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STATISTICAL MODELS AND EVALUATION CRITERIA USED IN POULTRY FARMING

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Abstract: This thesis study examined the statistical models and evaluation criteria used in poultry breeding, account considering live weight gain, egg weight and egg numbers. For this purpose, as an example of live weight increase; 9-week live weight gains of Ross-308 broiler line, as an example of egg weight; the average of 20-week egg weights of brown Lohmann laying hens and 9-week egg yields of Japanese quail were used as an example of the number of eggs. In modeling, for live weight gain; 10 different models for egg production; 11 different models and 8 different models for egg weight were considered. In evaluating the models; error mean squares, coefficient of determination, corrected coefficient of determination, Akaike Information Criterion, Corrected Akaike Information Criterion, Bayesian Information Criterion, Accuracy Factor, Bias Factor and Durbin-Watson autocorrelation values were taken into consideration. As a result of the study, in terms of live weight gain; The Cubic Piecewise regression model is the best in terms of egg yields; It was determined that the Modified Compartmental model and the Logistic model gave better results than the others in terms of egg weight. The worst models are in live weight gains; Brody and egg yields; It was concluded that there was a Quadratic Linear and Von Bertalanffy model for egg weight.

Keywords: Poultry, Growth, Eggs, Modeling

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1. Introduction

Poultry farming has found a wide range of applications when the short breeding process and the potential of white meat consumption to meet the needs of the increasing human population come together. Therefore, in parallel with breeding of poultry such as broiler chickens, turkeys, quails, geese and ducks, which are common poultry, breeding studies in the relevant field have also intensified, especially in the last decade. The process of reaching slaughter weight and egg yields of poultry such as broiler chickens, turkeys, quails, geese and ducks show differences within themselves. Despite these differences, live weight gains in all poultry are slow at the beginning, then fast and follow a course that slows down considerably when they reach slaughter weight. Egg yields, on the other hand, initially increase very rapidly and then follow a course that stabilizes. Egg weights, on the other hand, are low at the beginning and then stabilize within a certain range in all poultry. For this reason, to better understand the subject, it would be useful to briefly discuss the characteristics of commonly raised poultry such as broiler chickens, turkeys, quails, geese and ducks in terms of their slaughter weights and egg yields.

Broiler chicken breeding is done as mixed female-male. While the slaughter live weight was reached in 8-10 weeks in the 1980s, thanks to breeding studies, it has decreased to 35-42 days today and is approximately between 2100 g and 2800 g and the best genotypes are defined as Broiler. In commercial layer hens, the 18th to 72nd weeks are considered the laying period and the egg yield is 290-320 per chicken per year and the egg weight varies between 63-65 g (Anadolu Yarka, 2024).

Turkey breeding is done as mixed female-male. The slaughter live weight is between 16-18 weeks in female turkeys and 22-24 weeks in male turkeys and the males have a carcass weight of 19-20 kg and females have a carcass weight of 10-11 kg and the best genotypes are defined as pure or hybrid breeds. The average annual egg yield is between 60 and 90 (Erişir and Yıldız, 2000).

Quail production, the age at which they start laying eggs varies between 35-50 days. It reaches its highest level at approximately 56-60 days. In males, sperm production starts at an earlier age of 36 days. Slaughter live weight varies between 5-6 weeks and is approximately 120-150 grams and the best genotypes are defined as Japanese quails. Egg yield is an average of 250-300 pieces per year and egg weight is between 9-12 grams (Şentürk and Aktan, 2020.

Goose breeding, slaughter live weight is 10-12 weeks in intensive feeding, 20-30 weeks in pasture-based feeding and is approximately 3-3.5 kg and the best genotypes in Türkiye are defined as Domestic geese (Kars geese). Egg yield is an average of 15-60 pieces per season and egg weight is between 60-100 grams (TKYÇ, 2000).

Duck breeding, slaughter live weight is approximately two months, males have 4-4.5 kg and females have 3-3.5 kg carcass weight and the best genotypes are defined as Pekin ducks. Egg yield is an average of 150-200 per year, and egg weight is between 80-85 gr (Narahari et al., 1991).

Intensive breeding studies have been carried out to reach market weight in the shortest time in all poultry breeding, for which general information on growth, egg yield and weight is given above. In parallel with these studies, the number of statistical equations (for growth and egg yield curves) used in breeding studies has increased considerably with the developments in the field of computers and software. This situation has confused for breeders working in the relevant field regarding which models and criteria to use. The use of different equations and inadequate comparison criteria in different studies on the same subject has made the situation even more complicated. This complexity (Congleton et al., 1980; Gavora et al., 1982; Cason and Britton, 1988; Cason, 1990; Cason and Ware, 1990; Miyosh et al., 1996; Keskin et al., 2002; Narushin and Takma, 2003; Balcıoğlu et al., 2005; Anang and Indrijani, 2006; Topal and Bölükbaşı, 2008; Porter et al., 2010; Faridi et al., 2011; Şekeroğlu et al., 2013; Narinç et al., 2014; Demir et al., 2017; Karadavut et al., 2017; Türker et al., 2017; Yavuz et al., 2018; İzgi et al., 2020; Yalçınöz and Şahin, 2020) is seen more clearly when the literature is examined. In this study, the statistical equations used in modeling growth and egg yield curves in poultry farming and the evaluation criteria used in the comparison of these equations were examined. For this purpose, the statistical equations and evaluation criteria used in the literature for growth and egg yield curves were calculated using the SAS statistical package program on the original data sets in chickens and quails, and a detailed examination of the evaluation criteria of the models was made. Thus, it was aimed to partially prevent this confusion in the field of poultry farming and to present the most statistically appropriate models and evaluation criteria the use of researchers.

2. Materials and Methods

This study the data was obtained from commercial companies. In the live weight gain sample; 9-week averages including hatch weight of 50 commercial Ross-308 broiler lines were used, in the egg weight sample; 20 different weeks from the 21st to 40th weeks of 39 brown Lohmann layer hens were used, and in the egg number sample; 9-week egg yields of 80 Japanese quails (Coturnix japonica) were used. For this purpose, statistical equations and evaluation criteria used in the literature for growth and egg yield curves were calculated using the SAS statistical package program on the original data sets in chickens and quails, and a detailed examination of the evaluation criteria of the models was performed. Logistic, Gompertz, Gamma, Schunute, Brody, Richard, Negative Exponential, Von Bertalanffy, Cubic Piecewise and Cubic models were used in modeling poultry growth curves.

The equations used in modeling poultry growth curves are given in Table 1 (Ahmadu et al., 2017; Yalçınöz and Şahin; 2020; Yavuz et al., 2023). In Table 1; "Yt" represents the live weight gain on the t^th^ day, ''$\beta 1$, $\beta 2$, $\beta 3$ and $\beta 4$'' are the constants defined for the models, and ''a'' represents the node point in Cubic Piecewise regression. In the modeling of egg yield curves; Gompertz, Logistic, Richard, Schunute, McNally, Gamma, Cubic Piecewise, Quadratic, Quadratic Linear, Quadratic Piecewise and Modified Compartmental models were used.

The equations used in the modeling of egg yield curves are given in Table 2 (Ahmadu et al., 2017; Yalçınöz and Şahin; 2020; Yavuz et al., 2023 In Table 2; "Yt" represents the egg yield at time t, "β_0, β_1, β_2, β_3, β_4 and β_5" are the constants defined for the models, "a" is the nodal points in the piecewise regression, "p" is the fixation point, "e" is 2.7182, "p" is the asymptotic value of the highest egg yield, "f" is the rate of decrease in egg laying, "g" is the time until sexual maturity, "h" is the average number of eggs formed in the first week and "t" is the week.

Table 1. Equations used in modeling poultry growth curves

Models Names	Equalities
Logistic	$Y_t = \beta_0(1+\beta_1 \exp(-\beta_2 t))^{-1}$
Gompertz	$Y_t = \beta_0 \exp(-\beta_1 \exp(-\beta_2 t))$
Gamma	$Y_t = {\beta_0}^{\beta_1}(e^{-\beta_2 t})$
Schunute	$Y_t = Z_2 * Z_3$ $Z_1 = {\beta_4}^{(\beta_2)} - {\beta_3}^{(\beta_2)}$, $Z_2 = {\beta_3}^{(\beta_2 + Z_1)}$, $Z_3 = (1-e(-\beta_1 (X-X_1)/$ $(1-e(-\beta_1 (X_2-X_1))^{(1/\beta_2)}$
Brody	$Y_t = \beta_0(1-\beta_1 \exp(-\beta_2 t))$
Richard	$Y_t = \beta_0(1+\beta_1 \exp(-\beta_2 t))^{\beta_3}$
Negative Exponential	$Y_t = \beta_0 - (\beta_0 e^{-\beta_2 t})$
Von Bertalanffy	$Y_t = \beta_0(1-\beta_1 \exp(-\beta_2 t))^3$
Cubic Piecewise	$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \beta_4 (t-a)^3$
Cubic	$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3$

Table 2. Equations used in modeling egg yield curves

Models Names	Equalities
Gamma	$Y_t = \beta_0 t^{\beta_1} \exp(-\beta_2 t)$
McNally	$Y_t = \beta_0 t^{\beta_1} \exp(-\beta_2 t + \beta_3 t^{0.5})$
Logistic	$Y_t = \beta_0 (1 + \beta_1 \exp(-\beta_2 t))^{-1}$
Gompertz	$Y_t = \beta_0 \exp(-\beta_1 \exp(-\beta_2 t))$
Richard	$Y_t = \beta_0 (1 + \beta_1 \exp(-\beta_2 t))^{\beta_3}$
Schunute	$Y_t = K_2 * K_3$ $K_1 = \beta_4^{(\beta_2)} - \beta_3^{(\beta_2)}$, $K_2 = \beta_3^{(\beta_2 + K_1)}$, $K_3 = (1-e(-\beta_1 (X-X_1)/ (1-e(-\beta_1 (X_2-X_1))^{(1/\beta_2)}$
Modified Compartmental	$Y_t = \beta_0 exp(-\beta_1 t)/(1 + exp((-\beta_3(t - \beta_4))$
Quadratic	$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2$
Quadratic Piecewise	$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 (t - a)^2$
Quadratic Linear	$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + p$
Cubic Piecewise	$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \beta_4 (t - a)^3$

Cubic, Gompertz, logistic, Richard, Quadratic linear, Orskov, Sigmaidal and Von Bertalanffy models were used in the modeling of egg weight. The equations used in the modeling of egg weight are given in Table 3 (Ahmadu et al., 2017; Yalçınöz and Şahin; 2020; Yavuz et al., 2023). In Table 3; "Yt" represents the egg weight on the t[th] day, "β_1 , β_2 , β_3 and β_4 " are the constants defined for the models, "a" represents the node point in cubic piecewise regression and "p" represents the fixation point.

Table 3. Equations used in the modeling of egg weight

Models Names	Equalities
Gompertz	$Y_t = \beta_0 \exp(-\beta_1 \exp(-\beta_2 t))$
Logistic	$Y_t = \beta_0 (1 + \beta_1 \exp(-\beta_2 t))^{-1}$
Richard	$Y_t = \beta_0 (1 + \beta_1 \exp(-\beta_2 t))^{\beta_3}$
Orskov	$Y_t = \beta_0 + \beta_1 (1-e^{\beta_3 t})$
Sigmoidal	$Y_t = \beta_0 / (1+(\beta_1/t))^{\beta_2}$
Von Bertalanffy	$Y_t = \beta_0 (1 - \beta_1 \exp(-\beta_2 t))^3$
Quadratic Linear	$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + p$
Cubic Piecewise	$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \beta_4 (t - a)^3$

In the model evaluation criteria; Mean Square Error (MSE), Coefficient of Determination (CD), Corrected Coefficient of Determination (CCD), Akaike Information Criterion (AIC), Corrected Akaike Information Criterion (CAIC), Bayesian Information Criterion (BIC), Accuracy Factor (AF), Bias Factor (BF) and Durbin-Watson autocorrelation value (DW) are used (Kaplan and Gürcan, 2018). Model evaluation criteria are given in Table 4.

Table 4. Model evaluation criteria

Criterion	Equality
Mean Square Error	MSE = ESS/EDF
Coefficient of Determination	$R^2 = 1 - (MSE/SST)$
Adjusted Coefficient of Determination	$\bar{R}^2 = 1 - (1 - R^2)(n - 1/(n - p - 1))$
Accuracy Factor	$AF = 10^{\sum_{i=1}^{n} \lvert \log(\hat{Y}_i/Y_i) \rvert / n}$
Bias Factor	$BF = 10^{\sum_{i=1}^{n} \log(\hat{Y}_i/Y_i)/n}$
Durbin-Watson Value	$DW = \frac{\sum_{i=2}^{n} (e_1 - e_2)^2}{\sum_{i=1}^{n} e_1^2}$
Akaike Information Criterion	$AIC = nxln\left(\frac{MSE}{n}\right) + 2k$
Corrected Akaike Information Criterion	$CAIC = AIC + \left(\frac{2p(p+1)}{n-p-1}\right)$
Bayesian Information Criterion	$BIC = nxln\left(\frac{MSE}{n}\right) + kln(n)$

3. Results and Discussion

In this study, statistical models and evaluation criteria widely used in literature in poultry farming were investigated comprehensively by taking into account live weight gains, egg weight and egg numbers. In live weight gains; Logistic, Gompertz, Gamma, Schnute, Brody, Richard, Negative Exponential, Von Bertalanffy, Cubic Piecewise and Cubic regression models were used for point distribution of 9 weeks live weight gains of Ross-308 broiler line, and in egg weight; Cubic, Gompertz, Logistic, Richard, Quadratic Linear, Orskov, Sigmoidal and Von Bertalanffy models were applied to the 20-week egg weight average of brown Lohmann layer hens and Gompertz, Logistic, Richard, Schunute, McNally, Gamma, Cubic Piecewise, Quadratic, Quadratic Linear, Quadratic Piecewise and Modified Compartmental models were applied to the 9-week egg yields of Japanese quail for egg number. In the comparison of the models created for live weight gains, egg weights and egg yields; mean square error, coefficient of determination, corrected coefficient of determination, Akaike Information Criterion, Corrected Akaike Information Criterion, Bayesian Information Criterion, Accuracy Factor, Bias Factor and Durbin-Watson autocorrelation values were taken into consideration. As a result of the study, in terms of live weight gain; the best model was the cubic piecewise regression model, in terms of egg yields; It was determined that the modified Compartmental model and the Logistic model gave better results than the others in terms of egg weight. The worst models were Brody in live weight gains, Quadratic Linear in egg yields and Von Bertalanffy model in egg weight. The results obtained in the study are in line with this and similar studies that have been studied before, but when criteria such as Akaike Information Criterion, Corrected Akaike Information Criterion, Bayesian Information Criterion, Accuracy Factor, Bias Factor and Durbin-Watson autocorrelation values, which are based on calculations over error terms, are taken into consideration, it is seen that some models reported as the best models are not actually that good models. In this study, all of these criteria, especially those based on calculations over error terms, were taken into consideration and it was revealed that these criteria support each other. In the theses or articles to be written from now on, a comprehensive literature review should be conducted on the subject, evaluation criteria based on error terms should be taken into consideration, the tendencies of the models in creating curves and their biological interpretability should be taken into consideration by the researcher.

In the growth curves obtained from the averages of 9-week live weight gains including exit weight of the commercial Ross-308 broiler line (50 units); mean square error, coefficient of determination, corrected coefficient of determination, Akaike Information Criterion, Corrected Akaike Information Criterion, Bayesian Information Criterion, Accuracy Factor, Bias Factor and Durbin-Watson autocorrelation value were obtained as in Table 5.

Growth curves obtained from Logistic, Gompertz, Gamma, Schnute, Brody, Richard, Negative Exponential, Von Bertalanffy, Cubic Piecewise and Cubic Regression models are also given in Figure 1.

In Table 5, it is seen that Brody and Negative Exponential models have the worst results, while the Cubic Piecewise regression model stands out among the best results, albeit by a small margin. The estimated curve of the best model, Cubic Piecewise regression, is given in Figure 2, and the estimated curve of the Brody model with the worst result is given in Figure 3.

In the curves obtained from the average of the 9-week (80) egg count of the Japanese quail (Coturnix japonica); the Mean Square Error, Coefficient of Determination, Corrected Coefficient of Determination, Akaike Information Criterion, Corrected Akaike Information Criterion, Bayesian Information Criterion, Accuracy Factor, Bias Factor and Durbin-Watson autocorrelation value were obtained as in Table 6.

The egg production numbers of the Gompertz, Logistic, Richard, Schunute, McNally, Gamma, Cubic Piecewise, Quadratic, Quadratic Linear, Quadratic Piecewise and Modified Compartmental models are also given in Figure 4.

Table 5. Model comparison criteria for growth curves

Models	MSE	CD	CCD	AF	BF	DW	AIC	CAIC	BIC
1	7357.1	0.9964	0.994	1.25	0.8	1.62	50.21	60.21	83.07
2	1892.8	0.9991	0.998	1.28	0.7	1.86	44.90	54.90	70.85
3	960.3	0.9995	0.999	1.10	0.9	1.71	42.25	52.25	64.74
4	490.8	0.9998	0.999	1.04	1.0	3.41	40.92	60.92	59.26
5	19818.3	0.9709	0.953	1.19	1.3	1.30	54.08	64.08	98.99
6	490.8	0.9998	0.999	1.04	1.0	3.41	40.92	60.92	59.26
7	32465.4	0.9812	0.975	1.48	1.3	0.88	54.62	59.42	95.62
8	3638	0.9982	0.997	1.15	0.8	1.65	47.46	57.46	76.73
9	1079	0.9989	0.997	1.06	1.0	2.06	41.12	50.12	61.34
10	866.6	0.9989	0.998	1.07	1.0	2.58	41.14	51.14	62.18

1. Logistic, 2.Gompertz, 3.Gamma, 4.Schnute, 5.Brody, 6.Richard, 7.Negative Exponential, 8.Von Bertalanffy, 9.Cubic Piecewise, 10.Cubic Regression, MSE= Mean Square Error, CD= Coefficient of Determination, CCD= Corrected Coefficient of Determination, AF= Accuracy Factor, BF= Bias Factor, DW= Durbin-Watson, AIC= Akaike Information Criterion, CAIC= Corrected Akaike Information Criterion, BIC= Bayesian Information Criterion.

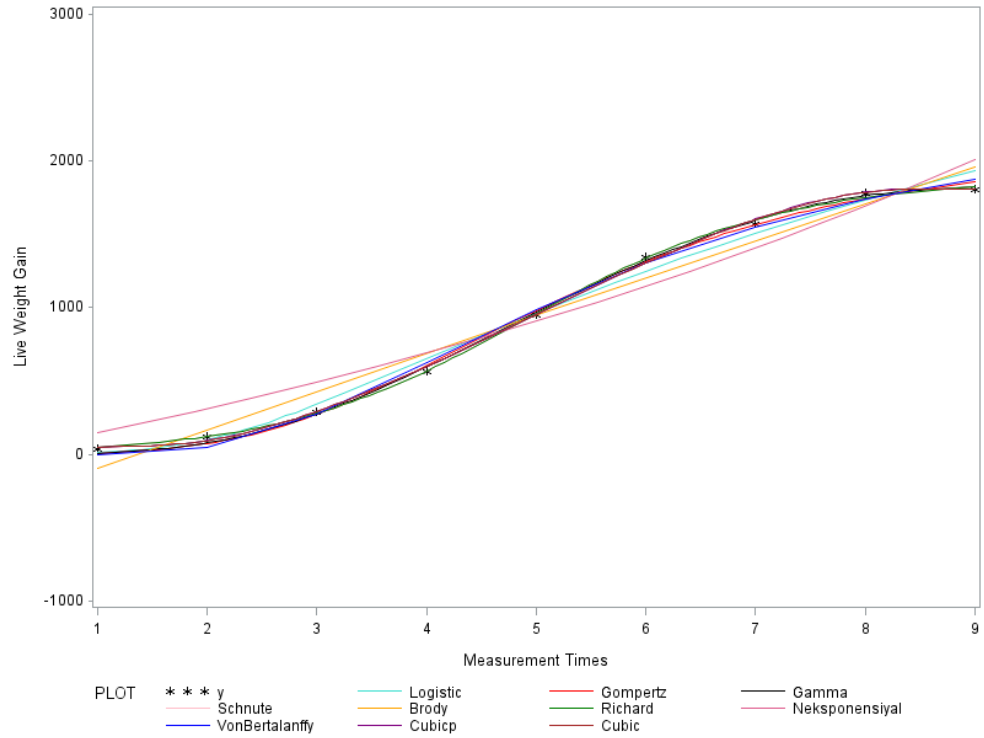

Figure 1. Curves of Logistic, Gompertz, Gamma, Schnute, Brody, Richard, Negative Exponential, Von Bertalanffy, Cubic Piecewise and Cubic Regression models for live weight gains.

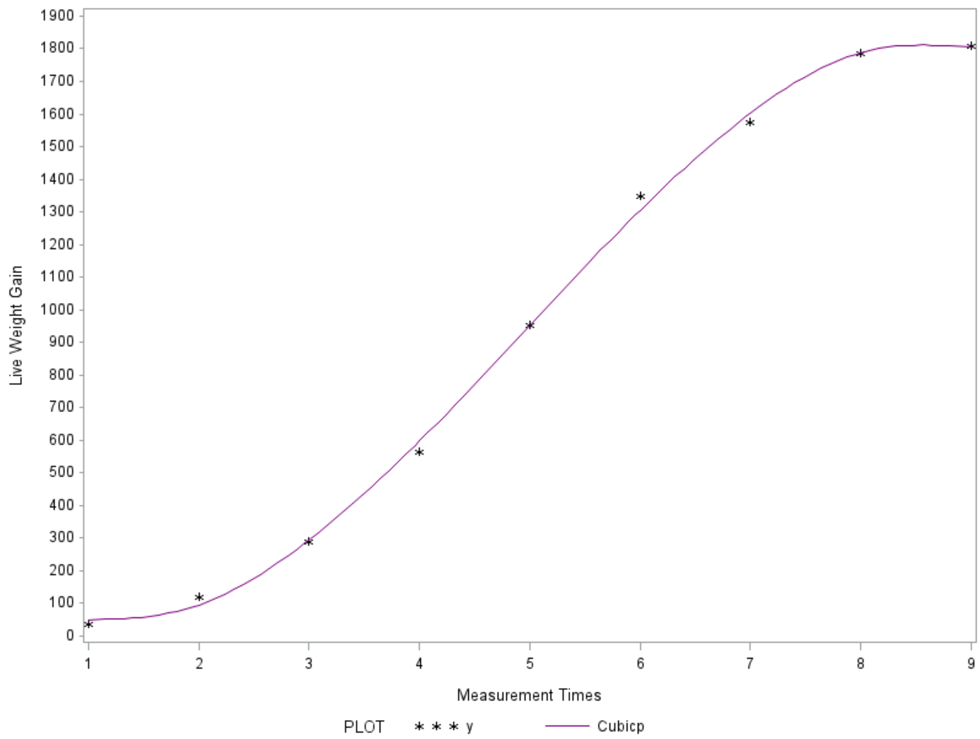

Figure 2. Growth curve of the Cubic Piecewise model with the best results in live weight gain.

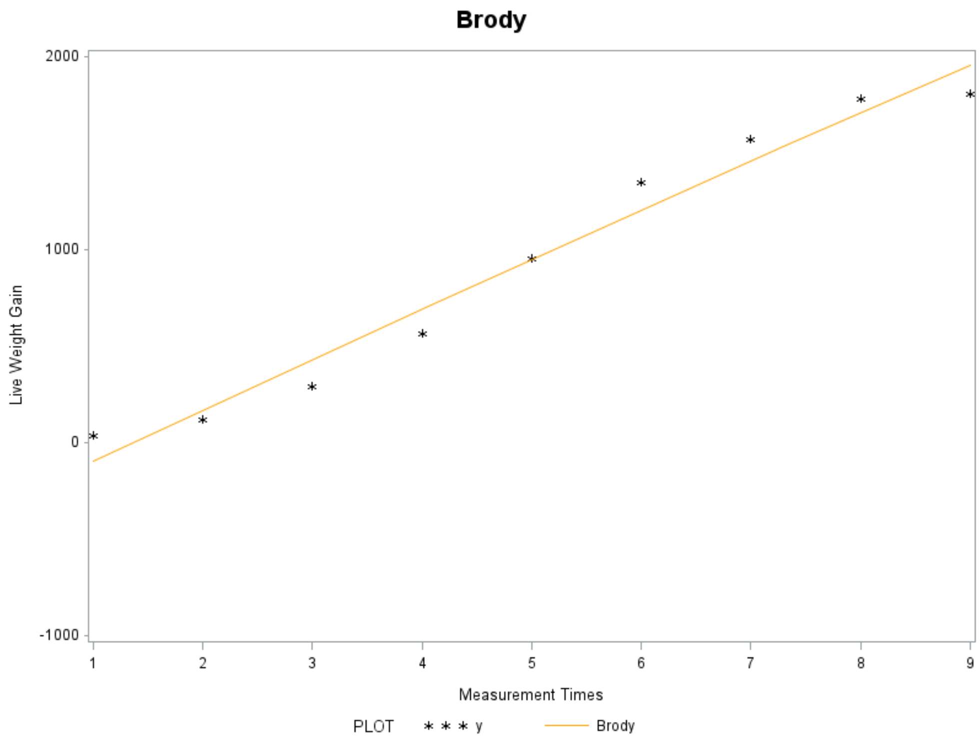

Figure 3. Growth curve of the Brody model with the worst results in live weight gain.

In Table 6, it is seen that the Quadratic Linear model has the worst results, while the Modified Compartmental model stands out among the best results, albeit by a small margin. The estimated curve of the Modified Compartmental model, which is the best model, is given in Figure 5, and the estimated curve of the Quadratic Linear model with the worst result is given in Figure 6.

In the egg yield curves obtained from the average egg weights of 20 different weeks from the 21st to the 40th week of the brown Lohmann layer hens (39 pieces); the mean square error, coefficient of determination, corrected coefficient of determination, Akaike Information Criterion, Corrected Akaike Information Criterion, Bayesian Information Criterion, Accuracy Factor, Bias Factor and Durbin-Watson autocorrelation value were obtained as in Table 7.

Table 6. Model comparison criteria for egg yield

Models	MSE	CD	CCD	AF	BF	DW	AIC	CAIC	BIC
1	30,0	0,993	0,988	1,11	0,98	1,498	28,70	38,709	33,553
2	20,83	0,995	0,992	1,09	0,98	1,495	27,28	37,284	30,271
3	36,33	0,991	0,986	1,13	0,98	1,535	29,45	39,458	35,277
4	16,80	0,997	0,993	1,05	1,00	1,150	27,73	47,730	28,891
5	14,77	0,996	0,993	1,07	1,00	1,936	27,94	47,942	29,378
6	63,00	0,984	0,975	1,14	1,03	1,117	31,60	41,609	40,231
7	6,750	0,989	0,977	1,02	1,00	2,577	23,29	43,294	18,676
8	21,66	0,946	0,928	1,09	0,99	1,865	25,43	30,237	28,427
9	24,50	0,939	0,902	1,10	0,99	1,657	27,91	37,918	31,731
10	26,00	0,946	0,913	1,09	0,99	1,867	27,43	37,437	30,624
11	10,18	0,998	0,996	1,06	0,98	2,073	25,77	45,775	24,390

1. Gompertz, 2.Logistic, 3.Richard, 4.Schunute, 5.McNally, 6.Gamma, 7.Cubic Piecewise, 8.Quadratic, 9.Quadratic Linear, 10.Quadratic Piecewise, 11.Modified Compartmental, MSE= Mean Square Error, CD= Coefficient of Determination, CCD= Corrected Coefficient of Determination, AF= Accuracy Factor, BF= Bias Factor, DW= Durbin-Watson, AIC= Akaike Information Criterion, CAIC= Corrected Akaike Information Criterion, BIC= Bayesian Information Criterion.

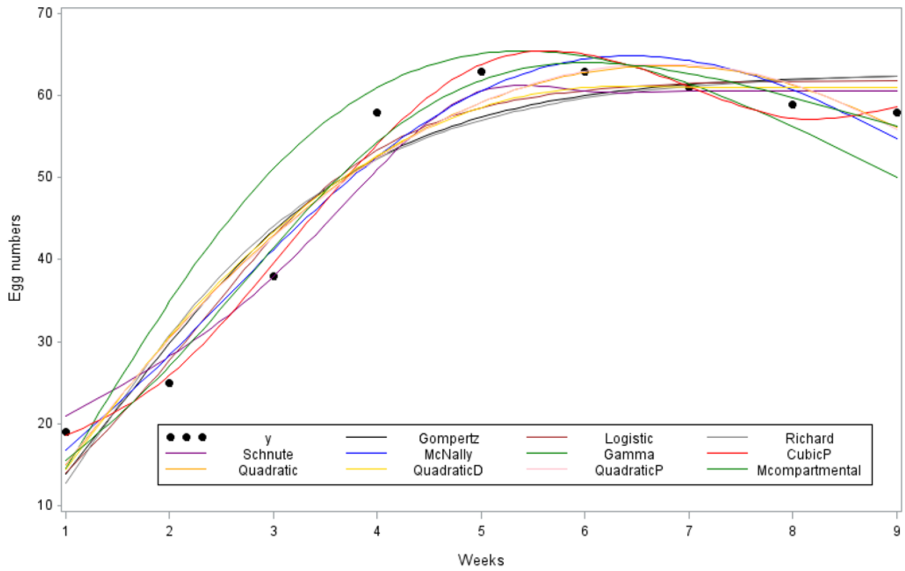

Figure 4. Curves of Gompertz, Logistic, Richard, Schunute, McNally, Gamma, Cubic Piecewise, Quadratic, Quadratic Linear, Quadratic Piecewise and Modified Compartmental models for egg yield.

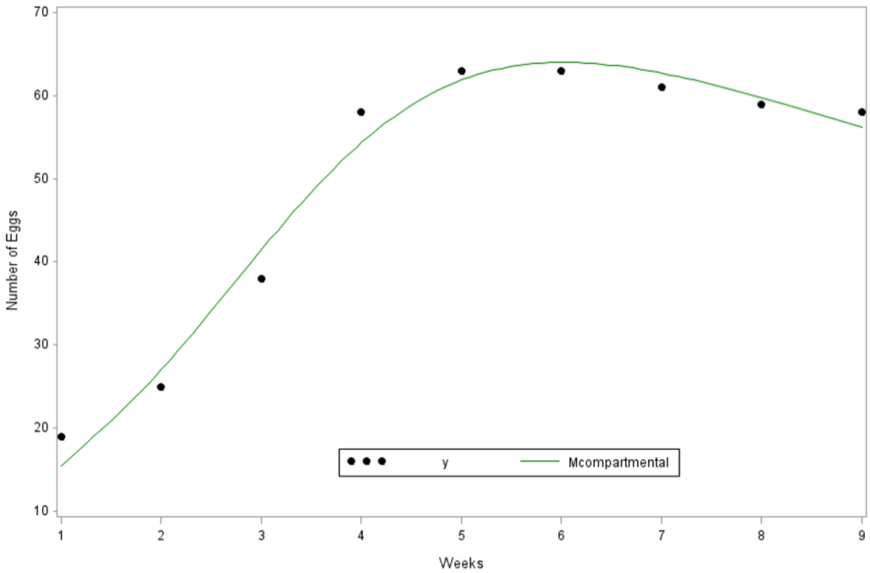

Figure 5. The yield curve of the modified compartmental model with the best results for egg yield.

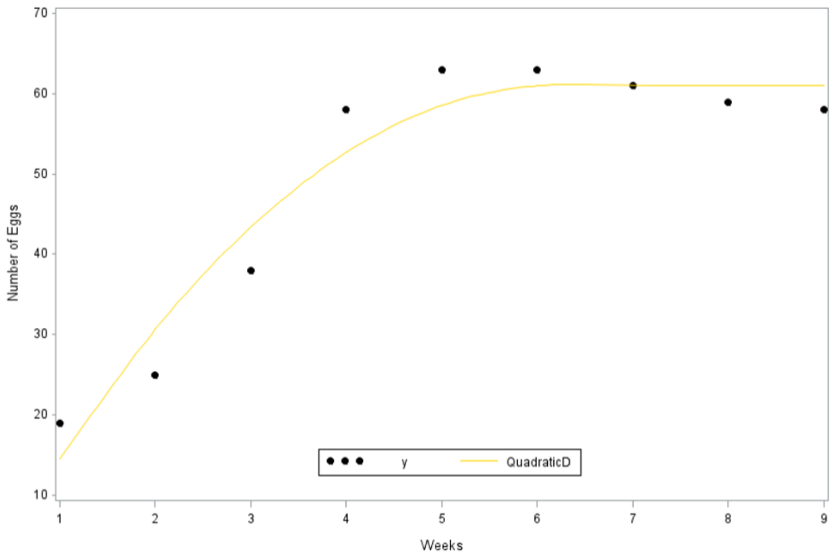

Figure 6. Efficiency curve of the Quadratic Linear model with the worst results for egg yield.

Table 7. Model comparison criteria for egg weights

Models	MSE	CD	CCD	AF	BF	DW	AIC	CAIC	BIC
1	1.225	0.9591	0.9445	1.01	1.00	3.097	31.26	37.72	13.28
2	1.801	0.9996	0.9995	1.01	1.00	1.907	31.70	34.36	17.50
3	1.466	0.9997	0.9996	1.01	1.00	2.272	29.91	32.57	13.38
4	1.489	0.9997	0.9996	1.01	1.00	2.230	30.04	32.71	13.70
5	1.522	0.9425	0.9317	1.01	1.00	2.179	30.23	32.90	14.13
6	2.289	0.9995	0.9994	1.01	1.00	1.589	33.78	36.44	22.29
7	1.499	0.9997	0.9996	1.01	1.00	2.214	30.10	32.77	13.83
8	7.009	0.7350	0.6854	1.01	1.00	2.561	43.50	46.168	44.680

1. Cubic, 2.Gompertz, 3.Logistic, 4.Richard, 5.Quadratic linear, 6.Orskov, 7.Sigmaidal, 8.Von Bertalanffy, MSE= Mean Square Error, CD= Coefficient of Determination, CCD= Corrected Coefficient of Determination, AF= Accuracy Factor, BF= Bias Factor, DW= Durbin-Watson, AIC= Akaike Information Criterion, CAIC= Corrected Akaike Information Criterion, BIC= Bayesian Information Criterion.

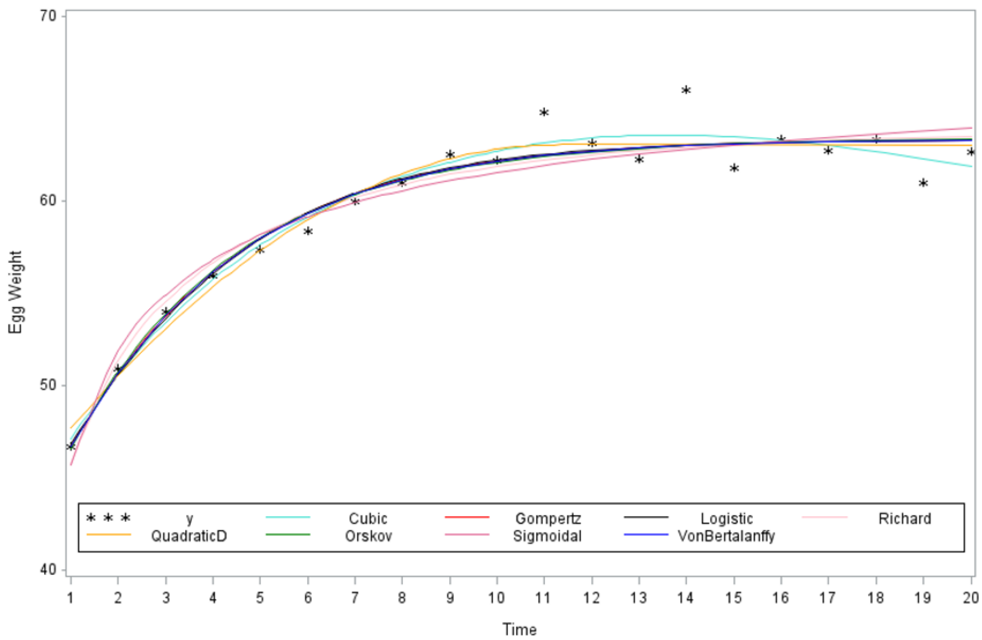

Figure 7. Curves of Cubic, Gompertz, logistic, Richard, Quadratic Linear, Orskov, Sigmoidal and Von Bertalanffy models for egg weights.

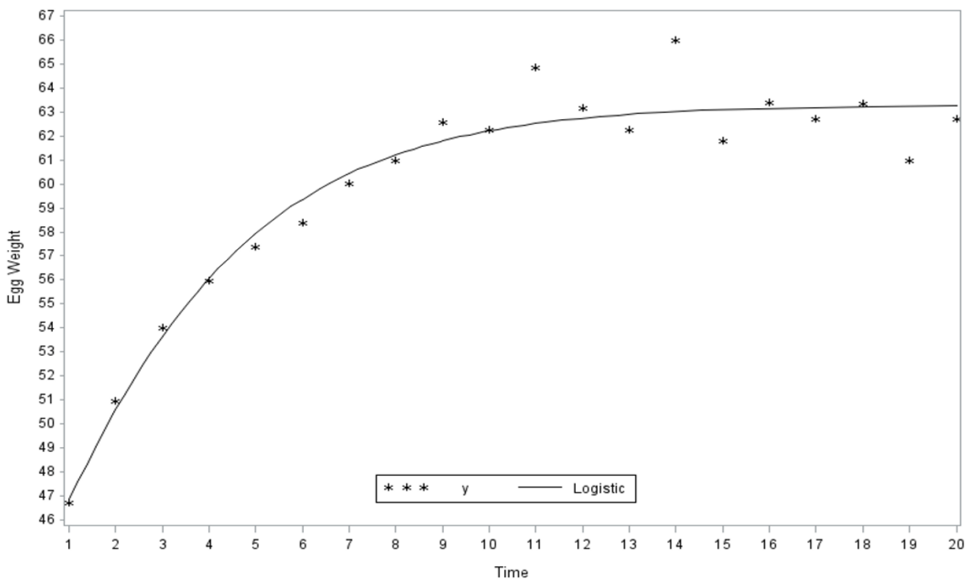

Figure 8. Yield curve of the Logistic model with the best results for egg weights.

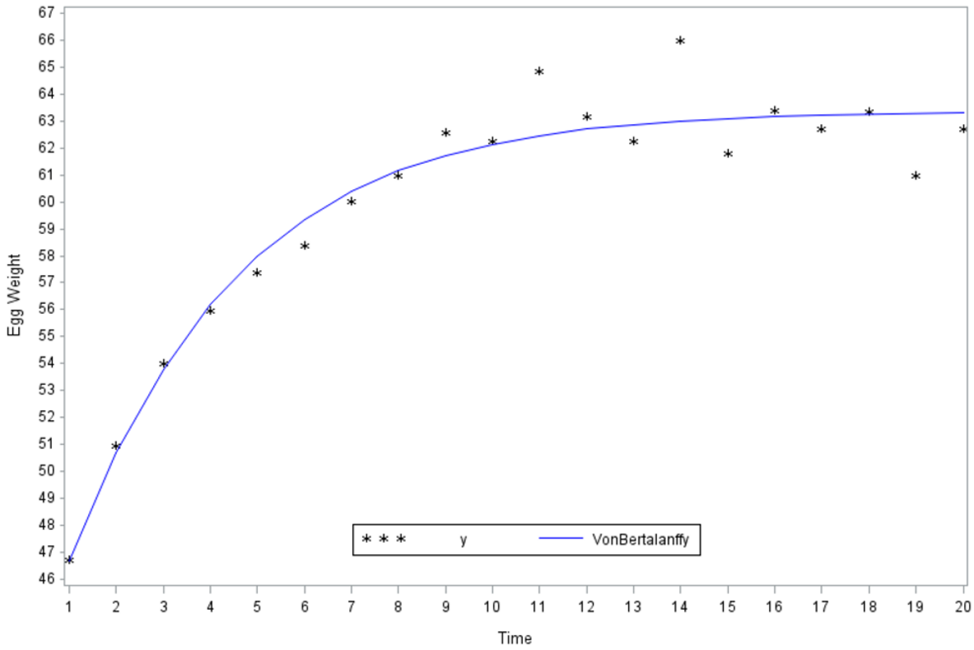

Figure 9. Yield curve of the Von Bertalanffy model with the worst results for egg weights.

The weight curves of the Cubic, Gompertz, Logistic, Richard, Quadratic Linear, Orskov, Sigmoidal and Von Bertalanffy models are given in Figure 7.

In Table 7, it is seen that the Von Bertalanffy model has the worst results, while the Logistic model stands out among the best results, albeit by a small margin. The estimated curve of the Logistic model, which is the best model, is given in Figure 8, and the estimated curve of the Von Bertalanffy model, which has the worst result, is given in Figure 9.

4. Conclusion

As a conclusion of the study, in terms of live weight gain; The Cubic Piecewise regression model is the best in terms of egg yields; It was determined that the Modified Compartmental model and the Logistic model gave better results than the others in terms of egg weight. The worst models are in live weight gains; Brody and egg yields; It was concluded that there was a Quadratic Linear and Von Bertalanffy model for egg weight.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	T.Ç.	İ.G.	E.Y.	M.Ş.
C	10	30	30	30
D	40	20	20	20
S				100
DCP	10	30	30	30
DAI		25	25	50
L	25	25	25	25
W	25	25	25	25
CR	25	25	25	25
SR	25	25	25	25
PM	25	25	25	25
FA	25	25	25	25

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required due to data was obtained from commercial companies. This study did not include any studies on animals or humans.

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References

Anadolu Yarka. 2024. URL: https://anadoluyarka.com.tr/gezen-tavuk-yumurtasi-uretim-ciftligi-nasil-olmali (access date: June 01, 2024).

Ahmadu A, Kabir M, Iyiola-Tunji AO, Akinsola OM, Igbadan H. 2017. Mathematical modelling of egg production curves of shikabrown parents. Nigerian Soc Anim Prod, 44(1): 61-75.

Anang A, Indrijani H. 2006. Mathematical models to describe egg production in laying hens J Ilmu Ternak, 6(2): 91-95.

Balcıoğlu MS, Kızılkaya K, Yolcu HI, Karabağ K. 2005. Analysis of growth characteristics in short-term divergently selected Japanese quail. South African J Anim Sci, 35(2): 83-89.

Cason JA, Britton WM. 1988. Comparison of compartmental and Adams-Bell models of poultry egg production. Poultry Sci, 67: 213-218.

Cason JA, Ware GO. 1990. Analysis of flock egg production curves using generalized growth functions. Poultry Sci, 69: 1064-1069.

Cason JA. 1990. Comparison of linear and curvilinear decreasing terms in logistic flock egg production models. Poultry Sci, 69: 1467-1470.

Congleton WR, Chamberlain JRJT, Muir FV, Hawes RO. 1980. Imitations of using the incomplete Gamma function to generate egg production curves. Poultry Sci, 60: 689-691.

Demir O, Macit M, Çelebi Ş, Esenbuğa N, Kaya H. 2017. Yumurtacı tavuk rasyonlarına değişik oranlarda katılan humat'ın yumurta verimine etkisinin Gamma ve Mcnally modelleri ile analizi. Alınteri J Agri Sci, 32(2): 81-86.

Erişir Z, Yıldız N, 2000. Bronz hindilerde damızlık yaşının kuluçka sonuçlarına etkileri. Yüzüncü Yıl Üniv Vet Fak Derg, 11(2): 87-89.

Faridi A, Mottaghitalab M, Rezaee F, France J. 2011. Narushin-Takma model as flexible alternatives for describing economic traits in broiler breeder flocks. Poultry Sci, 90: 507-515.

Gavora JS, Liljedah LE, Mcmillan LI, Ahlen K. 1982. Comparison of three mathematical models of egg production. British Poultry Sci, 23: 339-348.

İzgi V, Akkol S, Tekeli A. 2020. Genel doğrusal ve çok seviyeli doğrusal büyüme modelleri kullanılarak etlik piliçlerde büyümenin değerlendirilmesi. Türkiye Tar Araş Derg, 7(2): 163-171.

Kaplan S, Gürcan EK. 2018. Comparison of growth curves using non-linear regression function in Japanese quail. J Appl Anim Res, 46(1): 112-117.

Karadavut U, Taşkın A, Genç S. 2017. Farklı renkli ışıklarla zenginleştirilmiş kafeslerde yetiştirilen Japon bıldırcınlarında büyüme eğrisi modellerinin karşılaştırılması. Revista Brasil Zootec, 46: 839-846.

Keskin İ, Tozluca A, Genç A. 2002. Japon bıldırcınlarında (Coturnix japonica) büyüme eğrisi parametrelerinin yanlılığı. Hayv Araş Derg, 12(1): 55-58.

Miyoshi S, Luc MK, Kuchida K, Mitsumoto T. 1996. Application of nonlinear models to egg production curves in chickens. Jpn Poultry Sci, 33: 178-184.

Narahari D, Abdul Mujeer K, Maqbool A, Asha Rajini R, Sundararasu V. 1991. Factors influencing the hatching performance of duck eggs. British Poultry Sci, 32(2): 313-318.

Narinç D, Üçkardeş F, Aslan E. 2014. Egg production curve analyses in poultry science. World's Poultry Sci J, 70(4): 817-828.

Narushin VG, Takma C. 2003. Sigmoid model for the evaluation of growth and production curves in laying hens. Biosyst Eng, 84: 343-348.

Porter P, Kebreab E, Kuhi HD, Lopez S, Strathe AB, France J. 2010. Flexible alternatives to the Gompertz equation for describing growth with age in turkey hens. Poultry Sci, 89(2): 371-378.

Şentürk E, Aktan S. 2020. Relationships between egg weight and albumen height in quails and investigating the validity of the presumptions that is in commonly used quality measurements under diverse conditions. J Poultry Res, 17(2): 80-86.

Şekeroğlu A, Tahtalı Y, Sarıca M, Gülay MŞ, Abacı HS, Duman M. 2013. Comparison of growth curves of broiler under different stocking densities by Gompertz Model. Kafkas Univ Vet Fak Derg, 19(4): 669-672.

TKYÇ, 2020. 3rd Türkiye Goose Breeding Workshop and Goose Day Event. Kafkas University, Faculty of Veterinary Medicine Prof. Dr. Necdet Leloğlu Conference Hall. 17 February 2020.

Topal M, Bölükbaşı ŞC. 2008. Comparison of nonlinear growth curve models in broiler chickens. J Appl Anim Res, 34(2): 149-152.

Türker İ, Narinç D, Alkan S. 2017. Yerli ve yabancı yumurtacı hibrit sürülerde yumurta ağırlığının zamana bağlı değişiminin karşılaştırılması ve modellenmesi. Akad Zir Derg, 6(2): 169-176.

Yalçınöz E, Şahin M. 2020. Yumurtacı tavuklarda yumurta verim eğrilerinin modellenmesi. KSÜ Tar Doğa Derg, 23(5): 1373-1378.

Yavuz E, Abacı SH, Erensoy K, Şahin M. 2023. Modeling of individual egg weights of Lohmann-Brown layer hens. Turkish J Vet Anim Sci, 47(3): 229-335.

Yavuz E, Önem AB, Kaya F, Çanga D, Şahin M. 2018. Modeling of individual growth curves in Japanese Quails. BSJ Eng Sci, 2(1): 11-15.