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Determination of Body Weight-Age Relationship by Non-Linear Models in Japanese Quail

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Abstract: The objectives of this study were to determine the body weight-age with different models and to choose the best fitted model. The study was designed to collect a total of 8 weekly body weight records from 142 quails from birth up to 56 days of age in Tekirdag, Turkey. The Negative Exponential, Brody, Gompertz, Logistic and Bertalanffy Models were used to determine growth characteristics of quail in the present study. The model parameters were calculated for each model and the comparisons among the models were done based on the coefficient of determination (R^2), adjusted coefficient of determination (R^2_{adj}), Mean Square Error (MSE), the Akaike's Information Criteria (AIC), Residual Standard Deviation (RSD) and Residual Mean (RM) as fit criteria. As a conclusion, the Logistic Model (R^2 = 0.98, R^2_{adj} = 0.97, MSE = 9.79, AIC = 20.49, RSD = 3.13 and RM = 6.42) resulted in the best fit model for body weight-age in Japanese quail.

Key words: Growth curve, body weight, Japanese quail, non-liner models, MSE, Turkey

INTRODUCTION

The growth trait of livestock animals has studied for many years due to fact that this trait has an economically important for the practice of the animal husbandry. Growth can be described as positively change of live weight of living organism along with specified time period. The observed fluctuation can be explained by growth curve. Therefore, the changes of these parameters according to time can be given as a mathematical function of growth. As it is known that the age-weight relationship has become subjects of interest in animal science for a long time, however an early estimation of heritability and correlations for the growth curve parameters might be important criteria to access for selection targets (Soysal *et al*., 2002; Bilgin *et al*., 2003).

Many studies were conducted to investigate the age-weight relationship in the livestock animals by using various mathematical models. Especially, many non-linear models were used so frequently such as Logistic, Gompertz, Bertalanffy, Brody and Richards (DeNise and Brinks, 1985). Among them, Gompertz (1825)'s Model was used to calculate mortality rate. On the other hand, Logistic Model was recommended by Verhulst (1838). Brody (1945)'s Model was developed in 1945, Bertalanffy was reported in 1957. Richards (1959)'s Model was also recommended as a new model which have four parameters. In many studies, it was reported that this model was more appropriate than Brody. After that several new models are developed by several researchers (Brown *et al*., 1976; Heinrichs and Hargrove, 1987, 1994). Finding an appropriate model which is closely related with growth type in addition to the shape of growth curve is very important, since the model is changeable according to species and environment conditions (Nicholas *et al*., 1986). For example, Gompertz Model is more fitted than the other models for poultry species such as turkey, chicken and quail.

Growth curve characteristics were determined in two lines of quail by using three non-linear growth models (Gompertz, Bertalanffy and Logistic). Even if all growth models were used to fit the quail data well, Gompertz Model was detected the most fit than the others to describe the age and weight relationship (Akbas and Oguz, 1998). Line and gender effects were generally significant effects on growth curve parameters in that study. Logistic, Gompetz, Bartalanffy and Brody Models were used to determine of growth curve in quail. As a result, the best fitted model was selected as Logistic Model based on R^2 values (0.9950). The R^2 values of Gompertz, Bertalanffy and Brody model were detected as 0.9937, 0.9927 and 0.9866, respectively. Similarly, the rank of superiotory obtained among the mathematical models according to R^2, the results were displayed for Logistic

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(R^2 = 0.94), Polinomial (R^2 = 0.94), Gompertz (R^2 = 0.93), Logarithmic (R^2 = 0.81), Linear (R^2 = 0.53) for the general data in quails, respectively. In addition, Ozkan and Kocabas (2004) reported that the logistic growth function gave the best fit to the growth data of male and female quails for selected and unselected lines. Both Gompertz and Bertalanffy growth functions followed the logistic growth function in that study. Narinc *et al*. (2010) were used 11 different mathematical functions to determine the growth characteristics in Japanese quail. The results of the study recommended that the Gompertz Model was the most suitable model among the others in terms of fit criteria. Growth curve was searched based on the body weight and some body measurements in broiler chickens. Also, the Gompertz Model was well fitted for the weight-age, shank width-age, shank length-age and body length-age data than the other models. But the linear model fitted better for the breast bone length-age, breast width-age and breast circumference-age (Mendes, 2009). Therefore in light of many studies in this area, it is aimed to determine the body weight-age relationship from birth up to 56 days of age in quail and to choose the best fitted model among all models based on several fit criteria in the present study.

MATERIALS AND METHODS

Animal material: The experiment was conducted at the Poultry Research Unit of Namik Kemal University, Tekirdag in Turkey. The quail chicks were used from birth up to 56 days of age in the present study. A total of 142 quails as 102 female and 40 male animals were used in this experiment. Hatched chicks were wing-banded and their body weights were taken until 56 days as weekly. The selection for the body weight was not applied in the experiment herd. The gender determination of animal was completed based on the color of chest at 3 weeks of age. All animals were raised in quail battery brooders until 3 weeks of age and after that quails were located in the growing battery cages. The chicks were fed on starter and growing feeds of 28% crude protein and 3050 kcal kg^{-1} of metabolic energy and 20% crude protein and 2900 kcal kg^{-1} of metabolic energy, respectively. Feed and water were given as *ad libitum* to all animals in the cages. Lighting was applied as 23:1 h light; dark cycle for 1st week and then 16:8 h light; dark, respectively. During the experiment, all animals were weighed with 0.1 g by digital scale.

Statistics analysis: The Negative Exponential, Brody, Gompertz, Logistic and Von Bertalanffy Models were used

Table 1: Non-linear models used to estimate growth curve

Models	Functions	Y_i	t_i
Brody	W_t = A. (1- B. exp (-k.t))		
Negative exponential	W_t = A. (1 - exp (-k.t))		
Gompertz	W_t = A. exp (-B. exp (-k.t))	ln (B)/k	A/e
Logistic	W_t = A. (1+B. exp (-k.t))$^{-1}$	-ln (1/B)/k	A.0.5
Bertalanffy	W_t = A. (1 - B. exp (-k.t))^3	(ln B+ln3)/k	8.A/27

W_t: Body weight in at age t; A, B k: parameters of model; t: Age (day); Y_i: The production at Point of Inflection (POI); t_i: Age at POI

to determine growth characteristics of quail in present study. The whole parameters of non-linear models were estimated using generalized least squares with SPSS statistical package program. All the models applied in the study were shown in Table 1. All functions have expressed the weight (g) at (t) time W_t as functions of asymptotic (mature) weight (A), a constant of integration (time-scale parameter) B and a rate at which a logarithmic function of weight changes linearly per unit time (k). Y_i represents the production and age at the point of inflection (t_i) when growth rate is maximum (Akbas and Oguz, 1998; Soysal *et al*., 2002). Some fit criteria were used to determine the goodness of fit. These criteria were chosen as the coefficient of determination (R^2), adjusted coefficient of determination (R^2_{adj}), Mean Square Error (MSE), the Akaike's Information Criteria (AIC), Residual Standard Deviation (RSD) and Residual Mean (RM). Among these criteria, only two fit criteria were described below in detail (Akaike, 1974; Narinc *et al*., 2010). In addition, the body weight of animals was grouped based on the gender factor as male and female and gender factor was analyzed with t-test for each week. But this factor were found not important as statistically (p>0.05). The correlation coefficients were also showed among the growth curve parameters for different models:

:

$$RSD = (SSE)^{1/2}/(n - k)^{1/2}$$

$$AIC = n. \ln (SSE/n)+2k$$

Where:
RSD = Residual Standard Deviation
AIC = Akaike's Information Criteria
SSE = Sum Square of Error
n = The number of observations
k = The number of parameters

RESULTS AND DISCUSSION

The some descriptive statistics for curve parameters, production and age at point of inflection were shown in Table 2. The parameter A (asymptotic weight) were found by Brody, Gompertz, Bertalanffy, Logistic and Negative Exponential as 325.4, 186.9, 205.2, 174.2 and 505.2, respectively. At the same time, the parameter k which

Table 2: The mean, standard deviation of growth curve parameters and production and age at point of inflection (Y_i and t_i)

Models	A	B	k	Y_i	t_i
Brody	325.4±79.20	0.98±0.001	0.018±0.0024	-	-
Gompertz	186.9±3.200	3.80±1.250	0.066±0.0010	68.96±2.30	20.22±0.67
Bertalanffy	205.2±5.250	0.84±0.080	0.052±0.0050	60.80±2.83	17.60±0.89
Logistic	174.2±3.260	16.24±8.260	0.090±0.0040	87.10±3.45	30.97±1.23
Negative exponential	505.2±185.2	-	0.019±0.0010	-	-

Table 3: The goodness of fit criteria based on different models

Models	R^2	R^2_{adj}	MSE	AIC	RSD	RM
Brody	0.89	0.84	35.26	30.74	5.95	-38.30
Gompertz	0.97	0.96	14.67	23.72	3.84	-9.09
Bertalanffy	0.96	0.94	16.78	24.80	4.10	-11.52
Logistic	0.98	0.97	9.79	20.49	3.13	6.42
Negative exponential	0.76	0.66	85.89	37.32	9.28	-106.37

indicates earliness of maturing were detected 0.018, 0.066, 0.052, 0.09 and 0.019 for Brody, Gompertz, Bertalanffy, Logistic and Negative Exponential Models, respectively. The production (body weight) and age (day) at point of inflection were found 68.96 and 20.22; 60.80 and 17.70; 87.10 and 30.97 for Gompertz, Bertalanffy and Logistic Models, respectively.

The goodness of fit criteria values were shown in Table 3 for all models. According to the results, the R^2 and R^2_{adj} coefficients were detected as 0.89 and 0.84; 0.97 and 0.96; 0.96 and 0.94; 0.98 and 0.97; 0.76 and 0.66 for Brody, Gompertz, Bertalanffy, Logistic and Negative Exponential Models, respectively. The highest coefficients were obtained from Logistic Model for these criteria. Similarly, the MSE and AIC values were observed as 35.26 and 30.74; 14.67 and 23.72; 16.78 and 24.80; 9.79 and 20.49; 85.89 and 37.32 for Brody, Gompertz, Bertalanffy, Logistic and Negative Exponential Models, respectively. The smallest values were obtained from Logistic Model for these criteria. The RSD and RM values were detected 5.95 and -38.3; 3.84 and -9.09; 4.10 and -11.52; 3.13 and 6.42; 9.28 and -106.37 as Brody, Gompertz, Bertalanffy, Logistic and Negative Exponential Models, respectively. As a results, the Logistic Model was given the best fit to the growth data and it was followed by Gompertz and Bertalanffy in the present study.

The observed and predicted growth curves and deviations between observed and predicted values of models for body weight of quail were shown in Fig. 1 and 2, respectively. As it was shown in the Fig. 1 and 2, the Logistic, Gompertz and Bertalanffy growth curves were expressed more fit than the other models used in this study. The parameter A was found from Brody, Gompertz, Bertalanffy and Logistic as 325.4, 186.9, 205.2 and 174.2, respectively in the present study. The same parameter was observed as 187.5, 174.9, 173.9 and 172.3 for Brody, Logistic, Bertalanffy and Gompertz in quail, respectively. Similarly, the same parameters were detected 492.7, 201.9, 247.3 and 222.1 for Brody, Logistic, Bertalanffy and Gompertz in quail, respectively (Narinc *et al*., 2010). Akbas and Oguz (1998) reported that

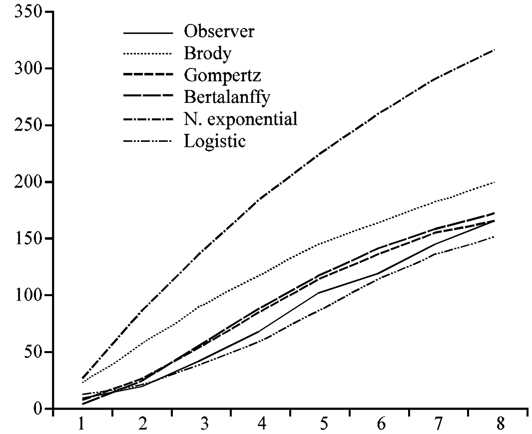

Fig. 1: Observed and predicted growth curve of models for body weight of quails

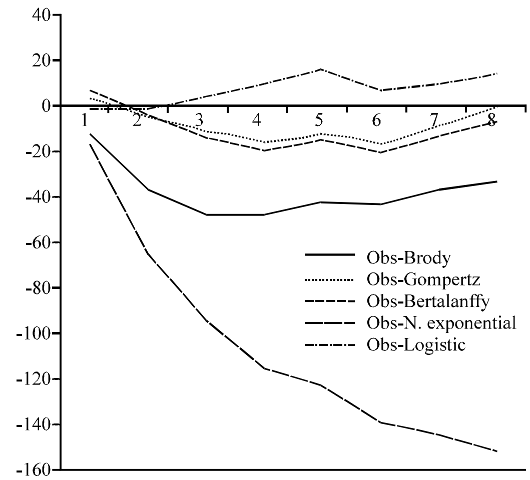

Fig. 2: Deviations between observed and predicted values of models for body weight of quails

these parameters were detected minimum 182.7 and maximum 278.2 for Gompertz, Logistic and Bertalanffy Models, respectively. Ozkan and Kocabas (2004) were also reported that these parameters were found minimum of 179.92 and maximum of 245.06 for Gompertz, Bertalanfy and Logistic Models. At the same time, the parameter of k was detected as 0.018, 0.066, 0.052 and 0.09 for Brody, Gompertz, Bertalanffy and Logistic Models in the present study, respectively. The (k) parameters of models were detected as 0.028; 0.09; 0.05 and 0.06 for Brody, Logistic, Bertalanffy and Gompertz, respectively. Similarly, the same parameters were observed 0.013, 0.139, 0.054 and 0.080 for Brody, Logistic, Bertalanffy and Gompertz in quails, respectively by Narinc *et al.* (2010). Akbas and Oguz (1998) reported these parameters as minimum of 0.046 and maximum 0.132 for Gompertz, Logistic and Bertalanffy Models. The same parameters were detected as minimum of 0.04 and maximum of 0.10 for Gompertz, Bertalanfy and Logistic Models (Ozkan and Kocabas, 2004).

In present study, the production and age at point of inflection were found 68.96 and 20.22; 60.80 and 17.70; 87.10 and 30.97 for Gompertz, Bertalanffy and Logistic Models, respectively. Narinc *et al.* (2010) found the production and age at point of inflection as 81.70 and 14.95; 64.85 and 28.01 for Gompertz Model, respectively. Akbas and Oguz (1998) and Ozkan and Kocabas (2004) reported the same values in the range of 74.85 and 18.74; 65.82 and 16.90; 89.66 and 20.74; 71.91 and 25; 58.99 and 17; 106.20 and 38, respectively. The highest R^2 and R^2_{adj} coefficients were observed as 0.98 and 0.97 for Logistic Model in the present study. Similarly, Ozkan and Kocabas (2004) observed 0.94; 0.99 as the highest R^2 for Logistic Model, respectively. Additionally, in the present study, the MSE and AIC values were detected 35.26 and 30.74; 14.67 and 23.72; 16.78 and 24.80; 9.79 and 20.49; 85.89 and 37.32 for Brody, Gompertz, Bertalanffy, Logistic and Negative Exponential Models, respectively. The smallest values were obtained from Logistic Model for these criteria. Narinc *et al.* (2010) also reported that the same values were 45.01 and 32.64; 0.31 and -2.01; 5.30 and 19.68; 13.81 and 24.37; 35.34 and 28.95 for Brody, Gompertz, Bertalanffy, Logistic and Negative Exponential Models, respectively.

The results of the current study indicated that the Logistic Model gave the best fit to the growth data as similarly reported by Ozkan and Kocabas (2004). At the same time, Akbas and Oguz (1998) and Narinc *et al.* (2010) reported that all growth models might be used to fit the quail data well including Logistic Model however, the Model of Gompertz was the best model based on the results among the all models.

CONCLUSION

The Logistic Model gave the best fit to the growth data of quail and this model was followed by Gompertz and Bertalanffy in the present study. Therefore, these models might be used to determine of body weight-age relationship very well in Japanese quail studies.

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