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Using maternal strain in tilapia production (*Oreochromis niloticus*)

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Abstract

The world's fish production has been growing in response to the great demand for healthy food and Brazil has the conditions to export fish. However, the development of the chain is necessary, with the use of production techniques and tested genetic material. Tilapia is an excellent breeder, however, studies on specialized varieties need to be performed. Therefore, this work was developed with the objective of evaluating the effect of using a maternal variety adapted to the region on morphometric performance and meat production of the offspring. Data from offspring originating from nine distinct genetic groups produced in the 2015/2016 aquaculture year were collected in the fish farming sector of the Federal University of Lavras. All animals were weighed and had their morphometry measured, then slaughtered and processed in order to obtain the weight of the cuts and processing residues. The general and specific combining ability and the maternal effect were estimated and the morphometric averages, cuts, and yields were grouped using the Scott-Knott method ($p<0.05$). In general, the genetic groups descending from MGTUFLAP variety had worse performance for head size and filet weight but obtained higher filet yield and lower carcass yield. The adapted variety had good general and specific combining ability, as well as a better maternal effect on the traits of head weight and filet yield. It is concluded that the MGTUFLAP variety as a maternal line provided a reduction in carcass weight and promoted an increase in fillet yield in its progenies.

Keywords: Diallel cross. Maternal effect. Morphometry. Fillet yield.

Introduction

Fish production in the world is in remarkable growth and not different from the world scenario Brazil has been breaking production records, having tilapia as the main species produced (PEIXE BR, 2022). *Oreochromis niloticus* was easily adapted to the environmental conditions present in Brazilian territory, allowing the reproduction and growth of the species to occur naturally, generating up to 3000 offspring per year and reaching 500 g, at around eight months (CÔA, MEDEIROS and BARBIERI, 2017).

Tilapia is an early and prolific species, starting reproduction when it reaches a weight close to 30 grams, making it impossible for females to feed during the reproductive period, because the reproducers of the species have parental care with the offspring (YU et al., 2014; EL-SAYED, MANSOUR and EZZAT, 2005; CAMPOS-MENDOZA et al., 2004). In view of the exquisite reproductive potential, little concern is given to studies linked to morphological characteristics and body condition of the matrices selected for breeding (QIANG et al., 2021; BLAY et al., 2021).

In fish, terminal crossing is used to obtain heterosis in the first generation, synthetic populations through the mating of three or more varieties of tilapia and open crossing, where the animals are not related, but from the same genetic group (LAGO et al., 2019). The main goal of breeding programs is weight gain, however, aiming for meat yields is important for sustainable fish production (BLAY et al., 2021).

The use of interspecific or intraspecific crossbreeding is fundamental to increasing the genetic variability of the group, seeking complementarity among the individuals selected for the crossbreeding (BENTSEN et al., 1998). The maternal effect on phenotypes objectified by fish production reported in the literature evidence that, even under a common environment, generates differences among the offspring (FEINER et al., 2016). The maternal effect can be justified by several factors, among them the size of the oocyte, the number of oocytes, and the size of the female among others (GREEN, 2008). Given the above, this work was developed with the objective of evaluating the effect of using a maternal variety on the morphometric performance and meat production of the offspring.

Material and methods

The phenotypic information used was obtained from contemporary animals, from the 2015/2016 production cycle, which was composed of the database generated by the genetic improvement program applied to aquatic organisms of the Federal University of Lavras, following protocol Ethics Committee on Animal Use of the Federal University of Lavras CEUA/ UFLA- 016/13.

The evaluated animals were offspring of incomplete diallel crossings using three tilapia varieties previously selected for the reproductive period of the university's fish farming sector. Two varieties commonly bred in the national fish farms and of known lineage were elected for the work, denominated commercial variety GI and commercial variety GF. The third variety employed is MGTUFLAP (UP), developed and adapted to the production system applied in fish culture at the Federal University of Lavras.

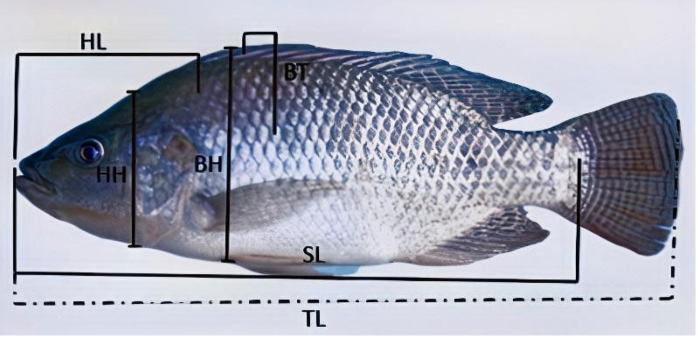
The broodstock remained separated in 1 m^3 hapa until reproductive success was achieved, allowing 150 post larvae from each pair to be collected and allocated separately by the genetic group in the fry laboratory. After 10 days the animals were placed in 60 L boxes, keeping them separated by families until they reached 20 grams and were individually identified by microchips.

The growth and fattening of the evaluated specimens were carried out in 500 L boxes with a closed recirculation system, continuous aeration, temperature maintained at 27ºC (± 0,5), and controlled photoperiod of 12:12. The fish were separated by sex to avoid early reproduction and received feed recommended for the phase twice a day until the apparent satiation of all animals in the box.

The animals were slaughtered, weighed on analytical scales, and with a pachymeter, all morphometric data were collected, following the collection pattern shown in Figure 1.

After morphological measurement of the animals, all were placed in boxes and immersed in cold water for stunning and subsequent slaughter, through the medullary section. In the

Figure 1: Methodology and location of phenotype collection using morphometry.



Note: Morphometric measurements for *O. niloticus*, standard length (SL), total length (TL), body height (BH) and body width (BT) at the first radius of the dorsal fin, the head length (HL), head height (HH).

Fish Processing Laboratory of the Animal Science Department of the Federal University of Lavras, the processing of the carcasses was carried out by trained personnel.

During the separation and weighing process, head weight (HW), carcass weight (CW), fillet weight (FW), and residue weight (RW) were collected. All individual weights obtained during the processing of the animal were used to estimate and evaluate body and residue yields.

General combining ability (GCA), specific combining ability (SCA), and maternal effect (ME) calculations were performed as described by Eler (2017). The normality of all variables was tested using the Shapiro-Wilk method and subsequently, the Scott-Knott test of means, $p < 0.05$ was performed using the Statistical Analysis System® statistical package (SAS Institute, 2023).

The sources of variation considered were genetic groups and sex, and body weight was considered a co-variable. The statistical model used was:

$$Yijk = \mu + Gi + Sj + b(\alpha ijk - \dot{X}) + ejik$$

Where: Yijk = k-th observation of genetic group i of sex j; Gi = effect of the genetic group; Sj = effect of sex; b = regression coefficient of the slaughter weight covariate, $\alpha ijk - \dot{X}$ = slaughter weight of fish k of genetic group i and sex j, eijk = random error.

Results

The mating between GE strains had no representatives because the reproductive failure was caused by the fights and death of the specimen. The other matings were successful and the pups were evaluated at the end of the experimental period.

The genetic groups evaluated were: MGTUFLAP (UP) x MGTUFLAP (UP), MGTUFLAP (UP) x commercial variety GE, commercial variety GE x MGTUFLAP (UP), commercial variety GI x commercial variety GI, commercial variety GI x commercial variety GE, commercial variety GE x commercial variety GI, commercial variety GI x MGTUFLAP (UP), MGTUFLAP (UP) x commercial variety GI (Table 1).

Animals descended from the MGTUFLAP (UP) variety, in general, have larger body sizes and lower head heights, as well as shorter head lengths. The matings with the commercial variety GI have similar results to those of the variety MGTUFLAP (UP), however, the efficiency for undesirable traits such as head size and height was observed in the genetic groups where the variety is present. The commercial variety GE was the most efficient for body width.

The matings using the variety MGTUFLAP (UP) were, on average, superior in phenotypic characteristics for the weight of cuts and

Table 1. Mean values of morphometric variables standard length (SL), body height (BH) and body width (BT), head length (HL), and head height (HH) were collected from the different genetic groups.

Trait	Genetic Group							
	UPxUP	**UPxGE**	**GExUP**	**GIxGI**	**GIxGE**	**GExGI**	**GIxUP**	**UPxGI**
Weigth (g)	481,85	560,23	450,68	490,55	488,97	531,31	396,65	443,43
SL (cm)	22,56 a	23,08 a	21,94 b	22,96 a	22,35 b	23,42 a	21,51 b	22,60 a
HL (cm)	7,38 b	8,00 a	7,41 b	7,68 a	7,62 a	7,94 a	7,16 b	7,55 a
BH(cm)	9,04 b	9,49 a	8,96 b	9,32 b	9,13 b	9,53 a	8,41 c	8,59 c
HH (cm)	8,37 b	8,76 a	8,27 b	8,59 a	8,48 a	8,78 a	7,83 c	8,16 b
BT(cm)	4,54 b	4,68 a	4,44 b	4,39 b	4,50 b	4,67 a	4,08 c	4,38 b

Note: Averages followed by different lowercase letters in the row differed by the Scott-Knott test at 5% probability.

residues, because in general, they obtained higher filet weight and lower weights of carcass, head, and residues when compared to other matings (Table 2). The matings using commercial varieties did not obtain such expressive results, but it is important to emphasize that with the variety MGTUFLAP (UP), the amount of biological material to be discarded is much greater.

The pure progenies MGTUFLAP (UP) had the lowest head yield, however, the averages of the genetic groups that have the variety as parents have the highest averages for carcass yield when compared to the other groups (Table 3). However, it is worth noting that, in general, the averages for residue yield of MGTUFLAP (UP) had variations in which it transitions between those that generate larger and smaller amounts of residue, depending on the crossbreeding performed.

The genetic groups using the commercial variety GI were the most efficient in residue reduction, with lower averages for carcass yield and residues yield traits, followed by the genetic groups consisting of the commercial variety GE. However, the averages for fillet yield of the genetic group MGTUFLAP (UP) in all matings were superior.

Among the studied traits, the specific and general ability to combine the most important for tilapia production, carcass and fillet weight, and carcass residues and fillet yield were calculated. The commercial GE strain was the lowest-performing strain among the crosses, increasing the average head weight of its progenies when used and showing a high maternal effect on the trait.

Commercial GE reduced the fillet yield of its progeny by 0.43% when used as sire and for this trait, the commercial GE female was the least significant for fillet yield. The commercial variety GI was relatively average, not impairing the performance of its progeny as much when mated (Table 4).

The variety adapted and developed at the university's fish farming sector was the one

Table 2. Mean values of the variables head weight (HW), carcass weight (CW), fillet weight (FW), and residue weight (WW) were collected from the different genetic groups.

Trait	Genetic Group							
	UPxUP	**UPxGE**	**GExUP**	**GIxGI**	**GIxGE**	**GExGI**	**GIxUP**	**UPxGI**
HW (g)	131,48 a	144,66 a	117,84 b	132,27 a	135,71 a	141,44 a	113,61 b	122,00 b
CW(g)	420,37 b	473,12 a	385,38 c	408,74 b	415,80 b	446,33 a	346,70 c	385,29 c
FW (g)	163,34 a	186,61 a	150,76 b	165,18 a	154,41 b	176,15 a	133,10 b	148,29 b
WW (g)	121,74 a	134,76 a	117,46 a	122,38 a	120,17 a	131,80 a	98,05 b	111,31 b

Note: Averages followed by different lowercase letters in the row differed by the Scott-Knott test at 5% probability.

Table 3. Mean values of the yield variables head yield (HY), carcass yield (CY), fillet yield (FY), and residue yield (WY) collected from the different genetic group

Trait	Genetic Group							
	UPxUP	**UPxGE**	**GExUP**	**GIxGI**	**GIxGE**	**GExGI**	**GIxUP**	**UPxGI**
HY (%)	19,41 b	27,62 a	26,33 a	26,95 a	27,97 a	26,61 a	28,63 a	27,68 a
CY (%)	86,66 a	85,72 b	85,11 b	85,74 b	84,58 b	84,58 b	87,15 a	86,95 a
FY (%)	33,60 a	32,97 a	33,13 a	33,33 a	30,59 b	32,22 a	33,16 a	33,25 a
WY (%)	25,04 a	24,22 b	25,56 a	23,88 b	23,81 b	24,48 b	24,24 b	24,29 b

Note: Averages followed by different lowercase letters in the row differ by the Scott-Knott test at 5% probability.

Table 4. Allelic combination capacities and maternal effect of *Oreochromis niloticus* varieties on two traits of economic importance.

Trait		Genetic Group		
		UP	GI	GE
CW (g)	GCA	-7,81	-5,14	19,43
	SCA	-46,55	17,47	21,4
	ME	-29,12	7,33	32,68
FW (g)	GCA	-2,18	-2,31	6,75
	SCA	-18,11	7,87	5,63
	ME	-10,02	3,55	9,69
CY (%)	GCA	0,60	0,02	-0,95
	SCA	1,65	-0,54	-1,36
	ME	0,73	-0,18	-0,81
FY (%)	GCA	0,34	-0,05	-0,43
	SCA	0,40	0,03	-0,89
	ME	0,42	0,17	-0,90

Note: Carcass weights (CW), fillet weights (FW), carcass yield (CY), fillet yield (FY), general combining ability (GCA), specific combining ability (SCA), and maternal effect (ME).

that stood out the most when used in genetic improvement. The progeny of the MGTUFLAP variety had the worst performance for fillet weight and, given the maternal effect for this trait, it is possible to state that the female of the variety decreased the averages for this trait (Table 4).

Even with lower performance as a mother for fillet weight, the female of the MGTUFLAP variety contributed the most to raising fillet yield when compared to the females of other strains. The MGTUFLAP variety was the one that stood out the most, since, when used, its progenies showed to have lower carcass weight and higher fillet yield, the main product of the production chain.

Discussion

Morphometric differences between fish strains are common because the formation of each lineage is the set of primitive species from various places in the world and these peculiarities promote morphological differences (BOSCOLO et al., 2001; OPIYO et al., 2020; LUNDSTEDT, LEONHARDT and DIAS, 1997). The genetic groups evaluated were morphometrically different as the evolution of each genetic group provided a number of morphological traits in the population. Differences in tilapia body morphology have been highlighted for years to estimate body performance and carcass characteristics.

Santos et al. (2007) observed morphometric differences when studying the body development of chitralada and supreme strains and reported that, among the models tested for growth prediction, there is the most appropriate for each variety. Significant differences in the measurement of the traits evaluated in the different genetic groups were observed, corroborating the presence of morphological differences between strains and fish species.

Evaluating an improved tilapia strain and a common strain, Boscolo et al. (2001) observed superiority in the morphometries of the genetically selected variety and reported performance independent of the culture environment. The groups used went through a selection process for growth characteristics and the commercial variety excelled the performance of the local variety MGTUFLAP.

The difference in body composition of different varieties of tilapia is noted in front of several factors, including the presence of selection, adaptability among others, the weight of the cuts follows the pattern of their measures, where the greater the anatomical structure, the greater will be its weight (ALLAMAN et al., 2013). It is possible to relate the body weights obtained in this study to the size of the sectioned structures, where genetic groups with higher morphometrics had higher weights of cuts.

Opiyo et al., (2020), Rutten, Bovenhuis, and Komen et al. (2004), and Leonhardt et al. (2006) observed that selecting fish for growth automatically raises fillet yield and yield of other body structures. Genetic improvement has provided genetically superior varieties for weight gain and with this, the body as a whole has grown together to meet the physiological needs of the animals. Santos et al. (2007) disagree with the growth of all body structures because only some structures increase. In the present study, results are presented to conclude that larger animals have higher fillet yield, however, the head has a plateau in development in pure MGTUFLAP offspring.

Allaman et al. (2013), working with MGTUFLAP during the period of development of the variety, observed that the performance was inferior when compared with the variety already inserted in the market and the Thai line. The results obtained allow verification that the strain developed at the fish farm of the Federal University of Lavras does not have inferiority in relation to the commercial varieties, since the descendants of the strain did not differ statistically.

The use of crossbreeding to obtain high performance in fish farming is common and reported as a tool for complementarity among strains (ALLAMAN et al., 2013; NIELSEN et al., 2010; REIS NETO et al., 2020). The efficiency of crossbreeding was not evident in the present study, since the genetic groups derived from crossbreeding did not differ from the pure animals, however, the offspring of crossbreeding had lower residue yield.

Body weight of fry and adults was significant in the assessment of the maternal effect, as the larger the egg circumference, the better the conditions for hatching and development at stages where the mouth is not functional (GJERDE and REFSTIE, 1984). The combining ability of the commercial varieties GI and GE was higher, highlighting the efficiency in increasing fillet weight and reducing carcass yield.

The morphological differences of the tilapia varieties may influence the performance of the parent line and the causes may be cytoplasmic effects or sex-linked inheritance, justifying the use of a maternal line (BENTSEN et al., 1998). Crossbreeding is an interesting tool, even if the heterosis is low, the increment in production can reach 10%. The variety MGTUFLAP without the same degree of selection presented as the best crossing option for gains in fillet yield and reduction in carcass weight.

Feiner et al. (2016) reported the need to use a maternal lineage to produce good fry and adults since the maternal effect has a great influence on the early stages that reflect up to the adult life of the animals. The definition of the strain to be applied as a mother should be tested in the region of cultivation to avoid environmental effects (ALLAMAN et al., 2013). The MGTUFLAP variety, besides being adapted to the region, was the best mother for the crosses, having the greatest maternal effect for fillet yield.

Conclusion

The use of a maternal lineage in tilapia production brings benefits and further studies should be performed. However, in the present study, the MGTUFLAP variety is the best option to be worked as a mother in crossings that will have the progenies bred in climatic conditions similar to those of the south-central region of Minas Gerais, Brazil.

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