P-ISSN: 2618-0723
E-ISSN: 2618-0731

NAAS Rating: 5.04
www.extensionjournal.com

International Journal of Agriculture Extension and Social Development

Volume 7; SP-Issue 1; Jan 2024; Page No. 06-08

Received: 05-10-2023
Accepted: 09-11-2023

Indexed Journal
Peer Reviewed Journal

Assessing the logistic growth function in connection to growth metrics

[1]Dinesh Kumar Sunwasiya and [2]Lokesh Kumar Chandolia

[1]Ph.D. Scholar, Division of Animal Genetics and Breeding, ICAR-NDRI, Karnal, Haryana, India

[2]Veterinary Officer, Government of Rajasthan, Rajasthan, India

DOI: https://doi.org/10.33545/26180723.2024.v7.i1Sa.229

Corresponding Author: Dinesh Kumar Sunwasiya

Abstract

This study set out to establish which of the different non-linear growth curve model - Von-Bertalanffy, Gompertz, Richards, Weibull, exponential function, and logistic - was most suitable for characterising the growth curve. A total of 715 female and 340 male kids body weight records, taken every three months from birth to the twelveth month of life, were included. Males had a higher asymptotic live weight ("A") than females did. The maturity rate ("C") of males was higher than that of females. In conclusion, live weight as a function of age for male and female goats and sheep was best calculated using non-linear growth models. Calculations were made for residual SS (SSE), residual MS (MSE), AICC, and R^2. The various goods an animal produces, including milk, meat, and other foods, are impacted by its growth. This phase of the animal's existence is crucial. Since it is hard to interpret a series of weight-age data points analytically, it is preferable to analyse animal growth statistically. Understanding evolutionary change is essential to creating successful breeding strategies, and this is where growth curve inheritance comes in.

Keywords: Body weight, goat, sheep

Introduction

A variety of non-linear mathematical functions have been used to define the growth curve for evaluating response to a particular treatment at different times, interaction between and within populations for identifying heavier animals at an early age, and Gompertz (Laird, 1965) [8], Bertalanffy (Bertalanffy, 1957) [3], Logistic (Nelder, 1961) [11], and negative exponential (Bathaei and Leroy, 1998) [1] (Magotra *et al*., 2021) [9].

Numerous studies have been undertaken in animal research to define the growth patterns of the animals. In addition to fitting standard models like simple linear or exponential growth to size-at-age data, these research also took into account models with sigmoidal (S-shaped) growth curves, the Brody model, and negative exponential growth models.

The latter is modelled by Richards, von Bertalanffy, Gompertz, and Verhulst (logistic growth). A Google Scholar search yielded about 22,500 and 15,500 results, respectively, for articles on the application of the Brody model for sheep and goats. The Verhulst model gave approximately 5500 and 3500 hits, the Gompertz model produced roughly 4000 and 2000 hits, and the von Bertalanffy model produced roughly 2500 and 1500 hits (Brunner and Kühleitner, 2020) [5].

Materials and Methods

The sheep and goats were maintained on a vast field grazing method. The goats grazed on the pasture for six to eight hours every day. The trees, bushes, and grasses that are available for the goat are classified as follows: Monsoon (Kair, Dhaman, Dudh, Patharchatta, Motha, Akra, and Thur), winter (Neem, Motha, Akra, Keekar, and Beri), and summer (post-harvest leftover residue of Gramme pea (Chickpea), Babul, Kair, and Khejri).

Statistical Analysis

Body weights were standardized for 30, 60, 120,150, 210, 240, 300 and 330 days using the following methodology (Warwick and Legates, 1979) [21].

$$P_i = Pnear_i + ADG\ (i - \text{age } Pnear_i)$$

where P_i is the standardized weight at standard age (i), Pnear is the weight nearest to standard age (i), ADG is average daily gain considered among the weights after standard age (i) and before standard age (i), (i) is age to which weight is standardized, and age $Pnear_i$, age to weight nearest to standard age (i) considering.

Average daily gain in the body weight of individual animal was calculated by using the following formula (Brody, 1964) [4].

$$\text{Average daily gain} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where: W_2= Final body weight (kg); W_1= Initial body weight (kg); t_2= Age of the animal at the end of the period (days); t_1= Age of the animal at the beginning of period (days)

Different mathematical models were used to estimate growth curve parameters using Sistastics 10 software.

Non-linear growth curve models	Equations
Logistic (Nelder, 1961) [11]	$W_t = A \times (1 + B \times e^{-kt})^{-1} + \varepsilon$

Where: W_t = the expected body weight (Kg) at 't' time; A= is the asymptotic weight; B= the folding point of growth; K = the rate of growth; m = Shape parameter; Ɛ= random error; e = the base of natural logarithm; t = time (birth to 12^{th} month of age).

Residuals were plotted graphically which gave an accuracy of the model to fit the growth curves.

$$e = y_i - \hat{y}_i$$

Where: y_i= Observed body weight at time "t"; $\hat{y}_i$= Predicted body weight by regression model at time "t".

The Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) was calculated as below (Topal and Balukbasi, 2008) [17].

$$\text{MAE} = \frac{\sum_i^n \lfloor y_i - \hat{y}_i \rfloor}{n}$$

$$\text{MAPE} = {}^{1}/_{n} \sum_i^n \frac{\lfloor y_i - \hat{y}_i \rfloor}{y_i}$$

Where: y_i = Observed body weight at time "t"; $\hat{y}_i$ = Predicted body weight by regression model at time "t"; n = Number of observations (data points).

In the case the sample size is smaller than the number of model parameter (N⁄K<40), the AIC might not be accurate then after use of Akaike's information Criteria (AICC) was appropriate and calculated as using the equation Motulsky and Christopoulus (2004) [10].

$$\text{AIC}_\text{C} = \text{AIC} + \frac{2p(p+1)}{n-p-1}$$

Where: AIC = Akaike's Information Criteria.

Therefore, AICC is a good static for comparison of models of different complexity because it adjust the residual sum of squares (RSS) for number of parameters in the model. A smaller numerical value of AICC indicates a better fit when comparing models.

The Chi-square (x^2) values is used to designate the relationship between actual and predicted body weights whether there is a significant difference between the predicted and the observed body weights.

$$\chi^2 = \frac{(y_i - \hat{y}_i)^2}{\hat{y}_i}$$

Where: Y_i = Observed body weight at time "t"; $\hat{y}_i$ = Predicted body weight by regression model at time "t".

Results and Discussion

Male, female, and both sexes had estimated asymptotic mature live body weight parameters (A) of 22.49±0.88, 20.99±0.88, and 21.46±0.87 kg, respectively. The results were in close agreement with the reports of Yadav *et al.*, (2009) [22] as 20.60 Kg in both sexes of Marwari sheep whereas, In contrary the present result that lower parameter (A) was observed by Thirunavukkarasu *et al.*, (2017) [16] as 19.34, 16.76 and 17.50 Kg in male, female and both sexes of Mechari sheep, respectively.

The study by Ganesan *et al.* (2015) [7] reported higher estimates of parameter (A) as 36.44 and 25.99 kg in male and female Madras red sheep. On the other hand, Tsukahara *et al.* (2008) [18] reported higher parameter (A) for both sexes, with values of 27.00 kg in Kambing Katjang goat, Tatar *et al.* (2009) [15] reporting 32.03 kg in young hair goat, Paul *et al.* (2016) [23] reporting 32.53 kg in non-descript goat, and Waheed *et al.* (2016) [19] reporting 27.10 kg in Thalli sheep.

For the male, female, and both sexes, the Folding Point of Growth Curve (B) for the Logistic Growth Model was found to be 3.84±0.58, 3.87±0.63, and 3.89±0.62, respectively. The results of Paul *et al.* (2016) [23], which measured 3.75 in non-descript goats, and Thirunavukkarasu *et al.* (2017) [16], which measured 3.98 in Mechari sheep for both sexes, supported the current investigation.

The higher parameter (B) was found to be 4.38 in Kambing Katjang goat by Tsukahara *et al.* (2008) [18] and 4.04 in both sexes of Young hair goat by Tatar *et al.* (2009) [15]; on the other hand, Behzadi *et al.* (2014) [2] observed as 5.09 and 5.09 in Baluchi sheep and 4.05 and 4.06 in Mechari sheep for male and female by Thirunavukkarasu *et al.* (2017) [6].

For the male, female, and both sexes, the rates of maturing and growth rate (K) for the Logistic Growth Model were found to be 0.41±0.05, 0.41±0.05, and 0.42±0.05, respectively. The current result was consistent with results from Nimase *et al.* (2018) [13], showing 0.47 and 0.50 in Madgyal sheep, respectively, in the male and female.

Behzadi *et al.* (2014) [2] found lower estimates of parameter (K) for male and female Baluchi sheep, namely 0.02 and 0.02; Thirunavukkarasu *et al.* (2017) [16] found lower estimates, namely 0.01 and 0.01 for male, female, and both sexes of Mechari sheep, respectively.

Contrary to the current findings, Tatar *et al.* (2009) [15] reported a higher parameter (K) for both sexes in young hair goats, with a value of 0.66, while Waheed *et al.* (2016) [19] reported a value of 0.60 in Thalli sheep.

Conclusion

The study discovered that a variety of factors contribute to variation in growth curve model parameters, including but not limited to flock size, species, breed, selection techniques, environmental and managerial conditions, farmer socioeconomic position, and nutritional traits of breeds and species.

Declarations of Competing Interest

The authors declare that they have no conflicts of interest associated with this publication.

References

1. Bathaei SS, Leroy PL. Genetic and phenotypic aspects of growth curve characteristics in Mehraban Iranian fat-tailed sheep. Small Ruminant Research. 1998;29:261-269.
2. Behzadi MR, Aslaminejad AA, Sharifi AR, Simianer H. Comparison of mathematical model for describing the growth of Baluchi sheep. Journal of Agricultural Sciences Technology. 2014;14:57-68.
3. Bertalanffy LV. Quantitative laws in metabolism and Growth. Quarterly Review Biology. 1957;32:217-230.
4. Brody S. Bioenergetics and Growth. Reinmhold Publishing Corporation, New York, USA; c1964. p. 502-514.
5. Brunner N, Kühleitner M. The growth of domestic goats and sheep: A Meta study with Bertalanffy-Pütter models. Veterinary and Animal Science. 2020;10:100135. https://doi.org/10.1016/j.vas.2020.100135
6. Burnham KP, Anderson DR. Multi-model inference: understanding AIC and BIC in model selection. Social Methods Res. 2004;33:261-304.
7. Ganesan R, Dhanavanthan P, Balasubramanyam D, Kumarasamy P, Kiruthika. Growth Modeling and Factors Affecting Growth Traits in Madras Red Sheep. Indian Journal Animal Research. 2015;49(1):20-25.
8. Laird AK. Dynamics of relative growth. Growth. 1965;29:249-263.
9. Magotra A, Bangar YC, Yadav AS. Growth curve modeling and genetic analysis of growth curve traits in Beetal goat. Small Ruminant Research. 2021;195:106300.
10. Motulsky H, Christopoulos A. Fitting models to biological data using linear and non-linear regression. Oxford University Press; c2004.
11. Nelder JA. The fitting of a generalization of the logistic curve. Biometrics. 1961;17:89-110.
12. Pires LC, Machado TMM, Carneiro PLS, Silva JBL, Barbosa ADHB, Torres RA, *et al*. Growth curve of Repartida goat reared in the Caatinga region, Brazil. Semina Ciencias Agrarias, Londrina. 2017;38(2):1041-1050.
13. Nimase RG, Kaandalkar YB, Bangar YC. Non-linear modeling for estimation of growth curve parameters in Madgyal sheep. Journal of Entomology and Zoology Studies. 2018;6(2):463-465.
14. Tariq MM, Iqbal F, Eyduran E, Bajwa MA, Huma ZE, Waheed A, *et al*. Comparison of non-linear functions to describe the growth in Mengali sheep breed of Balochistan. Pakistan Journal of Zoology. 2013;45(3):661-665.
15. Tatar MA, Tekel N, Ozkan M, Bartci I, Dellal G. The determination of growth function in young hair goat. Journal of Animal and Veterinary Advances. 2009;8(2):213-216.
16. Thirunavukkarasu M, Balan C, Kathiravan G, Jeichitra V. Non-linear growth modeling in Mechari breed of sheep. Journal of Entomology and Zoology Studies. 2017;5(5):2005-2008.
17. Topal M, Balukbasi SC. Comparison of nonlinear growth curve models in Broiler Chickens. Journal Applied Animal Research. 2008;8:149-152.
18. Tsukahara Y, Chomei Y, Oishi K, Panandam JM, Mukherjee TK, Hirooka H, *et al*. Analysis of growth patterns in purebred Kambing Katjang goat and its crosses with the German Fawn. Small Ruminant Research. 2008;80:8-15.
19. Waheed A, Eyduran E, Tariq MM, Ahmad S, Hameed T, Bukhari FA, *et al*. Comparison of the non-linear models defining the growth of Thalli sheep under desert conditions. Pakistan Journal of Zoology. 2016;48(2):423-426.
20. Waheed A, Khan MS, Ali S, Sarwar M. Estimation of Growth Curve Parameters in Beetal Goats. Leibniz Institute of Farm Animal Biology, Dummerstorf, Germany. Archiv Tierzucht. 2011;54(3):287-296.
21. Warwick EJ, Legates JE. Breeding and improvement of farm animals. 7th edition. McGraw-Hill Book, New York; c1979.
22. Yadav DK, Singh G, Jain A, Singh S, Paul AK. Fitting of growth models and evaluation of Marwari sheep under field conditions. Indian Journal of Animal Sciences. 2009;79(12):1242-1244.
23. Paul J, Modi A, Patel J. Predicting green product consumption using theory of planned behavior and reasoned action. Journal of retailing and consumer services. 2016 Mar 1;29:123-34.