Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

J E Z S Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(2): 463-465

Received: 08-01-2018
Accepted: 09-02-2018

Ravindra G Nimase
Assistant Professor, Department of Animal Husbandry and Dairy Science, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Yogesh B Kandalkar
Assistant Professor, Department of Animal Husbandry and Dairy Science, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Yogesh C Bangar
Scientist (Statistics), Department of Animal Genetics and Breeding, LUVAS, Hisar, Haryana, India

Correspondence
Yogesh C Bangar
Scientist (Statistics), Department of Animal Genetics and Breeding, LUVAS, Hisar, Haryana, India

Non-linear modeling for estimation of growth curve parameters in Madgyal sheep

Ravindra G Nimase, Yogesh B Kandalkar and Yogesh C Bangar

Abstract
The aim of the present study was to determine the most suitable model among six non-linear growth models *viz.*, Brody, Von Bertalanffy, Richards, Logistic, Gompertz and negative exponential, used for describing the growth curve of 215 Magdyal male and female lambs maintained at Department of Animal Husbandry and Dairy Science, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri (India) from 2006 to 2014. Non-linear modeling was done by using monthly body weights from birth to 12 months of age in male and female lambs separately. Among the models used, Brody model and Richards model showed close fitting for growth curve with high values of adjusted R^2 value (> 99%) and least values of root means square error (RMSE), Akaike's information criterion (AIC) and Bayesian information criterion (BIC). However, due to simple interpretation and high precision, Brody model was considered as most suitable model for growth curve characteristics of Madgyal sheep. The parameter estimates for asymptote weight (A), initial constant to asymptote weight (B) and maturation rate (k) under Brody model for male lambs were 28.35±0.86, 0.85±0.02 and 0.19±0.02, respectively, in case of female lambs, it were 25.23±0.20, 0.85±0.01 and 0.21±0.01, respectively.

Keywords: Madgyal sheep, growth curve, non-linear models, brody model

1. Introduction
India possesses 65.06 million sheep and ranks third in world's sheep population [1]. Madgyal sheep is indigenous breed of sheep and distributed in Jat and Atpadi tahsils of Sangli district of Maharashtra state of India [2]. It is mainly meat purpose breed and has very coarse wool. These breed have been evolved through selective breeding under drought conditions. Breed is remarkably tall and has white coat color with brown patches of different sizes. Both sexes are polled and nose is roman shape. Due to high growth rate, this breed is of special importance for growth traits studies [3].
Growth is defined as an increase in body size over time [4]. The non-linear models can be used to describe the growth curve characteristics in order to obtain biologically important growth parameters which can be useful for setting strategies for breeding, culling and feeding management [5]. Previous studies have reported comparative suitability of various non-linear models for growth curve fitting in various breeds of sheep [6, 7]. However, information related to growth curve characteristics of the Madgyal sheep is scarce until now. Therefore, the present study was undertaken to determine the most suitable non-linear model for fitting growth curve characteristics in Madgyal sheep.

2. Material and Methods
The data records of the monthly body weights from birth to 12 months of age for 215 Madgyal lambs born between years 2006 to 2014 were collected from inventory and weight registers maintained at Department of Animal Husbandry and Dairy Science, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra (India). The farm managerial practices included grazing in pasture, harvested fields and surrounding hillocks of farm, feeding of extra green and dry fodder along with definite quantity of concentrates. The weaning period for lambs was typically 3 months of age. The average monthly body weights for lambs were considered for further analysis.

2.1 Statistical Analysis
The following six non-linear models were used for fitting growth curve characteristics for male and female separately as:

Brody [8] : $W_t = A[1 - B\exp(-kt)]$

Von Bertalanffy [9] : $W_t = A[1 - B\exp(-kt)]^3$

Richards [10] : $W_t = A[1 - B\exp(-kt)]^{-m}$

Logistic [11] : $W_t = A/[1 + B\exp(-kt)]$

Gompertz [12] : $W_t = A\exp[-B\exp(-kt)]$

Negative exponential [13]: $W_t = A[1 - \exp(-kt)]$

W_t represents monthly body weight at age t (t=0, 1, 2….12); A represents asymptotic weight, which is interpreted as average weight of the mature sheep; and B is an integration constant related to initial animal weight. The value of B is defined by the initial values for W_t and t; k is the maturation rate, which is interpreted as weight change in relation to mature weight to indicate how fast the animal approaches adult weight (asymptote A) and m is the shaping parameter of curve which indicates inflection point. Exp represents exponential function.

The estimation of parameters with standard error for these models was undertaken using NLIN procedure in SAS 9.3 version [14]. SAS software uses Gauss-Newton method for iteration and provides least squares or weighted least squares estimates. Further, various non-linear models were compared using goodness of fit criteria i.e. adjusted coefficient of determination (R^2 adjusted); root means square error (RMSE), Akaike's information criterion (AIC) and Bayesian information criterion (BIC).

$$R^2_{adj} = 1 - \left(\frac{n-1}{n-p}\right)\left(1 - R^2\right) \qquad RMSE = \sqrt{\frac{RSS}{n-p-1}}$$

$$AIC = n\ \ln(RSS) + 2p \qquad BIC = n\ \ln\left(\frac{RSS}{n}\right) + p\ln(n)$$

Where R^2 represents multiple coefficient of determination[R^2=1-(RSS/TSS)]; RSS and TSS represent residual and total sum of squares, respectively; n and p represents number of observations and parameters in model, respectively. The model with highest R^2_{adj} value and lowest value of RMSE, AIC and BIC was considered as best model among various non-linear models for fitting growth curve of Madgyal sheep.

3. Results and Discussion

Non-linear modeling was performed separately for male and female lambs and the estimates of growth curve parameters are given in Table 1. The parameter A, asymptotic weight ranged between 22.96 to 25.31 and 25.40 to 31.75 kg for female and male lambs, respectively. These estimates were in accordance with the reports of Malhado *et al*. [5]. Further, male lambs had higher asymptotic weights than female lambs, which were also reported by Hossein-Zadeh [15] in Iranian Shall and Gbangboche *et al*. [16] in West African Dwarf sheep.

The Richards model provided maximum values for asymptotic weight in both sexes. Whereas, the estimate of parameter B was found as lowest due to Von Bertalanffy but highest for Logistic model. These results were in agreement with findings of Kopuzlu *et al*.[7] in Hemsin sheep.

The parameter k, maturation rate, was higher for females than males among all models suggesting female reach maturity earlier than male. These findings were consistent with the reports of Lupi *et al*. [17] in Segureña sheep. As compared to male lambs, female lambs had higher maturation rate (k) but lower asymptote weights (A). This indicates that early matured lambs have lower mature weights than late matured lambs, which might be due to negative correlation between A and k [15]. Among the all models, logistic model provided high maturity rate to reach mature weight in both sexes. Similar findings were also reported by Gbangboche *et al*. [16] in West African Dwarf sheep. The higher values of m parameter of the Richards model in male lambs indicated that male lambs reach inflection point earlier than female lambs. These findings were consistent with the reports of Kopuzlu *et al*. [7].

The results of goodness of fit criteria for various non-linear growth models fitted to weight-age relationship of male and female Madgyal lambs are given in Table 2. The adjusted R^2 value was highest for Brody and Richards model in female and male lambs, respectively. Similarly, lowest values of RMSE, AIC and BIC were observed for Brody and Richards model in female and male lambs, respectively. On the basis of goodness fit criteria, the models were ranked as follows: Brody--Richards--Von Bertalanffy--Gompertz--Logistic--Negative exponential for female lambs and Richards--Brody--Von Bertalanffy--Gompertz--Logistic-- Negative exponential in male sheep. Negative exponential model provided least fit for growth curve in both sexes.

In the present study, Brody and Richards models showed closer values for all goodness fit measures for fitting of growth curve characteristics in Madgyal sheep, which was also reported by Bilgin *et al*. [18] in Awassi and Morkaraman sheep. However, estimates of all growth parameters under Brody model had lower standard error than Richards model. These findings were in agreement with the reports of Kopuzlu *et al*. [7] and Akbas *et al*. [19]. The convergence difficulty for Richard model due to varied inflexion point was reported by Malhado *et al*. [5]. Additionally, Brody model had only three parameters which give simple interpretation. Therefore, on the basis of values of goodness fit measures, simplicity due to three parameters and precision due to low standard error, Brody model was considered most suitable model for fitting growth curve characteristics in Madgyal sheep. The best fit due to Brody model was also reported by Bahreini Behzadi *et al*. [6] in Baluchi, Gbangboche *et al*. [16] in West African Dwarf and Balan *et al*. [20] in Mecheri Sheep. These findings were in contrast with some previous studies [15, 17, 21, 22].

Table 1: Parameters Estimates (± SE) for growth curve characteristics in Madgyal sheep

Group	Parameter	Negative Exponential	Brody	Gompertz	Logistic	Von Bertalanffy	Richards
Female	A	23.61±0.93	25.23±0.20	23.60±0.35	22.96±0.45	23.96±0.30	25.31±0.39
	B		0.85±0.01	1.63±0.07	3.34±0.36	0.43±0.01	0.86±0.04
	K	0.30±0.04	0.21±0.01	0.36±0.02	0.50±0.04	0.31±0.01	0.21±0.02
	M						1.03±0.11
Male	A	26.07±1.16	28.35±0.86	26.22±0.78	25.40±0.78	26.68±0.78	31.75±3.22
	B		0.85±0.02	1.62±0.11	3.26±0.50	0.43±0.02	0.96±0.03
	k	0.28±0.04	0.19±0.02	0.33±0.04	0.47±0.06	0.29±0.03	0.11±0.05
	m						1.55±0.30

Table 2: The goodness of fit criteria for various non-linear models in Madgyal sheep

Group	Statistics	Negative Exponential	Brody	Gompertz	Logistic	Von Bertalanffy	Richards
Female	R^2 (adj)	95.50	99.93	99.45	98.57	99.69	99.92
	RMSE	1.33	0.16	0.46	0.75	0.35	0.17
	AIC	42.64	-10.78	16.03	28.46	8.73	-8.88
	BIC	10.42	-42.43	-15.62	-3.19	-22.92	-39.96
Male	R^2 (adj)	94.87	99.26	98.25	97.03	98.64	99.39
	RMSE	1.57	0.60	0.92	1.20	0.81	0.54
	AIC	46.98	22.64	33.73	40.65	30.48	20.70
	BIC	14.76	-9.00	2.08	9.00	-1.17	-10.38

4. Conclusion

Among the models used for fitting growth curve characteristics of Madgyal sheep, Brody and Richards models showed superior fit than other models. However, Brody model had higher precision (low standard error) and simplicity (three parameters). Therefore, Brody model was most appropriate model to describe the growth curve of studied animals. These findings can be helpful for optimum selection and culling of Madgyal sheep at farm.

5. Acknowledgements

The authors are thankful to the Head of Department of Animal Husbandry and Dairy Science, MPKV (Rahuri), Maharashtra India for the necessary facility to conduct this study. The authors also express their gratitude to the learned referee and the Editor-in-Chief for their valuable comments on the original version of the paper.

6. Reference

1. Livestock census, 2012. Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture and Farmers Welfare, Government of India, http://dahd.nic.in/ Retrieved on 31st August, 2016.
2. Waghmode PS, Sawane MP, Pawar VD, Ingawale MV. Effect of non-genetic factors on growth performance of Madgyal sheep. Indian Journal of Small Ruminants. 2008; 14(1):127-130.
3. Waghmode PS, Sawane MP, Pawar VD, Ingawale MV. Physical and morphological Characteristics of Madgyal sheep. Journal of Bombay Veterinary College. 2007; 15(1-2):42-45.
4. Topal M, Ozdemir M, Aksakal V, Yildiz N, Dogru U. Determination of the best nonlinear function in order to estimate growth in Morkaraman and Awassi lambs. Small Ruminant Research. 2004; 55:229-232.
5. Malhado CHM, Carneiro PLS, Affonso PRAM, Souza AAO, Sarmento JLR. Growth curves in Dorper sheep withthe local Brazilian breeds, Morada Nova, Rabo Largo, and Santa Ines. Small Ruminant Research. 2009; 84:16-21.
6. Bahreini Behzadi MR, Aslaminejad AA, Sharifi AR, Simianer H. Comparison of Mathematical Models for Describing the Growth of Baluchi Sheep. Journal of Agricultural Science and technology. 2014; 14:57-68.
7. Kopuzlu S, Sezgin E, Esenbuga N, Bilgin OC. Estimation of growth curve characteristics of Hemsin male and female sheep. Journal of Applied Animal Research. 2014; 42(2):228-232.
8. Brody S. Bioenergetics and growth. New York (NY): Reinhold, 1945.
9. Von Bertalanffy L. Quantitative laws in metabolism and growth. The Quarterly Review of Biology. 1957; 32(3):217-231.
10. Richards FJ. A flexible growth function for empirical use. Journal of Experimental Botany. 1959; 10:290-300.
11. Nelder JA. The fitting of a generalization of the logistic curve. Biometrics. 1961; 17:89-110.
12. Laird AK. Dynamics of relative growth. Growth. 1965; 29:249-263.
13. Brown JE, Fitzhugh Jr HA, Cartwright TC. A comparison of nonlinear models for describing weight–age relationships in cattle. Journal of Animal Science. 1976; 42:810-818.
14. SAS 9.3 software. SAS Institute Inc.: SAS/STAT® 13.1. 2013;User's Guide, Cary, NC
15. Hossein-Zadeh NG. Modeling the growth curve of Iranian Shall sheep using non-linear growth models. Small Ruminant Research. 2015; 130:60-66.
16. Gbangboche AB, Glele-Kakai R, Salifou S, Albuquerque LG, Leroy PL. Comparison of non-linear growth models to describe the growth curve in West African Dwarf sheep. Animal. 2008; 2(7):1003-1012.
17. Lupi TM, Nogales S, León JM, Barba C, Delgado JV. Characterization of commercial and biological growth curves in the Segureña sheep breed. Animal. 2015; 9(8):1341-1348.
18. Bilgin OC, Esenbuga N, Macit M, Karaoglu M. Growth curve characteristics in Awassi and Morkaraman sheep, Part I: comparison of nonlinear functions. Wool Technology and Sheep Breeding. 2004; 52:1-7.
19. Akbas Y, Tasky´n T, Demirören E. Comparison of several models to fit the growth curves of kivircik and daglic male lambs. Turkish Journal of Veterinary and Animal Sciences. 1999; 23(3):537-544.
20. Balan C, Kathiravan G, Thirunavukkarasu M, Jeichitra V. Non-linear growth modelling in Mecheri breed of sheep. Journal of Entomology and Zoology Studies. 2017; 5(5):2005-2008.
21. Tekel N, Sireli HD, Elicin M, Elicin A. Comparison of growth curve models on Awassi lambs. Indian Veterinary Journal. 2005; 82:179-182.
22. da Silva LSA, Fraga AB, da Silva FDL, Guimarães Beelen PM, de Oliveira Silva RM, Tonhati H *et al*. Growth curve in Santa Inês sheep. Small Ruminant Research. 2012; 105(1):182-185.