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MODELING OF INDIVIDUAL GROWTH CURVES IN JAPANESE QUAILS

Esra YAVUZ[1]*, Ayşe Betül ÖNEM[1], Fahrettin KAYA[2], Demet ÇANGA[3], Mustafa ŞAHİN[1]

[1]*Kahramanmaraş Sütçü Imam University, Faculty of Agriculture, Department of Animal Science, 46040, Onikişubat, Kahramanmaraş, Turkey.*

[2]*Kahramanmaraş Sütçü Imam University, Andırın Vocational School, Computer Technology Department, 46410, Andırın, Kahramanmaras, Turkey.*

[3]*Osmaniye Korkut Ata University, Department of Food Processing, 80050, Bahçe, Osmaniye,, Turkey.*

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Abstract

This study was conducted to determine the adaptation of the individual growth curves of Japanese quails to both female and male quail data modeled by using Richard, Logistic, Gompertz, Von Bertalanffy, Cubic Spline and Quadratic Spline models. In the study, 810 quail data consist of 298 females and 512 males were used as material. For six different models, Mean Square Error (MSE), Durbin-Watson autocorrelation test (DW), Akaike Information Criteria (AIC), Adjusted Determination Coefficient (adj. R^2) values were compared for both female and male quails. In addition model predictions of growth curve parameters were shown. As a result of this study for individual growth curve models in Japanese quails, MSE= 92.50 ± 17.69, adj.R^2=0.986 ± 0.001, AIC= |-19.21| ± 0.15 and DW= 2.21 ± 0.01 for female quails MSE= 35,391 ± 9.07, adj.R^2=0.997 ± 0.033, AIC= |-35.04| ± 0.29 and DW= 2.09 ± 0.91 for male quail. It was found the cubic Spline model, which was the best model for both female and male quails.

Keywords: Japanese quail, Growth curve, Models

***Corresponding author:** Kahramanmaraş Sütçü Imam University, Faculty of Agriculture, Department of Animal Science, 46040, Onikişubat, Kahramanmaraş, Turkey.
E mail: yavuz7346@gmail.com (E. YAVUZ)
Esra YAVUZ https://orcid.org/0000-0002-5589-297X
Ayşe Betül ÖNEM https://orcid.org/0000-0002-4613-1204
Fahrettin KAYA https://orcid.org/0000-0003-1666-4859
Demet ÇANGA https://orcid.org/0000-0003-3319-7084
Mustafa ŞAHİN https://orcid.org/0000-0003-3622-4543
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1. Introduction

Mathematical models that demonstrate age-growth relationships are used to determine feeding programs in farm animals, to determine the optimum slaughtering age and to estimate the effects of applied selection methods. With the asymptotic and monomolecular functions developed, we try to predict the age-growth associations of the features that are discussed in quail. Furthermore, it is tried to determine the parameter values that can be the selection criterion of these models (Hyankova et al., 2001).

Growth period analysis is needed in economic growth and optimum cutting time by using growth curves in animal husbandry. This study was conducted to in order to determine compliance with individual growth curves to both female and male quail data modeled by Richard, Logistic, Gompertz, Von Bertalanffy, Cubic Spline and Quadratic Spline for Japanese quail.

For six different models in Japanese quails MSE, adj. R^2, AIC and DW values were compared in both female and male quails. In addition, parameter estimates of individual growth curves for six different models are given. It has been shown that the longest selection programs in Japanese quails show that the growth curve characteristics may variability and that for the individual growth curve models, the cubic Spline model is the best model for both female quail and male quail. It has been shown that the parameters of high and low live weight ratios can be estimated according to live weight at 4th week (Anthony et al., 1986; Bilgin and Esenboğa, 2003).

2. Material and Method

2.1. Material

As the animal material of the study, a total of 810 breeding quail data, 298 females and 512 males, were obtained from the Japanese quail (Coturnix japonica) grown in Kahramanmaraş Sütçü İmam University, Faculty of Agriculture, Animal Science Department Animal Husbandry Facilities. During the trial, quails were free of 24% HP, 1.30% lysine, 0.5% methionine, 0.75% methionine + cystine, 0.8% Ca, 0.45% P and 2900 Kcal / Kg ME until 0-6 weeks of age; in the later period, it was fed with 20% HP, 1.15% lisin, 0.5% methionine, 0.76% methionine + cystine, 2.5% Ca, 0.55% P and 2900 Kcal / Kg ME. Records of quail animals that died during the period of the study trial were not evaluated.

2.2. Method

Six different functions were used for the individual growth curves in Japanese quails, including Richard, Logistic, Gompertz, Von Bertalanffy, Cubic Spline and Quadratic Spline modeling. Mathematical models of these functions used in the study are given in Table 1 (Onder et al., 2017).

Table 1. Model expressions and parameters of studied growth functions

Model	Expression
Richard	$W_t = \beta_0/(1+\beta_1\exp(-\beta_2 t))^{1/\beta_3}$
Logistic	$W_t = \beta_0/(1+\beta_1\exp(-\beta_2 t))$
Gompertz	$W_t = \beta_0\exp(-\beta_1\exp(-\beta_2 t))$
Von Bertalanffy	$W_t = {\beta_0}^{1-\beta_3} - \beta_1\exp((-\beta_2 t)^{1/1-\beta_3})$
Cubic Spline	$W_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \beta_4 (t-a)^3$
Quadratic Spline	$W_t = \beta_0 + \beta_1 t + \beta_2 t^2$

W_t: t. live weight in the day,

W: Asymptotic weight,

β_0, β_1 and β_2: Model constants describing the growth curve of Richard, Logistic, Gompertz and Quadratic Spline,

β_0, β_1, β_2 and β_3: Model constants defining the Von Bertalanffy growth curve,

β_0, β_1, β_2, β_3 and β_4: Model constants defining the cubic spline growth curve,

t: Age (in days),

e: Logarithmic base.

The growth curve parameters (W and β) were calculated using the SAS System for Windows 9.0 computer package program.

2.2.1. Goodness-of-fit criteria

Goodness of the fit of models was evaluated according to criteria Mean Square Error (MSE), Durbin-Watson autocorrelation test (DW), Akaike Information Criteria (AIC), Coefficient of determination (R^2).

The goodness-of-fit criteria to compare the studied functions that explain the growth of Japanese quail are as follows:

Determination Coefficient

R^2=1-(SSE/SST) (1)

where SSE is the sum of square errors and SST the total sum of squares.

Adjusted Determination Coefficient

Adj R^2=R^2-((k-1)/(n-k)(1-R^2)) (2)

where *n* is the number of observations and *k* the number of parameters.

Mean Square Error

MSE = SSE/(n-k) (3)

where *n* is the number of observations, SSE sum square of errors and *k* the number of parameters.

Akaike Information Criteria

AIC=n× ln(SSE/n)+2k (4)

where n is the number of observations, SSE sum square of errors and k the number of parameters (Soysal et al. 1999; Narinç et al. 2010; Üçkardeş et al. 2013;Talpaz et al. 1986).

3. Results

In the study, the values calculated by using live weight and weekly live weight gain of both female and male Japanese quails used and the individual growth curves by using Richard, Logistic, Gompertz, Von Bertalanffy, Cubic Spline and Quadratic Spline models are given in Table 2. It belongs to these models MSE, adj. R^2, AIC and DW values were given for both female and male quails. The model with the lowest MSE value according to Table 2 was found to be a Cubic Spline model for both female and male quails. It was also found that the model with the highest MSE value was Von Bertlanffy for the female quail and the Gompertz model for the male quail.

As seen in Table 2, adj. R^2values of all models were found to be between 0.945-0.986. Table 2 also shows AIC and DW values for both female and male quails of 6 different models.

In study Growth parameters of female and male quail estimated by Richard, Logistic, Gompertz, Von Bertalanffy, Cubic Spline and Quadratic Spline models are given in Table 3. With the highest values of the mean β0 parameter, female quail 228.5 and male quail 227.9 values were estimated in the Richard model. The β0 parameter calculated from the Richard model was found to be higher than the other models.

Table 2. Models of MSE, adj. R2, AIC and DW values

Model	Female			
	MSE	adj R^2	AIC	DW
Richard	104,22 ± 15,10	0.975 ± 0.001	|−0.019| ± 0,11	2,45 ± 0,01
Logistic	128,51 ± 17,93	0.976 ± 0.004	34.12 ± 0,03	2.96 ± 0,03
Gompertz	94,18 ± 15,99	0.985 ± 0.145	|−3.11| ± 0,89	1.96 ± 0,11
Von Bertalanffy	555,78 ± 186,61	0.945 ± 0.025	95.98 ± 0,01	3.75 ± 0,23
Cubic Spline	92,50 ± 17,69	0.986 ± 0.001	|−19.21| ± 0,15	2.21 ± 0,01
Quadratic Spline	104,48 ± 17,27	0.975 ± 0.002	0,97 ± 0,05	1.86 ± 0,12
	Male			
Richard	42,603 ± 20,162	0,996 ± 0,025	|−6.27| ± 0,42	2,21 ± 0,05
Logistic	79,110 ± 15,716	0,985 ± 0,091	45.22 ± 0,19	2.84 ± 0,33
Gompertz	85,118 ± 14,922	0,989 ± 0,001	|−5.32| ± 0,02	1.91 ± 0,05
Von Bertalanffy	84,800 ± 15,517	0,990 ± 0,001	67.49 ± 0,26	2.88 ± 0,03
Cubic Spline	35,391 ± 9,07	0,997 ± 0,033	|−35.04| ± 0,29	2.09 ± 0,91
Quadratic Spline	51,541 ± 17,482	0,993 ± 0,103	0,67 ± 0,19	1.75 ± 0,45

MSE= Mean Square Error, adj. R^2= Adjusted Determination Coefficient, AIC= Akaike Information Criteria, DW= Durbin-Watson Statistic.

Table 3. Estimates of parameters for the studied growth functions

Female						
Model	β_0	B_1	B_2	B_3	B_4	Plateau
Richard	228.5 ± 0.75	0.423 ± 0.08	3.764 ± 1.12	-	-	-
Logistic	209.7 ± 1.12	3.336 ± 0.95	0.81 ± 0.03	-	-	-
Gompertz	222.7 ± 5.89	1.706 ± 0.45	0.497 ± 0.02	-	-	-
Von Bertalanffy	0.651 ± 0.02	-0.488 ± 0.03	4.132 ± 0.95	170.4 ± 2.3	-	-
Cubic Spline	-10.98 ± 0.44	13.58 ± 1.11	5.08 ± 0.95	-0.38 ± 0.3	-0.71 ± 0.5	-
Quadratic Spline	-50.04 ± 1.09	48.28 ± 2.78	-2.12 ± 0.07	-	-	223.63 ± 4.78
Male						
Richard	227.9 ± 0.95	0.623 ± 0.08	3.531 ± 1.08	-	-	-
Logistic	207.5 ± 1.65	5.421 ± 0.76	0.61 ± 0.01	-	-	-
Gompertz	220.3 ± 5.31	1.902 ± 0.03	0.441 ± 0.01	-	-	-
Von Bertalanffy	0.632 ± 0.01	-0.681 ± 0.01	4.522 ± 0.03	175.8 ± 2.9	-	-
Cubic Spline	-9.63 ± 0.05	11.61 ± 0.19	5.14 ± 1.25	-0.45 ± 0.9	-0.82 ± 0.3	-
Quadratic Spline	-48.07 ± 2.19	44.33 ± 2.21	-2.59 ± 0.05	-	-	226.44 ± 3.79

In the study, weight at the point of inflection of the Richard, Logistic, Gompertz, Von Bertalanffy, Cubic Spline and Quadratic Spline Gompertz models were demonstrated for male quail (Figure 1) and for female quail (Figure 2).

As a result, it has been determined that the Cubic Spline regression, which has a flexible structure in terms of inflection point, is the most appropriate growth function for both female and male Japanese quails.

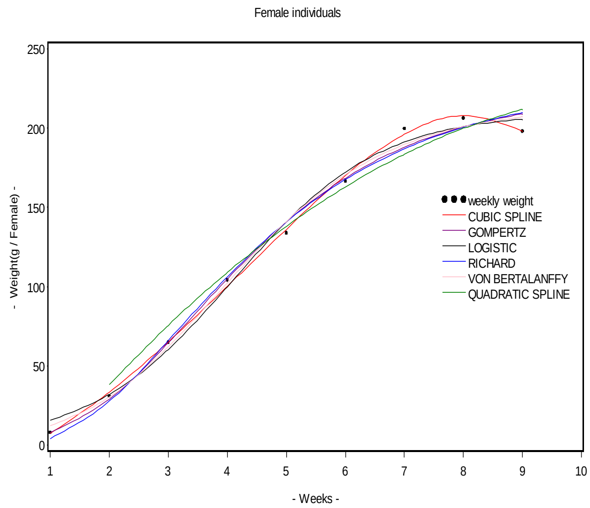

Figure 1. Growth curves of female quail by different growth functions.

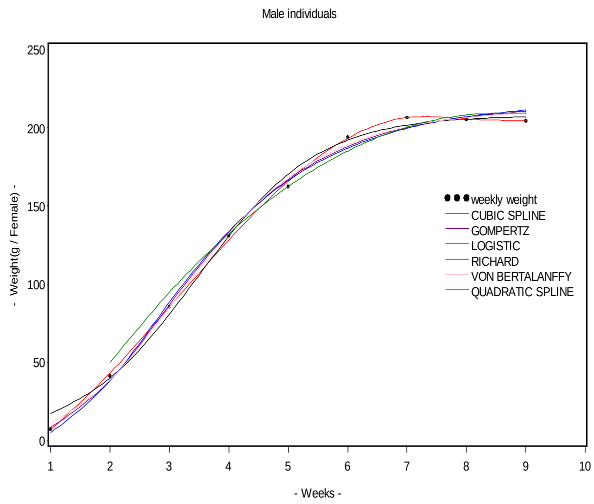

Figure 2. Growth curves of male quail by different growth functions.

4. Discussion

For six different models of Japanese quails, Mean Square Error, Durbin-Watson autocorrelation test, Akaike Information Criteria, Coefficient of determination values were compared for both female and male quails. In addition, model predictions of growth curve parameters are shown.

As seen in Table 2, adj. R^2 values of all models were found to be between 0.945-0.986. Many researchers (Alkan et al. 2009; Balcıoğlu et al. 2005) have displayed quite high values of the adj. R^2 values for growth models such as Logistic, Richards and Von Bertalanffy. In research, the best growth model for female quail was determined to be the Cubic Spline growth function according to the lowest values of MSE (92.50). Also, the best growth model for male quail was determined to be the Cubic Spline growth function according to the lowest values of MSE (35.391). The Cubic Spline model, which assesses the shape of a growth curve, has had limited use in quail (Aggrey et al. 2002). Beiki et al. (2013) in study investigated the growth patterns of quail using seven nonlinear regression models. They reported that the Richards growth curve was the best fitting model for quail growth data which is in disagreement with the results of the current study. Our results are in disagreement with the previous reports that Gompertz model was the best fitting model for galliforms (Narinç et al. 2010). Growth is a phenomenon depends on genetic and environmental conditions but it does not depend on species, line or family (Üçkardeş and Narinç 2014). Therefore, it is necessary to determine the best-fitting model for every studied flock. Moreover, the Gompertz model was defined for female the second best fitting function in the current study. Also, the Richard model was defined for male the second best fitting function in the current study. The models showed good fit to the quail growth data as indicated by adj. R^2 values.

Asymptotic weight parameter values of the Richards model for female and male quail (228.5 and 227.9) are in agreement with the value reported by Beiki et al. (2013) for their control group involving both sexes. In another study (Akbaş and Oğuz 1998), the estimated mature weight parameter ($\beta 0$) of the Gompertz model for the selection line (239.5 g) was higher than that of the control line (208.3 g) and that of female quail (244.4 g) were higher than male ones (203.5 g). Many studies in which the growth of Japanese quail was showed by the Gompertz model, the mature weight parameter was found to be from 204 to 281 (Narinç et al. 2009, Alkan et al. 2009 and Narinç et al. 2010). Alkan et al. (2009) showed selection to increase the live weight in Japanese quail. In study performed $\beta 0$ parameter values to be 295–306 and 151–164 g for a selected and a non-selected line, in order of. It is expected that quail growth and growth curve parameters can be changed via breeding studies or environmental practices (Narinç et al 2010).

As a result of study for individual growth curve models in Japanese quails, in female quails MSE= 92.50 ± 17.69, adj R^2=0.986 ± 0.001, AI=: |-19.21| ± 0.15 and DW= 2.21 ± 0.01 in male quail MSE= 35.391 ± 9.07, adj R^2= 0.997 ± 0.033, AIC= |-35.04| ± 0.29 and DW= 2.09 ± 0.91 the cubic spline model, which is the best model for both female and male quails was found.

Conflict of interest

The authors declare that there is no conflict of interest.

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