Praca oryginalna *Original paper*

Modelling of body weight in meat-type white quails and dual-purpose quails with nonlinear growth curves

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Received 07.06.2023 *Accepted 18.04.2024*

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Summary

This study aimed to determine the best nonlinear growth model to explain variation in live weights of meat-type white quails (Texas White) and dual-purpose quails (Japanese quails). A total of 96 quail chicks were used, including 48 Texas White quails and 48 Japanese quails. The experiment was continued for 42 days, and the live weights of the quails were measured weekly. The data obtained were analyzed with different nonlinear growth models (Brody, Lundqvist-Korf, Gompertz and von Bertalanffy). The coefficient of determination (R^2), mean squared error (MSE), root mean squared error (RMSE), Akaike's information criterion (AIC) and Bayesian information criterion (BIC) were used as criteria for determining the model that best describes growth. Coefficients of determination (R^2) for meat-type male quails in Brody, Lundqvist-Korf, Gompertz, and von Bartalanffy models were 0.981, 0.994, 0.998 and 0.996, respectively, whereas MSE values in these models were 202.064, 47.36, 17.434 and 37.635, respectively. For meat-type female quails, coefficients of determination were 0.987, 0.998, 0.999 and 0.998, respectively, and MSE values were 196.705, 23.852, 23.038 and 29.913, respectively. In the same models, R^2 values for male dual-purpose quails were 0.981, 0.994, 0.999 and 0.997, respectively, and MSE values were 150.434, 34.222, 9.83 and 25.499, respectively. R^2 values for female dual-purpose quails were 0.988, 0.997, 0.999, 0.999, respectively, and MSE values were 133.779, 20.536, 3.388 and 16.043, respectively. Thus, the Gompertz model was the one that best described growth in meat-type white quails and dual-purpose quails.

Keywords: Texas White, Japanese quail, live weight, non-linear models

In recent years, quail production has become an important variety of livestock farming because of its advantages, such as the rapid growth, early slaughter age, high fertility rate, high viability, low space requirement and disease resistance of quails, as well as low investment cost and quick financial gain (25, 37). Although quails are bred for both eggs and meat, the development of meat-type quail genotypes has come to the fore because of the increasing demand for quail meat. Today, Japanese quails are more commonly produced for this purpose; their females are used for egg production and the males are bred for meat. However, male quail carcasses obtained in dual purpose breeding are low in weight, and consumers demand higher carcass weight.

Texas White and Pharaoh quails are the leading genotypes grown for meat in the world (5). Texas White is a variety of the *Coturnix* genotype, which has been developed for meat production and is widely bred for this purpose. In the breeding of breed, Japanese quail and English White quail were used. Texas White quail is a meat-type genotype, and its live weight is greater than it is for quails of other genotypes. It is reported that it can 370-435 g at the end of the 8-9 week rearing period. However, the fact that Texas White requires a longer fattening period to reach the desired live weight can be seen as a disadvantage (39). Japanese quails are widely used in production and biological research because of their early sexual maturity, rapid growth, low feed consumption, high fertility rate, short generation interval, dual purpose (egg and meat) and low space requirements (9, 11, 19, 24, 42).

It provides information on growth modelling in poultry species, optimal slaughter age, general management and health conditions, age at sexual maturity and the effects of genetic breeding. The deviation in the standard growth curve of the production flock can be used to determine and eliminate performance losses resulting from care and nutrition errors and deficiencies during the fattening period (2, 30). Growth in animals is generally defined as an increase in both the weight and volume of the body and internal organs over a certain period of time. Growth occurs as a whole of some morphological and physiological changes in the body (40, 41). Because these processes vary significantly from one bird species to another, there is a need for the analysis and modelling of growth for each species or genotype. The modelling of growth provides important information about the effects of genetic breeding, optimum slaughter age and management-health conditions of the flock. During the fattening period, growth curves can be used to determine the causes of performance decreases, which are generally caused by care and feeding (2, 30).

Growth curves are modelled mostly by nonlinear models. This is because estimates outside the dataset range can be made more reliably than linear models, and several parameters with biological interpretation can be used to explain the entire growth process (43). However, since nonlinear models are complex and more difficult to analyze than linear models, many different algorithms have been developed for the estimation of model parameters (44).

For this purpose, the Gompertz, Richards, Weibull, Brody, von Bertalanffy and hyperbolastic models have been developed, and these models are used to examine the growth patterns of Japanese quails. Some researchers have reported that the Gompertz model is the most appropriate model for quails (28, 35). The Gompertz, Richards, Weibull, Brody, von Bertalanffy and hyperbolastic models have also been used to examine the growth patterns of Japanese quails (1, 21, 33). Many researchers have reported that the Gompertz model is the best model for describing the growth (age and weight) of meat-type quails (10, 17, 26, 34).

The aim of this study was to estimate body weight growth parameters for males and females of meat-type white quail and dual-purpose quail using nonlinear growth models.

Material and methods

The animal material of the study consisted of 48 (24 male and 24 female) meat-type Texas White quail chicks and 48 (24 male and 24 female) dual-purpose Japanese quail chicks aged one day. The chicks were housed in a brooder for the first 2 weeks and then in 5-storey quail rearing cages. During the experiment, the temperature and humidity values in the room where the experiment was carried out were measured and recorded daily. The average temperature was 17.2°C, and the relative humidity was 43.5%. The room was naturally ventilated, and fluorescent lamps were used for lighting. The lighting program was 24 hours of light in the first 3 days, and 16 hours of light and 8 hours of darkness in the following period. The feeds used in the experiment were obtained from a commercial enterprise. The quails were fed with feed containing 24% crude protein and 2922 kcal/kg ME in the first 2 weeks, and 21% crude protein and 2850 kcal/kg ME in the next 4 weeks. The feed and water were provided *ad libitum*. The experiment was continued for 6 weeks, and the live weight values were recorded weekly. To help visualize nonlinear growth models, average values of live weight obtained from 48 Texas White quails and 48 Japanese quails at regular intervals between ages 0 and 6 weeks are calculated (Tab. 1).

Tab. 1. Mean live weight (g) and standard deviation of live weight by sex and age (weeks) in meat-type (Texas White) and dual-purpose quail

Age (weeks)	Texas White quails, g (n = 48)		Dual-purpose quails, g (n = 48)	
	Male (n = 24)	Female (n = 24)	Male (n = 24)	Female (n = 24)
0	8.22 ± 4.02	9.60 ± 4.07	7.38 ± 3.97	8.67 ± 3.04
1	21.52 ± 4.95	25.50 ± 5.24	20.29 ± 3.43	24.96 ± 4.85
2	55.82 ± 5.49	74.07 ± 5.59	52.42 ± 3.87	63.62 ± 5.19
3	100.80 ± 5.73	125.53 ± 5.83	98.21 ± 5.64	113.42 ± 5.28
4	158.22 ± 10.14	189.83 ± 10.68	139.75 ± 10.78	159.75 ± 11.27
5	193.73 ± 15.78	227.69 ± 18.96	172.13 ± 15.19	199.00 ± 20.09
6	219.46 ± 21.95	272.79 ± 26.66	186.71 ± 20.58	223.63 ± 25.97

Tab. 2. Nonlinear growth models

Model	Mathematical equation	t_i	y_i
Brody	$y_t = A \cdot (1 - \exp(-k \cdot t))$	–	–
Lundqvist-Korf	$y_t = A \cdot \exp(-k \cdot t^{-m})$	$\left(\frac{mk}{m+1}\right)^{1/m}$	$A \cdot \exp\left(\frac{k}{t^m}\right) \exp\left(-\frac{m+1}{m}\right)$
Gompertz	$y_t = A \cdot \exp(-b \cdot \exp(-k \cdot t))$	$\ln(b)/k$	A/e
von Bertalanffy	$y_t = A \cdot (1 - \exp(-k \cdot t))^3$	$\ln(3b/k)$	$8A/27$

Explanations: A – asymptotic weight or maximum growth response (g); b – biological constant; k – growth rate; t – age in days; t_i – age at the point of inflection; y_t – body weight (g) at age (t); y_i – weight at the point of inflection. The values of t_i and y_i cannot be calculated in the Brody model (7, 16).

Four nonlinear functions commonly used in the determination of growth curves in animal breeding studies were investigated. These functions are known as the Brody, Lundqvist-Korf, Gompertz and von Bertalanffy models. Mathematical expressions associated with these models and their points of inflection are presented in Table 2. Inflection parameter determines the proportion of the final size at which the inflection point occurs (15, 32). Parameter predictions for the models were performed with the SPSS software by the iterative Levenberg-Marquardt method (3, 29).

The Brody, Lundqvist-Korf and Gompertz models used in the study are presented in Table 2. In these models, y represents the dependent variable (growth variable indicating age), t represents the independent variable (age), whereas A, b, k and m represent the predicted parameters. Here, exp is the base of the natural logarithm, and ε is the error term.

Statistical criteria for model selection. The performance of the models was evaluated on the basis of the mean squared error (RMSE), coefficient of determination, R^2, Akaike's information criterion (AIC) and Bayes information criterion (BIC) (8, 28).

$$R^2 = 1 - \frac{(y_i - \hat{y})^2}{(y_i - \bar{y})^2}$$

$$RMSE = \sqrt{\frac{1}{n-k}\sum_{i=1}^{n}(y_i - \hat{y})^2}$$

$$AIC = nlog\left(\frac{SSE}{n}\right) + 2k$$

$$BIC = nlog\left(\frac{SSE}{n}\right) + k\log(n)$$

Here, SSE stands for residual sum of squares obtained from function fitting to the data.

Results and discussion

The goodness-of-fit statistics for the four growth models examined are shown in Table 3. The Gompertz model was found to provide the best fit for both Texas White males and females and dual-purpose males and females.

The results for the most suitable Gompertz growth model are summarized as follows.

For Texas White males, the constants of the Gompertz model $y_t = A \cdot \exp(-t \cdot \exp(-k \cdot t))$ that best fit the relevant actual data should be given first. For this model, when $y_0 = 8.22$ in the equation given for $t = 0$, $b = 4.296$ is obtained. When the same steps are repeated for the

Tab. 3. Goodness-of-fit statistics for different models

Texas White quail (Male)					
Models	R²	MSE	RMSE	AIC	BIC
Brody	0.981	202.064	14.215	22.138	18.674
Lundqvist-Korf	0.994	47.360	6.882	17.728	14.263
Gompertz	0.998	17.434	4.175	14.690	11.225
von Bertalanffy	0.996	37.635	6.135	17.029	13.564
Texas White quail (Female)					
Models	R²	MSE	RMSE	AIC	BIC
Brody	0.987	196.705	14.025	22.057	18.592
Lundqvist-Korf	0.998	23.852	4.884	15.643	12.178
Gompertz	0.999	23.038	4.800	15.537	12.072
von Bertalanffy	0.998	29.913	5.469	16.331	12.866
Dual-purpose quail (Male)					
Models	R²	MSE	RMSE	AIC	BIC
Brody	0.981	150.434	12.265	21.241	17.777
Lundqvist-Korf	0.994	34.222	5.850	16.740	13.275
Gompertz	0.999	9.830	3.135	12.948	9.483
von Bertalanffy	0.997	25.499	5.050	15.846	12.381
Dual-purpose (Female)					
Models	R²	MSE	RMSE	AIC	BIC
Brody	0.988	133.779	11.566	20.885	17.420
Lundqvist-Korf	0.997	20.536	4.532	15.188	11.723
Gompertz	0.999	3.388	1.841	9.710	6.245
von Bertalanffy	0.999	16.043	4.005	14.437	10.972

Explanations: R^2 – coefficient of determination; AIC – Akaike's information criterion, BIC – Bayesian information criterion; MSE – mean squared error; RMSE: root mean squared error

Tab. 4. Growth curve parameters for different models

Models	Genotype	Sex	$A \pm s_{\bar{A}}$	$b \pm s_{\bar{b}}$	$k \pm s_{\bar{k}}$	$a \pm s_{\bar{\alpha}}$
Brody	Texas	M	45949.546 ± 4389364.663	1 ± 0.016	0.001 ± 0.081	
		F	56401.667 ± 4427012.354	1 ± 0.012	0.001 ± 0.065	
	Japanese	M	12517.957 ± 366288.961	1 ± 0.008	0.003 ± 0.081	
		F	28018.97 ± 1254050.183	1 ± 0.006	0.001 ± 0.065	
Lundqvist-Korf	Texas	M	1025.393 ± 852.733		4.219 ± 0.565	0.569 ± 0.232
		F	2256.464 ± 1785.344		4.589 ± 0.653	0.433 ± 0.129
	Japanese	M	547.284 ± 272.639		3.637 ± 0.303	0.694 ± 0.225
		F	1116.351 ± 650.433		3.995 ± 0.446	0.514 ± 0.142
Gompertz	Texas	M	273.59 ± 14.976	4.296 ± 0.339	0.502 ± 0.045	
		F	350.159 ± 20.825	3.930 ± 0.249	0.454 ± 0.04	
	Japanese	M	219.788 ± 8.301	4.247 ± 0.308	0.557 ± 0.04	
		F	275.272 ± 6.287	3.882 ± 0.119	0.492 ± 0.019	
von Bertalanffy	Texas	M	309.657 ± 36.006	0.863 ± 0.075	0.352 ± 0.06	
		F	409.207 ± 41.446	0.804 ± 0.041	0.308 ± 0.041	
	Japanese	M	238.563 ± 19.605	0.878 ± 0.081	0.415 ± 0.06	
		F	311.15 ± 22.259	0.803 ± 0.039	0.346 ± 0.037	

Explanations: A, b, k – model parameters; A – asymptotic weight; b – biological constant; k – growth rate; y_i – weight at the point of inflection; t_i – age at the point of inflection; M – male; F – female *t* variable, which indicates age, the *k* parameter of the exponentially decreasing growth rate y_t was found to be $k = 0.502$. In this case, the estimated Gompertz model is $y_t = 273.59 \cdot \exp(-4.296 \cdot (-0.502t))$. In Texas White females, body weight data were analysed and the most appropriate growth model was the Gompertz model $y_t = A \cdot \exp(-t \cdot \exp(-k \cdot t))$. By substituting $y_0 = 9.6$ in the equation for $t = 0$, one obtains $b = 3.93$. When the same steps are repeated for the variable *t*, which represents age, the *k* parameter of the exponentially decreasing growth rate y_t is found as $k = 0.454$. As a result, the Gompertz model is obtained as $y_t = 350.159 \cdot \exp(-3.93 \cdot (-0.454t))$.

For the Gompertz model $y_t = A \cdot \exp(-t \cdot \exp(-k \cdot t))$ for dual-purpose males, the most appropriate constants determined by analysing the data should be given first. If the value $y_0 = 7.38$ obtained for $t = 0$ is substituted in the equation, the value of $b = 4.247$ is found. When the same steps are repeated for the age variable *t*, the *k* parameter of the exponentially decreasing growth rate y_t is determined as $k = 0.557$. According to these results, a Gompertz model was estimated as $y_t = 219.788 \cdot \exp(-4.247 \cdot (-0.557t))$. For dual-purpose females, the constants of the Gompertz model $y_t = A \cdot \exp(-t \cdot \exp(-k \cdot t))$ that best fit the data should be selected first. When $y_0 = 8.67$ is substituted in the equation for $t = 0$, $b = 3.882$ is found. When the same steps are repeated for the variable *t*, which represents age, the *k* parameter of the exponentially decreasing growth rate y_t is obtained as $k = 0.492$. Accordingly, the Gompertz model was estimated as $y_t = 275.272 \cdot \exp(-3,882 \cdot (-0.492t))$. The results for all models are given in Table 4.

The inflection point results of the nonlinear models are presented in Table 5.

In the Gompertz model, for male and female Texas White quails, the t_i parameter, describing the inflection point age, was 2.90 and 3.02 weeks, respectively, while the y_i parameter, indicating the inflection point weight, was found to be 100.648 and 128.816 g, respectively. Likewise, the inflection point age t_i of male and female dual-purpose quails was determined as 2.60 and 2.76 weeks, respectively, while the inflection point weight y_i was calculated as 80.855 and 101.267 g, respectively. In male Texas White quails, t_i values obtained in Lundqvist-Korf, Gompertz and von Bertalanffy models were 2.11, 2.90 and 2 weeks, respectively, while y_i values were 179.41, 100.648 and 91.75 g, respectively. In female Texas White quails, t_i values obtained in Lundqvist-Korf, Gompertz and von Bertalanffy models were 2.13, 3.02 and 2.06 weeks, respectively, while y_i values were 123.983, 128.816 and 121.247 g, respectively. Similarly, as seen in Table 5, in male and female dual-purpose quails, t_i values were 1.78, 1.81;

Tab. 5. Age (t_i) and weight (y_i) at the point of inflection in different models

Models	Genotype	Sex	t_i	y_i
Brody	Texas White	Male	–	–
		Female	–	–
	Dual-purpose	Male	–	–
		Female	–	–
Lundqvist-Korf	Texas White	Male	2.11	179.410
		Female	2.13	123.983
	Dual-purpose	Male	1.78	217.954
		Female	1.81	158.792
Gompertz	Texas White	Male	2.90	100.648
		Female	3.02	128.816
	Dual-purpose	Male	2.60	80.855
		Female	2.76	101.267
von Bertalanffy	Texas White	Male	2.00	91.750
		Female	2.06	121.247
	Dual-purpose	Male	1.85	70.685
		Female	1.94	92.193

Tab. 6. Summary for Brody, Lundqvist-Korf, Gompertz, and von Bertalanffy growth models for Texas White males

Models	Source of variation	Sum of squares	Degrees of freedom	Mean squares	R^2
Brody	Regression	123726.508	3	41242.169	0.981
	Residual	808.256	4	202.064	
	General	124534.764	7		
Lundqvist-Korf	Regression	124277.757	3	41425.919	0.994
	Residual	189.439	4	47.360	
	General	124467.196	7		
Gompertz	Regression	124465.027	3	41488.342	0.998
	Residual	69.737	4	17.434	
	General	124534.764	7		
von Bertalanffy	Regression	124384.224	3	41461.408	0.996
	Residual	150.540	4	37.635	
	General	124534.764	7		

Tab. 7. Summary for Brody, Lundqvist-Korf, Gompertz, and von Bertalanffy growth models for Texas females

Models	Source of variation	Sum of squares	Degrees of freedom	Mean squares	R^2
Brody	Regression	183492.285	3	61164.095	0.987
	Residual	786.820	4	196.705	
	General	184279.105	7		
Lundqvist-Korf	Regression	184091.538	3	61363.846	0.998
	Residual	95.407	4	23.852	
	General	184186.945	7		
Gompertz	Regression	184186.952	3	61395.651	0.999
	Residual	92.153	4	23.038	
	General	184279.105	7		
von Bertalanffy	Regression	184159.453	3	61386.484	0.998
	Residual	119.652	4	29.913	
	General	184279.105	7		

Tab. 8. Summary for Brody, Lundqvist-Korf, Gompertz, and von Bertalanffy growth models for dual-purpose males

Models	Source of variation	Sum of squares	Degrees of freedom	Mean squares	R^2
Brody	Regression	96276.896	3	32092.299	0.981
	Residual	601.736	4	150.434	
	General	96878.633	7		
Lundqvist-Korf	Regression	96687.278	3	32229.093	0.994
	Residual	136.890	4	34.222	
	General	96824.168	7		
Gompertz	Regression	96839.312	3	32279.771	0.999
	Residual	39.321	4	9.830	
	General	96878.633	7		
von Bertalanffy	Regression	96776.637	3	32258.879	0.997
	Residual	101.995	4	25.499	
	General	96878.633	7		

Tab. 9. Summary for Brody, Lundqvist-Korf, Gompertz, and von Bertalanffy growth models for dual-purpose females

Models	Source of variation	Sum of squares	Degrees of freedom	Mean squares	R^2
Brody	Regression	132206.095	3	44068.698	0.988
	Residual	535.116	4	133.779	
	General	132741.211	7		
Lundqvist-Korf	Regression	132583.898	3	44194.633	0.997
	Residual	82.144	4	20.536	
	General	132666.042	7		
Gompertz	Regression	132727.657	3	44242.552	0.9999
	Residual	13.554	4	3.388	
	General	132741.211	7		
von Bertalanffy	Regression	132677.041	3	44225.680	0.999
	Residual	64.170	4	16.043	
	General	132741.211	7		

2.60, 2.76 and 1.85, 1.94 in Lundqvist-Korf, Gompertz and von Bertalanffy models, while y_i values were calculated as 217.954, 158.792; 80.855, 101.267 and 70.685, 92.193, respectively. ANOVA results for the Brody, Lundqvist-Korf, Gompertz and von Bertalanffy models applied to Texas White males are given in Table 6.

ANOVA results for the Brody, Lundqvist-Korf, Gompertz and von Bertalanffy models applied to Texas White females are given in Table 7.

ANOVA results for the Brody, Lundqvist-Korf, Gompertz and von Bertalanffy models applied to dual-purpose males are given in Table 8.

ANOVA results for the Brody, Lundqvist-Korf, Gompertz and von Bertalanffy models applied to dual-purpose females are given in Table 9.

In these models, obtaining the initial values of parameters, in other words, determining the initial value of the asymptotic size, is of great importance. In the present study, higher but closest to the observed highest average length has been considered to determine the initial value.

The most important values to be checked in the ANOVA table, derived during the modelling process of determining the above mentioned values, are R^2 and MSE (mean squared error (residual)), since MSE is a good measure to compare the errors, whereas R^2 value represents the proportion of the variance in the dependent variable which is explained by the model. Thus, a model with the highest coefficient of determination and the lowest MSE is considered as the best model. Tables 6-9 present the R^2 and MSE values for the models used in this study.

As seen in Tables 6-9, R^2 values are significantly high for all the models, indicating that the models are highly explained by the parameters. In terms of the R^2 criterion, the von Bertalanffy model is the second best model to explain the live weight after the Gompetz model. The growth curves obtained from regression analyses using the Brody, Lundqvist-Korf, Gompertz and von Bertalanffy models are presented in Figure 1 for Texas White males, in Figure 2 for Texas White females, in Figure 3 for dual-purpose males and in Figure 4 for dual-purpose females.

The predicted growth curves for male and female Texas White and Japanese quails obtained by using the four different growth curve models are shown in Figures 1-4. As can be seen in these figures, the Gompertz, Lundqvist-Korf, and von Bertalanffy models were in better agreement with the actual data than the Brody model was. In the Brody model, the initial live weight had different values for both male and female White Texas and Japanese quails.

Özkan M, and Kocabaş Z. (31) used the logistic, Gompertz and Bertalanffy models in their study on growth curves for quails and found the logistics model more suitable for both sexes than the other models.

Comparing the goodness of fit of various growth functions to quail data, numerous studies have shown that Gompertz functions accurately defined the age-weight relationship for dual-purpose quails (2, 4, 23, 36). Narinç D. et al. (30) applied Gompertz, Richards, logistic, Bertalanffy, Brody, negative exponential, Morgan-Mercer Flodin and hyperbolastic models for production of egg in quails. The most suitable among them proved to be the Gompertz model, with a value of $R^2 = 0.99998$. In the same study, the Gompertz model had a higher fit value. In a study by Faraji-Arough H. et al. (12), the Gompertz model was the best function to describe the growth curve for Italian Spotted and Wild quails, but the best model identified for Tuxedo, Scarlett, English White, White button and A&M Texas quails was the logistic growth model. The asymptotic weight parameter estimates obtained by fitting the Gompertz function are 219.788 for male dual-purpose quails and

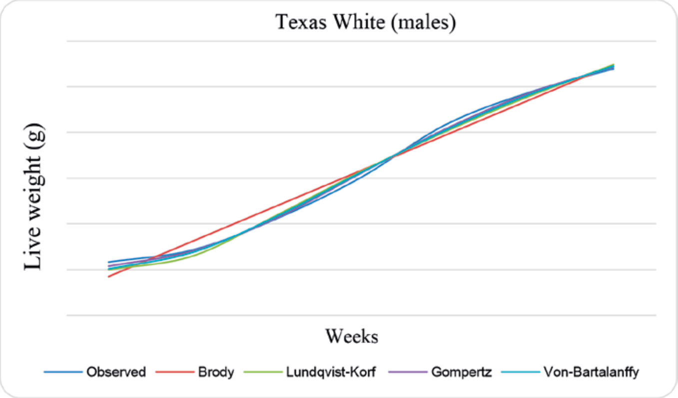

Fig. 1. Male Texas White quail's growth kinetics fitted to the different models

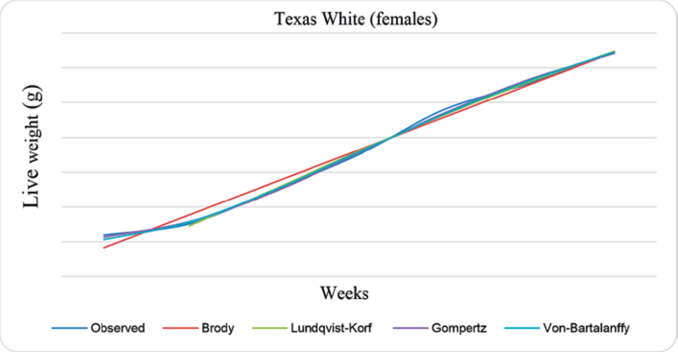

Fig. 2. Female Texas White quail's growth kinetics fitted to the different models

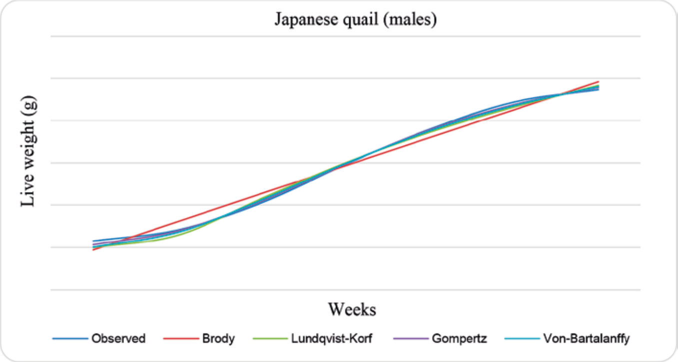

Fig. 3. Male Japanese quail's growth kinetics fitted to the different models

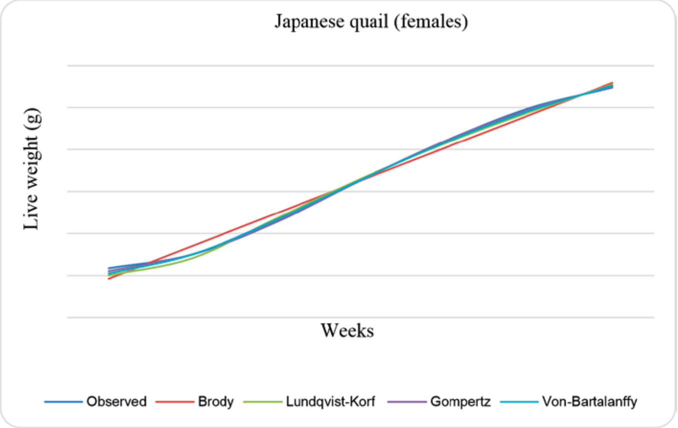

Fig. 4. Female Japanese quail's growth kinetics fitted to the different models

275.272 for female dual-purpose quails. These values of the *A* parameter are higher than those reported by Akbaş Y. and Oğuz I. (2), Alkan S. et al. (4) and Kızılkaya K. et al. (22). The differences in the parameter estimates of growth functions in different studies may result from differences in breeding, genotype, and environmental conditions.

In a study by Raji A.O. et al. (33), the asymptote regression, exponential, Gompertz, logistic, monomolecular, Richards, and Weibull models were compared to describe the growth of 300 quails from birth to 20 weeks of age. According to the criteria of goodness of fit, the Weibull model, with the most appropriate coefficient of determination (R^2), mean squared error, standard deviation and Akaike's information criterion values, best described body weight data for Japanese quails (33). It is different from the results obtained in this study. In a study by Haqani M. I. et al. (18), differences between the growth patterns of large and normal-sized Japanese quail strains and their F1 progeny were evaluated by fitting growth parameter values to nonlinear regression growth models, such as the Weibull, logistic, Gompertz, Richards, and Brody models. The results proved that the Richards and Gompertz models could best define the growth characteristics of both large and normal-sized quails. In a study by Kaplan S. and Gürcan E. K. (20), the Richards, Janoschek, Levakovich, Gompertz, logistic and von Bertalanffy models were tested to describe the growth of Japanese quails. In nonlinear growth models describing both male and female quails, R^2 values were found to be between 0.9991 and 0.9998, whereas MSE values ranged from 3.62 to 23.01. In the present study, MSE values for the Gompertz model, which was found most suitable for Japanese quails, were different, while R^2 values for that model were very similar. In another study, body weights of Japanese quails were examined with the Gompertz, Richards and logistic models of growth, and it was found that the Gompertz and Richards models yielded better results according to AIC (13). The results for the criterion of fit with the model and the goodness of fit agree with the results of the present study.

In this study, 4 different growth curves were analyzed using the live weights of heavy type (meat-type) Texas White and dual-purpose Japanese quails from one day to 6 weeks of age. According to R^2, MSE, RMSE, AIC and BIC statistics, the Gompertz model was the mathematical model that best fitted the growth curves for males and females of Texas White and Japanese quails. According to the Gompertz model, the adult body weight (*A*) of quails at 6 weeks of age was 219.788 g and 275.272 g for male and female Japanese quails, respectively, and 273.59 g and 350.159 g for male and female Texas White quails, respectively. Adult growth rate (*k*) was found to be 0.557 and 0.492 for male and female Japanese quails, respectively, and 0.502 and 0.454 for male and female Texas White quails, respectively. The age (weeks) at which body weight gain was the highest was 2.60 and 2.76 for male and female Japanese quail, respectively, and 2.90 and 3.02 for Texas White quail, respectively. That is, the period with the highest body weight gain was approximately the third week. At the end of this period, live weights were 80.855 g and 101.267 g for male and female Japanese quails, respectively, and 100.648 g and 128.816 g for male and female Texas White quails, respectively.

It was observed that the Texas White quails (meat-type) developed faster and had a higher body weight than the dual-purpose quails, and it would be advisable to consider the results obtained here in a selection based on growth curves. The small size of the carcass of quails limits consumer demand for them. Therefore, meat-type quails with heavier carcasses should be preferred.

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