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New Approaches to Determination of the Best Nonlinear Function Describing Growth at Early Phases of Kivircik and Morkaraman Breeds

[1]E. Eyduran, [2]M. Küçük, [3]K. Karakus and [1]T. Ozdemir
[1]Department of Animal Science, Faculty of Agriculture,
[2]Department of Animal Science, University of Veterinary Medicine, Van, Turkey
[3]Gevas Vocational High School, Gevas, Van
University of Yuzuncu Yil, 65080, Van, Turkey

Abstract: The present study was to determine the most suitable nonlinear growth model explaining growth at early stage of lambs of Morkaraman and Kıvırcık breeds from birth to 180th days of age. For this aim, Monomolecular, Gompertz, Logistic with 3 parameter, Richards, logistic with 4 parameter growth models were used for explaining the body weight-time relationship on 4 breed-sex groups; namely, Morkaraman-Male, Morkaraman-Female, Kıvırcık-Male and Kıvırcık-Female. These growth models were fitted to weight-age data on basis of averages of all groups at each period. Body weights of these lambs were recorded fortnightly from birth to 180th days of age. Criteria such as R^2 and Root Mean Square Error (RMSE) and Asymptotic Correlation Coefficients (ACC) between growth parameters in all models were used to determine the best growth model explaining growth at early stage of weight-age of these lambs. Apart from these criteria, we developed two new approaches derived from Asymptotic Correlation Coefficients (ACC), namely, Absolute Reduction Ratio (%) (ARR) and Absolute Reduction Ratio for Cut-off value (%) (ARRC). It was concluded that the most appropriate growth model explaining body weight-time relationship at early phase of four groups was found to be Gompertz growth model and new approaches gave more effective results about testing effectiveness of growth models.

Key words: Body weight, growth model, morkaraman breed, kıvırcık breed, Absolute Reduction Ratio, Absolute Reduction Ratio for Cut-off value

INTRODUCTION

Growth, which is an essential property of biological systems and an increase in body size per unit time, is described as a combination of hereditary and environmental effects (Carrijo and Duarte, 1999; Kucuk, 2004; Kucuk *et al.*, 2008). Growth is explained by non-linear models that have parameters with biological meaning such as age at point of inflection, weight at maturity and mature rate (Fitzhugh, 1976). The non-linear growth models such as Gompertz, Logistic, Brody and Richards models describe growth and development of sheep better than linear model because growth phenomenon illustrates in a sigmoid form and their growth rate is not the same in every part of lifetime. Studies on nonlinear growth models provide very useful information for breeding purposes (Akbas, 1996; Bathaei and Leroy 1998; Akbas *et al.*, 1999; Topal *et al.*, 2004; Keskin and Daşkıran, 2007; Kucuk *et al.*, 2008). Besides, early estimation of parameters of these nonlinear growth models are used as breeding criteria in improvement of growth associated characteristics that have economical importance in sheep breeding (Bilgin *et al.*, 2004). In other words, the models present useful clues on management problems, optimum slaughtering age, feeding regime regulation and especially time to reach maturity in sheep breeding (Akbas *et al.*, 1999; Kor *et al.*, 2006; Ersoy *et al.*, 2007; Keskin and Daşkıran, 2007; Kucuk *et al.*, 2008).

The aim of the present study was to estimate the most suitable nonlinear growth model explaining growth at early stage of lambs of Morkaraman and Kıvırcık breeds. For this aim, criteria such as R^2 and Root Mean Square Error (RMSE) and Asymptotic Correlation Coefficients (ACC) between growth parameters in all models, Absolute Reduction ratio (%) and Absolute Reduction ratio for Cut-off value (%) were used to determine the best growth model explaining growth at early stage of weight-age of these lambs. In order to test effectiveness of growth models, we developed two new approaches derived from Asymptotic Correlation Coefficients (ACC), namely, Absolute Reduction ratio (%) and Absolute Reduction ratio for Cut-off value (%).

Corresponding Author: Kadir Karakus, Department of Animal Science, Gevas Vocational High School, Gevas, Van, Turkey

MATERIALS AND METHODS

The body weight-age data were composed of 16 Morkaraman and 22 Kıvırcık lambs raised at Research and Application Farm of Faculty of Veterinary Medicine, Yuzuncu Yil University, Van, Turkey. All lambs were divided into 4 breed-sex groups; namely Morkaraman-Male (9), Morkaraman Female (7), Kıvırcık-Male (10) and Kıvırcık-Female (12), respectively.

Body weights of these lambs were recorded fortnightly from birth to 180th days of age. Lambing occurred in March each year. The lambs were nursed by their dams until approximately 2.5 months of age. They were kept under semi-intensive condition and concentrate feed amounts for the lambs were calculated as 1-2% of whole body weight, as described by Bilgin and Esenbuga (2003). They were grazed in daylight and in the open-shed barn during night.

The notation of linear and nonlinear growth models used to explain the body weight-age relationship of the Morkaraman and Kıvırcık lambs are given as follows:

Monomolecular:

$$W(t) = A^* (1 - B^* \exp(-k^* t))^1$$

Logistic with 3 parameters:

$$W(t) = A^* (1 + B^* \exp(-k^* t))^{-1}$$

Gompertz:

$$W(t) = A^* \exp(-B^* \exp(-k^* t))$$

Logistic with 4 parameters:

$$W(t) = A + (A-M)(1 + B^* \exp(-kt))$$

Richards:

$$W(t) = A^* (1 - B^* \exp(-kt))^M$$

Where,

Wt : Observed weight at t age.
A : Asymptotic limit of weight when age approaches infinity.
B : The rate of body weight gained after birth to mature body weight or point of inflection;
k : Maturing rate.
M : The shape parameter relating inflection point in Richards's growth function, which become where the predictable growth rate changes from an increasing to a decreasing function.
t : Age (Bilgin *et al*., 2004).

Determination Coefficient R^2 (%), Root of Mean Square Error (RMSE) and absolute correlation coefficients (ACC) between growth parameters in each non-linear model were used to select the most effective growth model. It is well-known that the most suitable model is the model having the highest the R-Square and ACC, but the lowest RMSE (Tedeschi, 2006; Kor *et al*., 2006; Keskin and Daşkıran, 2007). When ACC values become equal to 0.95, there will be no suspicions about the precision of the parameters in each model (Kor *et al*., 2006; Kucuk *et al*., 2008). Individual parameter estimates of the growth curves models were performed using Levenberg-Marquardt nonlinear least-squares algorithm in NCSS statistical package program (Anonymous, 2001). In addition to these criteria, we developed two new approaches on evaluating all of absolute correlation coefficients (ACC) between growth parameters; namely, Absolute Reduction ratio (%) and Absolute Reduction Ratio for Cut-off value (%).

The best growth model is:

- The highest determination coefficient R^2 (%).
- The lowest RMSE.
- The highest absolute asymptotic correlation coefficients (ACC) between growth parameters.
- Model having the least positive ARR (%) and ARRC (%) values.

The first approach: Absolute Reduction Ratio (%): In this study, it was developed a new approach on ACC between growth parameters in each non-linear model. This approach based on absolute reduction ratio (%). The ratio was performed using maximum ACC with minimum ACC for each model.

$$\text{Absolute reduction ratio (\%)} = \left| \frac{(\text{Min} - \text{Max})}{\text{max}} \times 100 \right|$$

It is expected that Absolute Reduction ratio will become equal to a positive value. The best model is a model whose the absolute reduction ratio has the least positive value.

For example, absolute asymptotic correlations in Logistic Growth model with 3 parameters fitted to body weight-time data of Morkaraman-Male lambs were found as 0.275676; 0.835312 and 0.705094. Corresponding values in Gompertz Growth model fitted to body weight-time data of Morkaraman-Male lambs were found as 0.940246; 0.952636 and 0.863500, respectively.

For Logistic Growth model with 3 parameters:

$$\text{Absolute reduction ratio (\%)} = \left| \frac{(\text{Min - Max})}{\text{max}} \times 100 \right|$$

$$= \left[\frac{0.275676 - 0.853512}{0.835312} \times 100 \right] = 67$$

For gompertz model:

$$\text{Absolute reduction ratio (\%)} = \left| \frac{(\text{Min - Max})}{\text{max}} \times 100 \right|$$

$$= \left[\frac{0.8635 - 0.952636}{0.952636} \times 100 \right] = 9.4$$

With respect to absolute reduction ratio of Gompertz model (9.4) was found to be much less than that of other model (67). That is, Gompertz model had more advantageous than other model.

The second approach: Absolute Reduction ratio for Cut-off value (%)

Every time, Max value in second approach was accepted as 0.95, which called cut-off value. The second approach is used all asymptotic correlation values for each model. The best model is a model whose the absolute reduction ratio for cut-off value has the least positive value.

Let'us obtain C_1, C_2 and C_3 asymptotic correlation coefficients for a model. Absolute Reduction ratio for Cut-off value (%) can be written as follows:

$$\left| \left(\sum_{i=1}^{n} \frac{(C_i - 0.95)}{0.95} \right) 100 \right| = \left| \frac{(C_1 - 0.95)}{0.95} 100 + \frac{(C_2 - 0.95)}{0.95} 100 + \frac{(C_3 - 0.95)}{0.95} 100 \right|$$

where, i is the number of correlation coefficients.

For example, Let'us obtain 0.275676, 0.835312 and 0.705094 in Logistic growth model:

$$= \left| \frac{(0.275676 - 0.95)}{0.95} 100 + \frac{(0.835312 - 0.95)}{0.95} 100 + \frac{(0.705094 - 0.95)}{0.95} 100 \right| = 109$$

and

Let'us obtain 0.940246, 0.952636 and 0.863500 in Gompertz growth model:

$$= \left| \frac{(0.940246 - 0.95)}{0.95} 100 + \frac{(0.8635 - 0.95)}{0.95} 100 + \frac{(0.952636 - 0.95)}{0.95} 100 \right| = 9.8$$

With regards to Absolute Reduction ratio for Cut-off values, Gompertz model was found to be much better than Logistic growth model (109 > 9.8).

RESULTS AND DISCUSSION

Table 1 presents parameter estimates, R^2 (%) and RMSE values, Absolute Reduction Ratio (%) (ARR) and Absolute Reduction Ratio for Cut-off value (%) (ARRC) of the nonlinear growth models used in explaining the weight-age relationship of 4 breed-sex groups.

As seen from Table 1, when all determination coefficients R^2 (%) for 4 groups are taken into consideration, all models fit weight-age data on growth at early of all groups well.

In Morkaraman male lambs, R^2 (%) values ranged from 99.74-99.99%, RMSE values ranged from 0.18-0.81, ARR values (%) ranged from 9.357-66.997 and ARRC values (%) ranged from 9.8-10.90. In Morkaraman female lambs, R^2 (%) values ranged from 99.74-99.90%, RMSE values ranged from 0.57-1.03, ARR values (%) ranged from 2.795-92.622 and ARRC values (%) ranged from 8.63-149.4. In Kıvırcık male lambs, R^2 (%) values ranged from 99.68-99.93%, RMSE values ranged from 0.49-0.99, ARR values (%) ranged from 8.523-66.969, ARRC values (%) ranged from 7.26-108.45. In Kıvırcık female lambs, R^2 (%) values ranged from 99.67-99.96%, RMSE values ranged from 0.33-0.86, ARR values (%) ranged from 6.855-72.235, ARRC values (%) ranged from 2.19-115.79.

Table 2 presents asymptotic correlation coefficients between parameters of nonlinear growth models for all breed-gender groups. Although, R^2 (%) and RMSE values of Gompertz and Logistic model with 4 parameters gave similar results in all groups (Table 1and 2), ACC, ARR (%) and ARRC (%) of Gompertz growth model was found to be more advantageous than those of Logistic model with 4 parameters. When all criteria are taken into consideration, Gompertz growth model fit weight-age data on growth at early of all groups well.

Determination coefficient of Gompertz growth model in the present study was found to be higher than previous studies (Akbas *et al*., 1999; Bilgin and Esenbuga, 2003; Topal *et al*., 2004; Tekel *et al*., 2005).

The differences of results of studies on growth models fitted to weight-age data of various breeds

Table 1: Parameter Estimates, R^2 (%), RMSE, ARR (%) and ARRC(%) values of nonlinear growth models for all breed-gender groups

Non-linear growth model	A	B	k	M	R^2 (%)	RMSE	ARR (%)	ARRC (%)
Morkaraman-Male								
Logistic with 3 parameters	49.5	7.146	0.0250		99.74	0.81	66.997	10.88
Gompertz	56.6	0.014	63.7900		99.97	0.28	9.357	9.80
Monomolecular	121.0	0.003	-10.7000		99.78	0.74	26.238	36.30
Richards	60.1	0.774	0.0120	58.2	99.98	0.24	29.969	43.90
Logistic with 4 parameters	55.5	2.909	0.0160	-13.2	99.99	0.18	14.962	10.90
Morkaraman-female								
Logistic with 3 parameters	61.1	8.803	2.0980		99.74	0.88	92.622	149.40
Gompertz	80.9	0.0099	100.8000		99.87	0.63	2.795	8.63
Monomolecular	1924.0	0.0001	-10.8000		99.64	1.03	22.808	32.00
Richards	98.9	0.7147	0.0070	103.2	99.88	0.64	48.223	90.10
Logistic with 4 parameters	-11.1	0.2262	-0.0100	74.8	99.90	0.57	15.460	10.03
Kıvırcık-male								
Logistic with 3 parameters	55.5	7.407	0.0250		99.73	0.91	66.969	108.45
Gompertz	64.1	0.014	66.5300		99.92	0.49	8.523	7.26
Monomolecular	158.0	0.002	-10.9800		99.68	0.99	25.400	34.97
Richards	65.9	0.895	0.0125	64.3	99.92	0.51	35.430	57.08
Logistic with 4 parameters	61.5	3.387	0.0170	-11.8	99.93	0.50	15.880	14.28
Kıvırcık-female								
Logistic with 3 parameters	48.7	7.356	0.0240		99.67	0.86	72.235	115.79
Gompertz	57.4	0.013	71.3000		99.93	0.39	6.855	2.19
Monomolecular	187.0	0.002	-12.7000		99.81	0.66	23.342	31.45
Richards	64.3	0.690	0.0094	64.40	99.96	0.33	38.112	64.18
Logistic with 4 parameters	-14.4	0.350	-0.0150	57.34	99.94	0.38	13.309	4.73

Table 2: Asymptotic correlation coefficients between parameters of nonlinear growth models for all breed-gender groups

Non-linear growth model	r_{AB}	r_{Ak}	r_{Bk}	r_{AM}	r_{BM}	r_{kM}
Morkaraman-male						
Logistic with 3 parameters	-0.275676	-0.835312	0.705094			
Gompertz	-0.940246	0.952636	-0.863500			
Monomolecular	-0.997813	-0.736002	0.771960			
Richards	-0.909851	-0.977614	0.972327	-0.684630	0.921870	0.815997
Logistic with 4 parameters	-0.846380	-0.958759	0.958186	-0.872069	0.995300	0.965646
Morkaraman-female						
Logistic with 3 parameters	-0.065856	-0.892618	0.471827			
Gompertz	-0.971488	0.994141	-0.966353			
Monomolecular	-0.999993	-0.771911	0.774029			
Richards	-0.954801	-0.991635	0.984181	0.744627	-0.513439	-0.654988
Logistic with 4 parameters	-0.983459	-0.973502	0.930078	-0.910323	0.831416	0.975962
Kıvırcık-male						
Logistic with 3 parameters	-0.277135	-0.839023	0.703540			
Gompertz	-0.943513	0.959647	-0.877852			
Monomolecular	-0.998534	-0.74487	0.774348			
Richards	-0.909255	-0.975566	0.973808	-0.629918	0.892014	0.777210
Logistic with 4 parameters	-0.836428	-0.954931	0.956344	-0.860714	0.994293	0.961643
Kıvırcık-female						
Logistic with 3 parameters	-0.237405	-0.855055	0.657574			
Gompertz	-0.951211	0.972301	-0.905646			
Monomolecular	-0.999329	-0.766069	0.785787			
Richards	-0.927855	-0.984510	0.976142	-0.609291	0.858653	0.733844
Logistic with 4 parameters	-0.994326	-0.972372	0.955226	-0.900358	0.861989	0.970794

are arisen from genotypic and environmental factors (Akbas*et al.*, 1999; Bilgin and Esenbuga, 2003; Bilgin *et al*., 2004; Topal *et al.*, 2004; Kor *et al.*, 2006; Tekel *et al.*, 2005; Keskin and Daşkıran, 2007; Kucuk *et al.*, 2008).

When Fig. 1-4 on Gompertz growth model were examined, all observation values for body weight were placed in prediction limits; therefore, there was no outlier.

By using these Gompertz growth curves, any deviation from the curve or fit to curve gave an idea about whether there might be any problem on the flock management.

As a result, Gompertz nonlinear growth model might help in the determination of management problems, regulation of feeding regimes and especially, determination of optimum slaughtering age due to economic efficiency on body weight at maturity.

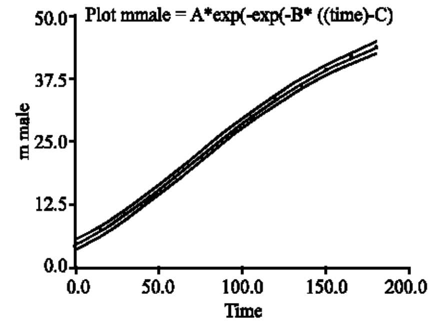

Fig. 1: Gompertz growth model for morkaraman male lambs

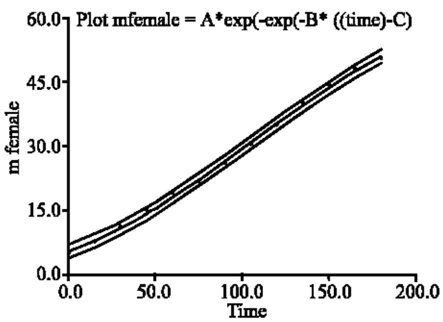

Fig. 2: Gompertz growth model for morkaraman female lambs

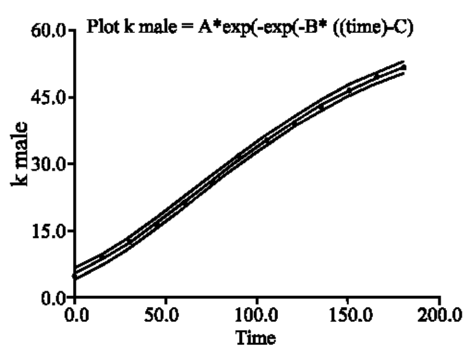

Fig. 3: Gompertz growth model for kıvırcık male lambs

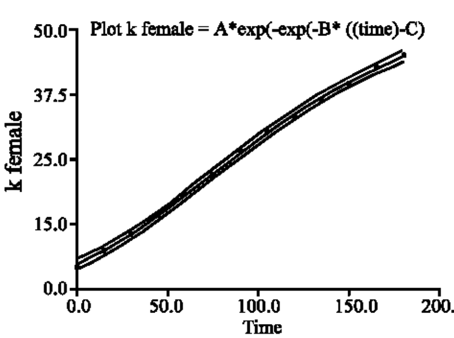

Fig. 4: Gompertz growth model for kıvırcık female lambs

CONCLUSION

Growth models provide valuable information on maturity and growth rate during growth periods and are likely to be useful for selection purposes with regard to realizing effective body weight production in lamb industry. With respect to determination of optimum slaughtering age, regulation of feeding regimes and determination of management problems, Gompertz nonlinear growth model was found to be more effective than other models. Expect for routine criteria, it was concluded that new approaches such as Absolute Reduction ratio (%) and Absolute Reduction Ratio for Cut-off value (%) suggested by the present study gave more effective results about testing effectiveness of growth models.

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