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Growth Curve Estimation for Male Pekin Ducks Raised in Türkiye

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***Abstract*:** *As in all livestock species, growth is the most important phenotype. Generally Gompertz and Richars models were preferred in poultry growth by the several researchers In this study we compared Brody, Gompertz, Logistic, Gamma, Schnute, Richard, Negative Exponential, and Bertalanffy models on body weight of male Pekin ducks raised in Türkiye using 110 male animals for 10 weeks of age. According to the goodness of fit criteria such as Mean Square Error, coefficient of determination, adjusted coefficient of determination, Accuracy Factor, Bias Factor, Durbin-Watson value, Akaike Information Criteria, and Bayesian Information Criteria, and interpretation of the growth curves and clustering hierarchical 3-D dendrograms the Schnute model was found to be suggestible model for 70 days growth for male Pekin ducks.*

Keywords: *Pekin Duck, Growth Curve, 3-D Clustering, Goodness of Fit, Schnute*

1. Introduction

The poultry industry in order to meet up with the world's poultry meat consumption rate need to produce birds with fast growth rate and high carcass yield in a short time [1]. Animal production has a high importance in Türkiye's economic structure and it is important for a balanced human nutrition [2,3]. To meet the requirement of protein of animal origin from an increasing population, the production of poultry other than chicken, such as turkeys, ducks and geese, is increasing [4]. The global production of waterfowl is a rapidly growing industry. In waterfowl production primarily animal is duck and Pekin duck (*Anas platyrhynchos*) is predominate duck worldwide [5]. The population of ducks in the world was esteemed as 1.17 million and it was produced approximately 3235471 tons of duck meat in 2019 [6]. As of 2017, duck existence in Türkiye is 492 thousand.

The animals have got usually a fixed fattening period or the predetermined slaughter weight of fattening, unpredicted individual differences in these animals may have an impact on growth and fattening performances. The fattening performance of the animal is affected by various internal and external factors. These internal factors may be genotype, gender, age etc., as well as external factors such as feed, water, climate, and management etc. [7]. As well-known from the results of previous researches, male ducks have a faster growth rate, better feed efficiency, and lower carcass fat when compared to female ducks [8]. Growth is an increase in size (height, length, weight) with advancing age and growth curve models provide a visual assessment for growth as a function of time. The models can be used for predicting body weight for a specific age from a dimensional perspective [9,10].

The methods for growth curves describe a sigmoidal shape of measurements against time, often using three and four parameters [11]. Generally asymptotic and parabolic functions are used to model data from agriculture.

If the dependent variable tends to approach the maximum point according to the levels of the independent variable, it is shows an asymptotic curve. However, if the dependent variable tends to decrease after it has reached the maximum, it shows a parabolic curve. Growth is generally shows asymptotic structure in animals and plants [12]. Growth curves illustrating changes on the size or weight and allow the data to be summarized by a few number of parameters known as growth curve parameters [13].

Generally Gompertz and Richards models were preferred for poultry growth by the several researchers [14-17]. In this study we aimed to compare Brody, Gompertz, Logistic, Gamma, Schnute, Richards, Negative Exponential, and Bertalanffy models on body weight of Pekin ducks raised in Türkiye using 110 male animals for 10 weeks of age.

2. Material Methods

The study was conducted at the Ondokuz Mayıs University Agricultural Faculty's Farm. The study used Pekin ducks, bought from a commercial hatchery, as animal material. All ducklings were transferred to a production house at daily age. Each animal was sexed from the cloaca, the wing numbers were attached to each individual. Ducks were reared with a feeding program to standard commercial practices. Ducks were fed a diet containing 22% crude protein (CP) and 2950 kcal/kg ME for the first four weeks and 16% CP and 3100 kcal/kg ME from the 5th to 10th weeks. Sawdust + straw were used as bedding material. The lighting schedule was 24 h light (L):0 h dark (D) during the first week, 22L: 2D for 2-4 weeks and 18L: 6D for 5-10 weeks. The temperature was between 28-35 °C during the first week and maintained between 20-32 °C from the 2nd week onwards [6]. Ducks were reared at a stocking density of 5 birds/m2. The experiment was completed with 110 male Pekin ducks.

For each gender groups Brody, Gompertz, Logistic, Gamma, Schnute, Richards, Negative Exponential, and Bertalanffy models were fitted to the data of the average growth curve and for the individual growth curves. Parameters were estimated using NLREG. The convergence criterion was used as 1.0E-10. SPSS software was used to analyze the data. To compare the fit, Mean Square Error (MSE), coefficient of determination (R^2), adjusted coefficient of determination (R^2adj), Accuracy Factor (AF), Bias Factor (BF), Durbin-Watson value (DW), Akaike Information Criteria (AIC), and Bayesian Information Criteria (BIC) were used as goodness of fit criteria (Table 1). Regardless of which of these criteria is used, it would be appropriate to take into account the Durbin-Watson value, which reveals the relationship of error terms, in model comparison [10].

TABLE I: Comparison Criteria

Criteria	Function
Mean Square Error (MSE)	SSE/SDF
Coefficient of determination (R^2)	1 − (SSE/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)	$\frac{\sum_{i=2}^{n}(e_1-e_2)^2}{\sum_{i=1}^{n}e_i^2}$
Akaike Information Criteria (AIC)	$nxln\left(\frac{SSE}{n}\right)+2k$
Adjusted Akaike Information Criteria (AICc)	$nxln\left(\frac{SSE}{n}\right)+\left(\frac{n(n+p)}{n-p-2}\right)$
Bayesian Information Criteria (BIC)	$nxln\left(\frac{SSE}{n}\right)+kln(n)$

SSE: Sum of Square Error, SDF: Degree of Freedom for Error, SST: Sum of Square Total, n: sample size, p: number of independent parameters, $\hat{Y}_i$: estimated value, Y_i: observed value, e_i: error term, k: number of parameters.

Brody, Gompertz, Logistic, Gamma, Schnute, Richards, Negative Exponential, and Bertalanffy model functions and age and weight of inflection points (IPA and IPW) of the models were given in Table 2 [12,18].

TABLE II: Function and inflection points for Brody, Gompertz, Logistic, Gamma, Schnute, Richards, Negative Exponential, and Bertalanffy models

Model	Function
Brody	$Y_t = \beta_0(1-\beta_1\exp(-\beta_2 t))$
Gompertz	$Y_t = \beta_0\exp(-\beta_1\exp(-\beta_2 t))$
Logistic	$Y_t = \beta_0(1+\beta_1\exp(-\beta_2 t))^{-1}$
Gamma	$Y_t = \beta_0{}^{\beta_1}(e^{-\beta_2 t})$
Schnute	$Yt = Z2 * Z3$ $Z1 = \beta 4(\beta 2) - \beta 3(\beta 2)$, $Z2 = \beta 3(\beta 2 + Z1)$, $Z3 = (1-e(-\beta 1\ (X-X1)/\ (1-e(-\beta 1\ (X2-X1))(1/\beta 2)$
Richards	$Y_t = \beta_0(1+\beta_1\exp(-\beta_2 t))^{\beta_3}$
Negative Exponential	$Y_t = \beta_0 - (\beta_0 e^{-\beta_2 t})$
Bertalanffy	$Y_t = \beta_0(1-\beta_1\exp(-\beta_2 t))^3$

Y_t: weight at time t, β_0: Asymptotic or predicted final mature weight, β_1: Scaling parameter (constant of integration), β_2: Instantaneous growth rate (per time unit) parameter, β_3 is scalar for included model, t: age at the inflection point, e: 2.718281, IPA: inflection point age, IPW: inflection point weight.

Principal component analysis (PCA) was used to identify effective goodness-of-fit criteria for methods and 3-D hierarchical cluster analysis was applied to cluster the examined methods using R software with FactoMineR and factoextra packages [19].

3. Results

Estimates of parameters and goodness-of-fit criteria are given in Table 3 and Table 4 for Brody, Gompertz, Logistic, Gamma, Schnute, Richards, Negative Exponential, and Bertalanffy models. For Gamma, Schnute, Brody and Negative Exponential models IPA and IPW were not estimated because a greater than zero second derivation of the functions could not be satisfied for any value of time (KOYA and GOSHU, 2013).

TABLE III: Parameter estimates for the growth models (Mean ± StdError)

Model	β_0	β_1	β_2	β_3
Brody	71.480 ±2.4481	142.086 ±7.071	0.018 ±0.0004	
Gompertz	4709.796 ±61.133	6.383 ±0.0905	0.059 ±0.0008	
Logistic	9.193 ±1.1403	2.550 ±0.0335	0.039 ±0.0007	
Gamma	0.085 ±0.0022	-0.540 ±0.0355	61.971 ±2.6793	154.487 ±8.5453
Schnute	149030.585 ±59566.6672	1.088 ±0.0727	0.004 ±0.0004	
Richards	4543.693 ±49.2852	23.293 ±5.7328	0.084 ±0.0023	0.489 ±0.0642
Negative Exponential	-108645.530 ±21922.9836		-0.002 ±0.0002	
Bertalanffy	175809.909 ±299133.1812	0.607 ±0.1359	0.280 ±0.2504	

TABLE IV: Parameter estimates for the growth models (Mean ± StdError)

Model	MSE	R^2	R^2adj	AIC	AICc	BIC	DW	AF	BF
Brody	28301.40	0.996	0.994	65.58	72.25	114.45	1.74	1.17	0.97
Gompertz	8641.19	0.999	0.999	59.59	66.26	100.66	1.75	1.28	0.81
Logistic	8181.93	0.999	0.999	59.38	66.05	100.18	1.59	1.90	0.55
Gamma	5053.65	0.999	0.999	58.19	70.19	95.22	2.60	1.09	1.02
Schnute	284395.10	0.912	0.874	74.03	80.69	133.89	2.58	1.40	1.23
Richards	32815.45	0.996	0.994	58.52	70.52	95.98	0.77	1.11	1.02
Negative Exponential	182502.30	0.978	0.972	73.14	76.57	134.07	1.07	1.30	1.17
Bertalanffy	1651488	0.793	0.704	72.89	79.56	131.29	0.95	1.81	0.78

Predicted average and observed growth curves were given in Figure 1 for male animals.

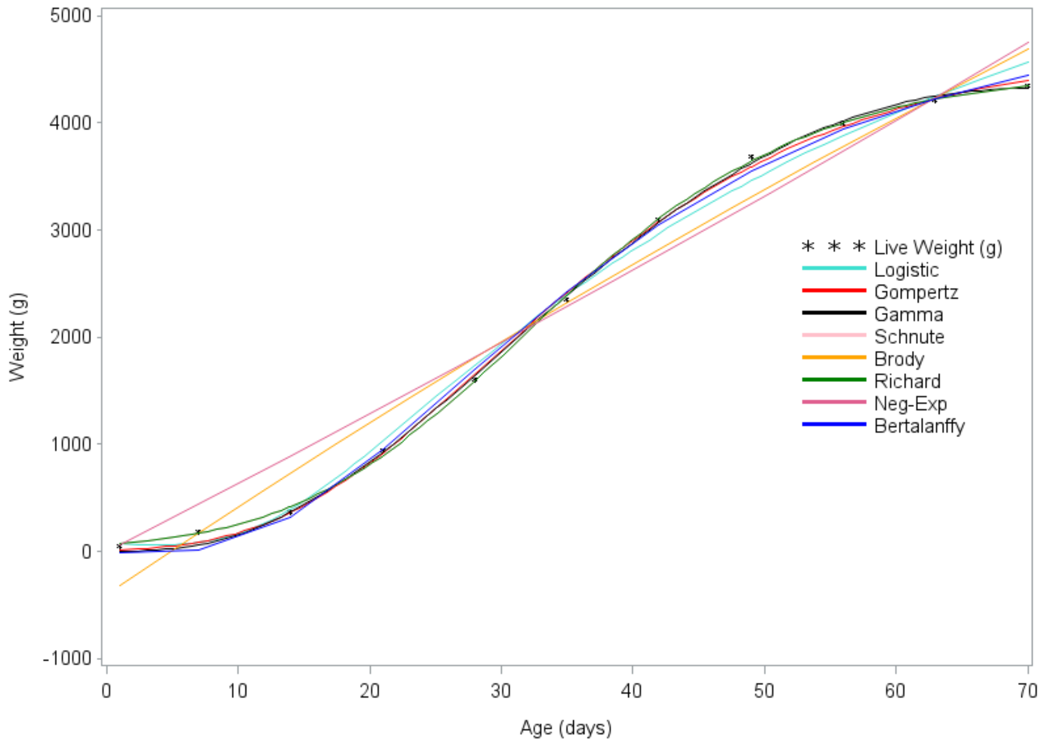

Fig. 1: Predicted average and observed growth curves for Brody, Gompertz, Logistic, Gamma, Schnute, Richards, Negative Exponential, and Bertalanffy models for male animals.

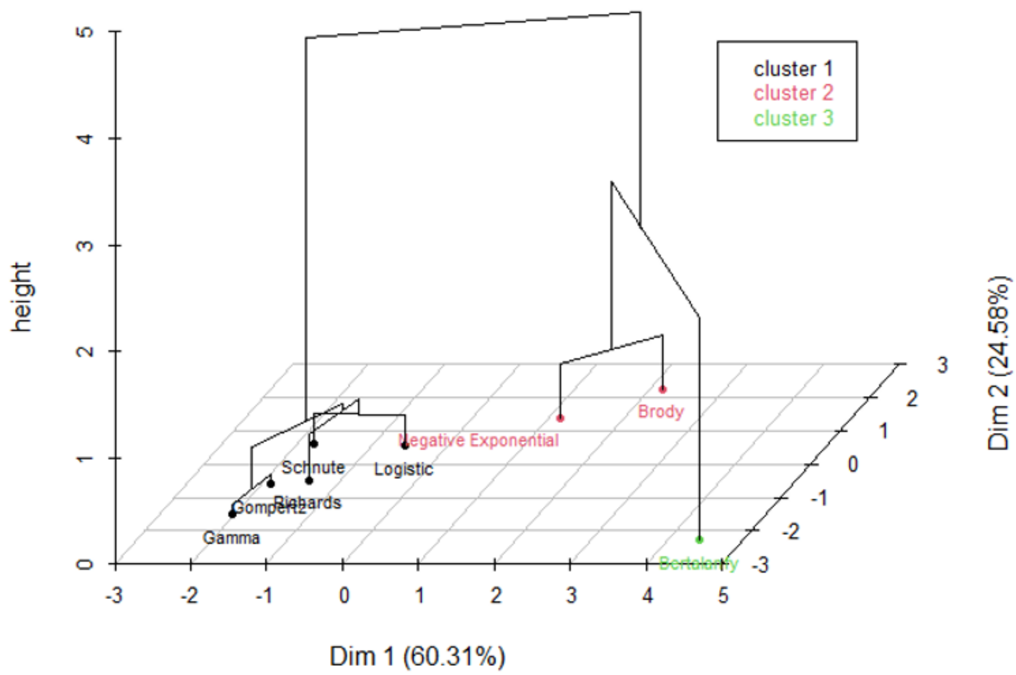

Fig. 2: Three-dimensional dendrogram of hierarchical clustering on the factor map for male animals.

4. Discussion and Conclusion

Concerning the parameter β_0 (mature weight the predicted value) the Negative exponential model showed minimum predicted values for males (-108645.530) as a negative value. For male animals the maximum mature weight the predicted value was observed using Bertalanffy (175809.909). Also the minimum positive β_0 value for male animals obtained from Schnute model (0.085). Önder et al. [10] mentioned Negative exponential model produced maximum β_0 values for both male and female animals and whereas the Logistic model produced minimum predicted values in Turkish native geese. If we only compare the models Önder et al. [10] used in their work, the Logistic model produced minimum values in our results which is similar. Concerning the parameter β_1 (Scaling parameter) we should take into account the Negative Exponential model doesn't have this parameter. The minimum β_1 values were observed from Schnute model as a negative values. The maximum β_1 values were observed from the Logistic model. Negative values for Schnute model can be referred to number of parameters of this model which have four parameters. Topal and Bolukbasi [17] estimated the minimum β_1 value using Bertalanffy model and the maximum values from Logistic model for female and male in broiler chickens. Concerning the parameter β_2 (Instantaneous growth rate), the minimum β_2 values were observed from Negative Exponential model. The maximum β_2 values were observed from the Schnute model. Önder et al. [10] indicated that the Logistic model produced maximum β_2 values for both male and female animals and when the Negative Exponential model produced minimum predicted values in Turkish native geese. Knížetová et al. [20] found positive β_2 value 0.079 for ducks (mixed gender) with using Richards model where we found 0.084 for male ducks. When we concerning the goodness-of-fit criteria; evaluating the MSE values showed that the lowest value was obtained from Richards and Schnute models male animals. The highest MSE values were from Negative Exponential model. When we consider the small mean square error is a measure of the suitability of the created model to the data set, the Schnute model, for male animals, can be preferred. Thinh et al. [6] found lower MSE values for Logistic, Gompertz and Brody models, but higher MSE value for Richards then our results. Wen et al. [13] found lower MSE values then ours for Gompertz, Brody, Logistic, Bertalanffy, and Richards models. Neysi et al. [14] found lower MSE values then our values for Gompertz, Brody, Logistic, Bertalanffy, and

Negative Exponential models. Yavuz et al. [21] declared that the Cubic Spline model showed the lowest MSE values when the second well-fit model was Gompertz.

When we interpret all the goodness-of-fit criteria it was easy to select the Schnute model for both gender of Pekin ducks because of the lowest MSE, AIC, AICc, BIC values, the highest R2 and R^2adj values, and good DW, AF and BF values. When we evaluate the goodness of fit criteria consist of Mean Square Error (MSE), coefficient of determination (R^2), adjusted coefficient of determination (R^2adj), Accuracy Factor (AF), Bias Factor (BF), Durbin-Watson value (DW), Akaike Information Criteria (AIC), and Bayesian Information Criteria (BIC), the Schnute model was found to be suggestible for 70 days growth for male Pekin ducks.

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