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Analysis of growth curves in different lineages of *Caipira* broiler type

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ABSTRACT. The objective of this work was to identify, by means of different statistical criteria the ideal nonlinear regression model to describe the growth curve of three lineages of *caipira* broiler for meat production. A total of 90 birds were used, being 30 birds from each of the following lineages: *Pescoço Pelado*, *Carijó* and *Pesadão Vermelho*. The individual body weight of broilers (1, 7, 14, 21, 28, 35, 42, 49, 56, 63, 70, 77, 84 and 91 days of age) was collected weekly for determination of growth curves by means of Models von Bertalanffy, Gompertz, Logistic, Richards and Brody. The parameters of Brody model did not converge to the weight of strains. The model that better adjusted to the data was Logistic.

Keywords: statistical model; birds; weight; age; lineage.

Análise de curvas de crescimento em diferentes linhagens de frangos de corte tipo *Caipira*

RESUMO. Objetivou-se com este trabalho identificar, por meio de diferentes critérios estatísticos, o modelo de regressão não linear mais adequado para descrever a curva de crescimento de três linhagens de frangos caipira para produção de carne. Utilizaram-se 90 aves caipiras, sendo 30 aves de cada uma das seguintes linhagens: *Pescoço Pelado*, *Carijó* e *Pesadão Vermelho*. Foi coletado semanalmente o peso corporal individual dos frangos (1, 7, 14, 21, 28, 35, 42, 49, 56, 63, 70, 77, 84 e 91 dias de idade) para determinação das curvas de crescimento por meio dos modelos Von Bertalanffy, Gompertz, Logístico, Richards e Brody. Os parâmetros do modelo Brody não convergiram, sendo então não adequado para descrever o peso dessas linhagens. O modelo que melhor se ajustou aos dados foi o Logístico.

Palavras-chaves: modelo estatístico; aves; peso; idade.

Introduction

The production of *caipira* broilers, or slow-growing birds, is one of the segments of alternative poultry farming that has been favorable, once, in addition to adding value to the product and using a production system that values animal welfare standards, serves both for small and medium-sized producers and for production on a commercial scale (Morais et al., 2015).

Among the lineages used in the production system we have the slow growing *Pescoço Pelado*, cinnamon and dark yellow skin, reddish plumage, reaching 2.3 kg weight around 70 days old, it is the most widespread lineage in Brazil. The *Carijó* lineage has a slow-growing barred-type plumage, presenting a dual ability to produce eggs and meat weighing 2.3 kg at 70 days of age. And the *Pesadão Vermelho* lineage has dark red plumage and black tail feathers and yellow skin and legs, at 70 days of age it reaches 2.4 kg (Clementino et al., 2007; Hellmeister Filho, Menten, Silva, Coelho, & Savino, 2003).

In poultry farming, it is extremely important to know the pattern and growth potential of birds, expressed in body weight and weight gain, which varies according to species or genetics, age and environmental factors that may influence the biological response. This development can be represented by growth curves, which are the description in mathematical equations of biological phenomena, thus, quantitative variables are taken to represent factors that influence the phenomenon, being that the information contained in a number of points, given by the coordinates of weight and time, can be summarized in a few parameters with biological interpretation, providing estimates of growth rate, degree of maturity and size at maturity (Laird & Howard, 1967; Rondon, Murakami, & Sakaguti, 2002). Thus, the parameters of the equations can help in research of nutritional requirements and in the elaboration of models to be used by the poultry companies providing information of the growth (Marcato et al., 2010).

The four most applied curves to represent growth in animal species are Brody, Logístico, Gompertz and Von Bertalanffy. All of them, are special cases of the Richards curve, which, is represented by the equation: $Y_t = A(1 \pm b \exp(-kt))^{1/(1-m)}$, wherein Y_t is the body weight the age t , A is the asymptotic value, b is the scale parameter, k is the maturity index and m is the inflection parameter, which determines the shape of the function (Tholon & Queiroz, 2009).

Since asymptotic value or asymptotic weight (A) is interpreted as adult animal weight, final weight or theoretical maximum weight. However, the scale parameter or integration constant (b) does not have biological interpretation, its function is to model the sigmoid from initial values of birth weight to adulthood. The maturity index (k) is the rate at which a logarithmic function of the weight changes linearly per unit of time. It can be, biologically, interpreted as growth rate or gain velocity, representing the slope of the growth curve (Veloso, Ferreira, Winkelstroter, Silva, Pires et al., 2015).

Considering these aspects, the aim of this work was to identify, through different statistical criteria, the best acceptable adjustment of the non-linear regression model to describe the growth curve of three lineages of *Caipira* broilers for meat production.

Material and methods

The experiment was conducted in the poultry sector of the School of Veterinary Medicine and Zootecny of the Federal University of Tocantins (UFT), municipality of Araguaína, northern region of Tocantins, from June to August 2016, with a mean temperature of 34°C maximum, 26.2°C minimum and relative humidity 64%.

Using 90 *caipira* birds, 30 birds from each of the following lineage: *Pesço Pelado*, *Carijó* and *Pesadão Vermelho*, obtained in the local commerce.

The day-old chicks were weighed and divided by lineage in experimental metal cages (1.00x1.00x0.40m) located inside the conventional shed (8m x 6m), covered with babassu straw, concrete floor and side curtains, managed according to the behavior of the birds. The cages were equipped with troughs and water troughs of the gutter type and contained a lighting system for heating the chicks. During the first three days, cup-type drinkers and dish type feeders were used to stimulate water and feed intake.

Until the 10th day of life, the birds were artificially heated using incandescent bulbs (60 W), installed inside the cages. At 29 days of age the birds were transferred to the pickets, following the same division, where each picket had a shelter covered with babassu straw, with pendula water tank and tubular feeder. Commercial rations based on maize and soybean meal

were used to meet the nutritional requirements of birds in the initial phase (1 to 28 days), growth (29 to 56 days) and termination (57 to 91 days). The centesimal composition of rations purchased in local commerce is shown in Table 1.

Table 1. Centesimal composition of the commercial rations provided in the initial phase, growth and termination.

Centesimal Composition	Rations	
	Initial	Growth and Termination
Metabolizable Energy (kcal kg ⁻¹)	2,909.81	2,926
Crude Protein (g)	204.04	188.03
Ethel Extract (g)	26.28	26.88
Crude Fiber (g)	31.72	30.25
Calcium (g)	9.70	0.748
Phosphorus Available	6.70	0.55
Total Lysine total (g)	9.78	8.88
Total Methionine (g)	2.81	2.60
Sodium (g)	1.47	1.47

Source: Provided by feed manufacturer.

The individual body weight of the chickens was measured weekly, (1, 7, 14, 21, 28, 35, 42, 49, 56, 63, 70, 77, 84 and 91 days of age).

For the determination of the growth curves of the body weight of the birds, the collected data were evaluated through the growth models:

Gompertz: $y = a \cdot \exp(-b \cdot \exp(-k \cdot \text{age}))$;
 Logistica: $y = a \cdot ((1 + b \cdot \exp(-k \cdot \text{age}))^{**} - 1)$;
 Bertalanffy: $y = a \cdot (1 - b \cdot \exp(-k \cdot \text{age}))^{**3}$;
 Richards: $y = a \cdot (1 - b \cdot (\exp(-k \cdot \text{age}))^{**}m)$;
 Brody: $y = a \cdot ((1 - b \cdot \exp(-k \cdot \text{age}))^{**}1)$;

Statistical analyzes were performed using the procedure for analysis of non-linear models (PROC NLIN) do *software* Statistical Analysis System (SAS, 2002) by the iterative method of Gauss-Newton.

The criteria used to choose the best fit model of the growth curve were the coefficient of determination (R^2), calculated by the $1 - (SQR/SQTc)$, being SQR the sum of squares of the residue and SQTc the total sum of squares corrected by the mean. The asymptotic standard deviation (ASD), calculated from the square root of the mean square of the residue of each model. The absolute mean deviation (AMD), as proposed by Sarmento (2006), calculated as:

$$AMD = \frac{\sum_{i=1}^n |Y_i - \hat{Y}_i|}{n}$$

In order to select the best model, the asymptotic index (AI), described by Ratkowsky (1993) was used, combining the ASD, AMD and R^2 criteria, assigning 100 values to the highest estimate of each criterion. The others are weighted in relation to that, as $AI = (ASD + AMD) - R^2$. The lower the index, the better the adjustment of the model.

Results and discussion

The slaughter weight of chickens is 2.3 kg on average, so that the *Pesçoço Pelado* lineage (PP) takes less time to reach the age of slaughter, followed by the *Pesadão Vermelho* and *Carijó* lineages (Table 2). However, Veloso et al. (2015) verified that the lineages *Pesçoço Pelado*, *Pesadão Vermelho* and *Carijó* reached a weight of 2.3 kg at 70 days of age.

The equations proposed by Von Bertalanffy, Gompertz and Logistic reached convergence, while the analysis carried out through the Richards Model only converged for the *Pesçoço Pelado* and *Pesadão* lineages. For the *Carijó* lineage that did not converge, showing that this model is not adequate for the description of the weights of this lineage. The equation proposed by Brody did not converge for any of the lineages studied (Table 3).

In all the models studied, the parameter "a" (weight at adult age) presented higher value for the *Pesçoço Pelado* (Table 3). This result shows that birds of the *Pesçoço Pelado* lineage tend to have the greatest weight in adulthood, and the birds of the *Pesadão* lineage, which presented lower values of "a" in the Bertalanffy and Gompertz models, tend to have less weight at maturity. In the logistic model the values of "a" of *Carijó* and *Pesadão* lineages are close.

The "k" parameter represents the speed at which the animal goes through the growth period until it becomes an adult. In the Bertalanffy, Gompertz and Logístico models the value of "k" is higher for the *Pesçoço Pelado*, indicating a higher growth rate, and lower for the *Carijó*, indicating a lower growth rate (Table 3).

According to Drumond et al. (2013), the value of R^2 would not be a good indicator for the choice of the

model, since they present high and very close values. However, in this study, R^2 values, although high, had a difference between the studied lineages, indicating the *Pesçoço Pelado* with the best adjustment and the *Pesadão* the worse adjustment to the model.

The lowest absolute mean deviation (AMD), asymptotic standard deviation (ASD), and asymptotic index (AI) were found in the *Pesçoço Pelado* lineage best adjustment to the models, while the *Pesadão* lineage presented the highest values of AMD, ASD and AI, indicating a worse adjustment to the models (Table 3).

The lowest AI value for the three studied lineages was observed in the logistic model, which is considered the best adjusted model, once AI is a criterion that takes R^2 , AMD and ASD into consideration. It is considered a complete criterion and so recommended as a model of choice.

Veloso et al. (2015) analyzed the models of growth curves for the *Pesçoço Pelado*, *Pesadão Vermelho*, *Tricolor*, *Carijó* and *Colorpak* lineages and confirmed that the Richards and Brody models did not adjust to the description of the growth of *Caipira* birds, and that the models Gompertz, Bertalanffy and Logístico adjusted to the growth of the studied lineages. From the three of them, the Bertalanffy model was the one that showed the best adjustment.

Up to 14 days of age, the different lineages showed a similar growth rate (Figure 1). However, after 14 days the highest growth rate was observed in the *Pesçoço Pelado* lineage, possibly due to genetics and its better adaptation to warm climate regions. Next, it was the *Pesadão* and last, with lowest growth rate was the *Carijó*, probably for being a bird of double aptitude (meat and eggs).

Table 2. Mean of body weights (g) at different ages for lineages (L) *Pesçoço Pelado* (PP), *Carijó* (CJ) and *Pesadão* (PD).

L	Body Weight (g)													
	1day	7days	14 days	21 days	28 days	35 days	42 days	49 days	56 days	63 days	70 days	77 days	84 days	91 days
PP	28.2	87.1	206.8	385.5	599.6	834.4	1107.2	1420.7	1696.2	2000.7	2245.8	2497.7	2723.2	2899.5
CJ	34.6	85.0	176.9	307.4	646.6	622.5	837.0	1064.0	1298.0	1552.0	1772.0	1984.0	2196.0	2331.0
PD	35.5	82.1	177.6	325.0	500.5	682.8	931.2	1093.4	1428.6	1663.3	1874.5	2089.1	2250.3	2449.8

Table 3. Estimated parameters for the growth curves of lineages (L) *Pesçoço Pelado* (PP), *Carijó* (CJ), and *Pesadão* (PD), according to the models Von Bertalanffy, Gompertz, Logístico and Richards.

	L	Estimated Parameters				R^2	AMD	ASD	A
		a	b	k	m				
Bertalanffy	PP	4686.30	0.86	0.01	-	0.96	165.39	249.83	83.47
	CJ	4449.00	0.83	0.01	-	0.91	228.54	352.46	123.00
	PD	4056.50	0.84	0.01	-	0.87	305.13	460.18	154.17
Gompertz	PP	3876.90	44360	0.03	-	0.96	166.86	249.58	81.74
	CJ	3414.80	43307	0.02	-	0.91	228.49	352.15	122.74
	PD	3298.40	43457	0.02	-	0.87	305.42	460.06	153.76
Logístico	PP	3149.40	25.44	0.06	-	0.96	180.87	254.78	72.93
	CJ	2613.70	25.38	0.05	-	0.91	235.67	353.57	116.98
	PD	2639.30	24.60	0.05	-	0.87	315.30	461.84	145.67
Richards	PP	4098.10	0.44	0.02	8.12	0.96	165.39	249.48	83.11
	CJ	NC	NC	NC	NC	NC	NC	NC	NC
	PD	3466.00	0.37	0.02	9.66	0.87	304.50	460.03	154.66

a= weight to adulthood; b= constant integration; k= maturity rate; R^2 = determination coefficient; AMD= absolute mean deviation; ASD= asymptotic standard deviation; AI= asymptotic index; NC= did not converge.

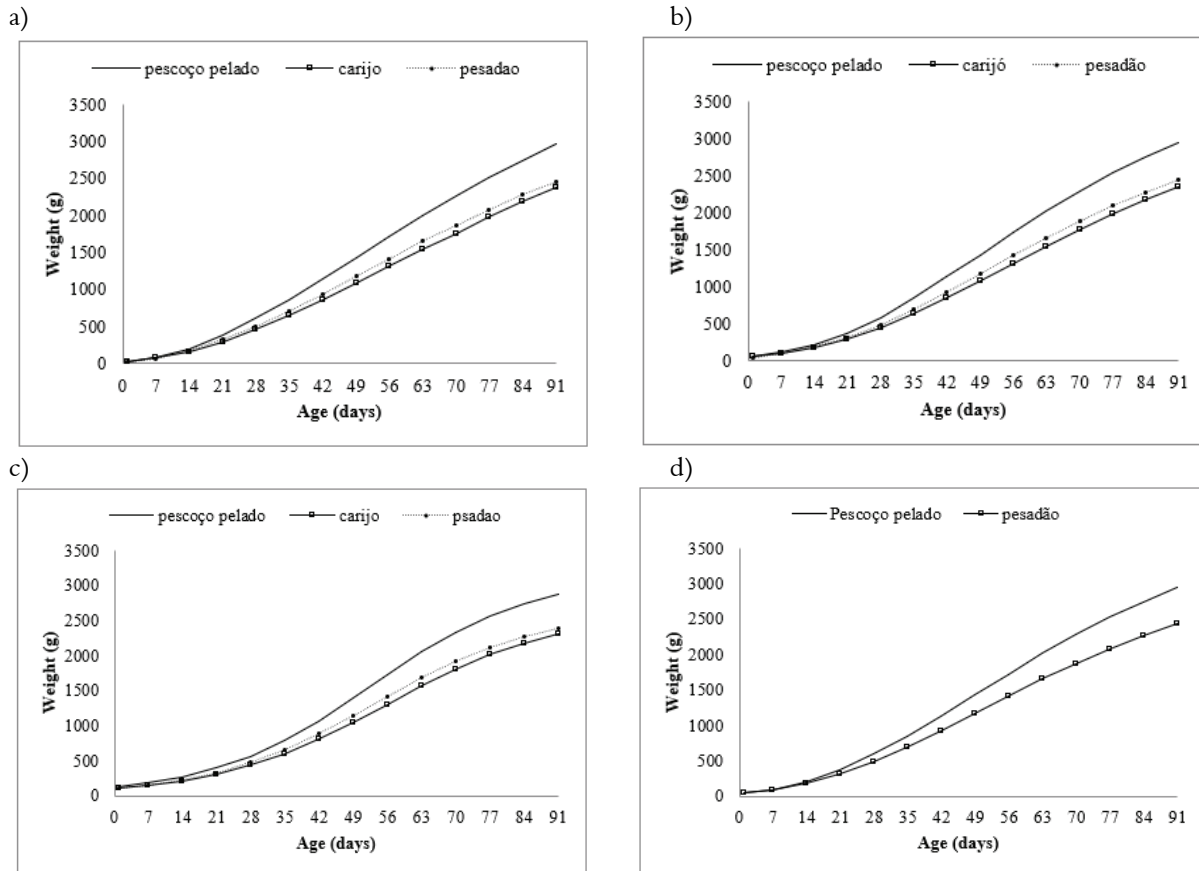


Figure 1. Growth curves of the different lineages according to the models: a) Von Bertalanffy; b) Gompertz; c) Logístico; d) Richards.

Morais et al. (2015) found different growth curves of the lineages, *Carijó*, *Pesadão*, *Pescoço Pelado*, and *Mista*, in which there was a divergence in the growth of birds from 35 days of age. The *Pescoço Pelado* lineage was the one that presented the slowest growth and the *Pesadão* lineage presented the fastest growth.

Conclusion

The model that best fit the data was the Logistic because it contained less asymptotic index.

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