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Morphological traits and growth performance of monosex male tilapia GIFT strain and Saint Peter®

Características morfológicas e desempenho de crescimento de monossexo macho de tilápia da variedade GIFT e Saint Peter®

Nilton Garcia Marengoni[1*]; Luciana Maria Curty Machado[2]; Carlos Antonio Lopes de Oliveira[3]; Grazyella Massako Yoshida[3]; Natali Miwa Kunita[3]; Ricardo Pereira Ribeiro[3]

Abstract

This study aimed to compare the morphological traits and growth performance of monosex populations of the Genetic Improved Farmed Tilapia (GIFT) and Saint Peter® of male tilapias reared in a mixed system. The experiment was carried out from June 2012 to November 2012 in Sgarbi fish farm, Palotina, Paraná State, Brazil. GIFT juveniles were obtained from the State University of Maringá (UEM/Codapar) fish farm broodstock, and the red hybrids were from the Sgarbi fish farm broodstock. The average genetic values of GIFT from three genetic groups (I, II, and III) were obtained by controlling individual pedigree and genetic evaluation using Best Linear Unbiased Prediction (BLUP). Information from complete GIFT pedigree since its introduction in Brazil was used, and the genetic groups were ranked as I (upper group), II (middle group), and III (inferior group). In all, 1,880 fish, including 480 GIFT strain and 1,400 red hybrids, with an average initial weight of 15 g, were placed in a semi-intensive system with a density of 4.7 fish m^{-2}. The fish were individually identified using Passive Integrated Transponder (PIT) tags. Harvesting was performed at the end of a 160 d period. The performance data including final weight and daily weight gain, and morphological traits including total length, standard length, body depth, head length, tail depth, tail width, body width, head length/standard length, body area and body volume were evaluated. Analysis of variance (ANOVA) and the Tukey test at 5% probability level were applied. The average final weight and daily weight gain among the three genetic groups of GIFT did not show significant differences. However all GIFT groups (I, II, and III) presented average values of performance and morphological traits higher that the Saint Peter®. Among the GIFT genetic groups, only body depth between groups I and III showed significant differences ($p<0.001$). The morphological traits and growth performance are superior in the GIFT strain, regardless of its genetic group, when compared to Saint Peter®, except for the head length/standard length ratio.

Key words: Mixed farming system, Nile tilapia, *Oreochromis* spp., red tilapia

Resumo

Este estudo teve como objetivo comparar as características morfológicas e o desempenho de populações monossexo macho de tilápia da variedade *Genetic Improved Farmed Tilapia* (GIFT) e Saint Peter® cultivadas em um sistema misto. O experimento foi conduzido durante o período de junho a novembro

[1] Prof. Associado, Centro de Ciências Agrárias, Universidade Estadual do Oeste do Paraná, Unioeste, Marechal Cândido Rondon, PR, Brasil. E-mail: ngmget@hotmail.com
[2] M.e em Recursos Pesqueiros e Engenharia de Pesca, Piscicultura Sgarbi, Palotina, PR, Brasil. E-mail: luciana.aqui@hotmail.com
[3] Pesquisadores do Grupo de Pesquisa PeixeGen, Centro de Ciências Agrárias, Universidade Estadual de Maringá, UEM, Maringá, PR, Brasil. E-mail: caloliveira@uem.br; grazyoshida@hotmail.com; nat_kunita@hotmail.com; rpribeiro@uem.br
[*] Author for correspondence

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de 2012, na Estação da Piscicultura Sgarbi, no Município de Palotina. Os juvenis da GIFT foram obtidos de reprodutores da Estação de Piscicultura da Universidade Estadual de Maringá (UEM/Codapar) e os híbridos vermelhos foram oriundos de reprodutores da Estação da Piscicultura Sgarbi. Os valores genéticos médios da variedade GIFT para três grupos genéticos (I, II e III) foram obtidos por meio de uma avaliação genética pelo *Best Linear Unbiased Prediction* (BLUP), utilizando o controle de parentesco das tilápias. Informação de pedigree completo da GIFT desde a sua introdução no Brasil foi utilizado e os grupos genéticos foram classificados como I (grupo superior), II (grupo intermediário) e III (grupo inferior). Utilizou-se o sistema semi-intensivo, sendo adotada a densidade de 4,7 peixes m^{-2} de lâmina de água. Foram alojados 480 peixes da variedade GIFT e 1400 peixes do híbrido vermelho, totalizando 1880 animais, com peso médio inicial de 15 g. Os peixes foram identificados individualmente através de *Passive Integrated Transponder (PIT) tags*. A despesca foi realizada ao final do período de 160 dias. Os dados de peso final e ganho em peso diário, e das características morfológicas incluindo comprimento total, comprimento padrão, comprimento da cabeça, altura da cauda, altura do corpo, largura da cauda, largura do corpo, comprimento da cabeça/comprimento padrão, área e volume corporal foram avaliados. Aplicou-se a análise de variância (ANOVA) e o teste de Tukey a 5% de probabilidade. Os valores médios de peso final e ganho em peso diário entre os três grupos genéticos da GIFT não apresentaram diferenças significativas. Porém, todos os grupos genéticos da GIFT apresentaram valores médios do desempenho e das características morfológicas superiores ao híbrido Saint Peter®. Entre os grupos genéticos da variedade GIFT houve diferença significativa ($p<0,001$) apenas para a altura do corpo entre os grupos I e III. As características morfológicas e de desempenho foram superiores para a variedade GIFT, independente do grupo genético, quando comparada à Saint Peter®, com exceção da relação comprimento da cabeça/comprimento padrão.
Palavras-chave: *Oreochromis* sp., sistema misto, tilápia do Nilo, tilápia vermelha

Introduction

The increased demand for fish from aquaculture has become prominent in the agricultural sector, ensuring aquaculture profitability. To ensure continued profitability, the selection of faster and more efficient growth strains is necessary, focusing on consumer market preferences for palatable food that is safe and environmentally friendly (FAO, 2014).

The Nile tilapia (*Oreochromis niloticus*) is the most commonly used in farming because of its hardiness, tolerance to various salinities, water temperatures, and production systems; rapid growth, high quality, and good acceptance in the consumer market (EL-SAYED, 2006; SILVA, 2009; KHAW et al., 2012). Like any species farmed, their growth performance and morphometric traits should be genetically improved to ensure successful growth and aquaculture profitability (PONZONI et al., 2011).

Since the base population formation in 1991, the growth rate of the Nile tilapia GIFT strain has been improved, accumulating at least a 64% genetic gain. Because of its high performance, this strain has been produced and disseminated in several countries, contributing to increased fish production and consumption, and improving small fish farmer profitability (KHAW et al., 2012).

The red hybrid (*Oreochromis* spp.) known as Saint Peter®, despite not having undergone a breeding program, is appreciated for its attractive color and efficient adaptation to mesohaline environments (HAMZAH et al., 2008; CAMPO, 2011). Red hybrids have also been developed to combine different traits of different tilapia species, including high prolificacy and growth, ease of handling and fish removal, and tolerance to cold and salinity (KUBITZA, 2011).

According to Silva and Freato (2007), in addition to fish weight, morphometric measurements can also be used as selection criteria in fish breeding programs. Recent studies on growth performance and morphometric traits (FÜLBER et al., 2010; PIRES et al., 2011; OLIVEIRA et al., 2013; REIS

NETO et al., 2014; SANTOS et al., 2014) indicated that there have been few studies of freshwater fish in Brazil. Therefore, there is a need to compare species or strains and evaluate critical factors.

The main challenge tilapia farmers face in improving productivity is the selection of strains or specific genotypes, due to high genetic variability. Performance and morphological traits are important because fish farmers can use these to estimate their economic output, and processing industries can support this by providing grants for improved performance development. The present study compared the morphological traits and growth performance of male monosex populations of GIFT, Saint Peter®, and three genetic GIFT groups farmed in mixed systems.

Materials and Methods

Local and evaluated strains

The experiment was carried out from June 2012 to November 2012 at the Sgarbi fish farm, Palotina city, Paraná State, Brazil (24º17'2'' S, 53º50'24'' W). Two genetic groups of *Oreochromis*: GIFT (*O. niloticus*) and a hybrid, *Oreochromis* spp., Saint Peter® were evaluated. GIFT (Genetically Improved Farmed Tilapia) is originally from Malaysia. This strain was initially developed by the International Center for Living Aquatic Resources Management (ICLARM) - Current WorldFish Center, by crossing eight strains, four wild and four domesticated African strains, in Asia (SILVA, 2009). The GIFT genetic tilapia breeding program in Brazil began in 2005 as a partnership between the State University of Maringá (UEM) and the WorldFish Center, resulting in 30 families receiving Nile tilapia GIFT strain to farm at the Fishfarm Station of UEM/ Codapar in Maringá, Paraná, Brazil (SANTOS et al., 2014).

According to Campo (2011), some red tilapias are the result of mating between hybrids or with pure specimens. The red tilapia Israeli or ND56, known as "Saint Peter" or "San Pietro" is a tetra hybrid resulting from crossing hybrid male (*O. niloticus* × *O. aureus*) with hybrid female (*O. mossambicus* × *O. uroleps hornorum*).

The GIFT juveniles were obtained from mating fourth generations (F4) from the genetic improvement program of the Fishfarm Station of UEM/Codapar (23º31'25''S, 52º03'12''W). The red hybrid was selected from the fry production station from December 2011 to March 2012 from the breeding stock of the fish farm Sgarbi, where the experiment was carried out.

Three genetic groups of GIFT strains

The average genetic values, Best Linear Unbiased Prediction (BLUP), of the GIFT strain from three genetic groups (I, II, and III) were obtained by genetic evaluation by controlling individual pedigree information from complete pedigree of GIFT since its introduction into Brazil. The genetic groups were ranked as I (upper group), II (middle group), and III (inferior group), according to the genetic values from individual pedigree. However, it was not possible to use this method for the hybrid Saint Peter® due to the lack of genetic information.

Experimental units and management

A 400-m^2 pond with an average depth of 1.0 m was used. The water supply and drainage were independent and screened to avoid possible predators. Pond preparation included total drainage, disinfection, liming, and fertilization as described by Boyd and Tucker (1998), thereby establishing a favorable environment for fish development.

A total of 1,880 fish, 480 GIFT and 1,400 red hybrid, with an average initial weight of 15 g, were placed in the pond. The fish were individually identified using Passive Integrated Transponder

(PIT) tags and their performance in the mixed system was performed as described by Neves et al. (2008).

Physical and chemical parameters of water and environmental conditions

The pond water temperature was monitored daily in the early morning and late afternoon. The hydrogen potential and water transparency were analyzed weekly. The average values of hardness, alkalinity, total alkalinity from carbonates and bicarbonates, ammonia, and nitrite were determined weekly from water samples analyzed in the Water Quality Laboratory of the Federal University of Paraná (UFPR), Campus Palotina.

Environmental variables (minimum, average, and maximum) such as air temperature and daily precipitation were obtained from the Meteorological Station of the Agronomic Institute of Paraná (IAPAR).

Feeding management

Feeding management was carried out by total biomass of the pond and water temperature as described by Boyd and Tucker (1998). The fish were fed twice daily with commercial food (Anhambi Alimentos Ltda.) specific for each stage of development. The daily feeding amounts ranged from 8% in the first week with commercial extruded feed (32% protein) to 2% in the last week with commercial extruded feed (28% protein). Samples were collected monthly for adjustment of feeding during the 160 d period.

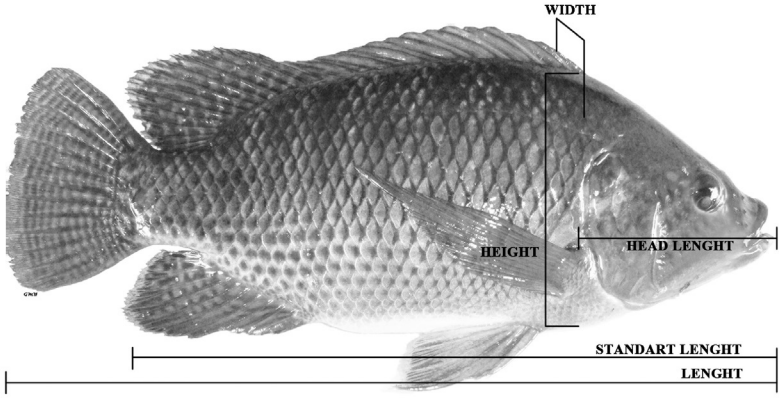
Fish sampling

Fish were harvested after 160 d. The pond water level was reduced by half to facilitate fish capture using monofilament trawl nets (15.0 m x 3.0 m). Individuals not captured with trawl nets were collected manually after draining all the water.

The information from all GIFT fish was collected. The fish samples included 190 GIFT and 102 red hybrid males. The fish were anesthetized (100 mg L^{-1} eugenol) to obtain morphometric measurements and weights (DELBON; RANZANI PAIVA, 2012). All fish used in this evaluation were transferred to other ponds of the Sgarbi fish farm as potential broodstock.

The individual weight of fish was obtained using a semi-analytical scale with 0.01 g precision. Total length (TL) was measured from the anterior extremity of the head to the extremity of the caudal fin; standard length (SL) was measured from the anterior extremity of the head to the insertion of the tail fin; body depth (BD), was measured ahead of the first ray of the dorsal fin; and body width (BW) was measured ahead of the first ray of the dorsal fin (Figure 1). The body area (BA) calculation considered the area of a trapezoid fish using the following equation: BA = [(BD + TD) x (SL – HL)]/2; where: BD = body depth; TD = tail depth; SL = standard length; HL = head length. The body volume (BV) of the edible part of the fish was calculated as a pyramid using the following equation: BV = [(BD x BW) x (TL – HL)]/3 – [(BW x TW) x (TL – SL)]/3; where: BD = body depth; BW = body width; TL = total length; HL = head length; TW = tail width; SL = standard length.

Figure 1. Morphological traits and measures used in genetic improvement program of Nile tilapia of GIFT strain from University of Maringá (UEM).



Statistical analyzes

The database was first checked to remove inconsistent data, and subsequently analyzed using PROC GLM software (STATISTICAL ANALYSIS SOFTWARE, 2004). The analysis of variance (ANOVA) and Tukey's test at 5% were used. The statistical models used in ANOVA considered the effects of the genetic group (GIFT and Saint Peter®) and age at harvesting as a covariate within the strain, since there was oscillation of age at harvesting only in GIFT.

The model used is described as: $y_{ijk} = m + G_1 + b_1 (I_j/G_1) + e_{ijk}$; where y_{ijk} is the observation of the trait analyzed; m is the overall constant, G_1 is the effect of GIFT strain and Saint Peter® or genetic groups of GIFT (I, II, and III), and the Saint Peter®; b_1 is the linear regression coefficient of the traits analyzed according to age within the GIFT strain; I_j/G_1 is the effect of age within the GIFT strain$_j$ and e_{ijk} is the random error associated with each observation.

Results and Discussion

Physical and chemical parameters of pond water

The physical and chemical parameters of the pond water in which the experiment was performed were within the comfort levels of the studied strains, with the exception of water temperature. The temperature sometimes oscillated below the recommended range (26–32 °C) tolerated by the strains (BOYD; TUCKER, 1998; EL-SAYED, 2006).

Performance traits

The average performances of GIFT and hybrid Saint Peter® are shown in Table 1. The results obtained for final weight and daily weight gain showed that GIFT was higher ($p<0.001$) compared to Saint Peter®. Similar results were obtained by Neumann et al. (2009), who evaluated the performance of two strains of *O. niloticus* (Nile tilapia and common Thai), and a hybrid *Oreochromis* spp. (red tilapia). The Thai strain showed intermediate performance between Nile tilapia and the red hybrid. The lower performance of Saint Peter® was also reported by Marengoni et al. (2009) assessing Chitralada I (F_1) and Chitralada II (F_2) and Saint Peter® in a water recirculation system. Marengoni et al. (2008) showed contradictory results to this work when assessing GIFT (Bouaké and Chitralada strains) performance during juvenile production in hapa culture. The authors found no significant differences in final weight and daily weight gain for the strains evaluated.

Tabela 1. Mean values, standard deviation, coefficient of variation (CV) and critical value (*p*) on growth performance of GIFT strain and hybrid Saint Peter® evaluated in fish ponds in western Paraná.

Trait (g)	GIFT	Saint Peter®	CV (%)	*p*
Final weight	338.28±67.07	193.87±43.31	20.52	<0.001
Daily weight gain	1.96±0.41	1.14±0.27	20.51	<0.001

In the present study, single sex populations of GIFT strains performed better in mixed culture systems compared to Saint Peter®. However, Neves et al. (2008) evaluated the growth performance of the Chitralada and Bouaké strains, in the same farming system with male and female populations, and concluded that there was no significant difference, although the performance of males was higher than females.

The best performance of GIFT tilapia was reported by Fülber et al. (2010) when evaluating the productive performance of Bouaké, Chitralada, and GIFT strains at different rearing stages, densities, and protein levels in northern Paraná, and found significant differences in final weight between strains. Similarly, Vieira et al. (2005) evaluated Chitralada (UEM/Codopar), Supreme (Aquaculture Aquabel), Bouaké (UEM/Codapar), and Chitralada (Aquabel) and showed that the Supreme strain was superior to the others in both phases. The effect of breeding on yield characteristics of genetically selected strains can be used to account for such differences. The performance difference between GIFT tilapia and Saint Peter® agree with the values found by Mainardes Pinto et al. (2011), assessing Thai and red Florida tilapia in cages, highlighting the increased performance ($p<0.05$) in the Thai strain.

Morphological traits

The average values of morphological traits are shown in Table 2. Significant differences were observed between tilapia strains. Mean values of morphological measurements of the TL, SL, BD, BW, HL, TD, TW, BV and BA of the fish were higher ($p<0.001$) for GIFT compared to Saint Peter®. However, the average values for HL/SL in the two strains tested showed no significant differences. Leonhardt et al. (2006) evaluating three strains of Nile tilapia obtained higher weight gain and larger head size for Thai tilapia compared to the local and hybrid fish. They also found differences in morphological traits and fillet yield.

The HL for GIFT (6.48 cm) and Saint Peter® (5.39 cm) are significantly different ($p<0.001$) in the present study (Table 2). However, HL/SL for both strains excelled at the same value (0.32), showing that GIFT had a better growth performance than the morphological measurements and the same HL/SL when compared with Saint Peter®.

Table 2. Mean values, standard deviation, coefficient of variation (CV) and critical value (*p*) of morphological traits of GIFT strain and hybrid Saint Peter® evaluated in fish ponds in western Paraná.

Trait (cm)	GIFT	Saint Peter®	CV (%)	*p*
Total length (TL)	25.67±1.78	21.39±1.58	7.05	<0.001
Standard length (SL)	19.78±1.49	16.50±1.25	7.53	<0.001
Body depth (BD)	7.69±0.68	6.32±0.66	9.32	<0.001
Body width (BW)	3.47±0.35	2.95±0.43	11.46	<0.001
Head length (HL)	6.48±0.47	5.39±0.39	7.27	<0.001
Tail depth (TD)	2.77±0.28	2.28±0.22	9.99	<0.001
Tail width (TW)	1.16±0.12	0.97±0.12	11.36	<0.001
Body area (BA)(1)	70.00±10.58	48.03±7.84	15.45	<0.001
Body volume (BV)(2)	166.58±31.99	96.54±20.86	19.90	<0.001
Relationship HL/SL	0.32±0.01	0.32±0.01	4.69	0.4666

(1) *BA = [(BD + TD) x (SL – HL)]/2;* (2) *BV = [(BD x BW) x (TL – HL)]/3 – [(BW x TW) x (TL – SL)]/3.*

Allaman et al. (2013) evaluating the morphological growth and weight gain of several strains of tilapia (Thai, Red, UFLA - kept at the fish culture of UFLA department since 1970 and Commercial - genetically improved commercial strain derived from the GIFT) by nonlinear models showed that UFLA presented the fastest growth regarding both weight and morphological measurements, followed by the Commercial, Thai and Red strains.

Of the ten morphological traits evaluated, nine presented significantly different growth between GIFT and Saint Peter® (Tables 2 and 4). This is probably due to different genetic diversity between the genetic groups. GIFT possibly has moderate genetic diversity, and a lower inbreeding coefficient compared with Saint Peter®, showing that this strain maintained controlled pedigree in farmed tilapias. GIFT strains also presented similar growth in the three genetic groups for nine of the ten morphological measures. Current studies analyzed weight gain and body forms throughout fish development showing differentiated growth standards (CAMPO, 2011; OLIVEIRA et al., 2013; SANTOS et al., 2013; REIS NETO et al., 2014).

Growth performance of the GIFT genotypes and Saint Peter®

The average of final weight and daily weight gain among the three genetic GIFT groups showed no significant differences. However, all genetic GIFT groups had superior performance ($p<0.05$) compared with Saint Peter® (Table 3).

Table 3. Mean values, standard deviations of performance and coefficient of variation (CV) of the genetic groups of GIFT strain compared to Saint Peter® evaluated in fish ponds in western Paraná.

Trait (g)	GIFT genetic group			Hybrid Saint Peter®	CV (%)
	I	II	III		
Final average weight	348.18±56.64a	336.08±75.28a	329.35±69.18a	193.87±43.31b	20.45
Daily weight gain	2.02±0.35a	1.95±0.47a	1.90±0.43a	1.14±0.27b	21.90

Different letters in the same row indicate significant differences ($p<0.05$) by Tukey test.

Studies evaluating the growth and survival of three groups of tilapias, GIFT, control of GIFT and Red grown in ponds in Malaysia, with diets containing 28% and 34% crude protein, also showed that GIFT strains presented higher performance compared to control and Red tilapia (SANTOS et al., 2014). Moreover, the superiority of genetically improved tilapia (GIFT and genetically male Nile tilapia (GMNT)) compared to conventional Nile tilapia (CNT) did not express differences in growth under standard laboratory rearing (MAMUN et al., 2007), differing from the present study using a mixed farming system in ponds under commercial conditions. The mean values of morphological traits of the three genetic GIFT groups are higher ($p<0.05$) than the Saint Peter® values (Table 4). The relative HL/SL of tilapia evaluated did not differ between genetic groups of GIFT or between them and the red hybrid. In this sense, all genetic groups, independent of the use of genetic breeding or hybridization, maintained good HL/SL indices.

Table 4. Mean values, standard deviations of morphological traits and coefficient of variation (CV) of the genetic groups of GIFT compared to Saint Peter® evaluated in fish ponds in western Paraná.

Trait (cm)	GIFT genetic group			Hybrid Saint Peter®	CV (%)
	I	II	III		
Total length (TL)	25.86±1.55a	25.55±1.97a	25.59±1.86a	21.39±1.58b	7.00
Standard length (SL)	19.92±1.31a	19.69±1.65a	19.71±1.54a	16.50±1.25b	7.49
Body depth (BD)	7.84±0.48a	7.69±0.64ab	7.53±0.85b	6.32±0.66c	9.21
Body width (BW)	3.48±0.22a	3.44±0.29a	3.50±0.49a	2.95±0.43b	11.62
Head length (HL)	6.53±0.44 a	6.44±0.44a	6.46±0.53a	5.39±0.39b	7.23
Tail depht (TD)	2.80±0.21a	2.82±0.32a	2.70±0.29a	2.28±0.22b	9.96
Tail width (TW)	1.18±0.10a	1.16±0.13a	1.13±0.13a	0.97±0.12b	11.34
Body area (BA)(1)	71.54±8.85a	70.13±11.44a	68.17±11.36a	48.03±7.87b	15.32
Body volume (BV)(2)	170.75±26.97a	165.08±33.64a	163.37±35.37a	96.54±20.86b	19.76
Relationship HL/SL	0.32±0.01a	0.32±0.01a	0.32±0.01a	0.32±0.01a	4.76

(1) $BA) = [(BD + TD) \times (SL - HL)]/2$; (2) $BV = [(BD \times BW) \times (TL - HL)]/3 - [(BW \times TW) \times (TL - SL)]/3$
Different letters in the same row indicate significant differences ($p<0.05$) by Tukey test.

Among the genetic GIFT groups there were only significant differences ($p<0.001$) or BD between groups I and III. These results can be explained, because the three genetic groups were defined by estimated breeding values (considered pedigree information, fixed, random effects, and covariate) and the statistics analyses using phenotypes values. However, the values of the HL/SL (0.32) for GIFT groups I, II, and III compared to the Red hybrid showed no significant differences.

Morphological measurements may be used to identify the most productive fish to be used in selection and breeding programs. These studies contribute to the fish body shape description that varies with the characteristics of each genetic group, and they can influence the body weight and fillet yield (OLIVEIRA et al., 2013). In this context, the values that interfere in processing income variables such as the HL/SL, were not affected by genetically improved body weight.

Variation in head proportions and other residues may be related to higher fillet yields (SOUZA et al., 2005). Thus, the head size can be considered an important trait for selecting strains in breeding programs aimed at improvements in the tilapia fillet yield (TURRA et al., 2010). Therefore, strains with

lower ratio values for HL/SL may be indicative of larger edible parts. Thus, the morphometric traits can be used as a selection criterion in the fish processing industry.

A number of red tilapia hybrids have been developed and commercially produced, generating high market acceptance for tilapia (EL-SAYED, 2006; SILVA, 2009; RAMÍREZ-PAREDES et al., 2012), but they have shown low production in response to lower growth compared with the wild type and improved groups of Nile tilapia (MOREIRA et al., 2005; RIDHA, 2006; ROMANA-EGUIA et al., 2010; RAMÍREZ-PAREDES et al., 2012; SANTOS et al., 2013). In this context, the importance of breeding programs is highlighted for the formation of a farmed tilapia base through the intersection of different origins and genetic variability control, and inbreeding through the pedigrees record.

Systems for tilapia production are becoming increasingly intensified, resulting in the need for more productive strains. The growth performance of three strains of the Nile tilapia (non-improved, genetically improved farmed tilapia - GIFT and the Freshwater Aquaculture Center selected tilapia) showed superior growth performance of improved strains compared with non-improved strains (RIDHA, 2006). Although the tilapia strains produced in Brazil have distinct market niches, the differentiated growth standards makes comparisons inevitable, and several works have already been carried out regarding this. The red tilapia produced by some companies stands out for being more attractive the consumer.

Conclusions

The morphological traits and growth performance are superior in the GIFT strain, regardless of its position in the classification ranking of the genetic value, when compared with Saint Peter®, with the exception of HL/SL.

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