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ANIMAL SCIENCE

Body yield and quality of fresh and post-freezing filet of Nile tilapia (*Oreochromis niloticus*) genetic groups

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Abstract: The aim of this study was to evaluate the body yield and quality of fresh and post-freezing filet of male and female fish of inbred and non-inbred AquaAmérica genetic group and the hybrid between the AquaAmérica and Tilamax varieties. Forty fish (20 males and 20 females) of each genetic group were housed in four 48-m^3 hapa net cages, getting 120 fish per cage. The fish were housed at 51 days of age and farmed for 269 days. Pre-slaughter weight was higher (P<0.05) in the AquaAmérica × Tilamax males (0.805±0.204 kg) than in the inbred AquaAmérica male (0.643±0.115 kg). Filet yield percentage was higher (P<0.05) in the AquaAmérica × Tilamax males (32.14±4.72%) than in the inbred AquaAmérica (28.15±2.67%) and non-inbred AquaAmérica (29.06±2.80%) males. Head and viscera yield percentages, pH, color values (L*, a* and b*), shear force, drip loss and cooking loss did not differ significantly between the genetic groups and sexes. Alterations in meat quality were observed after freezing. In conclusion, inbreeding in the AquaAmérica variety resulted in reduced slaughter weight for males; AquaAmérica × Tilamax males have a higher filet yield; and filet quality is not influenced by crossing, inbreeding, or sex, but is changed after freezing.

Key words: aquaculture, fish filet, fish meat quality, inbreeding, Nile tilapia varieties.

INTRODUCTION

Nile tilapia stands out as the second most widely farmed fish group in the world, representing 8.0% of 2016's world fish production (FAO 2018). In Brazil, Nile tilapia was the most widely produced aquatic organism in 2018, with 400.3 t, which ranked the country fourth in production of this species worldwide, only after China, Indonesia and Egypt (PeixeBR 2019).

In Brazil, Nile tilapia is the only aquaculture species for which a consolidated breeding program exists, which has contributed in recent years to increasing its production in relation to other species. In well-managed programs, fish breeding can provide gains of 8 to 12% per generation (Nguyen 2016), which can reach up to 15% (Ponzoni et al. 2005, 2011). Genetic selection for weight (the main goal of fish breeding programs) may not necessarily reflect on body yield and filet quality. Furthermore, selection may lead to increased inbreeding, which can affect those traits (Alexandru et al. 2014), For this reason, it is important to monitor these variables in selecting generations in breeding programs.

The GIFT (genetically improved farmed tilapia) variety was introduced in Brazil in 2005 (30 families). The fish were imported by the Universidade Estadual de Maringá (UEM), located in Maringá - PR, Brazil, in a partnership with the World Fish Center, located in Malaysia (Oliveira et al. 2012). This variety was composed of a cross between four wild African varieties (Ghana, Egypt, Kenya and Senegal) and four varieties domesticated in Asia (Israel, Singapore, Taiwan and Thailand) (Eknath et al. 2007). After the sixth GIFT generation in Brazil, local varieties of Nile tilapia were introduced into the UEM breeding program for the production of new families, creating a new variety called Tilamax. The AquaAmérica Nile tilapia variety was created in Brazil in 2012, from the GIFT variety previously bred with the tilapia virieties Chitralada Nile and Bouaké, introduced in 1996 and 1971, respectively (Oliveira et al. 2016, Garcia et al. 2017).

The main goal of fish breeding programs is to increase growth rates; however, filet yield is also considered an important trait to elevate the economic efficiency of the production chain (Turra et al. 2010, Rutten et al. 2004). In Nile tilapia, the filet yield is related to its body weight, processing methods (Azevedo et al. 2016) and intrinsic characteristics (Contreras-Guzmán 1994). The filet is the main product in the industrialization of Nile tilapia (Boscolo et al. 2001), and filet weight is a characteristic that should be taken into account by breeding programs (Rutten et al. 2005) just as meat quality, since it is one of the factors determining the consumer's perception (Olsson et al. 2003, Lauritzsen et al. 2004, Oliveira et al. 2008).

Although previous studies have evaluated the performance (Lima et al. 2015, Rodrigues et al. 2018), genetic parameters (Oliveira et al. 2015) and reproductive traits (Yoshida et al. 2015, Sarmento et al. 2018) of selectively bred varieties, there are no comparative studies with the most recently selectively bred varieties in Brazil investigating body yield and filet quality aspects, especially regarding the effects of inbreeding and crossing between varieties bred for those traits. The present study thus proposes to examine the body yield and quality of fresh and post-freezing filet of Nile tilapia genetic groups.

MATERIALS AND METHODS

Facilities and animals

The experiment was developed at the Experimental Fish Farming Station (20°49'96.58" S and 54°61'46.20" W) at the Universidade Federal de Mato Grosso do Sul (UFMS), in Campo Grande - MS, Brazil. Fish slaughter, qualitative analysis of meat and analysis of yield were performed at the Laboratório de Processamento e Qualidade de Carne at UFMS (Qualicarne/UFMS-FAMEZ). This research was approved by Ethics Committee on the Use of Animals at UFMS (approval no. 784/2016).

The fish used in the experiment originated from Nile tilapia breeders of varieties Tilamax and AquaAmérica, representing the seventh and second generations of selective breeding for weight gain, respectively. The animals were obtained by mating the varieties at the same study site. The AquaAmérica variety was evaluated at different degrees of relatedness [zero (non-inbred) and 25% (inbred)], and a genetic group derived from the cross between AquaAmérica females and Tilamax males was also examined.

A semi-intensive system with 10% water exchange per day was used for farming the fish. A final biomass of 1.5 kg fish/m^2 was estimated as recommended by Ribeiro (2001). Fish were fed twice daily (09h00 and 16h00) with different diets according to their weight. Mash feed was used in the weight range from 5 to 20 g (45% crude protein, 9% ether extract, 2.5% fibrous matter, 14% mineral matter and 12% moisture). From 20 to 100 g, the fish received extruded feed with 2-mm pellets (40% crude protein, 11% ether extract, 2.5% fibrous matter, 14% mineral matter and 12% moisture); from 100 to 300 g, the fish were fed extruded feed with 3-4-mm pellets (36% crude protein, 6% ether extract, 6% fibrous matter, 11% mineral matter and 12% moisture); lastly, from 300 to 1000 g, the fish received extruded feed with 5-6-mm pellets (32% crude protein, 6.5% ether extract, 4% fibrous matter, 14% mineral matter and 12% moisture). The animals were fed to apparent satiation.

Temperature (23.8 ± 1.7 ºC), dissolved oxygen (5.0 ± 2.7 mg/L), pH (8.1 ± 0.3) and electrical conductivity (109.3 ± 8.8 μS cm^{-1}) were measured daily throughout the experimental period using a YSI multiparameter meter (Yellow Springs Instruments). The concentrations of ammoniacal nitrogen ($N\text{-}NH_3$; 0.84 ± 0.7 mg L^{-1}), nitrite ($N\text{-}NO_2$; 0.04 ± 0.04 mg L^{-1}) and carbonate alkalinity ($CaCO_3$; 79.5 ± 11.1 mg L^{-1}) were measured monthly using a colorimetric kit (AlfaKit). All water quality indicators were within the adequate range for the development of tropical fish (Boyd 1998).

Forty fish (20 males and 20 females) of each genetic group were housed in four 48-m^3 hapa net cages, getting 120 fish per cage. Therefore, 160 fish from each genetic group (40 fish in each of the four hapas) were used in the experiment. Males and females were raised together. All fish were identified individually by a microchip (Animal tag). The animals were placed in the experimental units at 51 days of age. The average initial weight of the genetic groups is described as follows: inbred AquaAmérica - 12.23 ± 2.50 g (males) and 10.36 ± 1.85 g (females); non-inbred AquaAmérica - 11.33 ± 3.55 g (males) and 11.32 ± 3.35 g (females); and AquaAmérica × Tilamax hybrid - 18.14 ± 6.76 g (males) and 16.18 ± 7.04 g (females). The fish were farmed for 269 days, until completing 320 days of age.

Measured traits, slaughter and carcass yield determination

After the fish were fasted for 24 h, biometric measurements were performed to determine their final weight. Prior to slaughter, all fish were anesthetized in Eugenol solution (100 mg/L) and then decapitated, as indicated in the guidelines established by the Conselho Nacional de Controle de Experimentação Animal (CONCEA) for fish heavier than 200 g. Next, the fish were kept in cooler boxes with ice until analysis.

An electronic scale (9094, Toledo) was used for weighing the fish and determining the yield of their cuts. Slaughter, cutting and fileting were performed manually by a single trained person. The yield percentage of the fish parts was determined relative to the total fish weight before slaughter (pre-slaughter weight), according to the following equation: YEP (%) = (WEP/FWS) × 100, where YEP represents the yield percentage of the evaluated part (filet, viscera and head), WEP = weight of the evaluated part; and FWS = fish weight before slaughter. Samples were subsequently wrapped in polyethylene film and frozen for later analyses. For these analyses, 120 fish were used, with 40 fish of each genetic group (20 males and 20 females).

For the analyses of pH, color, cooking loss, drip loss and shear force, 120 filets from the left side (40 of each genetic group, 20 males and 20 females). The qualitative attributes were measured according to AMSA (2015). All variables were measured in the post freeze fillet, and for fresh fillet only color and pH were analyzed. After the fresh-filet attributes were analyzed, the filets (which were identified from slaughter) were frozen at a temperature of -16ºC for 150 days. After this period, they were placed in a cold chamber for thawing at 0 ± 2 ºC, for 24 h.

A portable pH meter (HI 99163, Hanna) calibrated with buffer solutions pH 4 and 7 was used to measure the pH. The intramuscular pH was determined in triplicate (three distinct regions of each filet) prior to the other tests and 20 min postmortem.

A chroma meter (CR-400, Konica Minolta) was used to determine the color based on the CIELAB system, which defines the L* [lightness, ranging from 0 (black) to 100 (white)], a* [green (–60) to red (+60)] and b* [blue (–60) to yellow (+60)] parameters. After these analyses, all filets were identified and stored in a freezer.

To determine drip losses, all samples were weighed before thawing. After 24 h, the thawed samples were weighed and the exudate released from each sample was also weighed. The weight values were used to determine drip loss.

Cooking loss was determined by weighing the samples before and after cooking. For this measurement, samples were weighed raw and then cooked in a conventional electric oven at 170 ºC. The temperature was monitored until the samples reached 71 ºC in their geometric center. After cooking, the samples were weighed again to calculate the fluid loss (drip loss) during cooking.

Shear force was determined using a texturometer (Brookfield CT3) with 25-kg capacity equipped with a Warner-Bratzler blade (HDP/WBV), at a descent speed of 3.3 mm/s, with values expressed in kg. For these assessments, after cooking, the filets were wrapped in polyethylene film and chilled at 20 ºC after two hours resting on a benchtop. Five sub-samples were taken from each fillet with the aid of a rectangular base (2 cm x 1 cm), so that the fillets were compressed axially until the sample was completely cut (Fantini et al. 2015). Therefore, in each genetic group, 40 fillets were evaluated (20 from males and 20 from females), with five sub-samples of each fillet. The average shear force of the sub-samples of each filet was used as the shear force value of each fish.

Statistical analyses

All analyses were carried out using the GLM procedure of SAS software version 9.0. Student's T test was applied at the 5% probability level for comparisons between the genetic groups and fresh and post-freezing filet.

RESULTS

Pre-slaughter weight was higher (P<0.05) in the AquaAmérica × Tilamax males compared to the inbred AquaAmérica group. Filet yield percentage was higher (P<0.05) in the AquaAmérica × Tilamax males than in the inbred and non-inbred AquaAmérica males. There was no difference in the females across the different genetic groups for pre-slaughter weight and filet yield percentage. Head and viscera yield percentages in the males and females did not differ significantly across genetic groups (Table I).

No significant differences were detected for pH, color (L*, a* and b*), shear force, drip loss, or cooking loss in the males (Table II) and females (Table III) across the genetic groups, between fresh and post-freezing filets. However, pH and a* were higher (P<0.05) in the fresh filet compared to its post-freezing version, regardless of animal sex. By contrast, L* and b* values were higher (P<0.05) in the post-freezing filled, in both males and females (Table II, III).

DISCUSSION

This is the first comparative study of body weight and filet characteristics of a selectively bred inbred and non-inbred Nile tilapia variety and a genetic group deriving from the cross between two selectively bred varieties. The results show that inbreeding level, crossing between the varieties and sex did not change filet quality. Meat quality was also found to be

Table I. Body yield (mean ± standard deviation) in males and females of different genetic varieties of Nile tilapia after 269 days production in Campo Grande, MS, Brazil.

Variable	Males				Females			
	Inbred AquaAmérica (n = 20)	Non-inbred AquaAmérica (n = 20)	AquaAmérica× Tilamax hybrid (n = 20)	P-value	Inbred AquaAmérica (n = 20)	Non-inbred AquaAmérica (n = 20)	AquaAmérica × Tilamax hybrid (n = 20)	P-value
Pre-slaughter weight (kg)	0.643 ± 0.115[b]	0.714 ± 0.095[ab]	0.805 ± 0.204[a]	0.0087	0.393 ± 0.100	0.470 ± 0.197	0.441 ± 0.145	0.2671
FiletYP (%)	28.15 ± 2.67[b]	29.06 ± 2.80[b]	32.14 ± 4.72[a]	0.0043	29.32 ± 2.61	31.30 ± 2.19	30.16 ± 3.19	0.0756
HeadYP (%)	23.50 ± 2.13	22.47 ± 2.72	22.29 ± 2.82	0.3482	24.64 ± 3.18	23.00 ± 1.93	24.42 ± 2.54	0.1203
ViscYP (%)	5.38 ± 1.66	5.46 ± 0.66	5.90 ± 0.93	0.3354	6.32 ± 1.43	6.24 ± 1.25	6.56 ± 1.50	0.7825

Different letters indicate that the means of the genetic groups within each sex differ statistically according to the T test (P<0.05). FiletYP (%): filet yield percentage; HeadYP (%): head yield percentage; ViscYP (%): viscera yield percentage.

altered after freezing in all genetic groups and sexes. However, males from the cross between the AquaAmérica and Tilamax varieties were heavier pre-slaughter and had a higher filet yield percentage than the inbred AquaAmérica variety, indicating a possible effect of inbreeding on the body yield traits.

Males of the inbred AquaAmérica, non-inbred AquaAmérica and AquaAmérica × Tilamax genetic groups showed a much higher pre-slaughter weight than the females. This finding confirms the heavier weight of males and selectively bred varieties (Gjerde et al. 2012, Bentsen et al. 2017, Lind et al. 2015) compared to their non-selectively bred counterparts (Verdal et al. 2017, Pires et al. 2011). It should be emphasized that the non-inbred AquaAmérica females weighed 65.8% of the males' weight, whereas the weights of the inbred AquaAmérica and AquaAmérica × Tilamax females represented 61.2% and 54.8% of the males' weight, respectively. This weight difference between males and females after 320 days of age demonstrates the sexual dimorphism for body size, which was less evidenced in the non-inbred AquaAmérica group. Nevertheless, the current results reinforce the importance of sex reversal in Nile tilapia farming, considering that males are heavier irrespective of genetic group.

In males the heavier pre-slaughter weight of the AquaAmérica × Tilamax genetic group compared to the inbred AquaAmérica reveals a negative effect of inbreeding. Moreover, the AquaAmérica × Tilamax genetic group presented a higher filet yield percentage than the inbred and non-inbred AquaAmérica varieties. Considering that the current Nile tilapia market is mainly focused on the sale of the filet, it is an important trait to be improved in selective breeding programs. Alterations in filet yield may be due to genetics (Geri et al. 1995), and, in the present study, they demonstrate that the cross between the varieties favored this characteristic.

The filet yield percentage found in the AquaAmérica variety (inbred and non-inbred) was slightly lower than the 30.1% observed by Thodesen et al. (2012) in males from the first generation of selectively bred GIFT; and than the 31.1, 34.6 and 34.5% obtained by Nguyen et al. (2010) for the fourth, fifth and six selection generations of GIFT. However, the filet yield percentage of the group derived from the AquaAmérica × Tilamax cross was similar to that observed by Nguyen et al. (2010) in the fourth generation, but lower than that observed by the same authors in the following generations. The lower filet yield percentage found in the current study may be due to the weight range of the fish, considering that larger fish typically have a

Table II. Quality of fresh filet and Post-freezing filet after 150 days (mean ± standard deviation) of males from different genetic groups of Nile tilapia.

	Inbred AquaAmérica		Non-inbred AquaAmérica		AquaAmérica × Tilamax hybrid	
Variable	**Fresh filet (n = 20)**	**Post-freezing filet (n = 20)**	**Fresh filet (n = 20)**	**Post-freezing filet (n = 20)**	**Fresh filet (n = 20)**	**Post-freezing filet (n = 20)**
pH	6.33 ± 0.23^{a}	6.01 ± 0.13^{b}	6.30 ± 0.26^{a}	6.06 ± 0.21^{b}	6.39 ± 0.22^{a}	5.97 ±0.13^{b}
Color - L*	43.67 ± 1.92^{b}	55.28 ± 3.84^{a}	43.50 ± 2.05^{b}	53.72 ± 4.68^{a}	43.33 ± 2.12^{b}	56.25 ± 2.98^{a}
Color - a*	1.18 ± 0.82^{a}	0.34 ± 0.78^{b}	1.46 ± 1.00^{a}	0.52 ± 0.63^{b}	1.11 ± 1.25^{a}	0.19 ± 1.21^{b}
Color - b*	0.71 ± 1.39^{b}	7.66 ± 2.34^{a}	0.74 ± 1.03^{b}	7.42 ± 1.78^{a}	0.52 ± 1.53^{b}	7.72 ± 2.16^{a}
Shear force (kg)	-	1.04 ± 0.14	-	1.08 ± 0.15	-	1.11 ± 0.17
Drip loss (%)	-	7.85 ± 3.06	-	7.43 ± 2.08	-	7.06 ± 2.46
Cooking loss (%)	-	29.38 ± 5.91	-	27.42 ± 10.94	-	27.92 ± 5.13

Different letters in the genetic groups indicate that the means for fresh filet and Post-freezing filet differ statistically according to the T test (P<0.05). There was no significant difference between the genetic groups for fresh and post-freezing filet. For each sample of the Shear Force variable, five sub-samples were performed. The * is not indicating that there is more information related to the track variable. It is part of the variable naming.

higher yield than smaller fish, as demonstrated by Thodesen et al. (2012) and Gjerde et al. (2012).

As shown in the study of Nguyen et al. (2010), the evolution of selectively bred varieties tends to improve their filet yield. Those authors concluded that after three generations of selective breeding for body weight, there was a significant increase in filet yield percentage. This demonstrates that filet yield percentage tends to improve in the subsequent selection generations of the AquaAmérica variety. The Tilamax variety, used to obtain the AquaAmérica × Tilamax genetic group, belongs to the seventh selection generation, which may explain their higher filet yield percentage compared to AquaAmérica, which is from the second selection generation.

Head and viscera yield percentages did not differ between the genetic groups. Results for these variables were similar to those reported in other studies (Silva at al. 2009, Neira et al. 2016, Rutten et al. 2005).

The qualitative traits of the filet were not influenced by the evaluated genetic groups, indicating that those traits are not changed, even in the inbred variety. Filet quality is a fundamental attribute when aiming at increasing fish consumption, which is still low in countries like Brazil, where fish consumption per capita between 2013 and 2018 was 5 to 10 kg/year (FAO 2018).

The pH values of fresh filet were similar across the genetic groups, which shows that this variable is more dependent on pre-slaughter management than on the fish genetics. The time between capture and slaughter may influence the pH of the filet, with longer slaughter times meaning increased levels of glycogen utilized and, consequently, decreased anaerobic lactic acid production, which culminates in a lower pH (Soares & Gonçalves 2012). These chemical reactions depend on the level of stress during slaughter and may accelerate the process of *rigor mortis*, in fish (Poli et al. 2005). Overall, the filet pH values measured in the different genetic groups and sexes were close to some reported in other studies with Nile tilapia, as found by Santo et al. (2016) from 6.19 to 6.36; and by Goes et al. (2018), values ranging from 6.15 to 6.30. However, lower values have also been described, such as the pH of 5.91 found by Rebouças et al. (2017), evidencing the great influence of environment

Table III. Qualityfresh filet and Post-freezing filet after 150 days (mean ± standard deviation) of females from different genetic groups of Nile tilapia.

Variable	Inbred AquaAmérica		Non-inbred AquaAmérica		AquaAmérica × Tilamax hybrid	
	Fresh filet (n = 20)	Post-freezing filet (n = 20)	Fresh filet (n = 20)	Post-freezing filet (n = 20)	Fresh filet (n = 20)	Post-freezing filet (n = 20)
pH	6.21 ± 0.27[a]	5.91 ± 0.13[b]	6.19 ± 0.19[a]	5.92 ± 0.11[b]	6.13 ± 0.21[a]	5.96 ± 0.10[b]
Color - L*	44.09 ± 2.81[b]	57.40 ± 4.00[a]	43.83 ± 2.64[b]	55.82 ± 3.73[a]	44.30 ± 3.37[b]	56.45 ± 3.35[a]
Color - a*	0.83 ± 1.30[a]	-0.18 ± 1.33[b]	0.91 ± 1.07[a]	0.36 ± 1.38[b]	1.12 ± 1.37[a]	0.08 ± 1.29[b]
Color - b*	0.66 ± 1.37[b]	7.65 ± 1.98[a]	0.76 ± 1.31[b]	8.38 ± 3.38[a]	0.78 ± 1.00[b]	7.78 ± 1.81[a]
Shear force (kg)	-	1.08 ± 0.186	-	1.10 ± 0.184	-	1.01 ± 0.162
Drip loss (%)	-	10.09 ± 2.88	-	9.84 ± 2.94	-	9.67 ± 4.30
Cooking loss (%)	-	32.94 ± 10.80	-	31.36 ± 4.44	-	30.36 ± 7.50

Different letters in the genetic groups indicate that the means for fresh filet and Post-freezing filet differ statistically according to the T test (P<0.05). There was no significant difference between the genetic groups for fresh and post-freezing filet. For each sample of the Shear Force variable, five sub-samples were performed. The * is not indicating that there is more information related to the track variable. It is part of the variable naming.

and/or pre-slaughter stress on the pH value in the fresh filet. The Brazilian law establishes a maximum pH value of fresh filet of 7.0 provided that its sensory characteristics are fully preserved (Brasil 2017); on this basis, the values obtained in the present study for the fresh filet can be considered adequate.

As *rigor mortis* sets in, the pH of fish meat tends to drop, subsequently rising again as the process ends (Ashie et al. 1996, Emire & Gebremariam 2010). Odoli (2009) found a pH change of 6.5 to 6.7 after storage of Nile tilapia filets at 1 ºC. Cartonilho & Jesus (2011), reported a pH change of 6.66 to 6.70 in the meat of tambaqui (*Colossoma macropomum*) post-freezing. In the present study, the post-freezing filet showed a lower pH than the fresh filet in all genetic groups (regardless of sex), but its value was closer to those obtained in other studies with fish.

In the current study, after the filet were stored (-16ºC) for 150 days, color parameters L* and b* increased while a* decreased, in all genetic groups (regardless of sex). These data corroborate those published by Zhao et al. (2017), who also found variations in Nile tilapia filets after storage at –18 ºC for 60 days. The similar filet color (L*, a* and b*) between the fish indicates that these variables are not influenced by the genetic group. The present results are consistent with those published in previous research (Lima et al. 2015, Rebouças et al. 2017). However, changes in filet color post-freezing were seen in all genetic groups, with the filet (regardless of sex) becoming lighter after 150 days of storage, which confirms the results obtained by Oliveira Filho et al. (2015).

A light color is an important characteristic influencing the consumer's choice for the filet. The a* color is linked to myoglobin present in the muscles (Maia & Ogawa 1999), and storage possible caused the myoglobin in the muscle to oxidize, making the filet lighter (Oliveira Filho et al. 2015, Venugopal 2006). Similarly, the storage of fillets may have increased the lipid peroxidation (Veeck et al. 2013) and modified the structure of the muscle tissue (Robb et al. 2000), which can justify the increase in color b* and color L*, respectively.

Shear force did not differ significantly across the genetic groups. Results for this variable were similar to the found by Wang et al. (2018)

in the filet after freezing. Those authors stressed that toughness (maximum force necessary to compress) is lower when the Nile tilapia filet undergoes several processes of freezing and thawing, indicating that freezing accelerates protein degradation in the meat. The storage period of 26 days reduces the compression force (Oliveira Filho et al. 2015), and this softening characteristic of the fish filet means deterioration and loss of quality (Truong et al. 2016). This change in meat texture after storage is due to a reduction in solubility and muscle protein denaturation (Sikorski et al. 1994, Hyldig & Nielsen 2001).

Drip and cooking losses in the filets were similar across the genetic groups (regardless of sex), confirming the lack of changes in filet texture across the groups. These variables are correlated with water retention, and when these losses are high, undesirable changes make take place in the filet, such as a reduction of juiciness and weight loss (Lakshmanan et al. 2007).

Drip losses in the filets of male and female fish were higher than those found in the experiment led by Wang et al. (2018), who observed 6.82% losses after freezing. By contrast, the cooking losses in the filet of males and females were similar to the 29.00% reported by Rebouças et al. (2017). Water-holding capacity decreases as *rigor mortis* is established; however, age, muscle function and antemortem stress may influence water-holding capacity in the meat (Judge et al. 1989). In the present study, no differences were observed between the genetic groups, and the results were very similar to those obtained in other research with fish.

CONCLUSIONS

Males from the genetic group derived from the AquaAmérica × Tilamax cross are heavier at pre-slaughter and have higher filet yield percentage than the inbred AquaAmérica variety. Filet quality is not influenced by the cross between the varieties, inbreeding, or sex. After freezing, there is a pH decline and changes in the color of filets of males and females of all genetic groups.

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