UNIVERSIDADE ESTADUAL DE MARINGÁ
CENTRO DE CIÊNCIAS AGRÁRIAS

ASSOCIAÇÃO GENÉTICA ENTRE CARACTERÍSTICAS DE CRESCIMENTO E DE CARCAÇA DE TILÁPIA DO NILO (*Oreochromis niloticus*)

Autor: André Luiz Seccatto Garcia
Orientador: Prof. Dr. Carlos Antonio Lopes de Oliveira

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Estado do Paraná
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Dissertação apresentada, como parte das exigências para obtenção do título de MESTRE EM ZOOTECNIA, no Programa de Pós-Graduação em Zootecnia da Universidade Estadual de Maringá - Área de concentração Produção Animal.

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DEDICO este trabalho àqueles que, antes de todos, tornaram tudo isso possível

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BIOGRAFIA

André Luiz Seccatto Garcia nasceu em Iracema do Oeste- PR, filho de Carlos Fernandes Garcia e Natalina Seccatto Garcia.

Em dezembro de 2014, concluiu o curso de Zootecnia pela Universidade Estadual de Maringá (UEM-PR).

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RESUMO

O objetivo deste trabalho foi estimar parâmetros genéticos para características de desempenho (ganho em peso diário, peso à biometria e peso ao abate), peso e rendimento de filé e percentual de gordura no filé, de tilápias do Nilo variedade Aquaamerica. Foram utilizados animais da terceira geração da variedade Aquaamerica, sendo que para as características de desempenho, o banco de dados continha informação de 2585 animais, machos e fêmeas, e para percentual de gordura, peso ao abate, peso e rendimento de filé foram avaliados apenas machos, sendo 1136, 1204, 1198 e 1198 animais respectivamente. Foi realizado o teste de diferentes modelos para cada característica e o melhor modelo selecionado com base no Critério de informação da Deviance (DIC). As análises foram realizadas utilizando o software GIBBS1F90 (BLUPF90 family of programs). Para a estimativa dos componentes de variância, herdabilidade e efeito de ambiente comum foram realizadas análises unicaráter utilizando modelo animal. As estimativas de herdabilidade variaram de 0,2 (gordura) a 0,41 (peso ao abate). Para a estimativa dos componentes de (co)variância e cálculo das correlações genéticas e fenotípicas foram realizadas análises bicarater considerando ganho em peso diário com gordura e rendimento de filé; peso final com gordura e rendimento de filé; e rendimento de filé e gordura. A correlação genética entre rendimento de filé e gordura foi a única significativa (0.6), dessa forma não é esperada resposta correlacionada no rendimento de filé quando se utiliza características de desempenho como critério de seleção. Por outro lado a correlação genética entre rendimento de filé e gordura aponta para a possibilidade de resposta correlacionada à seleção de modo que utilizando o rendimento de filé como critério de seleção, a resposta correlacionada esperada no percentual de gordura seria de 7,81% na próxima geração

Palavras chave: Rendimento de filé; Correlação genética; Tilápia; GIFT

ABSTRACT

The aim of this study was to estimate genetic parameters for performance traits (daily weight gain, weight at biometry and weight at slaughter), weight and fillet yield and fat percentage in the fillet of Nile tilapia strain Aquaamerica. Animals from the third generation of Aquaamerica strain were used and for performance traits. The data contained information of 2585 animals, males and females, and for fat percentage, weight at slaughter, weight and fillet yield only males were evaluated, with 1136, 1204, 1198 and 1198 animals respectively. Different models were tested for each trait and the best model was selected based on the Deviance Information Criterion (DIC). Analyses were performed using the software GIBBS1F90 (BLUPF90 family of programs). For the estimation of variance components, heritability and common environmental effect were performed univariate analyzes using animal model. Heritability estimates were moderated and ranged between 0.2 (fat) to 0.41 (slaughter weight). For the estimation of (co)variance components and calculation of genetic and phenotypic correlations, bivariate analyzes were performed considering daily weight gain with fat and fillet yield; final weight with fat and fillet yield; and fillet yield and fat. Only the genetic correlation between fillet yield and fat was significant (0.6), thus no correlated responses are expected in fillet yield when using performance traits as selection criteria. On the other hand the genetic correlation between fat and fillet yield points to the possibility of correlated response to selection therefore, if using fillet yield as selection criteria, the expected correlated response on fat percentage would be 7.81% in the next generation.

Keywords: fillet yield; genetic correlation; tilapia; GIFT

I- INTRODUÇÃO

1.1- Panorama da aquicultura mundial

De acordo com dados da FAO 2016 (Food and Agriculture Organization), o volume de produtos de origem animal provenientes da aquicultura (peixes, moluscos, crustáceos, entre outros), somou cerca de 167 milhões de toneladas em 2014. Dessas, aproximadamente 93 milhões são provenientes da pesca extrativista e outras 74 milhões de toneladas provindas da produção de organismos aquáticos.

Das 74 milhões de toneladas, 65 milhões são produzidas no continente asiático, com destaque para a China, Índia e Indonésia que ocupam as três primeiras posições no ranking, produzindo 45,4, 4,8 e 4,2 milhões de toneladas, respectivamente. Depois da Ásia, o continente que concentra a maior produção de organismos aquáticos é o Americano, com cerca de três milhões de toneladas, com destaque para o Chile, com 1,2 milhões, e o Brasil, com 561,8 mil toneladas (FAO 2016).

Dentro da aquicultura, a produção de peixes (piscicultura), seja ela em água doce ou salgada, tem grande contribuição no volume total produzido. Entre as espécies de peixes de água doce produzidas, as carpas são as que têm maior contribuição, com as espécies *Ctenopharyngodon idellus, Hypophthalmichthys molitrix* e *Cyprinus carpio,* somando 14,6 milhões de toneladas, seguidas pela tilápia do Nilo (*Oreochromis niloticus*) com 3,7 milhões de toneladas (FAO 2016).

1.2- Produção de tilápias

Sendo a quarta espécie de peixe mais cultivada em água doce, a tilápia é produzida em mais de 100 países e com os mais diversos sistemas de produção, que vão desde produções artesanais até sistemas de produção intensivos e com alto grau de tecnificação (Ana and Bjorndal 2008; Fitzsimmons et al. 2011).

A produção mundial de tilápia do Nilo chegou à marca de 3,7 milhões de toneladas em 2014 e a China continua sendo o maior produtor, com 1,28 milhões de toneladas, seguida da Indonésia Egito e Peru, com 999,7; 759,6 e 461,1 mil toneladas, respectivamente (FAO 2016).

Características como carne saborosa, tolerância a baixas concentrações de oxigênio dissolvido e a altas concentrações de amônia, além do hábito alimentar onívoro, fazem com que a tilápia seja uma espécie de destaque na produção aquícola mundial (Watanabe et al. 2002).

A demanda por produtos oriundos da criação de tilápias é grande, o que faz com que mesmo em países com um volume de produção expressivo, como a China, boa parte da produção seja destinada para o consumo interno.

No mercado internacional, os Estados Unidos é o maior país importador de tilápia, sendo que o principal produto importado é o filé congelado, proveniente principalmente da China (Fitzsimmons et al. 2011).

1.3- Piscicultura brasileira

Segundo dados do IBGE 2015, a produção de peixes de água doce no Brasil foi de 483,2 mil toneladas, o que representa um acréscimo de 1,5% em relação a 2014. As regiões Norte, Sudeste e Sul apresentaram aumento na produção de 6,2; 12,7 e 13,1% respectivamente, enquanto que nas regiões Nordeste e Centro-oeste, foram registradas quedas de 4,7 e 19,7%. O Estado de Rondônia se manteve como maior produtor, com 84,5 mil toneladas, enquanto que o Paraná subiu para a segunda colocação no ranking, produzindo 69,3 mil toneladas em 2015.

Em 2015, a tilápia e o tambaqui continuaram ocupando as primeiras posições no ranking de espécies mais cultivadas. No ano de 2015, a produção de tilápias ultrapassou a marca de 219 mil toneladas, o que representa 45,4% da despesca nacional e um aumento de 9,7% na produção dessa espécie com relação ao ano anterior (IBGE 2015).

O município de Jaguaribara no Ceará foi o maior produtor de tilápias, com 13,8 mil toneladas, seguido por Nova Aurora e Assis Chateaubriand no Paraná, com 9,1 e 7 mil toneladas (IBGE 2015).

Tendo em vista o cenário otimista para a produção e comercialização de tilápias, bem como as características favoráveis ao cultivo presentes no Brasil como clima, disponibilidade de recursos agrícolas e hídricos, a tilapicultura (produção de tilápias) pode ser objetivo de investimentos para aumentar a produção e a geração de renda para pequenos, médios e grandes produtores.

1.4- Melhoramento genético de tilápias

Além de melhorias nos aspectos nutricionais, de estrutura para produção e da cadeia produtiva como um todo, o melhoramento genético tem contribuído e pode contribuir ainda mais com a produção de tilápias.

Os principais programas de melhoramento genético de tilápias têm como foco a espécie *Oreochromis niloticus* (tilápia do Nilo) (Fitzsimmons et al. 2011). Algumas variedades têm sido desenvolvidas ao longo dos anos, como por exemplo a variedade GST (Genomar Supreme Tilapia) e a variedade GIFT (Genetically improved farmed tilapia), desenvolvida pelo International Center for Living Aquatic Resources Management (ICLARM) e posteriormente pelo World Fish Center, na Malasya.

A variedade GIFT foi formada a partir de 20 anos de seleção, e envolveu oito diferentes variedades de tilápias, sendo quatro capturadas da natureza, entre os anos de 1988 e 1989 no Egito, Gana, Quênia e Senegal; e outras quatro variedades já utilizadas em sistemas de produção, provenientes de Israel, Singapura, Tailândia e Taiwan (Bentsen et al. 1998).

No Brasil, a variedade GIFT foi introduzida em 2005, por meio de um convênio entre o World Fish Center- Malasya e a Universidade Estadual de Maringá, com apoio da Secretaria Especial de Aquicultura e Pesca da Presidência da República (SEAP-PR). Foram recebidas 30 famílias GIFT com 20 indivíduos por família e então deu-se início ao programa de melhoramento genético, e o mesmo continua sendo desenvolvido até o presente momento.

O principal critério de seleção utilizado nos programas de melhoramento genético de tilápias é a taxa de crescimento, que é medida por meio do ganho em peso diário. A seleção para essas características ao longo dos anos tem proporcionado ganhos significativos na performance produtiva dos animais.

Diversos trabalhos têm apresentado ganhos variando entre 4 e 13% por geração na taxa de crescimento (Bentsen et al. 1998; Ponzoni et al. 2005; Thodesen et al. 2011; Hamzah et al. 2014; de Oliveira et al. 2016). Oliveira et al. 2012 mostraram que o programa de melhoramento genético conduzido pela Universidade Estadual de Maringá obteve ganhos médios de 4% por geração e um ganho acumulado de 28% no período de 2006 a 2010.

Como resultado desses trabalhos, temos que ao longo das gerações de seleção, tem-se uma melhora no desempenho produtivo da tilápia no que diz respeito à taxa de crescimento. Oliveira et al. 2012, avaliando o desempenho de animais melhorados, encontraram uma redução de 21 dias no período de cultivo de tilápias, cultivadas em tanques rede no Estado de São Paulo, o que demonstra que a melhora na taxa de crescimento dos animais se traduz na prática em redução no período de cultivo.

Além dos ganhos obtidos até o momento com a seleção para taxa de crescimento, as estimativas de herdabilidade encontradas na literatura, que variam de 0,12 a 0,48 (Ponzoni et al. 2005; Rutten et al. 2005; Eknath et al. 2007; Nguyen et al. 2010a; de Oliveira et al. 2016), sugerem a continuidade dos ganhos genéticos por várias gerações.

1.5- Rendimento e peso de filé

Embora a taxa de crescimento seja o principal critério de seleção, tem havido uma procura, por parte da indústria e dos produtores, por peixes que apresentem alto rendimento de filé e de carcaça.

Essa procura se deve ao fato de o filé ser um dos principais produtos vindos da produção de tilápias e, segundo Sussel (2013), cerca de 80% da produção nas regiões Sul e Sudeste é vendida na forma de filé. Além disso, Nguyen et al. (2010a) aponta que em alguns países tem havido uma mudança no sistema de pagamento aos produtores, deixando de ser pelo peso do peixe inteiro e passando a ser pelo peso do filé. Sendo assim, melhorar características como peso e rendimento de filé vem se tornando uma necessidade da indústria e dos produtores.

O rendimento de filé da tilápia é inferior quando comparado ao de outras espécies como, por exemplo, o salmão: 69% (Powell et al. 2008), truta: 64,3% (Quillet et al. 2005) e Lavaret (*Coregonus lavaretus*): 56,4% (Kause et al. 2011). Além disso, fatores como o grau de mecanização do processo de filetagem, destreza do filetador, método de filetagem e tamanho dos animais podem influenciar o rendimento e o peso do filé (Macedo-Viégas et al. 2004).

De maneira geral, o rendimento de filé da tilápia varia de 32 a 39,1% e o peso de filé fica entre 177,7 e 355g (Garduño-Lugo et al. 2003; Macedo-Viégas et al. 2004; Rutten et al. 2004; Rutten et al. 2005; Nguyen et al. 2010a; Thodesen et al. 2012; Neira et al. 2016)

Tendo em vista a importância das características do filé (peso e rendimento) para a indústria, alguns trabalhos investigaram as suas relações com as características de desempenho. Os resultados mostram que há uma correlação genética forte e positiva entre peso final e peso de filé, variando entre 0,89 e 0,96; porém, correlações genéticas próximas de 0 quando avaliando peso final e rendimento de filé (Nguyen et al. 2010b; Gjerde et al. 2012). Nguyen et al. 2010 explicaram que esses resultados de correlação mostram que o incremento no peso final está relacionado também com um incremento no peso do filé e não só de vísceras e de outros constituíntes do corpo dos peixes. Por outro lado, a correlação genética encontrada entre peso final e rendimento de filé sugere que não há possibilidade de resposta correlacionada para rendimento de filé quando os animais são selecionados para taxa de crescimento.

Com base nessa perspectiva e considerando a importância do rendimento de filé, alguns programas de melhoramento genético têm buscado outras alternativas à seleção para taxa de crescimento de maneira a apresentarem ganhos no rendimento de filé. Uma dessas alternativas pode ser a mudança do critério de seleção, utilizando o próprio rendimento de filé como critério. Porém, para a obtenção do rendimento de filé é necessário abater um grande número de animais, o que implica em aumento da mão de obra e dos custos, além da perda de candidatos à seleção.

Sendo assim, alguns trabalhos têm sido feitos na tentativa de estabelecer métodos diferentes para se obter o rendimento de filé, de modo a evitar o abate dos animais como, por exemplo, equações de predição e o uso de medidas corporais (Rutten et al. 2004; Rutten et al. 2005). Entretanto, essas estratégias não se mostraram muito efetivas para a predição do rendimento de filé, sendo necessários mais estudos para o estabelecimento de tais métodos.

Outra alternativa é inclusão do rendimento de filé em um programa de seleção multi-características, como demonstrado por Thodesen et al. (2011); Thodesen et al. (2012), que apresentaram ganhos de 0,2 pontos percentuais por geração no rendimento de filé em um programa de melhoramento de tilápias na China, com peso final e rendimento de filé como critérios de seleção. Esses autores ressaltaram que apesar de o incremento no rendimento de filé por geração ser pequeno, essa resposta a longo prazo poderia trazer melhorias significativas para o sistema de produção.

Embora existam algumas dificuldades para se realizar seleção para rendimento de filé em tilápias, a importância econômica dessa característica pode justificar os esforços já realizados e os que ainda serão feitos.

1.6- Qualidade de carne

A taxa de crescimento e as características de filé são as mais importantes para o cenário atual do melhoramento genético de tilápias, uma vez que essas características contribuem para a melhora na eficiência produtiva. Ainda assim, outro aspecto importante a ser considerado na produção de tilápias é a qualidade da carne, seja pelos aspectos sensoriais ou pelos aspectos relacionados à saúde do consumidor (Grunert 2005).

Dentre esses aspectos, frescor, textura, sabor, odor e suculência, são atributos de qualidade relacionados aos aspectos sensoriais da carne, enquanto que segurança alimentar, a composição química e nutricional estão relacionados com a saúde e bem estar do consumidor (Olafsdottir et al. 2004; Hamzah et al. 2016).

Em se tratando da composição química, um atributo interessante atrelado ao consumo de peixes é o perfil de ácidos graxos, especialmente em relação aos ácidos graxos poli-insaturados (PUFA). De acordo com Connor (2000), os ácidos graxos poli-insaturados, especialmente ômega-3 (n-3 PUFAs), têm benefícios para a saúde humana e desempenham papéis importantes na prevenção de doenças, principalmente sobre as doenças cardíacas.

Entretanto, alguns estudos com peixes de água doce, incluindo a tilápia, demonstraram que essas espécies têm baixo teor de ácido alfa-linolênico (18:3n-3) (Carbonera et al. 2014) e também apontam que a relação dos ácidos graxos n-6:n-3 também não é o ideal para o consumo humano (Young 2009).

Neste cenário, alguns estudos têm realizado modificações na dieta dos peixes, incluindo fontes de ômega-3, com o intuito de melhorar o perfil de ácidos graxos do filé de tilápias. Esses estudos têm demonstrado resultados satisfatórios, o que indica a possibilidade de melhorar o perfil de ácidos graxos, bem como a relação de n-6:n-3 no filé, melhorando assim sua qualidade nutricional (Visentainer et al. 2005; de Souza et al. 2007; Carbonera et al. 2014; dos Santos et al. 2014).

Com o intuito de suprir as atuais e futuras demandas dos consumidores e fornecer produtos de melhor qualidade, Hamzah et al. (2016) sugerem que é importante discernir os fatores que estão por trás das características de qualidade da carne.

Sendo assim, alguns trabalhos têm sido realizados para avaliar a base genética desses atributos de qualidade como, por exemplo, o estudo de Hamzah et al. (2016), que estimou parâmetros genéticos para percentual de gordura, proteína e umidade, para cor e textura do filé de tilápias. Já Nguyen et al. (2010b) investigaram a base genética dos ácidos graxos no filé. Os autores de ambos os trabalhos ressaltaram que embora a seleção para taxa de crescimento não tenha afetado os atributos de qualidade de carne, é importante o monitoramento dessas características dentro dos programas de melhoramento genético.

Além do monitoramento, ações podem ser tomadas no intuito de melhorar geneticamente os peixes, não só para características produtivas, mas também para características de qualidade de carne possibilitando, assim, aprimorar o desempenho produtivo e melhorar a eficiência do sistema de produção da tilápia, além de fornecer ao consumidor final um produto de qualidade superior.

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II- Genetic parameters for growth performance, fillet traits, and fat percentage of male Nile tilapia (*Oreochromis niloticus*)

3.1- ABSTRACT

Breeding programs have being focused on improving growth using body weight and daily weight gain as main selection criteria but despite the importance of performance improvement, fillet and carcass yield and quality attributes are also of some interest. Fillet traits (fillet weight and fillet yield) and fat content were measured on 1136 male and put together with 2585 records on growth traits (body weight, weight at slaughter and daily weight gain) of both sex from third generation of Aquaamerica strain. Different models were tested for each trait and used to estimate genetic parameters for fat content of fillet and growth traits. Genetic and phenotypic correlations were estimated using multiple trait animal models. The heritability estimates were moderate (0.2-0.32) and slightly higher for body weight at slaughter (0.41). The genetic correlation was significant for fillet yield with fat (0.6) but not significant for growth traits with fillet yield and fat. Changes in fillet yield and in fat content are not expected when using growth performance as a selection criterion but correlated responses are expected in fat content if selecting for higher fillet yield.

KEYWORDS: fillet yield; genetic correlations; tilapia; GIFT

3.2- INTRODUCTION

Nile tilapia production system is focused on improving growth rate and reducing age at harvest in order to enhance production efficiency. Thus, Nile tilapia breeding programs are mainly focused on growth performance, and so the main selection criteria is body weight or daily weight gain (Ponzoni et al. 2005; Thodesen et al. 2011; Bentsen et al. 2012; Hamzah et al. 2014). Furthermore, as males have higher growth rate, monosex male cultures are frequently used in tilapia production, to increase weight gain (Beardmore et al. 2001).

Although growth rate is an important trait to enrich production efficiency, some producers and industries are concerned about some other important traits, such as fillet weight and yield. As pointed out by Nguyen et al. 2010a, in some countries the payment system is changing from the hole-body weight to fillet weight. In Brazil, fillet yield seems to be the second trait of major importance followed by growth performance.

However, improving fillet yield is not a simple task once to get records it is necessary to slaughter a great number of animals, increasing costs and reducing the number of candidates to selection. As an alternative to slaughter, some studies have tried to develop equations to predict fillet and carcass traits, and also investigated its genetic correlations with body measurements (Rutten et al. 2004; Rutten et al. 2005; Fernandes et al. 2015). Unfortunately, either prediction equations or indirect response to selection on body measurements do not seem to be effective manners to achieve improvements on fillet yield.

Growth and fillet traits are from major importance for industries and farmers to improve efficiency and to reduce costs, nonetheless quality attributes are also important for consumers (Grunert 2005) and as pointed out by Hamzah et al. 2016, to discern the factors behind flash quality is crucial so that we could supply consumer’s actual and future demands. Thus, some papers have presented some insights on flesh quality and sensorial attributes of tilapia fillets and its relationship with growth and filet traits (Nguyen et al. 2010b; Hamzah et al. 2016).

Along these lines, the aim of our study was to estimate genetic parameters and evaluate the genetic relationship between growth traits, fillet yield and fat content in a male population of Nile tilapia.

3.3- MATERIALS AND METHODS

Animals and growing system

The animals used in this study were from the third generation of the genetic improvement program of Aquaamerica Company in Brazil. Biometrics within the growing period and slaughter procedures were in accordance to the State University of Maringá Animal Ethics Committee.

The 2585 fingerlings from 59 families were individually identified using PIT Tags in Alfenas-MG at Aquaamerica facilities and transferred to the floating cages experimental unit at State University of Maringá in Diamante do Norte- PR where they were raised for 251 days from April to December 2015 in three floating cages.

During the raising period two biometrics were done and body weight (BW), total length (from the head to the caudal fin) and standard length (from the head to the insertion of the caudal fin) were recorded.

On the last measurement made in November, the body weight and sex were recorded, and 1485 males were separated and distributed in two floating cages and were fed for one more month until the slaughter.

Slaughter procedures

Before the slaughter, the two cages containing the 1485 males were starved for 24 hours and than they were killed by cold shock placing them into iced water.

At the slaughter, the TAG number was annotated and to obtain the body weight at slaughter (BWS) each fish was individually weighted in the same digital scale used on the measurements, during the growing period. The fish were decapitated, gutted and skinned by hand and then filleted by one trained person.

The fillets were rinsed, dried and fillet weight (FW) was recorded by weighting the fillets from both sides of each fish. The left sides of the fillets were not used for any posterior analysis and so they were labeled and packed according to commercial standard. The right side of the fillets were labeled with the TAG number and individually packed using a vacuum machine. All fillets were stored in freezer at a temperature of -10 ºC and transported to the meet quality laboratory at State University of Maringá, for fat content analysis.

Fat content analysis

For fat content analysis, the fillets were defrosted on a fridge at 4ºC and a tissue sample was taken from the frontal part covering the dorsal and ventral part of the fillet. The bones were removed and the meat was grounded with a kitchen grinder. From this

grounded meat, a sample was took and the fat content analysis was carried according to the Bligh-Dyer method (Bligh and Dyer 1959)(Bligh and Dyer 1959) with adaptations. A 15g sample of the grounded and homogenized meat was weighted in a digital scale (nearest 0.01g), mixed with 30 mL of methanol and 15 mL of chloroform, and agitated for 5 minutes in magnetic stirrer. Then was added 15 mL of chloroform and agitated for 2 more minutes, and finally 15 mL of distillated water was added to the mixture and agitated for 5 more minutes.
The content was filtered on Buchner funnel with qualitative filter paper and light suction, and then placed in a separating funnel for 24 hours. After the separation period, chloroform-lipid fase was collected in dried and tared flask (DF) and the chloroform was evaporated in Rotary Evaporator and the flask with the lipid content was weighted (LF). The lipid percentage was calculated as ((LF- DF)/15)*100.

Test models and genetic analysis

We proposed different statistics models for each trait; all tested models included the animal effect, common environment effect (c^2) and the floating cage effect. Also, weight at tagging (WT), age at biometry (AB), age at slaughter (AS) and body weight at slaughter (BWS) were tested as covariables with linear and quadratic effects. For DWG and BW, the sex (S) effect was also considered (Table 1). The adopted criterion to select the best model for each trait was the deviance information criterion (DIC) (Spiegelhalter et al. 2002).
Once the best models were chosen, single trait analysis were performed in order to estimate the variance components, common environment effect and heritabilities. Two trait analysis were performed to estimate genetic and phenotypic correlations between daily weight gain and fat content (DWG_FAT), daily weight gain and fillet yield (DWG_FY), body weight and fat content (BW_FAT), body weight and fillet yield (BW_FY) and fillet yield and fat content (FY_FAT).
To estimate (co)variance components the programs GIBBS1F90 and POSTGIBBSF90 from BLUPF90 Family of programs (Misztal et al. 2015) were used. The package CODA (Plummer et al. 2006) implemented on R (R Foundation for Statistical Computing, Vienna 2011) was used for convergence diagnosis.

TABLE 1: Description of the effects on the tested models

Model	S	WT	AB	AS	BWS
M1	✓	✓	✓	-	-
M2	✓	✓	-	-	-
M3	✓	-	✓	-	-
M4	-	✓	-	✓	-
M5	-	-	-	✓	-
M6	-	✓	-	-	-
M7	-	-	-	-	✓

3.4- RESULTS

Basic statistics are presented for daily weight gain (DWG), weight at tagging (WT), body weight (BW) and age at biometry (AB), reordered on males and females and for body weight at slaughter (BWS), age at slaughter (AS), fillet weight (FW), fillet yield (FY) and fat content (FAT), recorded only on males (Table 2). DWG and FY were calculated as DWG= BW/AB and FY= (FW/BWS)*100.

TABLE 2: Recorded information and descriptive statistics.

Traits (unit)	n	Minimum	Maximum	Mean	CV (%)
Daily weight gain (g/day)	2585	0.32	4.6	1.78 (0.71)	39.89
Weight at tagging (g)	2585	3.4	121.2	16.76 (11.33)	67.60
Body weight (g)	2585	86.14	1431	523.23 (225.3)	43.06
Age at biometry (days)	2585	267	327	290 (16.4)	5.66
Age at slaughter (days)	1204	302	362	325 (16.41)	5.05
Weight at slaughter (g)	1204	123	1487	647.45 (259.93)	40.15
Fillet weight (g)	1198	39	503	218.59 (89.92)	41.14
Fillet yield (%)	1198	25.3	42.7	33.76 (2.05)	6.07
FAT (%)	1136	0.54	6.47	2.56 (0.9)	35.16

- (SD): Standard deviation

The best models were M1 for DWG and BW, M5 for BWS and M7 for FW, FY and FAT (Table 3). The selected model for DWG and BW was M1 and included weight at tagging and age at biometry as covariables. For BWS the best model (M5) included age at slaughter as covariable and model M7 was the chosen one for 3 traits (FW, FY and FAT), and included body weight at slaughter as covariable (Table 3).

TABLE 3: DIC value of the tested models for each trait

Traits	M1	M2	M3	M4	M5	M6	M7
DWG	2969.5*	3039.72	3186.04	x	x	x	x
BW	50182*	50263	50220	x	x	x	x
BWS	x	x	x	14938	14611*	14949	x
FW	x	x	x	12504	12217	12509	9926*
FY	x	x	x	4870	4868	4871	4779*
FAT	x	x	x	2768	2775	2760	2630*

* - Model with the smallest DIC

All estimates were significant (0⊄CrI) and the heritability for the studied traits were moderated ranging from 0.2 (FAT) to 0.41 (BWS) (Table 4). Furthermore, the estimates were the same for DWG, BW and FW (0.23).
The common environment effect (c^2) ranged from 0.05 (FW) to 0.33 (BWS) (Table 4). The estimated c^2 for FW and FY were similar, 0.05 and 0.06 respectively.

TABLE 4: Variance components and heritability estimates

Traits	σ²p	c²	h²
DWG	0.16 (0.01) (0.15 0.18)	0.16 (0.04) (0.1 0.24)	0.23(0.08) (0.08 0.4)
BW	14790(745) (13510 16400)	0.2(0.04) (0.13 0.28)	0.23(0.09) (0.07 0.41)
BWS	36360(3977.4) (29760 45290)	0.33(0.11) (0.13 0.54)	0.41(0.22) (0.04 0.8)
FW	265.35(14.92) (239.2 297.83)	0.05(0.04) (0.002 0.16)	0.23(0.11) (0.03 0.44)
FY	4.09(0.26) (3.64 4.66)	0.06(0.05) (0.003 0.17)	0.32(0.11) (0.09 0.55)
FAT	0.73(0.04) (0.65 0.83)	0.1(0.05) (0.01 0.22)	0.2(0.11) (0.01 0.44)

- σ²p: Phenotypic variance;
- c²: Common environment effect
- h²: Heritability
- (SD): Standard deviation
- (Credible interval 95%)

Regarding the genetic correlations, out of 5 two trait analysis performed (Table 5), only the correlation between fillet yield and fat content (FY_FAT) was significant (0⊄CrI). The phenotypic correlations between daily weight gain and fillet yield (DWG_FY), body weight and fillet yield (BW_FY) and fillet yield and fat content (FY_FAT) were significant (0⊄CrI) and presented values ranging from 0.19 for body weight and fillet yield to 0.3 for fillet yield and fat.

TABLE 5: Genetic and phenotypic correlations

Traits	Corr_g	Corr_y
DWG_FAT	-0.09 (0.34) (-0.67 0.57)	0.024 (0.05) (-0.09 0.13)
DWG_FY	-0.4 (0.34) (-0.97 0.29)	0.2 (0.05) (0.1 0.29)
BW_FAT	-0.1 (0.35) (-0.7 0.6)	0.014 (0.05) (-0.0980.12)
BW_FY	-0.032 (0.32) (-0.94 0.33)	0.19(0.05) (0.008 0.29)
FY_FAT	0.6 (0.19) (0.14 0.86)	0.28 (0.04) (0.21 0.36)

-(SD): Standard deviation
- (Credible interval 95%)
- Corr g: Genetic correlations
- Corr y: Phenotypic correlations

As soon as the genetic correlation between fillet yield and fat content was high, the expected correlated response to selection was calculated. Considering fillet yield as the selection criteria and a selection intensity of 1.55, the expected correlated response in fat content would be an increment of 7.81% and in the opposite case with the same selection intensity, the expected correlated response on fillet yield is an increment of 1.42% per generation.

3.5- DISCUSSION

Descriptive statistics

The body weight and the daily weight gain of the animals used in our evaluations (Table 1) were smaller than the values that the industry and farmers are used to work with in Brazil. These differences are related to the fact that we used animals from the nucleus of the breeding program and thus the obtained performance is not the same as from commercial lines. The fillet yield and weight (Table 1) were similar to those found in literature, ranging from 32 to 39.1% and from 177.7 to 355g respectively (Garduño-Lugo et al. 2003; Rutten et al. 2004; Rutten et al. 2005; Nguyen et al. 2010a; Thodesen et al. 2012; Neira et al. 2016). The fillet fat percentage found in literature ranged from 0.8 to 6.38% (Garduño-Lugo et al. 2007; Kayan et al. 2015; Hamzah et al. 2016). The 2.56% found in our trial (Table 1) is within this range and is similar to the 2.07 found by (Garduño-Lugo et al. 2003). This wide range on the fat content may be due to different raising systems and diets, different lipid extraction methods, the body weight of the fish and also the part of the fillet that was used to perform the lipid analysis, as pointed out by Kayan et al. 2015.

Regarding the basic statistics and the genetic parameters, it is important to note that for fillet traits and fat content we just got records on males and thus some differences can be found when comparing our results with other papers.

Heritability and common environment effect

Heritability estimates for body weight and daily weight gain (Table 4) are in accordance to the values found in literature, ranging from 0.12 to 0.48 (Ponzoni et al. 2005; Rutten et al. 2005; Eknath et al. 2007; Nguyen et al. 2010a; de Oliveira et al. 2016). Growth traits are the main selection criteria in Nile tilapia breeding programs and these heritability estimates suggests that genetic improvement can still be done.

The heritability for fillet yield (Table 4) was higher than the estimates found in literature which ranges from 0.06 to 0.30 (Rutten et al. 2005; Nguyen et al. 2010a; Gjerde et al. 2012; Thodesen et al. 2012). Our estimate for fillet weight (Table 4) was in the middle range from those found by Rutten et al. 2005, Nguyen et al. 2010, Gjerde et al. 2012 and Thodesen et al. 2012, which were 0.24, 0.33, 0.16 and 0.3 respectively. As well as for growth traits, the heritability estimates for fillet yield and weight showed that genetic progress can be done and fillet traits can be genetically improved.

Our heritability estimate for fat content (Table 4) was bigger than reported in Atlantic Salmon (0.17) (Vieira et al. 2007), and smaller than found in other species, for instance, Rainbow Trout (0.25) (Quillet et al. 2005), European whitefish (0.37) (Kause et al. 2011) and Common Carp (0.58) (Kocour et al. 2007). Furthermore, our estimate was slightly higher than the 0.11 found by Hamzah et al. 2016. Our result suggests that would be possible to make genetic changes in the fat content through direct selection.

The common environment effect for BW (Table 4) was higher than the values found in the literature which ranges from 0.06 to 0.16 (Ponzoni et al. 2005; Rutten et al. 2005;

Eknath et al. 2007; Nguyen et al. 2010a; de Oliveira et al. 2016). Our estimate suggests that this effect was an important variation source in the performance of the animals. For fillet weight our estimate (Table 4) was similar to the ones found by Rutten et al. 2005, Nguyen et al. 2010a and (Thodesen et al. 2012), but was lower than the value found by Gjerde et al. 2012. The value for fillet yield (Table 4) was in accordance with the papers related above and also lower than the estimate found by Gjerde et al. 2012. These results showed that for fillet yield, the common environment effect had less importance than for fillet weight and growth traits.

Correlated response to selection and genetic correlations

No correlated response in fillet yield is expected when using growth traits as selection criteria. Our results (Table 5) are in accordance with those found by Nguyen et al. 2010a and Thodesen et al. 2012 witch found genetic correlations near 0 for body weight and fillet yield.

These results suggest that to achieve some improvement on fillet yield, it should be included as a selection criteria in one-trait or multi-trait selection. Thodesen et al. 2012 presented a slow but significant genetic response on fillet yield when selecting for both higher growth and fillet yield a multi-trait selection.

Correlated responses are also not expected in fat content when selecting for growth rate. The genetic correlations between DWG and FAT and BW and FAT were not significant (Table 5). Our results differ from those found by Hamzah et al. 2016 (0.26) and Powell et al. 2008 (0.8), who presented genetic correlations between body weight and fat% in Nile tilapia and Atlantic Salmon respectively. Hamzah et al. 2016 suggests that great changes on fat content are unlikely to happen, but a small and gradual increase can occur when selecting for high growth.

The genetic correlation between FY and FAT (0.6) was higher than the value found by (Hamzah et al. 2016) and leads us to a possible correlated response in fat content if selecting for higher fillet yield. Thus, when using our results and the candidates to selection, the expected correlated response on fat content if selecting for higher fillet yield would generate an increase of 7.81% on the next generation. Therefore, selecting fish for higher fillet yield may lead to an increase in the fat content.

Regarding the fat content on Nile tilapia fillets an important issue to be considered is its fatty acids (FA) profile as soon as according to Connor 2000 polyunsaturated fatty acids (PUFA), especially omega-3 (n-3 PUFA), have benefits to human nutrition and health and play important roles on prevention of diseases, mainly on coronary heart diseases. Some studies on fresh water fish (tilapia included) reported low content of alpha-linolenic acid (LNA, 18:3n-3) (Carbonera et al. 2014) and also Young 2009 pointed out that the ratio of n-6 and n-3 fatty acids (FA) is not optimum.

To deal with this not optimum ratio, Nguyen et al. 2010b investigated the genetic basis of fatty acids and found that the selection process for high growth had no effect on FA profile of Nile tilapia fillets. Even though the selection process does not seem to cause changes on the FA profile, some studies on tilapia nutrition has demonstrated possible improvements on the fatty acid profile of Nile tilapia fillets (Visentainer et al. 2005; de Souza et al. 2007; Carbonera et al. 2014; dos Santos et al. 2014).

Thereby, gathering our findings regarding the genetic correlation between fillet yield and fat content and the ones made on tilapia's nutrition perhaps would be possible to increase fillet yield and fat content and change its FA profile in order to provide industries and market with fish with a higher fillet yield and a good source of essential fatty acids.

3.6- STATEMENT OF AUTHOR CONTRIBUTIONS

We estimated genetic parameters for fat content, growth and fillet traits of Nile tilapia from Aquaamerica strain. There still is genetic variation for body weight and daily weight gain and thus genetic progress can be made. There is also possibility for improvement on fillet yield using it as the selection criteria or in a multi trait selection with growth traits. It is also possible to improve fat content on fillet using direct selection or by exploring correlated responses with fillet yield.

All procedures performed in studies involving animals were in accordance with the ethical standards of the institution or practice at which the studies were conducted.

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Brown B, Aaron M (2001) The politics of nature. In: Smith J (ed) The rise of modern genomics, 3rd edn. Wiley, New York, pp 230257

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Cartwright J (2007) Big stars have weather too. IOP Publishing PhysicsWeb. http://physicsweb.org/articles/news/11/6/16/1. Accessed 26 June 2007

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