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Effects of heat and cold shock-induced triploidy on productive parameters of silver catfish (*Rhamdia quelen*) late-hatched in the reproductive season

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ABSTRACT

This study was carried out in order to assess the productive performance of triploids of silver catfish (*Rhamdia quelen*) obtained by heat (HT) and cold shock (CT) at the end of the reproductive season. In hatchery, HT larvae reached the highest survival rate since they exhibited the lowest cannibalism rate among all groups. Although mean weight of larvae in HT group was lower in comparison with CT and diploid counterparts, the final biomass of HT was the highest due to the great survival rate observed in this group. At the end of the fattening trial both HT and CT groups showed better productive parameters than diploid control group. The mean weight of HT and CT were significantly higher than diploids. The condition factor was significantly higher in HT in comparison with CT and diploid fish. However, only CT males and females showed significantly higher carcass weight than control fish. Also carcass yield was greater in triploid females although only CT males displayed significantly higher carcass yield than their diploid counterparts. The gonadosomatic index (GSI) exhibited a different pattern in each sex. In males, CT showed a significantly lower GSI in comparison with HT and diploid fish. Control females displayed the highest GSI with significant differences with both triploid groups. In addition, CT males and females accumulated significantly higher percentage of abdominal fat than their control counterparts. A strong negative correlation between GSI and carcass yield in females was observed. These results demonstrate that HT and CT of *R. quelen* exhibited superior productive parameters than control fish in both hatchery and fattening period. Since some variables assessed were better in HT while others were improved in CT group, the election of heat or cold shock-induced triploids for culture should be based on the productive aims of each fish farm.

Statement of relevance

Rhamdia quelen triploids show better parameters for culture.

1. Introduction

The silver catfish or South American catfish (*Rhamdia quelen*) is a neotropical fish species that present some encouraging characteristics for farming such as easy handling, good feed efficiency and fast growth (Bockmann and Guazzelli, 2003). Since it can grow optimally during summer and withstands cold winters, it is a proper candidate for aquaculture production in temperate climate zones (Pereira et al., 2006; Vargas and Bessonart, 2007). Moreover, its tasty meat and absence of intramuscular bones increase its acceptance among consumers (Gomes et al., 2000; Luchini, 1988). All these favorable attributes have led to active investigation of intensive breeding systems on larvae and juvenile stages of this species (Barcellos et al., 2004; Bombardelli et al., 2015; Pes et al., 2016; Rodrigues-Galdino et al., 2009).

R. quelen has many favorable characteristics for farming, but its early sexual maturity observed before the first year of age could affect its growth parameters (Baldisserotto and Radünz Neto, 2004). Gonadal development is accompanied by endocrine, behavioral and body composition changes that lead to lower growth rates (Olaya-Nieto et al., 2010). This is related to the use of energy from diet to produce gametes rather

Abbreviations: CG, control group; CT, cold-shock triploids; dph, days post-hatch; GSI, gonadosomatic index; HT, heat-shock triploids.

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than for somatic growth, an undesirable characteristic in fish farming (Huergo and Zaniboni-Filho, 2006; Vozzi et al., 2003).

One way to avoid the above-mentioned problems is by means of triploidy induction, a biotechnological methodology that allows to generate reproductively sterile individuals (triploids) that have better growth and feed conversion rates when compared with non-chromosome manipulated fish (diploids) (Maxime, 2008; Piferrer et al., 2009; Tiwary et al., 2004). Currently, thermal shock is one of the most frequently used techniques to obtain triploid fish due to its easy handling and low cost. Newly fertilized eggs are submitted to variation of water temperature, up or above the physiological optimum temperature for development. Established protocols of thermal shock to obtain triploids of *R. quelen* achieve an efficiency of 98% and 75% when fertilized eggs are subjected to 4 °C or 36 °C, respectively (da Silva et al., 2007; Vozzi et al., 2003).

Moreover, females of *R. quelen* are multiple spawners with two reproductive peaks in spring and summer (Gomes et al., 2000). In order to take advantage of two reproductive cycles per female per year, larvae hatched late in summer can be retained in indoor tanks with food restriction until temperature rise after cold seasons. It is possible to improve the growth rates and growth efficiency of some farmed fish species by exploiting the compensatory growth response, a period of accelerated somatic growth following the interruption of fasting conditions. Many authors have proposed that the causes behind this phenomenon are related to hormonal and biochemical complex changes (Hornick et al., 2000; Won and Borski, 2013). Particularly, *R. quelen* could experience long periods of starvation in captivity during pre-harvesting, transport management, and under some feeding regimes with food restriction (Barcellos et al., 2010; Menezes et al., 2015; Sánchez et al., 2008).

Considering these facts, the implementation of a regimen of long food restriction followed by re-feeding could be a useful management tool to improve growth performance of *R. quelen*.

Due to combined effects of triploidy induction and compensatory growth on *R. quelen* productive performance remain unknown, the aim of this work was to determine the usefulness of a joint strategic approach to improved growth of *R. quelen* that hatched late in summer under intensive rearing conditions.

2. Materials and methods

2.1. Water quality assessment

Water quality parameters were measured through each part of the experiment. Temperature, pH, conductivity and total dissolved solids (TDS) were determined using a multiparameter meter (Hanna Instruments, Rhode Island). Water hardness and nitrite/nitrate concentrations were assessed through a complexometric tritation method and using semi-quantitative test, respectively.

2.2. Brood stock management

The brood stock of *R. quelen*, employed in this study, belongs to the Experimental Aquaculture Research Center (CIPEX) at the School of Veterinary Sciences of the National University of Rosario (Argentina). Brooders were first fed once a day with a commercial feed (28% crude protein, Kilomax, Mixes del Sur) and then, one month before the beginning of the experiment were fed with a high-energy and protein feed (3720 kcal kg^{-1} of metabolizable energy/40% crude protein) prepared at CIPEX facilities. Fish were maintained under natural conditions of photoperiod in 9500 L circular tanks with proper continuous aeration. Water parameters values were temperature 22.9 ± 0.3 °C, pH 8.5 ± 0.04, conductivity 1719 ± 13 μS cm^{-1}, TDS 1238 ± 9.6 mg L^{-1}, and nitrite and nitrate 0 mg L^{-1}.

2.3. Spawning and gamete collection

At the end of January 2014, two males (208.5 ± 9.2 g) and four females (283.5 ± 7.8 g) were selected from the brood stock based on their secondary sex characteristics and induced to spawn by intramuscular injection of pituitary extract from *Prochilodus lineatus* applied just below the dorsal fin. Females received 5 mg kg^{-1} distributed in two doses and males were injected with 2.5 mg kg^{-1} of pituitary extract in a single dose as was previously described for this species (Baldisserotto and Radünz Neto, 2004).

Gametes were obtained in both sexes by manual extrusion of the abdominal region in a cephalo-caudal direction. Soon after gametes collection, an estimated number of 57,000 oocytes were mixed with milt and a small quantity of freshwater was added to allow for fertilization.

2.4. Triploidy induction and ploidy evaluation

After in vitro fertilization, eggs were collected and randomly distributed in three groups of approximately the same number of individuals. Two groups were used to produce triploid fish by the immersion of eggs in water at 36 °C during 5 min after 5 min post fertilization (Vozzi et al., 2003) or in water at 4 °C for the period of 20 min following 3 min post fertilization (da Silva et al., 2007). They constituted the groups of triploids obtained by heat (HT) or cold (CT) shocks, respectively. The third group was constituted by diploid fish (untreated) and thus considered the control group (CG).

Eggs from each group were placed in separate Zoug jars of 60 L of capacity an incubated at 24 ± 1 °C during approximately 36 h until hatching occurred. After that, larvae were transferred to open circulation tanks until yolk sac resorption.

The efficiency of triploidy induction methods was assessed by means of AgNOR's technique in sixty randomly selected fish from each group (Howell, 1982; Ploton et al., 1986), obtaining 77% and 87% of triploids for HT and CT, respectively.

2.5. Larviculture

After yolk sac resorption, nearly 5 days post-hatch (dph), larvae from each group were stocked in triplicate in 6 L transparent aquaria at a density of 30 larvae L^{-1}. They were fed ad libitum with *Artemia* sp. nauplii, six times a day until 26 dph. Water renewal and supplementary aeration were continuous. Water quality parameters registered were temperature 23.7 ± 0.2 °C, pH 7.6 ± 0.05, conductivity 1895 ± 109 μS cm^{-1}, TDS 1433 ± 109, water hardness 112 ± 4.5 mg L^{-1} $CaCO_3$, and nitrates and nitrites 0 mg L^{-1}.

2.6. Retention period (food restriction period)

After larviculture, fingerlings were adapted to dry feed during a week and then relocated in 300 L tanks with a water recirculation system. Fish were retained for 7 months until environmental temperature arose and allow transferring the fish to external tanks. The fish fry were fed once a day with a commercial ration (32% crude protein, Kilomax, Mixes del Sur) at 2% of live weight only when the water temperature was over 16 °C. Feed was crushed and sifted at size of 210 μm, 210–420 μm and 420–840 μm according mouth size. During this period water parameters values were temperature 18.5 ± 0.3 °C, pH 7.6 ± 0.1, conductivity 2633 ± 66 μS cm^{-1}, TDS 1300 ± 30 mg L^{-1}, water hardness 89 ± 10.4 mg L^{-1} $CaCO_3$, and nitrite and nitrate 0 mg L^{-1}.

2.7. Fattening (refeeding period)

Towards the end of the retention period, juveniles were transferred to three 9500 L external tanks previously divided in two parts using a plastic mesh, and therefore each experimental group was subject to rearing in duplicate. A week before transferring the fish, tanks were

fertilized using 300 g m^{-3} of *Medicago sativa* and covered with a sun protection mesh to reduce luminosity and attack by predators. The initial stock density was of 5.7 fish m^{-3} and fish were fed twice a day with commercial ration (32% crude protein, Kilomax, Mixes del Sur) at 7% of live weight. Fattening was extended during 180 days and monthly biometries were performed to adjust the amount of offered feed. Water parameters were temperature 24 ± 0.2 °C, pH 8.4 ± 0.1, conductivity 1518 ± 3.3 μS cm^{-1}, TDS 1102 ± 2.5 mg L^{-1}, and nitrite and nitrate 0 mg L^{-1}.

2.8. Variables measured

Fish weight was registered weekly or monthly during larviculture or fattening periods, respectively.

Furthermore, at the end of each stage, final biomass, mean weight, daily weight gain, specific growth rate, condition factor and survival rate were calculated. Additionally, at the end of larviculture, cannibalism rate was also estimated according to the following mathematical equation: Cannibalism rate = {1 − [(final fish number + dead fish number)/initial fish number]} × 100; where dead fish number, are those dead larvae retired from aquariums during daily controls.

At the end of fattening period, all fish from each group were euthanized by an anesthetic overdose (benzocaine 100 ppm) and sectioning the spinal cord. Fish were weighed to determined body weight, eviscerated and the weight of gonads and abdominal fat were registered separately to calculate condition factor, gonadosomatic index (GSI) and the percentage of abdominal fat.

Then, specimens were decapitated and weighed again to determinate the carcass weight and calculate carcass yield.

2.9. Statistical analysis

Differences among groups for same time of sampling or among samplings from the same treatment were analyzed with one-way ANOVA, followed by Bonferroni's multiple comparison test. Significant differences in carcass yield, GSI and percentage of abdominal fat between sexes were assessed by a *t*-test. When data did not meet the assumptions for parametric analyses, they were assessed by non-parametric tests. Differences were considered significant at $P < 0.05$. The correlation coefficient between GSI in each sex and body weight, percentage of abdominal fat and carcass yield for each group was also calculated. All tests were done using JMP Software Version 5.1.1 (SAS Institute Inc.).

3. Results

3.1. Larviculture

The mean weight did not show statistical differences among groups at 12 and 19 dph. However, at 26 dph mean weight was significantly higher in CT regarding HT. No significant difference was observed between CT and CG or CG and HT (Fig. 1A). CT group showed significantly higher daily weight gain than HT group, although no significant differences were seen in the mean values of specific growth rate among groups (Table 1).

On the other hand, the survival rate at the end of larviculture exhibited significant differences among groups. The HT group showed the highest mean value (93.5%), while CG (65.2%) and CT (52.5%) exhibited lower percentages (Fig. 1B). The cannibalism rate was significantly lower in HT (4.2%) in relation to CG (22.8%) or CT (23.5%) (Fig. 1C). Due to this, the final biomass was significantly higher in HT compared with CG and CT (Fig. 1D).

3.2. Retention period

Productive parameters registered in this period are detailed in Table 2. Low values observed in daily weight gain in all groups were related with food restriction. No significant mortalities during retention time were observed.

3.3. Fattening

Fish from CG exhibited a significantly higher mean weight than HT at the beginning of the trial (Fig. 2A). As the fattening progressed, this condition was reversed since HT and CT showed significantly higher values than CG in this variable (Fig. 2A). The mean weight in HT increased among biometries, except in the last one. This was not observed in CG and CT, as mean weight increase was less pronounced among samplings (Fig. 2A).

The condition factor was significantly higher in HT in comparison with CG and CT (Table 3).

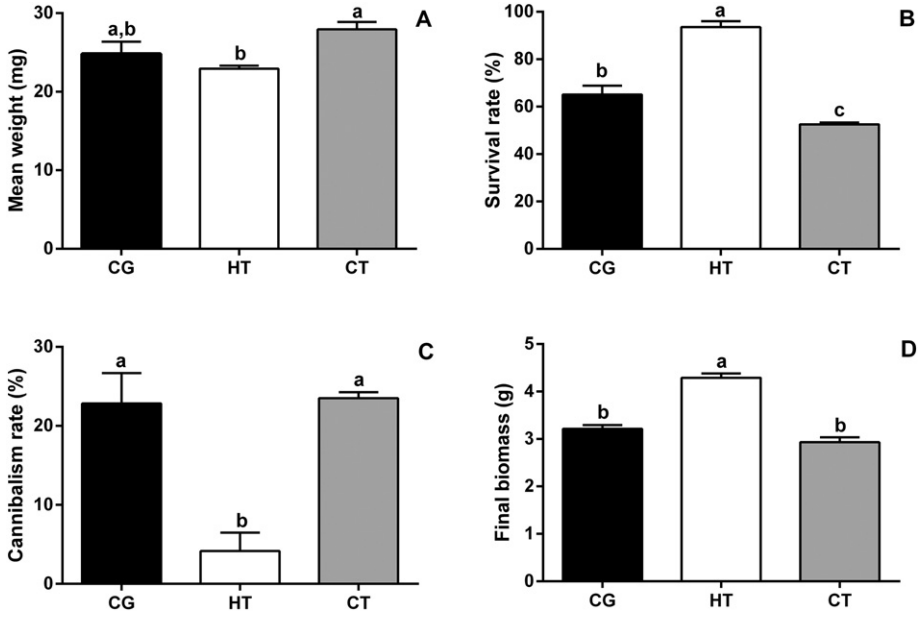

Fig. 1. Performance parameters of diploids and triploids of *R. quelen* after 21 days in larviculture. A) Mean weight. B) Survival rate. C) Cannibalism rate. D) Final biomass. Different letters indicate significant differences among groups ($P < 0.05$). All values were expressed as mean ± standard error of the mean. CG: control group; HT: heat triploids; CT: cold triploids.

Table 1
Growth parameters of diploids and triploids of *R. quelen* after 21 days in larviculture.

	Group		
Parameter	CG	HT	CT
Daily weight gain (mg day^{-1})	1.1 ± 0.1^{a,b}	1.0 ± 0.0^{b}	1.3 ± 0.1^{a}
Specific growth rate (%)	11.6 ± 0.3^{a}	11.9 ± 0.1^{a}	11.4 ± 0.2^{a}

Values are expressed as mean ± standard error of the mean from data obtained from each replica (n = 3). Different superscript letters indicate significant differences among groups (P < 0.05). CG: control group; HT: heat triploids; CT: cold triploids.

Moreover, daily weight gain, specific growth rate, survival rate and final biomass were higher on treated groups regarding to CG (Table 3). Between triploid groups, CT exhibited the highest values for the above-mentioned variables except for condition factor (Table 3).

Only males and females from CT group displayed significantly higher carcass weight than their diploid counterpart (Fig. 2B). However, when data for this variable was not discriminated by sex, triploid fish from both group showed significantly higher carcass weight than CG (data not shown). If carcass weight was compared between sexes in each treatment group, CG and HT females exhibited significantly higher values than males (Fig. 2B). Similarly, carcass yield was significantly greater in triploid females (Fig. 2C), but only CT males displayed significant differences with CG counterparts (Fig. 2C). When the variable was compared between sexes in each treatment group, only CG males showed significantly higher carcass yield than CG females (Fig. 2C).

The GSI exhibited a different performance in each sex. In males, CT displayed a significantly lower GSI in comparison with HT and CG (Fig. 2D). In females, CG showed the highest GSI with significant differences with both triploid groups (Fig. 2D). When GSI was compared within each group between sexes, the higher significant values were observed in females or males for CG or HT groups, respectively, while no variations were observed in CT (Fig. 2D). In some triploid males milt discharging was observed during manipulation.

Additionally, the percentage of abdominal fat was significantly higher in males and females from CT group than in CG counterparts (Fig. 2E). No significant differences between sexes were observed (Fig. 2E).

No correlation between GSI and body weight was detected. GSI and percentage of abdominal fat showed no association, except for CG females in which the correlation coefficient (r) between both variables were −0.93 (p < 0.0001). When association between GSI and carcass yield was assessed in each sex, although in males these variables exhibited no association, a strong negative correlation in females was observed. r values were −0.92 (P = 0.0002), −0.76 (P = 0.0453) and −0.98 (P = 0.0038) for CG, HT, CT, respectively.

4. Discussion

Fish hatchery is a critical period due to all organs and biological systems develop during the embryonic and larval stages, and how these systems are established during early development will influence the quantity and quality of fingerlings for later grow-out production (Drolet et al., 1991; Kjørsvik et al., 2011; Silveira et al., 2013). Since factors as survival, growth and aggressiveness are typical parameters for the evaluation of success in larval fish rearing (Atencio-García and Zaniboni-Filho, 2006; Camargo and Urbinati, 2008; Cunha et al., 2013; Park et al., 2006), these variables were assessed to determine the effects of ploidy level in *R. quelen* larviculture.

Table 2
Initial and final mean weight of diploids and triploids of *R. quelen* during seven months of food restriction.

	Group		
Parameter	CG	HT	CT
Initial mean weight (mg)	31.5 ± 1.9^{a}	24.2 ± 0.5^{b}	33.5 ± 1.0^{a}
Final mean weight (mg)	1779 ± 99^{a}	1427 ± 47^{b}	1650 ± 113^{a,b}
Daily weight gain (mg day^{-1})	8.3 ± 0.3^{a}	6.7 ± 0.2^{a}	7.7 ± 0.4^{a}
Specific growth rate (%)	1.9 ± 0.0^{a}	1.9 ± 0.0^{a}	1.9 ± 0.0^{a}

Values are expressed as mean ± standard error of the mean from data obtained from each replica (n = 3). Different superscript letters indicate significant differences among groups (P < 0.05). CG: control group; HT: heat triploids; CT: cold triploids.

During the first 19 dph, no significant differences were registered on mean weight among groups. In line with our results, previous works conducted on *R. quelen* larvae showed that they have similar growing on first 10 dph of life independently of the offered food (Cardoso et al., 2004; Carneiro et al., 2003; Fukushima et al., 2011; Hernández et al., 2009; Uliana et al., 2001).

However, on 26 dph we recorded significant changes in mean weight between triploid groups. This variation could be attributed to different survival rate since HT showed the highest value, and therefore, larvae were cultured at a higher density. The mean weight obtained for CG and CT was coincident with other reports in which *R. quelen* larvae were fed with *Artemia* nauplii on first 20 dph (Behr et al., 2000; Hernández et al., 2006; Ruales et al., 2009). In line with mean weight variations among groups, CT exhibited a significantly higher daily weight gain in comparison with HT. Although specific growth rate did not differ between diploids and triploids the values observed in our study are consistent with those previously reported in *R. quelen* (Carneiro et al., 2003; Townsend et al., 2003).

As was mentioned above, the survival rate during hatchery showed the maximum value in HT group with a 93.5% survival. Fukushima et al. (2011) also describe higher survival rate in triploids of *R. quelen* obtained by a pressure shock in comparison with diploids but values reported by them were very much lower than ours were. However, variations in survival rate between HT and CT in our study remains unknown since both group showed similar rates of triploid fish and were subjected to the same cultured conditions. Lower survival rate in CG and CT determined a lower stocking density at the end of the trial, and therefore, an increased mean weight and a lower final biomass in both group. Supporting our results, it has been reported, at least in diploids, that low density of fish might increment growth hormone expression (Menezes et al., 2015; Pouey et al., 2011) allowing better individual growth but at expense of biomass.

R. quelen larvae are cannibalistic during the first weeks of life (Baldisserotto and Radünz Neto, 2004). In a previous study, Fukushima et al. (2011) described a similar cannibalistic behavior in both diploid and triploid of *R. quelen* although it was mainly observed in diploid larvae (Behr et al., 2000). However, they did not quantify this variable. In our study, HT exhibited the lowest cannibalism rate. This explains in part the high survival rate described in this triploid fish and makes HT the most promissory group for intensive hatchery of *R. quelen*. Some studies suggest that the reduction in cannibalistic behavior in triploids is related to a decrease in the number of brain and sensory cells (Fraser et al., 2012; Fukushima et al., 2011; Maxime, 2008; Tiwary et al., 1999). This histological characteristic was confirmed in the hypothalamus of HT *R. quelen* (unpublished results), the main center for integration of information and behavioral response in fish (Jobling, 2012).

Results about growth of triploids at juvenile stage vary greatly among fishes or even within the same fish species since triploid fish may grow faster, equally or slower than their diploid counterpart (Dunham, 2011; Maxime, 2008; Tiwary et al., 2004).

No studies were previously conducted to test the impact in productive parameters of long periods of food restriction and refeeding in juvenile triploids of *R. quelen*. Our results showed that triploid fish registered significant higher mean values in mean weight regarding diploid fish through most part of the fattening trial. Similar results were described for other triploid catfishes such as *Ictalurus punctatus* (Wolters et al., 1982), *Silurus glanis* (Krasznai and Márían, 1986), *Clarias macrocephalus* (Fast et al., 1995), *Heteropneustes fossilis* (Tiwary et al., 1997) and *Clarias fuscus* (Qin et al., 1998).

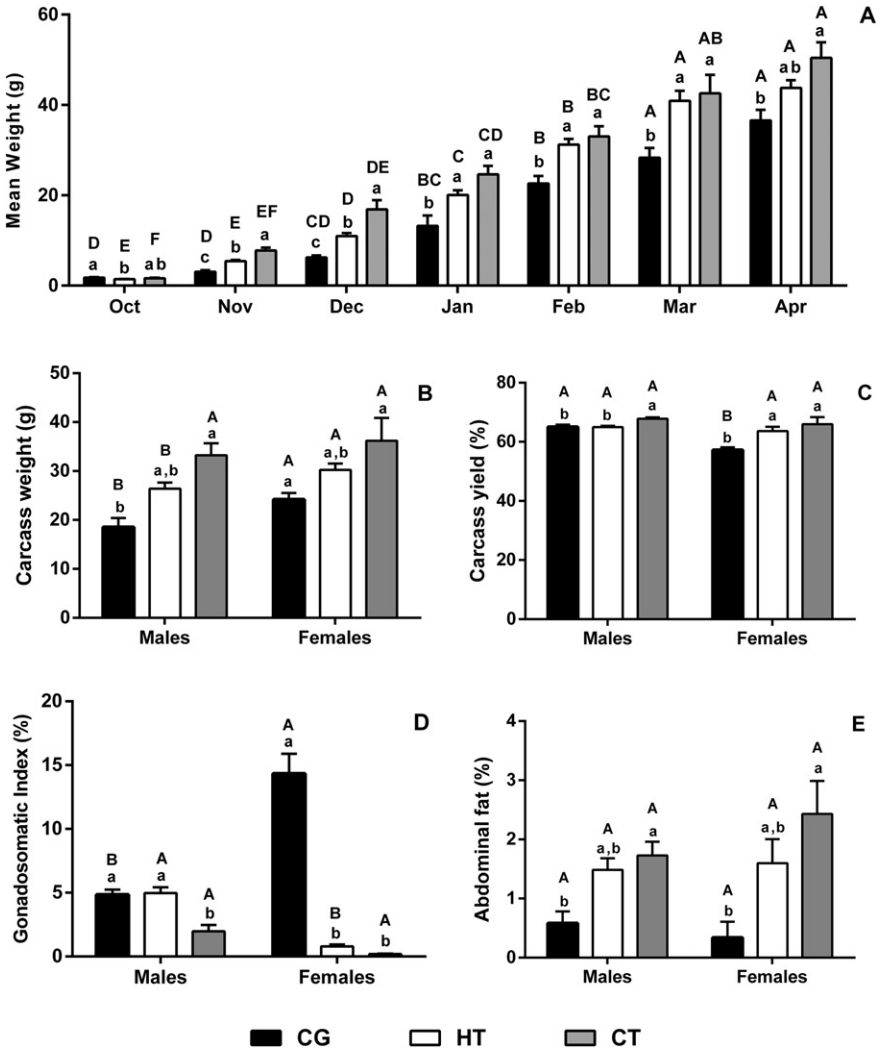

Fig. 2. Productive parameters of diploids and triploids of *R. quelen* during the fattening trial. A) Mean weight. B) Carcass weight. C) Carcass yield. D) Gonadosomatic index. E) Percentage of abdominal fat. In Panel A, different upper case letters indicate significant differences among biometries for the same treatment group ($P < 0.05$). In Panels B, C, D and E, different upper case letters indicate significant differences between sexes for the same treatment group ($P < 0.05$). In all figures different lower case letters indicate significant differences among treatment groups ($P < 0.05$). All values were expressed as mean ± standard error of the mean. CG: control group; HT: heat triploids; CT: cold triploids.

Although in other studies performed in catfish species no differences in the condition factor between diploids and triploids were observed (Fast et al., 1995; Qin et al., 1998), in *R. quelen* HT registered the highest condition factor with significant variations in comparison with the other two groups. Hussain et al. (1995) suggest that in *Oreochromis niloticus*, triploids exhibits higher condition factor than diploids due to accumulation of more visceral fat. This is in agreement with the results obtained in *R. quelen* discussed below although variations in condition factor between HT and CT remains unanswered.

Table 3
Growth parameters of diploids and triploids of *R. quelen* after six month fattening.

	Group		
Parameter	CG	HT	CT
Condition factor	1.8 ± 0.1[b]	2.1 ± 0.9[a]	1.9 ± 0.1[b]
Daily weight gain (mg day^{-1})	194 ± 16	234 ± 8	326 ± 7
Specific growth rate (%)	1.7 ± 0.1	1.9 ± 0.1	2.3 ± 0.2
Survival rate (%)	74 ± 1	100 ± 0	100 ± 0
Final biomass (g)	621.5 ± 6.5	1053.1 ± 13.1	1198.1 ± 17.9

Values are expressed as mean ± standard error of the mean from data obtained from each replica (n = 2) except for condition factor (CG, n = 20; HT and CT, n = 27). Different superscript letters indicate significant differences between groups ($P < 0.05$). CG: control group; HT: heat triploids; CT: cold triploids.

During fattening period, HT and CT groups reached the maximum survival rate and highest final biomass while CG presented the lowest values among all groups. Coincidently, daily weight gain and specific growth rate were higher in triploids regarding diploids. Particularly, CT reached the highest final biomass value between triploids. High final biomass in triploid fish was due to higher survival rate and faster growth.

Many organisms exhibit faster growth (compensatory growth) during recovery from fasting. The fast growth rate is characterized by hyperphagia, improved feed conversion efficiency, and elevated specific growth rate due to complex endocrine responses during distinct metabolic states (Ali et al., 2003; Won and Borski, 2013). In fact, it has been reported that fasting/refeeding model and ploidy modify the levels of GH/IGF axis components, metabolites and genes involved in the regulation of growth and metabolism in several species (Cleveland and Weber, 2014; Peterson and Waldbieser, 2009; Terova et al., 2007; Zhong Huan et al., 2012). Particularly, fasting increase GH and change levels of cortisol, glucose, and glycogen in *R. quelen* juvenile diploids (Barcellos et al., 2010; Menezes et al., 2015). So far, it is unknown what happen with GH/IGF axis components and other genes involved in growth during fasting/refeeding periods for triploids of this species.

Since nutrition is one of the most important factors influencing the ability of cultured fish to exhibit their genetic potential for growth

(Başçınar et al., 2007; Valente et al., 2013), it is probable that *R. quelen* responded to long food restriction in a different way due to ploidy level. As stated above, response to fasting/refeeding is multifactorial and therefore further studies are needed to a better understanding of *R. quelen* growth in such conditions.

Both males and females from CT group showed significantly higher carcass weight than their diploid counterpart. However, if data was not categorized by sex, triploid fish from both group displayed significantly higher carcass weight than CG, showing that under the same rearing conditions triploids produced higher size fillets. Heavier fillets were also described in triploids of *C. macrocephalus* (Fast et al., 1995) and *C. fuscus* (Qin et al., 1998). Another interesting fact regarding carcass weight was that CG and HT females of *R. quelen* exhibited significantly higher values than males. On the contrary, in *C. fuscus,* Qin et al. (1998) reported a higher carcass weight in triploid and diploid males in comparison with their female counterparts.

Carcass yield was also greater in triploid females and CT males of *R. quelen* in comparison with their diploid counterparts indicating that triploids produced proportionally more flesh. Similar results were reported in *Cyprinus carpio* (Basavaraju et al., 2002) and *Gadus morhua* (Derayat et al., 2013; Feindel et al., 2011). In *O. niloticus*, females triploids but not males triploids had higher carcass yield in comparison with their sibling diploids (Hussain et al., 1995). In *R. quelen,* differences in carcass yield between sexes were only observed in diploids in line with that described by Basavaraju et al. (2002) in *C. carpio*. Moreover, since no differences in carcass yield between sexes of triploid *R. quelen* were observed, both triploids males and females can be cultured with the same productive benefits.

Several authors reported lower gonadal development in triploid fish regarding diploids although some differences between sexes can exist among species (Basavaraju et al., 2002; Hussain et al., 1995; Siraj et al., 1993; Tiwary et al., 2000). In *R. quelen,* both triploid females had significantly lowers GSI than CG whereas HT males did not show significant differences in GSI with their diploid counterpart. Similar results were observed in *C. carpio* (Basavaraju et al., 2002), *H. fossilis* (Tiwary et al., 2000), *Scophthalmus maximus* (Cal et al., 2006), *G. morhua* (Feindel et al., 2011). In the later species, milt evacuation occurred during manipulation of triploid males in a similar way to that reported in *R. quelen*. Moreover, differences in correlation between GSI and carcass yield in each sex could be attributable to variations in energy allocation for reproduction in males and females due to the energy demand for sperm production is much less than that for eggs (Lester et al., 2004). r values for these variables in females of all groups pointed out a strong negative association between GSI and carcass yield since carcass yield rose as GSI decreased. Therefore, culture of female triploids instead of diploids of *R. quelen* constitutes an interesting option for farmers in order to maximize their benefits.

Finally, the percentage of abdominal fat in *R. quelen* was higher in fish with lower GSI. This is in agreement with that reported by Hussain et al. (1995) in *O. niloticus* and could be related with the reduction of energy allocation from fat deposits to reproduction in triploid fish.

In conclusion, we demonstrate that HT and CT of *R. quelen* had better productive parameters than their diploid counterparts during hatchery and also in the fattening period. Due to some parameters were better in HT while others were improved in CT, the choice of culture triploids obtain by heat or cold shock should be based on the productive aims. For example, if the purpose of a fish farm is produce fry for sale therefore culture of HT *R. quelen* must be considered due to its low cannibalism and high survival rate during hatchery. On the other hand, if a fish farm is only dedicated to juveniles fattening, culture of CT *R. quelen* could be the best choice because of their higher carcass weight and carcass yield. Finally, these promising productive parameters of triploid of *R. quelen* make necessary more studies in the future, such as molecular biology, in order to achieve a better understanding of the physiology of triploid fish.

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