editura Tehnică, Bucharest. [In Romanian]

Sharma J. G., Chakrabarti R., 1998 Effects of different stocking densities on survival and growth of grass carp, *Ctenopharyngodon idella,* larvae using recirculating system. Journal of Applied Aquaculture **8**:79-83.

Van de Nieuwegiessen P. G., 2009 Welfare of African catfish, effects of stocking density, PhD Thesis, Wageningen University. The Netherlands, ISBN: 978-90-8504-986-9.

Received: 20 December 2010. Accepted: 26 February 2011. Published online: 27 February 2011.
Authors:
Ionica Enache, Dunărea de Jos University of Galaţi, Faculty of Food Science and Engineering, Str. Domnească no. 47, 800008-Galați, Romania, enaoana@yahoo.com
Victor Cristea, Dunărea de Jos University of Galaţi, Faculty of Food Science and Engineering, Str. Domnească no. 47, 800008-Galați, Romania.
Tudor Ionescu, Dunărea de Jos University of Galaţi, Faculty of Food Science and Engineering, Str. Domnească no. 47, 800008-Galați, Romania.
Săndita (Plăcintă) Ion, Dunărea de Jos University of Galaţi, Faculty of Food Science and Engineering, Str. Domnească no. 47, 800008-Galați, Romania.
How to cite this article:
Enache I., Cristea V., Ionescu T., Ion S., 2011 The influence of stocking density on the growth of common carp, *Cyprinus carpio,* in a recirculating aquaculture system. AACL Bioflux **4**(2):146-153.