THE INFLUENCE OF LIGHT INTENSITY ON THE GROWTH PERFORMANCE OF COMMON CARP IN A RECIRCULATING AQUACULTURE SYSTEM CONDITION

Ionica (Bancu) Enache[1*], V. Cristea[1], T. Ionescu[1], Lorena Dediu[1], Angelica Docan[1]

[1] *„Dunărea de Jos" University of Galați, Faculty of Food Science and Engineering, Galati, Romania*

Abstract

The paper is a presentation of aspects regarding the influence of light intensity on growth carp (Cyprinus carpio L.), breeding in a recirculating aquaculture system (RAS). The experiment covered a 28 day-period, was made in four pilot rearing units, 500 litres in volume/unit. Two kind of light intensity variants were compared, with repetition: in first variant we used 280 lx luminosity and in the second version 90 lux. The stocking density was about the same in all variants: 70,5 kg/m^3. The technological indicators that showed up at the end of the experiment revealed the following: the biomass gain in V_1 was 21,75 kg/m^3 and 20,57 kg/m^3 in V_2; the specific growth rate (SGR), calculated as a mean value on the two repetitions of each variant, was 0,895 g%/day (V_1) and 0,845 g%/day (V_2); the feed conversion ratio (FCR), calculated as a mean value on the two repetitions of each variant, was of 1,45 g pellets/g biomass gain (V_1) and 1,535 g pellets/g biomass gain (V_2). The research showed that common carp has a very good technological plasticity in relation to light intensity. The growth performance parameters showed that variation of light intensity did not influence significantly fish growing.

Key words: carp, light intensity, RAS

INTRODUCTION

The carp is one of the most important species in aquaculture, known for its rapid growth and high tolerance to environment conditions. Its tolerance is of great importance all the more so the modern fish-farming is interested in recirculating aquaculture systems ([3], [13]). In order to improve the RAS technologies it is important to learn more about the behaviour and performance of culture species breeding under the conditions of the production system. This aspect is highly important because the artificial habitat, different of the natural ones, can harm the organism's process of feeding, breeding and state of health [14].

Among its numerous advantages, the recirculating aquaculture system allows the improvement of the portent capacity as related to the environment quality control level, leading to the reduction of stress conditions. The intensive breeding of aquatic organisms in recirculating systems outlines their feasibility from a technological point of view as well as their efficiency at an economic level [9]. The main factors studied through the technological monitoring in a recirculating aquaculture system are as it follows: the inadequate water quality (chemism, temperature, transparency, turbidity, the amount of germs, etc.), the repeated manipulation of biomass culture, the inadequate colours of the walls and the bottom of the breeding units [14], big stocking densities of biomass culture [6], food or starving deficiencies, brightness degree outside the technological comfort [1].

Numerous experiments have shown that the physiological conditions, as well as fish breeding, can be influenced by the light spectrum and its intensity [7]. The two light parameters, the spectral structure and the intensity, can be easily manipulated from a technical point of view and at a small cost within the recirculating systems [9]. The literature of speciality offers complete information regarding the physiology of the fish

*Corresponding author: enaoana@yahoo.com
The manuscript was received: 22.06.2012
Accepted for publication: 25.08.2012

visual system and this piece of information supports the theory according to which the latter is sufficiently developed to answer to a variety of wave lengths and light intensity. Some authors suggest that the red light has a positive effect on *Oncorhynchus myckiss* compared with white light. On the other hand, it was proved that the blue- green light favours the breeding and survival of other species [9]. The differences between the results probably reflect a greater variability of fish visibility in accordance with their natural environment.

The aquaculture field is familiar to researches oriented on photoperiodic influence [2, 5, and 15] and the light intensity on the performance of biomass culture growth. In this context, the main reason of our experiment was to determine the technological plasticity of juvenile carp (*Cyprinus carpio)* which grew in a recirculating system, as related to the light intensity. We have also tried to assess the possible impact of the light spectral structure on the technological plasticity, respectively the performance of culture biomass breeding.

MATERIAL AND METHODS

The experiment was carried out within the pilot recirculating system of the Aquaculture, Environmental Sciences and Cadastre Department - „Dunarea de Jos" University of Galaţi. The experimental activity lasted for 28 days, from October until November 2010, in four breeding units with a capacity of 500 l/unit.

The configuration of the pilot recirculating system of the carp intensive breeding (Figure 1) projected and realized consisted of integrating some technological water treatment equipment (mechanical, biological and chemical filters) with breeding units, adequately shaped in relation to the technology followed [4].

The recirculating system, according to which the components of the recirculating system were shaped, is $4m^3/h$, ensuring the changing of the entire volume of water from a breeding tank, at every half an hour.

In order to assess the technological plasticity of the juvenile carp (*Cyprinus carpio*) a different light intensity was created within the breeding units by obstructing them with the help of polycarbonate sheets of different colours, white and respectively blue. The filtration of the light while penetrating through the tanks' covers obviously leads to a differentiation of the light radiation spectrum structure. The polycarbonate sheets used in order to make the caps were 0.6 mm thick. The light intensity was measured at the surface of the water with a lux meter TESTO 545 and the results were 280 lx for V_1 (the tanks covered with white caps) and 90 lx for V_2 (the tanks covered with blue caps). The light intensity was measured in different spots of the breeding units (centre of the tank, half-distance between the centre and the margin of the tank and at margin of the tank) and at the end an average between all these was calculated and the result obtained represented the values previously mentioned.

Both experimental variants were isolated from external factors (solar radiation). The technological spot where the experiment was carried out was lighted 24 hours a day by 36 watt neon fluorescent lamps, the same light intensity (400 lx) being maintained during the whole experiment, the only variation being the colour of the polycarbonate sheets.

The biological material used during the experiment is represented by 16 months-old carp sapling provided by The Ecological, Aquatic and Aquaculture Development Research Institute from Galaţi, Brateş reproduction station. Two variants were experimented having approximately the same intensity:

- Experimental variant 1:

B_1-70.54 kg/m^3-251 examples with an average mass of 141 g/exemplary,

B_2-70.65 kg/m^3-244 examples with an average mass of 145 g/exemplary.

- Experimental variant 2:

B_3-70.77 kg/m^3-253 examples with an average mass of 140 g/exemplary,

B_4-71.42 kg/m^3-258 examples with an average mass of 138 g/exemplary.

Figure 1 Recirculating system layout (Cristea, 2008)

At the end of the experiment, there were made somatic measurements on a sample of 20 examples from each tank, thus determining the total length (L) and the body weight (W).

The food used for the biomass culture was ALLER MASTER-like fodder with 4 mm granulation and 35% protein content (Table 1) an adequate content for the age of the examples studies during the experiment [12]. The portion used during this experiment was of 1.3% of the body weight. The fodder was automatically distributed by a feeding strap of 5 kg. The food was continuously administered within breeding units between 9A.M-9-P.M., thus ensuring equal opportunities for all the examples in the tank.

Table 1 Chemical composition of ALLER MASTER 4mm pellets

Parameter	Quantity
Crude protein	35%
Crude fat	9.9%
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 substance	6.1%
P in dry substance	1.3%
Energy in dry substance	4865/20.3 Kcal/MJ
Vitamin A	2500(IE)
Vitamin D3	500(IE)
Vitamin E	150(mg)
Ingredients: fish flour, soybean, pea protein, flour, rapeseed, wheat, fish oil, vegetable oil, minerals and vitamins.	

Data statistic information

The statistic analysis was carried out with the help of the parametric test T-Student which allowed comparing the average of the results.

RESULTS AND DISCUSSIONS

The water quality parameters within the recirculating system: temperature (19.2^0C-21.4^0C), dissolved oxygen (4.1-5.6 mg/l), nitrate (between 7.9-14.4 mg/l), ammonium (0.3-0.4 mg/l) and pH (between 7.1-7.8) registered constant values during the experiment. Regarding the dynamics of the water quality parameters, no major modifications or peaks during the day or after feeding were registered.

Growth technological indicators for *Cyprinus carpio* juvenile are summarized in Table 2 and graphically represented in Figures 2 and 3. Both the table and figures indicate a better growth of crop biomass in version V_1 (tanks B1, B_2).

In both experimental variants, V_1 (tanks B_1, B_2) and V_2 (tanks B_3, B_4), significant growth gains were achieved, under the circumstances of a 98-100% survival rate. In variant V_1, which we used white caps, increased growth was higher than V_2.

The analyses of the average values of each variant showed an increase of fish biomass of 21.75kg/m^3 in V_1 and 20.57 kg/m^3 in V_2. The daily growth rate (DGR) the technological indicator showing a theoretically linear growth of fish, ranged from 282.16 to 290.11 g/day in V_1 and 264.53 to 276.97 g/day in V_2. In terms of individual variation in growth increment recorded 44-49 g in version V_1 and 41-43 g in version V_2.

Table 2 Technological indicators for common carp growth (*Cyprinus carpio)*

Experimental variant	**V_1**	**V_1**	**V_2**	**V_2**
Indicator/tank	**B_1**	**B_2**	**B_3**	**B_4**
Initial biomass (kg)	35270	35324	35384	35712
Initial biomass (kg/m^3)	70.54	70.65	70.77	71.42
Final biomass (kg)	46294	46046	45436	46237
Final biomass (kg/m^3)	92.59	92.09	90.87	92.47
Increase biomass growth (kg)	11024	10722	10052	10525
Increase biomass growth (kg/m^3)	22.05	21.44	20.10	21.05
Initial number of fish	251	244	253	258
Final number of fish	249	244	248	258
Survival (%)	99	100	98	100
Initial average weight (g/egg)	141	145	140	138
Final average weight (g/egg)	186	189	183	179
Growing days	30	30	30	30
GR (daily growth rate) (g/day)	290.11	282.16	264.53	276.97
SGR (%/day)	0.91	0.88	0.83	0.86
Individual growth gain (g)	49	44	43	41
Total amount of feed distributed (g)	15750	15750	15750	15750
FCR (g feed/g gain biomass)	1.43	1.47	1.57	1.50
PER (g /g protein)	2.00	1.95	1.82	1.91
Daily biomass (% biomass)	1.3	1.3	1.3	1.3
Crude protein feed (PB %)	35.0	35.0	35.0	35.0

Figure 2 presents the examples growth rhythm in the two variants. There are close values among the repetitions of variant V_1 (tanks B_1 and B_2) the results being repeated, just as in the case of variant V_2 (tanks B_3 and B_4). The average mass of carp examples (Figure 3) of the two variants registered close values both in V_1 and in V_2.

The parametric test T-student was performed on the basis of somatic measurements at the end of the experiment (Table 3). The value obtained ($p>0.05$) confirms the idea that light intensity in the case of our experiment did not significantly influenced the growth of biomass culture.

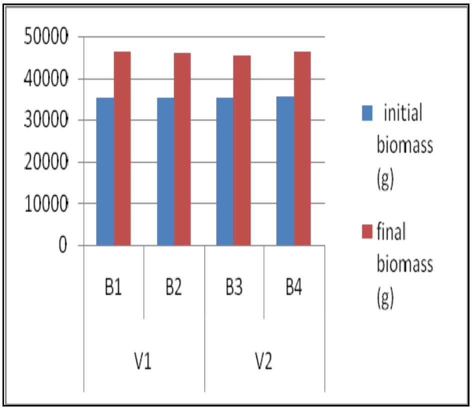

Figure 2 Biomass dynamics of culture

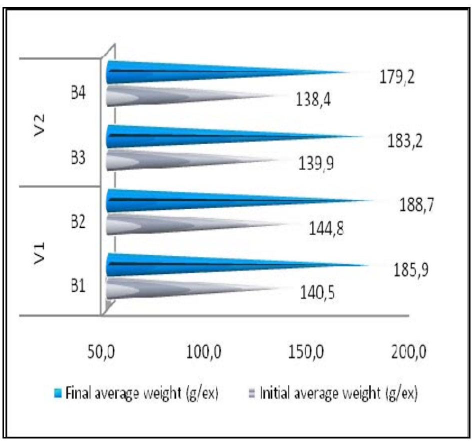

Figure 3 Evolution of average mass

Table 3 Somatic measurements at the end of the experiment (harvesting)

Parameter/ Variant	L (cm) (Std. Dev.)	W (g) (Std Dev.)
B1	23.02±2.92	195.3±86.44
B2	24.18±3.31	212±87.68
B3	22.89±2.85	189.6±74.47
B4	22.74±2.2	176.4±58.31

Among the most important technological indicators there is the specific growth rate (SGR) and feed conversion rate (FCR). The specific growth rate (SGR) represents a parameter which accurately indicates the dynamic of the individual growth and/or of the culture biomass. Both indicators were higher in the case of variant V_1. Thus, in V_1 the SGR value obtained was of 0.895 g%/day and the FCR of 1.45 g fodder/g efficiency growth, whereas in the V_2 the SGR obtained was of 0.845 g%/day and the FCR of 1.535 g fodder/g efficiency growth. In figure 4 we can notice the reverse correlation which logically exists in the evolution of SGR and FCR; a low FCR is always obtained when the SGR increases. Food conversion ratio (FCR) varied reversely proportional to the protein efficiency ratio (PER). Regarding the efficiency of protein use, PER (Figure 5), better results were obtained for a higher light intensity (1.975 g/g protein) but with insignificant differences between the experimental variants studied.

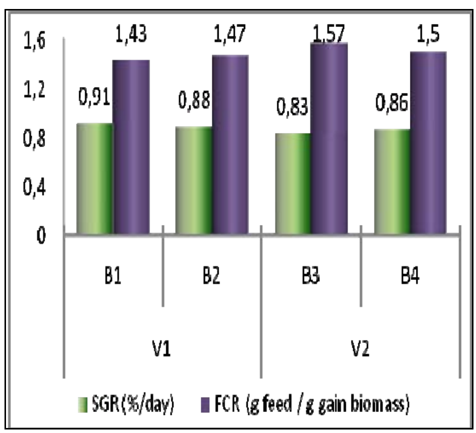

Figure 4 The variation of feed conversion ratio (FCR) and specific growth rate (SGR)

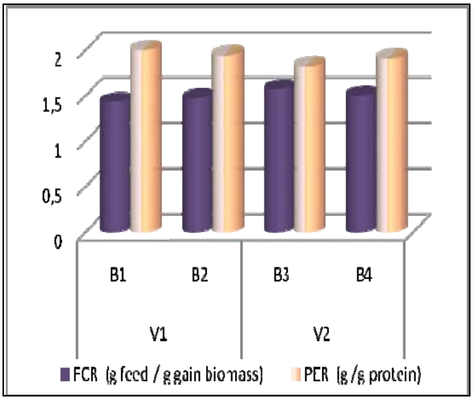

Figure 5 Variation of feed conversion factor (FCR) and a protein efficiency ratio (PER)

The initial stocking density was of 70.59 kg/m^3 for the first variant and 71.09 kg/m^3 for the second variant. At the end of the experiment, the stocking density obtained in V_1 was of 92.34 kg/m^3 and in V_2 of 91.67 kg/m^3. This indicates a growth of the biomass with 30.80 % of initial biomass in version V_1, respectively 28.94% in V_2 and a growth of 0.73 % of V_1 as opposed to V_2.

CONCLUSIONS

The main aim of our experiment was to determine the technological plasticity of the juvenile carp (*Cyprinus carpio*) in relation to the light intensity, brought in a recirculating system. We have also tried to assess the potential impact of the light spectrum structure on the technological plasticity, respectively the performance of the culture biomass growth.

The water quality parameters for the two experimental variants were not influenced by light intensity, remaining constant for the entire period of the experiment. There was not noticed any difference in the colouring of the tegument for the two variants. Similar studies in the research field have revealed that in the case of other fish there is a correlation between luminosity and specific pigmentation of the tegument [11] .

The experiment indicated a remarkable technological plasticity of the biological material for both luminosity variants (light intensity, radiation spectrum structure).

Regarding the growth performance indicators, there were evidentiated different but insignificant values between the two variants. Thus, each of the technological parameters (biomass efficiency, SGR, FCR, PER, DGR, etc.) showed in Table 2 are higher with only 5-6% in the case of the variant with the higher intensity light (280 lx). The results obtained confirm the conclusions of other researchers who have tackled the issue of light influence on culture biomass within recirculating systems [10], [14].

One of the conclusions obtained from the data statistic transformation within the experiment ($p>0.05$) is that a lower light intensity and, possibly a certain structure of the light spectrum, can influence the growth performance parameters but not significantly, aspect which was confirmed by other authors [8], [9]. The speciality literature recommends the use of a light intensity between 150-300 lx for a carp species [10].

Knowing the fact that a higher light intensity (2200 lx) [1] determines the increase of the swimming activity for fish, thing which implicitly leads to stress, we recommend that when the design of the aquaculture recirculating system is established, the degree of light is established on the basis of thorough research regarding the eco-physiology of the culture species.

The influence of light on the culture biomass is extremely complex and this is why ulterior research is necessary in order to solve a series of aspects regarding the relationship between light radiations parameters (wave length, intensity, energy, spectrum structure, etc.) and the metabolic activity of aquatic organisms, respectively the chance to study the luminosity at the level of breeding units as main instrument of technological management.

ACKNOWLEDGEMENTS

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.

REFERENCES

[1] Almazan-Rueda P., Schrama J.W. and Verreth J.A.J.: Behavioral responses under feeding methods and light regimes of the African catfish (*Clarias gariepinus*) juveniles, Aquaculture 231, 2004, p 347-359.

[2] Biswas Amal Kumar and Takeuchi Toshio: Effect of different photoperiod cycles on metabolic rateand energy loss of fed and unfed adult tilapia *Oreochromis niloticus*: Part II, Fisheries Science 68, 2002, p 543–553.

[3] Cristea V., Grecu I., Ceapă C.: Ingineria sistemelor recirculante, Editura Didactică şi Pedagogică, Bucureşti, 2002.

[4] Cristea V.: "Parteneriat ştiințific pentru dezvoltarea unui sistem recirculant pilot în scopul promovării şi implementării unor tehnologii inovative de acvacultură superintensivă" Etape de executie: IV/ 2008 & V/ 2008, Etapa IV - Experimentarea sistemelor recirculante, Etapa V - Evaluarea celor trei tehnologii sub aspectul performantei tehnologice, impactului asupra componentelor mediului si economic. Finantator: Ministerul Educatiei şi Cercetarii, Autoritatea Nationala pentru Cercetare Stiintifica Modul I CEEX Programul : A G R A L

[5] El-Sayed M. Abdel-Fattah, Kawanna Mamdouh: Effects of photoperiod on the performance of farmed Nile tilapia Oreochromis niloticus: I. Growth, feed utilization efficiency and survival of fry and fingerlings, Aquaculture 231, 2004, p 393–402.

[6] Enache Ionica, Cristea Victor, Ionescu Tudor si Ion Săndita: The influence of stocking density on the growth of common carp, *Cyprinus carpio*, in a recirculating aquaculture system, AACL Bioflux, Volume 4, Issue 2, 2011, p 146-153.

[7] Herve Migaud, Cowan Mairi, Taylor John, Ferguson W. Hugh : The effect of spectral composotion and light intensity on melatonin, stress and retinal damage in post-smolt Atlantic salmon, *Salmo salar*, Aquaculture 270, 2007, p 390-404.

[8] Karakatsouli Nafsika, Papoutsoglou E. Sofronios, Pizzonia Gianluca, Tsatsos Georgios, Tsopelakos Aristeidis, Chadio Stella, Kalogiannis Dimitris, Dalla Christina, Polissidis Alexia, Papadopoulou-Daifoti Zeta: Effects of light spectrum on growth and physiological status of gilthead seabream *Sparus aurata* and rainbow trout *Oncorhynchus mykiss* reared under recirculating system conditions, Aquacultural Engineering 36, 2007, p 302–309.

[9] Karakatsouli Nafsika, Papoutsoglou E. Sofronios, Panopoulos Georgios, Papoutsoglou S. Eustratios, Chadio Stella, Kalogiannis Dimitris: Effects of light spectrum on growth and stress response of rainbow trout *Oncorhynchus mykiss* reared under recirculating system conditions, Aquacultural Engineering 38, 2008, p 36–42.

[10] Karakatsouli Nafsika, Papoutsoglou S. Eustratios, Sotiropoulos Nikolaos, Mourtikas Dimitrios, Stigen-Martinsen Tone, Papoutsoglou E. Sofronios: Effects of light spectrum, rearing density and light intensity on growth performance of scaled and mirror common carp, *Cyprinus carpio*, reared under recirculating system conditions, Aquacultural Engineering 42, 2010, p 121–127.

[11] Kelley L. Jennifer, Phillips Bree, Cummins H. Gabrielle, Shand Julia: Changes in the visual environment affect colour signal brightness and shoaling behaviour in a freshwater fish, Animal Behaviour xxx, 2012, p 1-9.

[12] Oprea L., Georgescu R.: Nutritia si alimenttia pestilor, Editura Tehnica, Bucuresti, 2000, 272 p.

[13] Ruchin A.B.: Effect of Photoperiod on Growth, Physiologica and Hematological Indices of Juvenile Siberian Sturgeon, *Acipenser baerii*, Biology Bulletin, Vol. 34, No. 6, 2007, pp. 583–589

[14] Strand A., Alanara A., Staffan F., Magnhagen C.: Effect of tank colour and light intensity on feed intake, growth rate and energy expenditure of juvenile Eurasian perch, *Perca fluviatilis* L. Aquaculture 272, 2007, p 312-318.

[15] Taylor J.F., North B.P., Porter M.J.R., Bromage N.R., Migaud H.: Photoperiod can be used to enhance growth and improve feedingefficiency in farmed rainbow trout, *Oncorhynchus mykiss*, Aquaculture 256, 2006, p 216–234.