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Weight and morphometric growth of different strains of tilapia (*Oreochromis sp*)

Ivan Bezerra Allaman[1], Rafael Vilhena Reis Neto[2], Rilke Tadeu Fonseca de Freitas[2], Thiago Archangelo Freato[3], Aline de Assis Lago[2], Adriano Carvalho Costa[2], Renato Ribeiro de Lima[4]

[1] *Departamento de Ciências Exatas e Tecnológicas – Universidade Estadual de Santa Cruz, Ilhéus/BA, Brazil.*
[2] *Departamento de Zootecnia – Universidade Federal de Lavras, Lavras/MG, Brazil.*
[3] *Empresa de Pesquisa Agropecuária de Minas Gerais – EPAMIG*
[4] *Departamento de Ciências Exatas – Universidade Federal de Lavras, Lavras/MG, Brazil.*

ABSTRACT - The objective of this study was to evaluate the morphometric growth and weight gain of strains of tilapia (Thai, Red, UFLA and Commercial) by nonlinear models. Initially, 500 male fingerlings of each strain, at 85 (Red and UFLA) and 86 (Thai and Commercial) days of age, were stocked separately in raceways with 56 m^3. Twenty fish of each strain were randomly sampled, weighed and measured monthly. Five nonlinear models (Brody, von Bertalanffy, Gompertz, logistic and exponential) were tested, choosing one that best fit to the data. The variables studied were: weight, standard length (SL), head length (HL), height 1 (H1), height 2 (H2), height 3 (H3), first distance (D1), second distance (D2), first width (W1), second width (W2) and third width (W3). The exponential model had the best fit to weight and morphometric data, with the exception of W2, in which the best fitted model was von Bertalanffy. The convergence of the exponential model to data indicates that the cultivation period studied was not enough for the strains to reach maturity weight. The UFLA strain presented the lowest value for parameter "a" (initial weight estimate), 8.71 g, and the highest for parameter k (specific growth rate), 0.0127, when compared with other evaluated strains. However, the highest k of UFLA was not enough to overcome the final weight observed for the Commercial strain (603.1 g), which was higher than all other strains. Regarding the morphometric measurements, the UFLA strain also had the highest k for the variables SL, HL, HH, H1, H2, H3 and D2, and similar k to Commercial and Thai strains for the variables D1 and W3 respectively. The strains differ as to weight gain and morphometric growth.

Key Words: absolute growth rate, aquaculture, nonlinear models, relative growth rate

Introduction

Toughness, disease resistance, meat quality and, mainly fast growth are characteristics that make tilapia one of the most cultivated fish species in the world (Lahav & Ra'nan, 1997). In Brazil, the culture of three strains of tilapia is practiced in the whole Brazilian territory; each one with peculiarities that value it in the consumer market. The Thai strain was one of the first to be introduced in Brazil, standing out for its toughness and good performance; the genetically improved farmed tilapia (GIFT), developed in the Philippines and currently improved by Universidade Estadual de Maringá, stands out for its high performance; the red tilapia, produced by some companies, stands out for being more attractive to the eyes of the consumer and its clear skin.

Studies of weight development are important because they can generate more knowledge of productive efficiency (Fitzhugh Jr., 1976), thus contributing to increase the profit of producers.

The morphometric study is not recent, and the interest in searching the forms in fish is particularly important due to the fact that some morphometric measures are related to the weight of the carcass and the fillet (Santos, 2004; Gonçalves et al., 2001). It is also essential for the choice of fishing equipment, storage, processing in the industry and meat yield (Contreras-Guzmán, 1994).

There are several models in the literature to describe both plant and animal growth. Amongst them, the exponential (Malthus, 1798), logistic (Nelder, 1961), Gompertz (Gompertz, 1825), Brody (Brody, 1945) and von Bertalanffy (Bertalanffy, 1957) models are the most used.

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 in this sense. Several studies analyzed the relation between the characteristics of the carcass with the morphometric measures of the fish, but few evaluated the weight growth and the forms of the body throughout the animal development.

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Corresponding author: ivanalaman@gmail.com

The objective of this study is to evaluate the weight and morphometric growth of tilapia strains (Thai, Red, UFLA and Commercial) by nonlinear models.

Material and Methods

The experiment was carried out at the Fish Growth Station of Universidade Federal de Lavras (UFLA), in Lavras, MG, Brazil, for a period comprising the fall (from March to May), winter (from June to August) and spring (from September to the beginning of December) of 2012.

This study evaluated the following strains of tilapia: Chitralada (Thai); a genetically improved commercial strain derived from the GIFT (Commercial, obtained from the International Center for Living Aquatic Resources Management - ICLARM); a red tilapia strain; and Nile tilapia, kept at the fish growing department of UFLA since 1970.

Initially, 500 fingerlings from a single sex male population (treated with 17α-methyltestosterone) were cultivated separately in four raceways with 56 m^3 and fed a commercial feed with nutritional levels in accordance with the life phase of the fish (42%, 32% and 28% protein for the spawning phase, 10-100 g; for the growth phase, 100-300 g; and for the finishing phase, 300-600 g, respectively) twice daily. The daily amount was supplied in accordance with the biomass of the tanks, varying from 7% in the first week to 4% in the last one. The densities of initial and final storage (disregarding the mortality observed in the period) were, respectively, 8.92 and 5.36 fish/m^3.

Random samples of 20 fish of each strain were removed monthly; after 48 hours of fasting the fish were slaughtered by sectioning the bone marrow followed by bleeding and weighing with the aid of a semi-analytical balance scale graduated in grams (g).

During the experimental period the levels of dissolved oxygen (mg/L) and water temperature (ºC) of the culture raceways were monitored daily (early morning and late afternoon).

The measures evaluated were: standard length (SL, cm), head length (HL, mm), head height (HH, mm), height measured before the 1st ray of the dorsal fin (H1, mm), height measured before the 1st ray of the anal fin (H2, mm), height measured in the lower circumference of the peduncle (H3, mm), distance from the extremity of the operculum to the 1st ray of the anal fin (D1, mm), distance from the 1st ray of the anal fin to lower circumference of the peduncle (D2, mm), width of the body measured before the 1st ray of the dorsal fin (W1, mm), width of the body measured before the 1st ray of the anal fin (W2, mm) and width of the body measured before the foremost circumference of the peduncle (W3, mm). The experimental design was completely randomized, and each fish was considered an experimental unit. In view of the suspicion of covariance between the experimental units, the statistics of Durbin-Watson was used to ensure that the temporal dependence between the experimental units be zero.

The estimate of the growth parameters of the strain was given by nonlinear regression analyses of the weight and body measures according to the age, testing the Brody, Gompertz, von Bertalanffy, logistic and exponential growth models (Table 1). The functions were evaluated and chosen by the adjusted determination coefficient (adjusted R^2) and mean square error (QME). The adjusted determination coefficient was calculated as:,

$$R^2_{ajusted} = 1 - \left[\frac{(n-i)(1-R^2)}{n-p}\right]$$

where R^2 = determination coefficient; n = number of comments used to adjust the curve; p = number of parameters in the function, including the intercept; i = intercept adjustment, which was 1 in case of function intercept and 0 if not.

The parameters A and k of the models presented in Table 1 have important biological interpretations. The parameter A represents the superior asymptotic weight or adult weight of the animal and parameter k represents the maturity rate, i.e., the relation between the relative growth rate and the adult weight of the animal. The higher the k value, the most precocious is the animal. The parameter "a" of the exponential model represents the initial weight of the animal.

The data were adjusted by the weighted least squares method inversely proportional to the variance of different ages of different strains, which increased according to the advance of the age (Figure 1). In the case of the body measures, the use of the weighting for adjustment of models was not necessary, since the variances did not increase as the age advanced.

The procedure nls of the Stats package, version 2.10.0 (R Core Team, 2010) was used for adjustment of the nonlinear models. With this function, the argument

Table 1 - Nonlinear models normally used to describe animal growth and to determine growth rate

Model	Equation	Growth rate (g/day)
Exponential	$y = a e^{\frac{t}{k}}$	-
Brody	$y = A(1 - Be^{-kt})$	$ABke^{-kt}$
von Bertalanffy	$y = A(1 - Be^{-kt})^3$	$3ABke^{-kt}(1 - Be^{-kt})^2$
Gompertz	$y = A\mathrm{e}^{-Be^{-kt}}$	$ABke^{-kt}\mathrm{e}^{-Be^{-kt}}$
Logistic	$y = A(1 + Be^{-kt})^{-1}$	$ABke^{-kt}(1 + Be^{-kt})^{-2}$

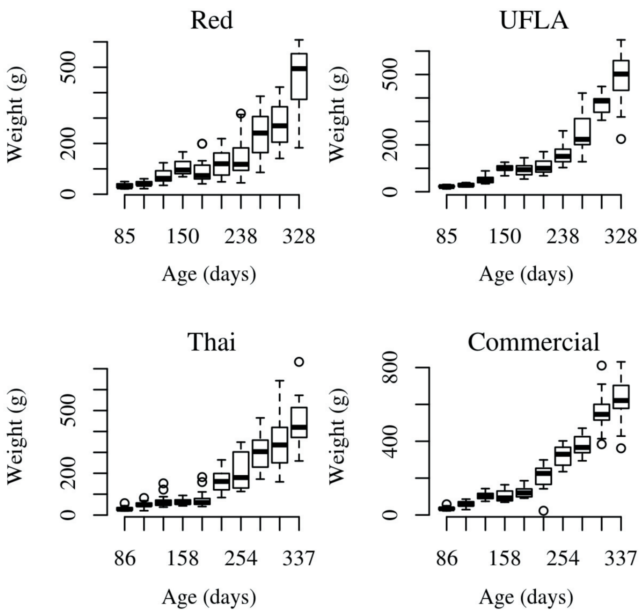

Figure 1 - Box-plot of the body weight according to age of Red, UFLA, Thai and Commercial strains.

“weights” was used so that the function could perform the adjustment by the weighed least squares by the inverse of the variance. The default Gauss-Newton algorithm was used by the nls function.

The likelihood-ratio test (TRV) was used to verify the equality of the parameters between the different models to determine if only one curve would be adequate to describe the weight (Table 2) and morphometric growth, regardless of strain, as suggested by Regazzi & Silva (2004). The statistics of the TRV test is given by:

$$L = \left(\frac{\hat{\sigma}^2_{\Omega}}{\hat{\sigma}^2_{\omega}}\right)^{n/2}$$

where n = the number of observations; $\hat{\sigma}^2_{\Omega}$ = the estimate of maximum likelihood of σ^2 with no restriction in the parametric space; and $\hat{\sigma}^2_{\omega}$ = the estimate of maximum likelihood of σ^2 with the linear restrictions in accordance with the following assumptions: H_0^1 – restricted parameter space by $A_{Thai} = A_{UFLA} = A_{Commercial} = A_{Red}$; H_0^2 – restricted parameter space by $B_{Thai} = B_{UFLA} = B_{Commercial} = B_{Red}$; and H_0^3 – restricted parameter space by $k_{Thai} = k_{UFLA} = k_{Commercial} = k_{Red.}$

The growth accumulated in each season of the year was evaluated by the Area Under the Curve technique (AUC). The seasons evaluated were fall, winter and spring, which comprised the ages of 85 to 150, 150 to 238 and 238 to 328 days, respectively. The AUC variable was determined according to Shaner & Finney (1977), as

$$\sum_{i=1}^{n}\left[(Y_{i+1}+Y_i)/2\right]\left[X_{i+1}-X_i\right]$$

where Y_i = weight or metric measure of the i-th observation; X_i = age (days) of i-th observation; n = total observations.

In view of the heterogeneity of the variances detected by means of Levene’s test of car package (version 2.0-10) (Fox & Weisberg, 2010) and because the Box-Cox Transformation (Box & Cox, 1964) did not overcome this problem, thus making the variance analysis impossible, a choice was made for the general linear models. With this method, the analysis of deviance (ANODEV) was used with the aid of the function GLM of the package Stats (version 2.10.0) (R Core Team, 2010) in an 4 × 3 factorial arrangement (strains × seasons of the year), in accordance with the following systematic part of the model:

$$y_{ijk} = \mu + L_i + E_j + (LE)_{ij}$$

where y_{ijk} = the value of the area under the curve referring to strain i in season j in repetition k; μ = the overall mean; L_i = the effect of strain i, with $i = 1, 2, 3, 4$; E_j = the effect of the season of year j, with $j = 1, 2, 3$; and $(LE)_{ij}$ = the effect of the interaction between factors L and E.

Inverse Gamma Distribution was used to model the data. The comparison test of the means of variable AUC was carried out by the function glht of the package Multcomp (version 1.2-10) (Hothorn et al., 2008).

The data relating to the initial and final average weights of the strains were subjected to variance analysis; means were compared by the Scott Knott multiple comparisons test of the ScottKnott package version 1.1.0 (Jelihovschi et al., 2010), adopting α = 0.05. The statistical model used was:

$$y_{ij} = \mu + L_i + \varepsilon_{ik}$$

where y_{ij} = observation relating to the i-th strain in the k-th repetition; μ = overall mean; L_i = effect of the i-th level of the strain L, with i = 1, 2, 3, 4; ε_{ik} = the experimental error inherent to all the observations $\varepsilon_{ik} \sim N(0, \sigma^2)$.

All analyses were performed on software R (R Core Team, 2010).

Results and Discussion

The minimum, maximum and average amount of oxygen dissolved in each tank for each strain were respectively: Thai (1.5; 8.14 and 3.80); Red (1.88; 6.57; 3.64); Commercial (1.78; 6.00; 3.62); and UFLA (1.02; 7.08 and 3.67). As for temperature, the minimum, maximum and average values were respectively: Thai (12.8; 28.00 and 22.07); Red (12.40; 29.70; 21.39); Commercial (12.10; 28.20; 21.51); UFLA (12.60; 27.90 and 21.67).

The von Bertalanffy model ($QME_{Thai} = 6.48$, $R^2 = 0.8374$; $QME_{UFLA} = 5.26$, $R^2 = 0.8567$; $QME_{Commercial} = 7.38$;

$R^2 = 0.8594$) was, among the sigmoid models, the only one that provided adequate convergence and adjustment, as compared with the exponential model ($QME_{Thai} = 7.19$; $R^2 = 0.8187$; $QME_{UFLA} = 6.44$; $R^2 = 0.8237$; $QME_{Commercial} = 8.57$; $R^2 = 0.8292$), with the metric measurement W2 (Figure 2), and only with the UFLA, Thai and Commercial strains. There is no convergence for the Brody, logistic and Gompertz models for the other metric measurements and body weight. For the remaining variables such as weight, SL, HL, HH, H1, H2, H3, D1, D2, W1 and W3, the exponential model was the only one that adequately fit to the data for all the evaluated strains (Figure 3).

Evaluating the growth of two strains of tilapia of up to 160 days of age, Santos et al. (2008) pointed the exponential model as an efficient tool when used for short evaluation periods, especially to estimate the parameters of estimated initial weight and specific growth rate. Santos et al. (2007) used body weight, instead of the age, to evaluate the growth of the morphometric measures of the Commercial and Thai strains; the functions of Gompertz and von Bertalanffy were the best models obtained. Gomiero et al. (2009) also used body weight to evaluate the morphometric growth of piracanjuba fish *Brycon orbignyanus* and found that the functions of Brody and von Bertalanffy were the best models.

For the area under the curve, the Commercial strain obtained the highest growth ($P<0.05$) in all seasons of the year for body weight and for all metric measurements, with exception of HH, D1 and W1, where the Commercial strain was similar to UFLA during spring (Table 3). The UFLA, Thai and Commercial strains grew 19% more than Red, from the fall to winter, as regards weight gain. However, from winter to spring, the weight gain of UFLA was 24% higher than the Thai and Commercial strains, and 16% higher than Red.

At the end of the experiment, the Commercial strain obtained higher average weight ($P<0.05$) than the other strains studied (Table 4). The average initial weight of UFLA was lower ($P<0.05$), as compared with the other strains. However, the average final weight was similar ($P>0.05$) to Red and Thai.

Dan & Little (2000) observed higher ($P<0.05$) average weight gain for the GIFT tilapia strain cultivated in fish cages, in comparison with the Thai and Vietnamese tilapia, during a period of 184 days.

The results of a comparative study between two strains of Atlantic salmon, one from a genetic selection program for growth and another from the natural media, revealed superiority ($P<0.05$) of the strain selected for weight gain, body composition and feed efficiency, indicating the efficiency of the genetic improvement of this species (Wolters et al., 2009). On the other hand, in a study of diallel crosses between varieties of common carp, the hybridization of varieties improved with strains

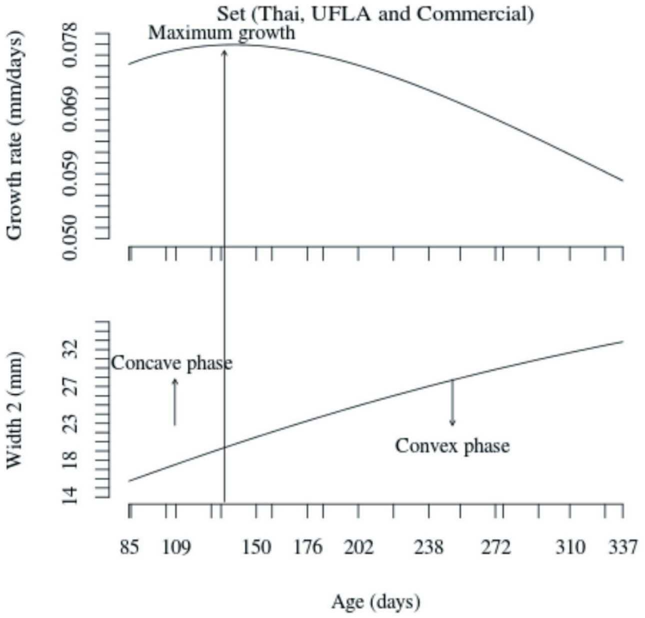

Figure 2 - Growth rates and curves of the measure of width 2 estimated by the von Bertalanffy model for Thai, UFLA and Commercial strains, throughout the development.

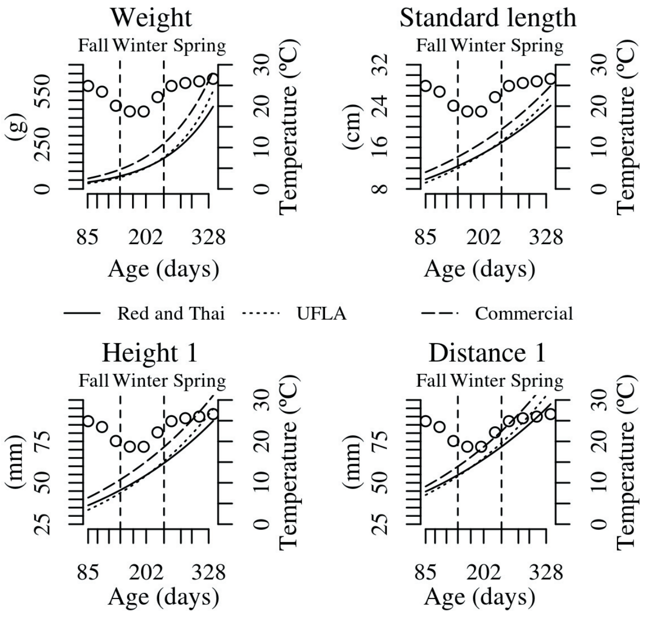

Figure 3 - Weight, standard length (SL), height 1 (H1) and distance 1 (D1), in terms of age (days), adjusted by the exponential model of Red, UFLA, Commercial and Thai strains.

cultivated in the experimental area was a good alternative to obtain fish with good resistance to diseases, and growth, demonstrating the importance of the adaptation of the species to fish culture (Nielsen et al., 2010).

There were differences (P<0.05) between the strains as to the parameters initial weight and specific growth rate of the exponential model for body weight, and for all metric measurements, with the exception of W1, for which there were no differences (P>0.05) between the strains (Table 5). The strain UFLA presented higher specific growth rate (P<0.01) for body weight and for all metric measurements, with the exception of D1 and W3, which were similar to the strains Commercial and Thai, respectively. The Red strain obtained the lowest specific growth rate for body weight, along with Thai, which in turn was similar to the Commercial strain. These results were similar for the metric measurements HH and H1. The specific growth rates of SL, HL, H2, H3 and D2, for the Red, Thai and Commercial strains were similar and lower than UFLA. For the measurements HH and H1, the specific growth rate was highest for UFLA; the Commercial strain was similar to Thai and higher than Red which, in turn, was

Table 2 - Average weight in grams of each strain at each age

Age (days)	Strains		Age (days)	Strains	
	UFLA	Red		Commercial	Thai
85	22.45(4.69)	32.61(8.92)	86	35.45(9.13)	30.09(9.19)
104	28.59(6.15)	41.21(10.68)	109	58.70(15.92)	49.70(14.95)
127	51.65(14.64)	70.75(28.14)	132	106.55(22.25)	66.65(28.20)
150	98.75(14.88)	105.50(32.01)	158	103.40(31.35)	64.05(15.33)
176	92.15(25.28)	88.80(46.60)	184	124.05(28.87)	74.25(37.55)
202	106.60(27.08)	121.80(50.35)	220	209.60(66.59)	162.05(49.47)
238	159.90(43.36)	144.55(78.76)	254	323.45(54.04)	211.10(85.97)
272	248.75(78.38)	232.95(82.59)	276	378.60(54.01)	296.65(74.95)
294	375.50(40.34)	271.55(79.31)	310	560.00(92.05)	349.20(123.79)
328	486.75(104.54)	462.15(118.20)	337	624.70(111.70)	440.10(111.43)

Numbers in parentheses indicate standard deviation.

Table 3 - Means of the area under the curve for body measures of Red, Thai, UFLA and Commercial (Com) strains in each season (fall, winter and spring)

Variables	Seasons											
	Fall				Winter				Spring			
	Strains											
	Red	Thai	UFLA	Com	Red	Thai	UFLA	Com	Red	Thai	UFLA	Com
Weight	3966b	3948b	3137c	5714a	10058c	12395b	9862c	18024a	24440c	27220b	28472b	39672a
SL	737c	837b	686d	927a	1239c	1460b	1284c	1679a	1724c	1804bc	1872b	2032a
Head length	2255c	2609b	2106d	2911a	3731c	4438b	3799c	5096a	5091c	5427b	5606b	6126a
Head height	2313c	2565b	2138d	2800a	3832c	4574b	4002c	5193a	5260b	5366b	5864a	6077a
Height 1	2781c	3003b	2523d	3398a	4573c	5281b	4621c	6176a	6337c	6458c	6903b	7452a
Height 2	2635b	2725b	2322c	3164a	4544c	5036b	4496c	6066a	6399b	6199b	6648b	7382a
Height 3	985c	1066b	908d	1215a	1664c	1932b	1705c	2278a	2347c	2373c	2551b	2776a
Distance 1	3355c	3650b	3159c	3964a	5534c	6142b	5679c	7084a	7378bc	7189c	7818ab	8301a
Distance 2	1442c	1670b	1274d	1897a	2646c	3081b	2656c	3552a	3494c	3772b	3798b	4183a
Width1	1392b	1449b	1280c	1676a	2371c	2569b	2376c	3039a	3091bc	2930c	3171ab	3358a
Width 2	772c	872b	730c	1010a	1507c	1605b	1516bc	1923a	2113b	1973c	2076bc	2283a
Width 3	336b	339b	285c	385a	568c	622b	549c	686a	785b	766b	773b	863a

Means followed by a different letter in the row within each season significantly differ (P<0.01) by the Z test.
SL - standard length.

Table 4 - Initial and final ages, and initial and final average weight of Red, UFLA, Commercial and Thai strains, with their respective coefficients of variation (CV)

Strains	Initial			Final		
	Age (days)	Weight (g)	CV (%)	Age (days)	Weight (g)	CV (%)
Red	85	32.6a	27.4	328	462.2b	25.6
UFLA	85	22.5b	20.9	328	486.8b	21.5
Commercial	86	35.5a	25.7	337	603.1a	18.5
Thai	86	30.1a	30.5	337	409.8b	27.2

Means followed by different lowercase letters in the same column significantly differ (P<0.05) by the Scott-Knott test.

Table 5 - Equality test of the parameters of the exponential model for Red, Thai, UFLA and Commercial (Com) strains, for the growth variables

Variables	Parameters								Adjusted R^2			
	a				k							
	Red	Thai	UFLA	Com	Red	Thai	UFLA	Com	Red	Thai	UFLA	Com
Weight	14.94ab	12.99b	8.71c	17.28a	0.0102c	0.0107bc	0.0127a	0.0111b	0.99	0.99	0.99	0.99
SL	7.31b	7.37b	6.49c	8.27a	0.0034b	0.0036b	0.0041a	0.0036b	0.82	0.87	0.92	0.93
Head length	23.21b	23.25b	19.96c	26.44a	0.0032b	0.0034b	0.0040a	0.0034b	0.77	0.86	0.92	0.92
Head height	23.50ab	23.44b	20.20c	25.24a	0.0032c	0.0034bc	0.0041a	0.0036b	0.77	0.85	0.90	0.91
Height 1	27.95ab	26.46b	23.71c	30.08a	0.0033c	0.0036bc	0.0041a	0.0036b	0.76	0.85	0.91	0.90
Height 2	25.53ab	23.46bc	21.76c	27.28a	0.0037b	0.0039b	0.0043a	0.0039b	0.78	0.83	0.90	0.91
Heaight 3	9.58b	9.21b	8.40c	10.70a	0.0036b	0.0038b	0.0043a	0.0038b	0.79	0.85	0.90	0.89
Distance 1	35.27ab	33.55bc	31.36c	35.60a	0.0030c	0.0032bc	0.0036a	0.0035ab	0.73	0.78	0.87	0.91
Distance 2	15.09b	14.93b	12.15c	17.33a	0.0034b	0.0037b	0.0044a	0.0035b	0.80	0.76	0.82	0.83
Width 1	15.10ab	13.74c	13.97bc	15.88a	0.0029a	0.0032a	0.0032a	0.0032a	0.75	0.79	0.83	0.86
Width 3	3.49a	3.02b	2.84b	3.48a	0.0032c	0.0037ab	0.0039a	0.0036b	0.80	0.86	0.87	0.85

Estimates with different letters in the same row differ ($P<0.05$) according to the likelihood test.
SL - standard length.
Parameters: a - initial weight; k - specific growth rate.

similar to Thai. In relation to W2, there were no significant differences between Thai, UFLA and Commercial as to the parameters A, B and k (Table 6).

The fact that UFLA was not under genetic selection, being cultivated at the place of the experiment during many years, suggests that its best specific growth rate is due to its better adaptation to the environment conditions.

Beniga & Circa (1997) compared the growth of three pure strain of Nile tilapia (*Oreochromis niloticus*) with a local Philippine strain in net cages and observed that the three pure strains presented better growth rate, but lower survival rates than the local strain. Despite the lower survival rate, the results of the economic analysis revealed productivity and financial gains with the pure strain.

Comparing the growth rates of the Thai and the same Commercial strain studied in this experiment, but cultivated in net cages and weighting up to 200 g, Santos et al. (2008) found a significant difference between the strains, wherein Commercial (0.025) was superior to Thai (0.017). Osure & Phelps (2006) observed that the culture and the improvement of the local strain were more advantageous in relation to survival and initial growth, than the introduction of strain imported from other regions.

Of the eleven morphometric measures evaluated, nine presented growth standard similar to the strains Red and Thai. This fact is probably due to a genetic relationship between the strains, as Red is a hybrid from the crossing of Nile tilapias and other species of tilapia (*Oreochromis mossambicus* or *Oreochromis aureus*) (El-Sayed, 2006). Another interesting result of this study was the fact that UFLA presented a growth standard different from the other strains, also in 9 of the 11 morphometric measures. The thirty-one years of geographic isolation provided the strain UFLA with a particular and inherent morphometric characteristic, which makes it unique and distinct from the other tilapia ancestries.

The parameters of the exponential model obtained in this work suggest that the initial performance of the fingerlings is an important factor for the attainment of higher weights at the end of the period of culture, because the higher growth rate of UFLA, which presented the lowest observed and estimated initial weight, was not enough to reach the final weight of the Commercial strain, which presented the highest observed and estimated initial weight. On the other hand, the low growth rate of Red was one of the main reasons why it could not keep the difference of weight presented at the beginning of the culture period, as compared with UFLA.

This study demonstrated that the UFLA strain can be a good option for culture in regions whose climatic conditions are similar to the conditions of the south region of Minas Gerais. The Commercial strain presented excellent results due to the many years under genetic improvement. It is worth mentioning that although the UFLA strain presented excellent results, it is not yet part of genetic improvement program, but there are projects to include it in an improvement program.

Table 6 - Equality test estimators of the von Bertalanffy model for Thai, UFLA and Commercial strains, for the variable width 2

Strains	Parameters			Adjusted R^2
	A^{NS}	B^{NS}	k^{NS}	
Thai	50.10	0.575	0.0032	0.84
UFLA	36.08	0.579	0.0051	0.86
Commercial	48.73	0.562	0.0039	0.86

^{NS} - not significant according to the likelihood test.

Conclusions

The tilapia strains studied differed as to the growth speed of body weight and morphometric measures; UFLA presented the fastest growth both as regards weight and morphometric measures, followed by the Commercial, Thai and Red strains.

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