Pakistan J. Zool., vol. 49(2), pp 543-547, 2017. DOI: http://dx.doi.org/10.17582/journal.pjz/2017.49.2.543.547

Determination of Appropriate Growth Models for Early Selection Possibilities in Goats

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Article Information
Received 25 Septmeber 2016
Revised 16 October 2016
Accepted 18 November 2016
Available online 10 February 2017

Authors' Contributions
BC and OY conceived and designed the study and BC and MMT wrote the article, SK analyzed the data. TB helped in acquisition of data.

Key words
Colored mohair goats, Growth models, Kids, Birth type.

ABSTRACT

Growth models present a visual assessment of growth as a function of time and predict body weight at a specific age. We investigated the growth characteristics of Colored Mohair goat using four nonlinear growth models. Thirty (n=22 males and n=8 females) Colored Mohair kids were used. The kids were weighed at 2-week intervals from birth to 150 days. The Monomolecular, Gompertz, Richards and Three Parameter Logistic models were used. The best model was determined by considering the root mean square error, R^2% and asymptotic correlation coefficient criteria. We concluded that the Gompertz and Richards models were favourable for singletons and that the Richards model was favorable for determining twin Colored Mohair goat growth characteristics. Birth type should be considered in subsequent genetic evaluations. Furthermore, producing heavier carcasses (13-17 kg) in < 150 days may increase productivity and efficiency of the goat farming system.

INTRODUCTION

The goat is well-known in developing countries because of its higher tolerance to under nourishment compared to that of other animals. Thus, goat farming is an important branch of livestock production on low quality range land (Gul *et al*., 2016).

Growth is a trait of interest in domestic animals. The primary definition of growth is given by the increase in size, number, or mass with time. However, this does not include the phenomenology and etiology of growth. Growth should be evaluated by growth rate or by weight and size increases during different stages of life, because it is a continuous function during an animal's life, from the first embryonic stages up to adult age (mature weight) (Arango and Van Vleck, 2002). Analyzing growth curves - that is, the acquisition of data for the same animal or plant over a certain period - is a basic task in biological research (Spilke *et al*., 2009). Growth models are designed explore longitudinal data of individuals over time, and numerous mathematical models have been used to model growth of biological systems. France *et al*. (1996) reported that growth functions have been used in animal science since the early years of this century. A useful monograph on the theory of feeding and growth in animals is that by Parks (1982).

Researchers defining growth by different growth models on various breeds reported that the interpretation of growth varied according to breed and model (Jenkins and Leymaster, 1993; Kocabas *et al*., 1997; Akbas *et al*., 1999). In the world, researches used growth curves in sheep and goats to estimate adult body weight and increase in live weight (Jenkins and Leymaster, 1993; Salah *et al*., 1988; Nasholm and Danell, 1990).

The white Angora goat is normally associated with mohair production. However, in addition to the White Angora goat, there are Colored mohair goats in the east and southeast regions of Anatolia in Turkey. These goats have been raised, especially in Siirt, Batman, and Şırnak provinces for a long time. The animals have black, white, brown, grey, yellow, red, and light brown mohair color (Yalçın, 1986). Therefore, these animals are preferred to product colored mohair for industry.

However, there was no study about determining of growth curve for Colored mohair goat. The main objective

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0030-9923/2017/0002-0543 $ 9.00/0

of this study was to determine favorable growth model or models and to estimate growth parameters of Colored mohair goat by using four nonlinear growth models.

MATERIALS AND METHODS

This study was carried out at Research and Experimental Farm of the Yuzuncu Yil University in Van province, Turkey. Van is located between 37˚ 43′ to 39˚ 26′ North latitudes and 42˚ 40′ to 44˚ 30′ East longitudes. Data were obtained from totally Thirty (22 males and 8 females) Colored mohair goats.

The kids were fed colostrum immediately after birth and were numbered for registration. The kids were kept with their mothers for the first week and were then separated into lots. The goats were grazed on pasture during the day when weather conditions permitted and the kids were kept together with their does overnight. The kids were offered a feed concentrate and forage beginning in the second and were weaned at 105 days. The BWs of the kids were measured at 2-week intervals from birth to 150-days.

Growth curves for body weight of kids were determined by Monomolecular, Gompertz, Richards, and Three Parameter Logistic models. The mentioned models were described as follows:

Monomoleculer model: $Y_t = a \times [1-e^{-b\,(t-k)}] + \varepsilon$

Gompertz model: $Y_t = a \times \exp[-b \times \exp(-k \times t)] + \varepsilon$

Richards model: $Y_t = a / [1+ b \times \exp(-k \times t)]^{1/m} + \varepsilon$

Three Parameter Logistic model: $Y_t = a / [1+b \times \exp(-k \times t)] + \varepsilon$

For the model equations: Y_t is body weight at time t, a is asymptote or mature body weight, b is scale parameter, k is maturity index, m is inflection parameter which determine function shape, e is the base of natural logarithm, and ε is error term.

Parameter estimation related to the above-mentioned models was performed using Levenberg-Arquardt nonlinear least squares algorithm in NCSS statistical package program (Hintze, 2007).

After the analyses were completed, the model parameters were used to predict the growth data from birth to day 150 and the correlations between the observed and predicted growth curves were calculated.

RMSE, R^2 and asymptotic correlations were evaluated to compare the effectiveness of the models and coefficients. When comparing the model, highest R^2 and lowest RMSE values were considered to better fit. In addition, asymptotic correlation coefficients should be high (absolute value higher than 0.95) (Gage and Tyler, 1985; Cellario and Fenaux, 1990; Neter *et al*., 1990; Draper and Smith, 1998; Lamare and Mladenov, 2000).

RESULTS

Mean and standard deviation BWs at 15-day intervals from birth to 150 days are presented in Table I. The growth model parameter estimates for the singleton and twin kids are presented in Table II. The RMSE, R^2 and asymptotic correlation coefficients between the parameters are given in Table III.

DISCUSSION

As shown in Table I, the birth weights of the singleton and twin kids were 2.36 and 1.93 kg, respectively. Body weight increased in both birth types; however, the values were generally higher for singletons than those for twins.

Table I.- Descriptive statistics and comparative results for the kids.

Days	Singleton (n=22)				Twin (n=8)				
	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.	p
0	2.36	0.268	1.9	2.8	1.93	0.301	1.4	2.4	0.001
15	4.08	0.662	2.0	5.0	2.96	0.555	2.0	4.0	0.001
30	5.56	1.253	2.2	7.7	3.80	0.659	3.0	4.8	0.001
45	7.44	1.318	3.6	9.5	5.20	0.932	3.7	6.8	0.001
60	9.96	1.684	5.0	12.5	6.88	1.437	4.5	9.0	0.001
75	11.33	1.607	6.9	13.9	8.16	1.463	5.5	10.6	0.001
90	13.28	1.978	9.0	17.0	10.19	1.629	7.0	13.0	0.001
105	14.01	2.039	10.0	18.0	10.79	1.757	7.0	13.0	0.001
120	14.76	2.129	10.0	19.0	11.40	1.825	7.0	14.0	0.001
135	15.85	2.115	11.3	19.5	12.42	1.665	8.7	14.6	0.001
150	17.00	2.412	12.0	21.0	13.58	1.816	10.0	15.0	0.001

Table II.- Model parameter estimates.

Growth Models	Birth Type	a	b	K	m
Monomolecular	Singleton	27.245 ± 3.714	0.00606 ± 0.00136	-12.230 ± 3.191	
	Twin	40.585 ± 2.278	0.00249 ± 0.00163	-15.308 ± 5.121	
Three- parameter logistic	Singleton	17.194 ± .437	5.311 ± 0.437	0.0313 ± 0.00020	
	Twin	14.353 ± 0.486	6.160 ± 0.488	0.0283 ± 0.00194	
Gompertz	Singleton	18.865 ± 0.593	0.0188 ± 0.00126	38.990 ± 2.189	
	Twin	16.696 ± 1.008	0.0155 ± 0.00151	52.345 ± 4.737	
Richards	Singleton	18.820 ± 1.301	1.0158 ± 0.428	0.01906 ± 0.0055	39.315 ± 9.201
	Twin	15.172 ± 1.493	1.498 ± 0.656	0.0219 ± 0.00840	59.262 ± 8.838

Table III.- Root mean square error (RMSE), determination coefficients (R^2) and asymptotic correlations for the parameters.

Growth Models	Birth Type	R^2 %	RMSE	ab	ak	bk	am	bm	km
Monomolecular	Singleton	99.38	0.441	-0,991	-0,724	0,792			
	Twin	99.07	0.436	-0,999	-0,785	0,813			
Three-parameter logistic	Singleton	99.53	0.386	-0.241	-0.800	0.702			
	Twin	99.53	0.098	-0.211	-0.845	0.643			
Gompertz	Singleton	99.70	0.307	-0.918	0.883	-0.738			
	Twin	99.53	0.313	-0.947	0.962	-0.884			
Richards	Singleton	99.70	0.328	-0.876	-0.958	0.969	-0.739	0.967	0.891
	Twin	99.57	0.319	-0.894	-0.959	0.978	-0.608	0.893	0.796

Standard deviations were generally reasonable for both birth types. Birth type differences were observed at all ages from birth to 150 days. As reported by Hussain *et al.* (2006) sex, type of birth and age affect the performance of an individual. It is, therefore, imperative to estimate the extent of all such factors so that the genetic variation among animals can be used to design breeding plans for further improvement.

As shown in Table II, the highest value for parameter was obtained using the monomolecular model followed by the Gompertz, Richards and three parameter logistic models for twins. The Monomolecular model had the highest value for singletons. All models except the monomolecular estimated slightly lower values for twins. This can be explained by the lower birth weight of the twins. The "a" parameter indicates mature weight or asymptotic weight of the animals. In other words, this parameter shows the potential final weight of the animals over time. Thus, twins could potentially reach 40.585 kg by 150 days according to the monomolecular model but only 14.353 kg based on the three-parameter logistic model. Furthermore, the highest estimate for the "b" parameter was obtained from the three- parameter logistic model, whereas the lowest value was calculated from the monomolecular model. Only small differences in the "b" parameter were observed between the singletons and twins. The "b" parameter is a scale parameter and does not have biological meaning. However, it is related to BW from birth to maturity; *i.e.* asymptotic weight and determines the shape of the growth curve.

The "k" parameter is the maturity index. A small maturity index indicates that the animal is late maturing, whereas a large value indicates early maturation. The Gompertz model estimated the highest values for this parameter. The maturity index values calculated using the three-parameter logistic and Richards model were very similar, whereas the estimates by the monomolecular model were negative.

The point of inflection "m" is where the estimated growth rate changes from an increasing to a decreasing function in the Richards model, as the rate of change is maximum at the point of inflection. The degree of maturity at the point of inflection in the Richards model is a function of the inflection parameter (Karakus *et al*., 2008). Thus, growth rate increases until reaching the inflection point (maximum) and then decreases to zero at the asymptote or mature weight.

According to the Richards model, the mean inflection parameters for singletons and twins were 39.315 and 59.262 days, respectively. Thus, the time to inflection for singletons was much earlier than that for twins.

As shown in Table III, the R^2 values of the models were similar and quite high. The lowest value (99.07%) was calculated with the monomolecular model for twins, whereas the highest value (99.70 %) was recorded using the Gompertz and Richards models for singletons. In addition to R^2, the RMSE was also used to evaluate model performance. The RMSE values of the models were 0.098 - 0.441. The three-parameter logistic model provided the lowest RMSE value, whereas its R^2 value was 99.53%. Furthermore, the models with the highest R^2 values were about 0.31-fold the RMS values.

The asymptotic correlations between the parameters are shown in Table III. The maturity index (k parameter) was highly correlated with the other parameters. Similarly, correlations between asymptotic weight (a) and the scale parameter (b) were high for all models, except those for the three-parameter logistic model.

We evaluated four different growth models to determine the growth changes in herd of Colored Mohair kids. Growth is explained well using mathematical models, goodness of fit criteria are used to compare models. In this study, the R^2 values of the models were very high (99.07-99.70%). Similarly, Karakus *et al* (2008) reported that for 15 days interval measurements of Norduz lambs, determination coefficients to Logistic, Gompertz and Richards models were found 99.5%, 99.4% and 99.5%, respectively, while 99.7% for all models at 30 days interval measurements. However, some authors reported slightly lower R^2 values for Logistic, Richards and Gompertz models (Kor *et al*., 2006; Tatar *et al*., 2009; Yıldız *et al*., 2009; Akkol *et al*., 2011).

According to our findings the growth pattern of Colored Mohair goats was similar to that of the other breeds that have been studied. We concluded that the Richards and Gompertz growth models provided the most suitable values for BWs of Colored Mohair kids. The Richards growth model was the most appropriate for this herd of Colored Mohair goats.

Similarly, Tariq *et al*. (2011) reported that Gompertz model gave reliable results for the body weight–age relationship of Mengali sheep. Accordingly, Ozdemir and Dellal (2009) suggested to both Logistic and Gompertz growth models (non-linear models) for drawing growth curves in the young Angora goat. Furthermore, Filho *et al*. (2014) emphasized that Richards model was adequate for describing the growth curve of dairy goats. However, Tatar *et al*. (2009) noted that Brody and Bertalanfy models were suitable for growth model of Hair goats.

In addition, Brown *et al*. (2013) used five nonlinear models to fit weight-age data for female cattle of diverse breeding and management. Their findings indicated that three models, von Bertalanffy, Gompertz and logistic, consistently overestimated weights at early ages and the logistic underestimated mature weight. A four-parameter model, Richards, more accurately fit the data but was computationally more difficult than the three-parameter models.

CONCLUSION

As conclusion, body weight and growth rate are economically important features, requiring particular attention in breeding programs. Gompertz and Richards models for single and only Richards model for twins explained the growth characteristic of Colored mohair goats very well. The parameter estimations can be preferable. In addition, it can be stated that observed and predicted curves matched well. Birth type was found an effective factor on weight and growth parameters of Colored Mohair goats. Thus it can be emphasized that this factor should be taken into consideration in subsequent genetic evaluation. Producing heavier carcasses (13-17 kg) at < 150 days of age may increase the productivity and efficiency of the farming system. However, the present study provides only initial information on growth potential of Colored Mohair goats.

ACKNOWLEDGMENT

Special thanks to Assoc. Prof. Ecevit Eyduran for his contribution on improving the MS.

Conflict of interest statement

We declare that we have no conflict of interest.

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