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The Determination of Growth Curve Models in Malya Sheep from Weaning to Two Years of Age

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ABSTRACT

This research was carried out to determine the growth curve models for Malya ewes. Twenty sheep were fed *ad-libitum* with roughages from weaning to approximately 48 month of age. Each sheep was provided with 200 g concentrate feed (16% CP; 2500 kcal kg^{-1} metabolic energy) until the end of mating period and then 250 g from the end of mating period to the middle of gestation period. Towards the last month of pregnancy, the daily amount of concentrate feed was gradually increased to 500 g. Twenty sheep were weighed at 28 days intervals in 45 different control periods between weaning age through 2 years of age. The growth curve parameters, coefficients of determination (R^2), mean square predicted errors (MSPE) and correlations between live weights and residuals (RESC) were determined for Linear, Quadratic, Cubic, Gompertz and Logistic models by using live weight data of Malya sheep. The highest R^2 values, the lowest MSPE and RESC values, similarity between actual and estimated live weight values were used to evaluate the fitness of the growth curve models. R^2 values of Linear, Quadratic, Cubic, Gompertz and Logistic model were determined as 83.13%, 91.04%, 92.04%, 91.55% and 91.22%, respectively, while MSPE values were 65.900, 34.657, 30.894, 32.956 and 34.101, respectively. Also, RESC values were found as 0.469, 0.287, 0.279, 0.299 and 0.333, respectively. These findings revealed that the best fit to the growth curves of Malya ewes was acquired with Cubic Model. However, all models can be accepted satisfactory to determine the growth in this period except for linear model. These results can be useful for farmers in defining proper breeding and feeding strategies.

Keywords: Malya sheep; Body weight; Growth curve; Linear model; Non-linear model

Malya Koyunlarında Sütten Kesim ile Ergin Yaş Arası Dönemde Büyüme Eğrisi Modellerinin Belirlenmesi

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ÖZET

Bu araştırma, Malya koyunlarının büyüme eğrilerini belirlemek amacıyla yapılmıştır. Yirmi baş Malya koyununa sütten kesimden yaklaşık 48 aylık yaşa kadar kaba yem serbest olarak verilmiştir. Koyunlara aşım sezonunun sonuna kadar 200 g gün^{-1}, aşım sezonu bitiminden gebeliğin ortalarına kadar 250 g gün^{-1} konsantre yem (%16 HP ve 2500 kcal kg^{-1} metabolik enerji) verilmiştir. Gebelik döneminin ortasından sonuna doğru ise yem kademeli artırılarak 500 g gün^{-1}'e çıkarılmıştır. Bu büyüme periyodu içerisinde sütten kesimden 2 yaşına kadar koyunlar 28 gün ara ile 45 kez tartılarak canlı ağırlıkları belirlenmiştir. Bu canlı ağırlık verileri kullanılarak Doğrusal, Kuadratik, Kübik, Gompertz ve Logistik modellerin büyüme eğrisi parametreleri, belirleme katsayıları (R^2), hata kareler ortalamaları (HKO), artık değerler ile gerçek veriler arasındaki korelasyonlar (AGAK) ve gerçekleşen ve tahmin edilen canlı ağırlıklar arasındaki benzerlikler saptanmıştır. Doğrusal, Kuadratik, Kübik, Gompertz ve Logistik modellerde belirleme katsayısı (R^2) sırasıyla %83.13, %91.04, %92.04, %91.55 ve %91.22, HKO ise sırasıyla 65.900, 34.657, 30.894, 32.956 ve 34.101 olarak saptanmıştır. AGAK değerleri ise 0.469, 0.287, 0.279, 0.299 ve 0.333 olarak bulunmuştur. Bu değerler dikkate alındığında en iyi uyumun Kübik modelden elde edildiği ortaya çıkmıştır. Bununla beraber doğrusal model dışındaki diğer tüm modellerin bu periyottaki büyümeyi yeterince tanımlayabildikleri kabul edilebilir. Bu sonuçlar yetiştiricilere uygun yetiştirme ve beslenme stratejilerini tanımlamak için önem arz etmektedir.

Anahtar Kelimeler: Malya koyunu; Vücut ağırlığı; Büyüme eğrisi; Doğrusal model; Doğrusal olmayan model

1. Introduction

There have been various sheep breeds and types adapted to the different geographical and climatic conditions in Turkey. Most of them are fat-tailed sheep breeds. Malya sheep is one of the semi-fat tailed crossbred (5/8 Akkaraman sheep + 3/8 German wool-meat merino sheep).

The growth characteristics are the result of interactions between environmental conditions and the genetic structure of individuals (Kor et al 2006). Although, each subspecies and sheep breeds have their own unique growth curve, there are also important differences between the individuals within the same breed (Özen 1997).

The development and growth of an animal can be measured by weighing both whole body and certain parts of the body (Efe 1990). Since the growth of farm animals is fundamental of all aspects of production, many studies were conducted to determine the growth curves of farm animals by several authors. These studies focused especially on sheep and goat (Kocabaş et al 1997; Akbaş et al 1999; Esenbuga et al 2000; Topal et al 2004; Kor et al 2006; Keskin & Dağ 2006; Karakuş et al 2008; Aytekin et al 2009; Keskin et al 2009; Özdemir & Dellal 2009; Aytekin et al 2010; Daskiran et al 2010), on poultry (Soysal et al 1999; Yakupoglu & Atil 2001; Çamdeviren & Taşdelen 2002; Şengül & Kiraz 2005; Çetin et al 2007; Norris et al 2007; Koncagül & Cadirci 2009, 2010; Narinç et al 2010) and on cattle (Brown et al 1976; Lopez de Torre et al 1992; Bayram et al 2004; Colak et al 2006).

The growth curve is the curvilinear manifestation of the visible changes occurring in body weight and body measurements from the birth to maturation. The changes in body weight and size occurring in a particular period were usually explained with growth curve models (Yıldız et al 2009).

Linear and non-linear growth models are widely used to determine the growth curves of farm animals. The models used to determine the relationship between growth and age in farm animals were categorized in two main groups as monomolecular and asymptotic functions. Asymptotic functions include non-linear models, which explain the relationship between age and growth throughout the life of an organism. Monomolecular functions are models representing S-shaped growth curve in the relationship between age and growth curves (Efe 1990). As growth in farm animals is not linear, the non-linear models would be more appropriate than linear models for the estimation of growth curves. However, due to the small number of data, the use of linear models to estimate the growth curve is also becoming mandatory.

The aim of the present study was to compare commonly used growth curve models and to determine the best model describing the growth curve of Malya sheep.

2. Material and Methods

The experiment was conducted at Selcuk University, Agricultural Faculty Farm (Konya, Turkey) located at 37° 17¢ N latitude and 32° 31¢ E longitude and 1016 m above sea level. Winters are cold and snowy, and summers are hot and arid in Konya. Twenty female Malya lambs born in Agricultural Faculty Farm were used. The lambs were penned in well-ventilated enclosures and fed as a group throughout 1260 days. The lambs were weaned at 2.5 months of age. At weaning, the lambs were individually weighed with 0.1 kg accuracy and then their live weights were recorded at 28 days intervals in 45 different control periods. The feed contained 2500 kcal kg^{-1} metabolic energy and crude protein content of feed ranged between 12% and 16% at different growth periods. The roughage was given *ad-libitum* to the all animals throughout the whole periods. Each sheep was provided with 200 g day^{-1} concentrate feed containing 16% CP and 2500 kcal kg^{-1} metabolic energy until the end of mating period and then the daily amount of concentrate feed was increased to 250 g until the middle of gestation period. Towards the last month of pregnancy, the amount of concentrate feed was gradually increased to 500 g. In addition, ewes consumed dry alfalfa hay and beet pulp *ad-libitum*. Free access to water was available throughout the day.

The following equations of Linear, second and third degree models (Quadratic and Cubic) and non-linear models (Gompertz and Logistic) were used to estimate the growth curves in Malya sheep by using Statistica (1995) package program.

Linear model : $Y_t = a + b \times t$ (1)

Quadratic model : $Y_t = a + b \times t + c \times T^2$ (2)

Cubic model : $Y_t = (a + (b \times t) + (c \times T^2) + (d \times t^3))$ (3)

Gompertz model : $Y_t = a \times Exp(-b \times Exp(-c \times t))$ (4)

Logistic model : $Y_t = a/(1 + b \times Exp\ (-c \times t))$ (5)

Where Y is the live weight at control time *t;* *a* is the initial live weight for Linear; Quadratic and Cubic models and asymptotic live weight for Gompertz and Logistic models; b, c and d are the model parameters which characterize the shape of the curve. The growth curve parameters of models (*a*, *b*, c, and *d*), coefficients of determination (R^2), Mean Square Predicted Errors (MSPE) and correlations between observed live weights and residuals (RESC) were determined. The models representing higher R^2, lower MSPE and RESC values were selected as the best fitting models.

3. Results and Discussion

Growth curve parameters and standard errors estimated by the models for live weight of Malya sheep were presented in Table 1. The highest value for parameter "*a* was obtained from the simple linear model (34.05) in respect of initial body weight. The highest value for the parameter *a* was obtained from the Gompertz model (71.17), which is one of the non-linear models based on adult live weight. The highest parameter *b,* which is responsible for the rising phase of the curve, was obtained from the Cubic model (3.35). It was followed by the Quadratic (2.64) and Logistic (2.28) models, respectively.

Due to nature of simple linear model, parameter *c* cannot be predicted. The parameter *c*, highlighting the pattern of decline in growth rate at time *t*, represented the highest value for the logistic model (0.14). It was followed by the Gompertz model (0.11). In addition, the lowest parameter *c* was obtained from Cubic model (-0.08). The parameter *d*, which is the only characteristic for the Cubic model, had negative value near to zero (- 0.00058).

Akbas et al (1999) determined parameter *a* and *b* and R^2 as 6.90, 0.129 and 93.4% for Daglıc male lambs and 9.51, 0.145 and 97.3% for Kivircik male lambs by simple linear model. The estimated *a*, *b*, *c* and R^2 values for Gompertz model were 113.16, 2.87, 0.0047 and 99.63% for Daglıc male lambs, and 88.18, 2.35, 0.0054 and 99.28% for Kivircik male lambs, repectively (Akbas et al 1999). The same values for Logistic model were reported as 79.93, 6.81, 0.008 and 99.37% for Daglıc male lambs, and 76.33, 6.25, 0.0093 and 98.67% for Kivircik male lambs, respectively. Parameter *a* and *b* values determined in our study were higher than the values of Akbas et al (1999) for linear model. The R^2 value in our study was lower than the R^2 value of Akbas et al (1999) for linear model. In our study, *a*, *b*, *c* and R^2 values for Gompertz and Logistic models were lower than the values determined by Akbas et al (1999) except for the value of parameter *c* (0.14) for Logistic model.

Aytekin et al (2010) determined the R^2 values of Linear, Quadratic, Cubic and Gompertz model for Malya lambs weaned at 2 different live weights as 93.143, 98.652, 98.932 and 98.597 and 91.406, 98.530, 98.903 and 98.317, respectively. In our study, the R^2 values of Linear, Quadratic, Cubic and Gompertz model were lower than the R^2 values determined by Aytekin et al (2010), whereas MSPE and RESC values in our study were higher than MSPE and RESC values determined by Aytekin et al (2010). However, parameter *a* values for all models in the study of Aytekin et al (2010) were lower than our parameter *a* values, while parameters *b*, *c* and *d* values were higher than our parameters *b*, *c* and *d* values.

Table 1- The model parameter values and standard errors estimated by several models in respect of live weight of Malya sheep

Çizelge 1- Malya koyunlarında canlı ağırlık bakımından çeşitli modeller ile tahmin edilen model parametre değerleri ve standart hataları

Models	*Model parameters*			
	$a \pm S_{\bar{a}}$	$b \pm S_{\bar{b}}$	$c \pm S_{\bar{c}}$	$d \pm S_{\bar{d}}$
Linear	34.05 ± 1.203	0.99 ± 0.049		
Quadratic	21.40 ± 1.267	2.64 ± 0.144	- 0.04 ± 0.003	
Cubic	18.58 ± 0.828	3.35 ± 0.249	-0.08 ± 0.015	- 0.00058 ± 0.00024
Gompertz	71.17 ± 2.481	1.31 ± 0.078	0.11 ± 0.009	
Logistic	70.15 ± 2.225	2.28 ± 0.220	0.14 ± 0.010	

The coefficients of determination (R^2), Mean Square Predicted Errors (MSPE) and correlations between observed live weights and residuals (RESC) for Linear, Quadratic, Cubic, Gompertz and Logistic models were presented in Table 2. R^2, MSPE and RESC are crucial values in the determination of the best fitting model or models. In our study R^2 values for Linear, Quadratic, Cubic, Gompertz and Logistic models were found as 83.13, 91.04, 92.04, 91.55 and 91.22, respectively. MSPE and RESC values were determined as 65.900, 34.657, 30.894, 32.956 and 34.101, and 0.469, 0.287, 0.279, 0.299 and 0.333, respectively. The highest R^2 value was obtained from Cubic model (92.04). All R^2 values were similar except for R^2 value obtained from Linear model. The highest MSPE value (65.900) was obtained from Linear model and the lowest from Cubic model (30.894). All models had similar MSPE values except for Linear model. MSPE and RESC values had the same trend for all models.

Table 2- The determination coefficients (R^2), mean square predicted error (MSPE), correlation between observed live weight and residuals (RESC) and standard errors of models in Malya sheep

Çizelge 2- Malya koyunlarında modellere ait belirleme katsayıları (R^2), hata kareler ortalamaları (HKO), artık değerler ile gerçek veriler arasındaki korelasyonları (AGAK) ve standart hataları

Models	*R^2*	*MSPE*	*RESC*
Linear	83.13 ± 0.015	65.900 ± 6.170	0.469
Quadratic	91.04 ± 0.010	34.657 ± 3.056	0.287
Cubic	92.04 ± 0.009	30.894 ± 2.425	0.279
Gompertz	91.55 ± 0.016	32.956 ± 3.295	0.299
Logistic	91.22 ± 0.017	34.101 ± 3.425	0.333

Actual and estimated live weight values of Malya sheep based on the models from weaning to mature age were given in Table 3. The cubic model represented the best prediction for the actual weaning weight (16.23 kg vs. 21.852 kg). On the other hand, best fit for the last control period (44th) with respect to the actual weight (64.45 kg) was obtained from the Quadratic and Cubic models (66.517 kg and 68.666 kg). Average actual weight gain during the study was 48.22 kg. The best prediction of average actual weight gain was obtained from Cubic model (46.810 kg). Also, adequate predictions in respect of the mature live weight (approximately at the 37th month and nearly 70 kg live weight) were acquired by all models.

R^2 values of the Linear model explaining the growth curve of Akkaraman, Awassi x Akkaraman and Malya x Akkaraman lambs during the fattening period were determined as 0.990, 0.993 and 0.989, respectively by Kocabas et al (1997). These R^2 values were higher than our values for all models. Sireli & Ertugrul (2004) determined R^2 and MSPE values for Dorset Down x Akkaraman (BD_1), Akkaraman and Akkaraman x BD_1 lambs as 0.99, 0.99 and 0.99; 0.457, 1.397 and 1.054, respectively by using Logistic model. In our study, the R^2 value (91.22%) for Logistic model was lower while MSPE value (34.101) was higher than the values of above mentioned study.

Table 3- Actual and estimated live weight of Malya lambs based on models from weaning to mature age (kg)

Çizelge 3- Malya koyunlarının sütten kesimden ergin yaşa kadar gerçekleşen ve modeller ile tahmin edilen canlı ağırlık değerleri (kg)

Control period	*Actual*	*Estimated live weights*				
		Linear	*Quadratic*	*Cubic*	*Gompertz*	*Logistic*
1	16.23	35.042	24.001	21.852	23.796	24.232
4	33.15	38.008	31.369	30.808	31.997	31.201
7	42.05	40.974	38.076	38.524	39.681	38.429
10	46.20	43.940	44.124	45.094	46.318	45.247
13	52.53	46.907	49.511	50.612	51.760	51.169
15	57.73	48.884	52.735	53.753	54.757	54.511
16	55.50	49.873	54.238	55.172	56.082	55.997
19	54.55	52.839	58.304	58.869	59.450	59.761
22	61.75	55.805	61.711	61.795	62.044	62.608
24	68.35	57.783	63.615	63.364	63.425	64.086
25	67.05	58.772	64.457	64.045	64.028	64.718
28	61.60	61.738	66.543	65.713	65.543	66.257
31	60.50	64.704	67.969	66.894	66.696	67.370
34	67.75	67.670	68.734	67.681	67.575	68.168
37	79.20	70.637	68.839	68.168	68.246	68.738
40	68.75	73.603	68.284	68.449	68.757	69.144
43	64.40	76.569	67.069	68.618	69.149	69.433
44	64.45	77.558	66.517	68.666	69.258	69.509
Average live weight gain	48.22	42.516	42.516	46.810	45.462	45.277

R^2 and MSPE values of growth curve of Anatolian Merino lambs during the fattening period were determined as 0.990 and 0.80, respectively by Linear model, 0.990 and 0.79, respectively by Quadratic model (Keskin & Dağ 2006). R^2 values of Linear and Quadratic models (83.13% and 91.04%) were lower, whereas MSPE values (65.9 and 34.657) were higher than our values. Aytekin et al (2009) reported that the highest R^2 values were obtained from Linear, Quadratic, Cubic models used to identify the growth curve of Akkaraman and Anatolian Merino lambs during the fattening period. The findings of Aytekin et al (2009) were higher than our findings. However, MSPE and RESC values determined by Aytekin et al (2009) were lower than those of our study.

The models representing higher R^2 and lower MSPE and RESC values should be recommended as a best-fitting model to describe the growth curve. Our R^2, MSPE and RESC values demonstrated that the Cubic model was the best fitting model, and it was followed by the Gompertz, Quadratic and Logistic models, respectively.

The actual and estimated live weight values of Malya sheep during growth period considering the models are presented in Figure 1. As seen in Figure 1, the estimated growth curves of different models for Malya sheep were similar except for the growth curve of linear model. The actual live weights of Malya sheep declined at 15th, 24th and 37th control periods (Fig. 1). This can be explained by parturition events of sheep at these periods. Sheep gave first birth at the age of 17-18 months, second birth at the age of 26-27 months and third birth at the age of 39-40 months. Glucose requirement of fetus increases, while appetite and feed intake of ewe decline towards the end of pregnancy. As a result, ewes cannot consume enough organic matter, especially glucose. Energy and glucose requirement of fetus may not be fulfilled. In this case, sheep have to use the body storage materials (glycogen and fat tissue). The ewes carrying particularly twins or triplets need more body storage agents in order to supply energy requirements of twins or triplets. In this case, ewes become weakened at birth and lose body weight until reaching maximum daily milk yield (Sezenler et al 2008).

Up to date, many studies were carried on post-natal growth of farm animals with different models and a number of suggestions were made on this subject. In recent years, studies have focused on pre-natal growth. The studies on this subject are of great importance in order to increase future yields of farm animals in Turkey.

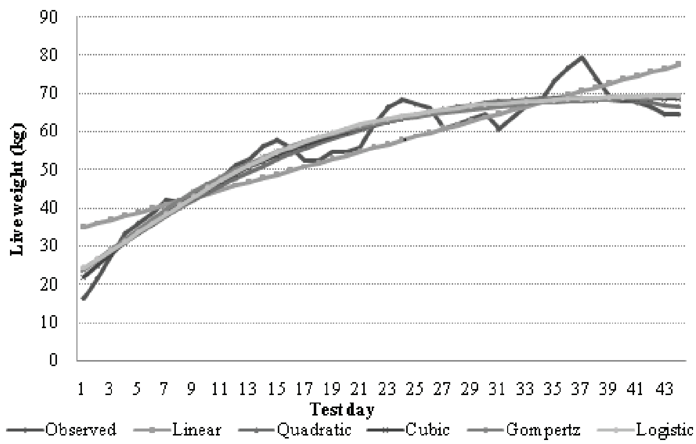

Figure 1- The observed and estimated growth curves by several models in Malya sheep

Şekil 1- Malya koyunlarının gerçekleşen ve çeşitli modeller ile tahmin edilen büyüme eğrileri

4. Conclusions

In the present study, higher R^2 value, lower MSPE and RESC values and similarity of actual and estimated live weight values were preferred in order to determine the best-fit model for Malya sheep. Our values revealed that the best fit to the growth curves of Malya ewes was acquired with cubic model. However, all the models except for the linear model described adequately the growth of Malya sheep in this period. These results are of great importance to determine appropriate rearing and nutrition strategies for growers.

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