COMPARISON OF NON-LINEAR EQUATIONS TO MODEL THE GROWTH OF MINHOTA BREED CATTLE

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Abstract – The Minhota breed cattle is an autochthonous variety adapted to the north of Portugal and extensive production system. Data from 536 cattle (265 males and 271 females), 267 heifers and cows and 29 bulls were obtained by weighing at different ages in order to establish the growth profiles. Based on those data, the suitability of several equations to describe the growth of cattle from the Minhota variety was studied. In all situations, mathematical models were formulated with parameters of clear biological meaning. Bertalanffy and Brody equations were the most satisfactory equations to model the growth of males and females, respectively.

Key Words – Minhota bovine breed, Growth curves, Non-linear equations.

I. INTRODUCTION

The livestock in the "Douro and Minho" area is from the quantitative point of view an important agricultural activity, represented by 19.000 meat farmers, 10.000 with dairy farmer with 40.000 meat animals and 115.000 dairy cows. In this area, there are several breed with Stud Book (Arouquesa, Barrosã, Cachena, Maronesa, Minhota and Marinhoa) that producing weaned calves at 5-10 months of age. These bovine breeds are rustic and they are reared under traditional systems. The use of local breeds as an alternative beef production system has important advantages, as these breeds are closely related to the environment and they help to maintain biodiversity and sustainable agricultural production, especially in depressed areas. A first step in the management of these resources includes their growth description and characterization. In this context, non-linear equations as Weibull, Gompertz, logistic, etc., are the most adequate tools to model those data and perform the corresponding parametric evaluations [1]. On the other hand, the current market situation determines local breeds to be produced in restrictive areas but it is necessary to increase their census and to guarantee that the production of this kind of meat reaches acceptable economic profits.

The main use of the Minhota breed is to produce meat, and the livestock production system is mainly focused on small family farms, using indoor systems or traditional grazing. The sale of cattle for slaughter is carried out between the ages of 5-7 months (150 kg of carcass weight) and 8-10 months (195 kg of carcass weight), which is the product, sought by industry, butchers and supermarket retailers.

For the Minhota breed, no studies on growth of cattle to adulthood exist. Thus, the main aim of this work is to study calf growth in both sexes of Minhota breed, using growth curves and estimates of weight at maturity using nonlinear growth models.

II. MATERIALS AND METHODS

II.1. Animal material for growth modelling

Live weight (LW) data from 536 cattle (265 males and 271 females), 267 heifers and cows and 29 bulls were obtained at different ages between July 2003 and April 2005 from 178 farms of the Douro e Minho area using an electronic bascule (FX1-Iconix) with capacity up to 2,000 kg. Growth curves were obtained based on the ages and weights of animals using data from birth to adulthood. The maximum age was 5.2 and 6.0 years in males and females, respectively,

corresponding to a total of 1,622 measurements. The data have been used to characterize growth to adulthood in the Minhota breed.

II.2. Modelling and Statistical analysis

The complete curve of full live weight was modelled by four equations (Brody, Logistic, Bertalanffy and Gompertz) to compare and select the best option. Two of these models (Logistic and Gompertz) are mathematically defined to describe mainly sigmoid profiles, whereas Brody is only adequate for hyperbolic trends, and Bertalanffy is indicated for both tendencies. Fitting to nonlinear equations was performed by minimisation of the sum of quadratic differences between observed and predicted values, using the non linear least-squares (quasi-Newton) method provided by SIMFIT version 5.5. Estimation of confidence intervals (Student's t test), consistence of equations (Fisher's F test) and residual analysis (Durbin-Watson test) were also performed using SIMFIT. Two criteria based on the information theory: Akaike information criterion (AIC) and Bayesian information criterion (BIC) were used to compare the predictive ability of non-linear equations to model cow live weight data [1,2]. Furthermore, bias (B_f) and accuracy (A_f) factors of data fitting to the non-linear equations were also calculated [3].

III. RESULTS AND DISCUSSION

Experimental data of live weight growth for female and male animals were modelled by the equations defined in Table 1. Parametric estimates and statistical analysis performed on the numerical fittings are summarized in Table 2. All equations were statistically robust (p-values <0.001 from Fisher's F test) and the parametric estimations were almost always significant (Student's t test, $\alpha = 0.05$). The ability of the equations to predict the experimental data profiles were remarkable with a goodness of fit of not less than 0.93. This statistical parameter was higher for males than females, but the amount of data in the asymptotic phase was much lower for males. The d-value from the Durbin-Watson test indicated a low autocorrelation among the residues. In addition, the value of the bias and accuracy factors were always close to one and therefore reaffirmed the validity of the equations evaluated. The statistical comparisons to ascertain the most adequate equation to predict the live weight growths were mainly performed by means of AIC and BIC methods. For adult males, the best option was the Bertalanffy equation followed by the Gompertz one. In the case of females, Brody´s equation surpassed the Bertalanffy equation and the other options. These results were also corroborated by the values of R^2, A_f and B_f. Experimental results from cow live weight growth and corresponding description according to the equation (1) for females and equation (4) for males are depicted in Figure 1.

Figure 1. Live weight growth of cow males and females from Miñota breed. Experimental data of live weight (points) were fitted to equation [4] for the males and equation [1] for the females (continuous lines for both cases). The independent variable t is the animal age. Values of R^2 and RSD (residual standard deviation, in kg units) are also indicated.

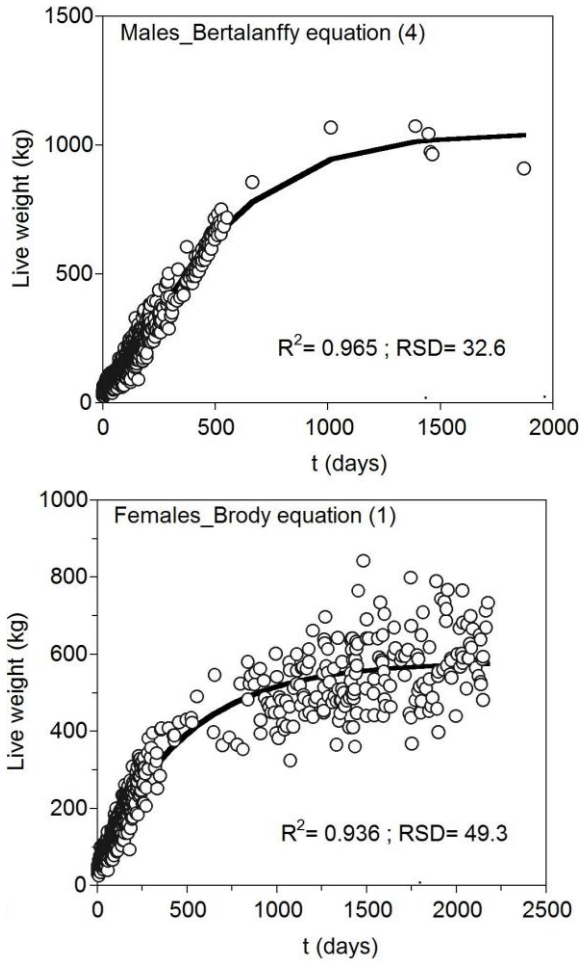

Table 2. Parametric estimations and confidence intervals (α = 0.05) corresponding to the equations from Table 1 to model the live weight growth of Minhota breed cattle. ns: non-significant, R^2: coefficient of determination, *p*-value from Fisher's F test (α = 0.05). A_f: accuracy factor (dimensionless); B_f: bias factor (dimensionless); *d*: value calculated by Durbin-Watson test (dimensionless).

SEX	Brody	Logistic	Gompertz	Bertalanffy
MALES				
G_m	1290.0±67.9	934.8±27.4	1003.2±26.8	1048.5±29.4
v_m	-	1.580±0.036	1.406±0.026	1.355±0.025
λ	-	57.86±5.92	13.15±3.82	-1.417 (ns)
μ_m	0.0012±0.0001	0.0068±0.0002	0.0038±0.0001	0.0029±0.0001
τ	561.7±41.4	353.7±11.1	372.1±11.6	393.5±13.6
t_m	-	649.0±11.2	630.4±19.7	1159.9±41.0
t_i	-	353.7±11.1	275.7±8.7	227.9±7.9
b	0.990±0.004	-	-	0.646±0.006
R^2	0.949	0.952	0.964	0.965
B_f (bias factor)	0.951	1.109	1.048	1.017
A_f (accuracy factor)	1.256	1.244	1.176	1.166
d (Durbin-Watson test)	1.235	1.288	1.673	1.732
p-value	<0.001	<0.001	<0.001	<0.001
FEMALES				
G_m	579.1±9.8	542.5±7.1	548.9±7.2	554.4±7.5
v_m	-	1.173±0.072	0.993±0.059	0.950±0.055
λ	-	5.394 (ns)	-30.98 (ns)	-40.87 (ns)
μ_m	0.0022±0.0001	0.0086±0.0005	0.0049±0.0003	0.0039±0.0001
τ	293.0±41.4	236.7±8.6	247.1±10.3	256.8±11.6
t_m	-	468.1±21.8	447.1±22.0	835.1±46.8
t_i	-	236.7±8.6	172.5±6.7	132.0±5.6
b	0.939±0.011	-	-	0.555±0.016
R^2	0.936	0.927	0.931	0.933
B_f (bias factor)	1.013	1.050	1.035	1.029
A_f (accuracy factor)	1.155	1.176	1.158	1.153
d (Durbin-Watson test)	1.857	1.620	1.724	1.771
p-value	<0.001	<0.001	<0.001	<0.001

To our knowledge, this is the first time that lives weight data of Minhota cows has been modelled using non-linear equations. As expected, the live weight growth parameters of males (G_m, v_m, τ and t_m) were significantly higher than the females for all equations studied (Table 2). The females weighed 55% of the final weight of males, based on G_m value. This coincides with the results for the Maronesa variety [4] but is inferior to those in the Alentejana [5], Mirandesa [6] and Arouquesa breeds [7]. By contrast, the specific maximum live weight rates (μ_m) were lower in males, which concur with other reports [5]. The correlation between the Gm and μ_m parameters was, in both cases, negative but with higher values for males (data not shown). Similar correlations have been observed by several authors [5,8], thus demonstrating that weights at maturity are commonly associated with reduced specific growth rates and vice versa.

In previous articles, we have analysed the capacity of several non-linear equations to model the live weight growths of different species [1,9,10]. From those assessments, the logistic equation was reported as the most suitable due to its fitting ability and the biological meaning of its parameters. The lack of sigmoidity in the present live weight data caused equation (2) to be more inaccurate compared to the less sigmoid equations of Brody and Bertalanffy. Although useful to simulate hyperbolic live weight growth data, equation (1) is inconsistent with non-linear profiles, and the number of parameters with biological or geometrical meaning is limited. Moreover, it presents difficulties in predicting mature weight (G_m) with low intervals of confidence (Table 2) and underestimates initial weights. Some of those deficiencies have already been found by other authors [11]. On the other hand, the sigmoid equations (Gompertz and logistic) habitually overestimate the initial weights in line with our findings for both sexes (data not shown).

IV. CONCLUSION

Four non-linear equations were evaluated for modelling the growths of cattle from the NW Portuguese Minhota variety with different results for males and females. In the case of males, Bertalanffy was the best option, whereas the Brody model showed the best results for describing female growth.

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