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Comparison of Growth Curve Models on Broilers II. Comparison of Models

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Abstract: Gompertz and Bertalanffy growth curve models were compared on broiler age-weight data set. One hundred forty one chickens of two genotypes were fed as *ad libitum* and individual body weights were recorded in every week from hatching to 6 weeks of age. For the parameters estimation, Levenberg-Marquardt iterative nonlinear estimation algorithm was used on mean body weights for each week. Fitting criteria were the estimation of the asymptotic final weight (A), coefficients of determination and goodness-of-fit, determined by residual variances and Durbin-Watson statistics. Both models accurately described the growth of the broiler based on coefficient of determination (R^2) ($\geq$.998). Residual variances and A values in Gompertz model were smaller than the Bertalanffy model. Gompertz model provided a better description of growth curve of broiler, summarizing age-weight data into three growth curve parameters.

Keywords: Growth curve models, gompertz, bertalanffy, broiler

Introduction

The term, growth curve, usually evokes, the image of a sigmoid curve depicting a lifetime sequence of measures of size, often body weight (Fitzhugh, 1976). Mathematical models of growth curves are useful because they provide a mean for visualizing growth patterns over time, and the equations can be used to predict the expected weight of a group of animals at a specific age (Tzeng and Becker, 1981). So growth curves are important to all animal scientist, regardless of specialization, who are concerned with the effects of their research and recommendation on lifetime production efficiency (Fitzhugh, 1976).

Three-parameter models, Gompertz and Bertalanffy were fitted on mean weights of broilers. Parameters of these nonlinear models should be interpretable biologically, although it is hard to believe that a model with three or four parameters could describe so complicated a process as growth from birth to death (Koops, 1986). However, Eisen (1976) clarified that the essential feature of these functions is that they provide estimates of parameters that are biologically interpretable, such as age at point of inflection, asymptotic weight and mean absolute growth rate. The objective was to compare Gompertz and Bertalanffy growth curve models when fitted to mean age-weight data of broilers.

Materials and Methods

Data were collected from Cobb400 and Hubbard commercial lines and the number of broilers were 56 (24 female, 32 male) and 85 (64 female, 21 male), respectively. Chickens were reared on litter floor pens with feed and water available *ad libitum*. Continuous light was provided to 3 days post hatch after which lighting was reduced to 23 h. Body weights were recorded for each bird weekly to an accuracy of $\pm$0.01 g, through an age of 6 weeks. Chickens were wing banded at hatch day and sexes being determined by plumage characteristics after the birds were grown.

Table 1: Model functions of Gomperz and Bertalanffy models.

Model	Equation
Gompertz	$Y = A \exp(-B \exp(-K t))$
Bertalanffy	$Y = A (1-B \exp(-K t))^3$

Because of computational and interpretable easiness, Gompertz and Bertalanffy with three-parameter models were preferred for fitting on mean weights of all broilers for each week. Equations of Gompertz and Bertalanffy models are given in Table 1.

Table 2: R^2 values of two models on two genotypes and sexes

Models	Sex	Cobb 400	Hubbard
Gompertz	Female	0.99943	0.99913
	Male	0.99825	0.99862
Bertalanffy	Female	0.99897	0.99662
	Male	0.99736	0.99930

Table 3: Durbin-Watson statistics

	Gompertz	Bertalanffy
Female	3.45683	2.93880
Male	3.32593	2.87225
Cobb 400	1.63974	1.55927
Hubbard	3.41317	2.93493

Table 4: Residual variances for two genotypes and sexes

Models	Sex	Cobb 400	Hubbard
Gompertz	Female	278.63	388.53
	Male	1048.98	619.88
Bertalanffy	Female	503.78	377.48
	Male	1583.05	619.89

The interpretation of the parameters is as follows: Y: prediction of the weight at age t, A: asymptotic or predicted final weights, B: integration constant; time scale parameter, K: function of theratio of maximum growth rate to mature size (maturing index), t: time.

Parameters were estimated by GLM procedure and Levenberg-Marquardt iteration algorithm using SPSS packed program (1994). All beginning values of the parameters were taken from previous studies. A convergence criterion was 1.0E-08. The necessary information about parameters estimation can be obtained from Yakupoglu and Atil (2001). Examining for accuracy of model used fitting criteria were:

Coefficient of determination (R^2)
Durbin-Watson statistic (DW)
Residual variances
A parameter values

Coefficient of determination (R^2), Durbin-Watson(DW) statistic and residual variances were calculated to judge goodness of fit.The first criterion was coefficient of determination which measures the proportion of total variation in the mean, explained by the model. It will take values between 0 to 1and is used to evaluate the goodness of fit for the estimated model.

The second criterion was Durbin-Watson statistic. Durbin-

Table 5: A parameter estimation and general residual variances

	Gompertz Model		Bertalanffy Model		
	A	Residual Variance	A	Residual Variance	
Cobb 400	2628.84	191.22	Cobb 400	3703.83	751.12
Hubbard	3026.16	344.92	Hubbard	5308.14	552.13
Female	2904.26	369.96	Female	4922.79	595.62
Male	3135.36	627.91	Male	5156.33	990.18

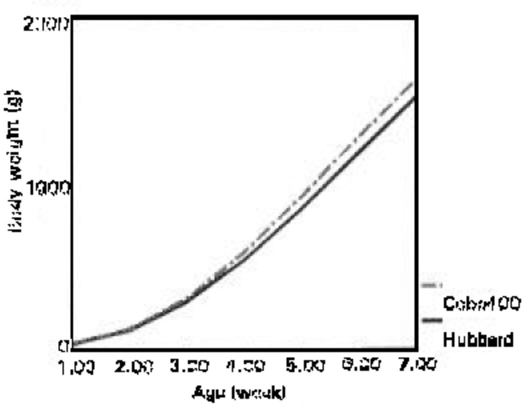

Fig. 1: Predicted Gompertz growth curves for genotypes

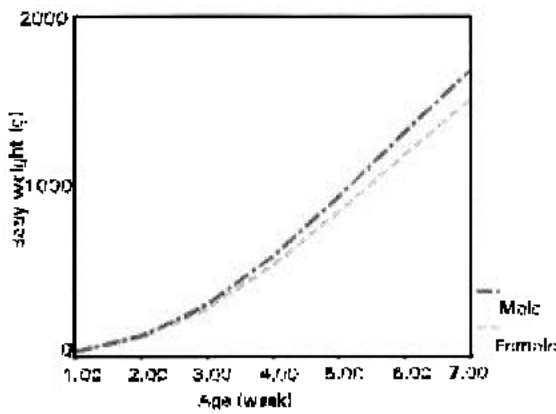

Fig. 3: Predicted Gompertz growth curves for sexes.

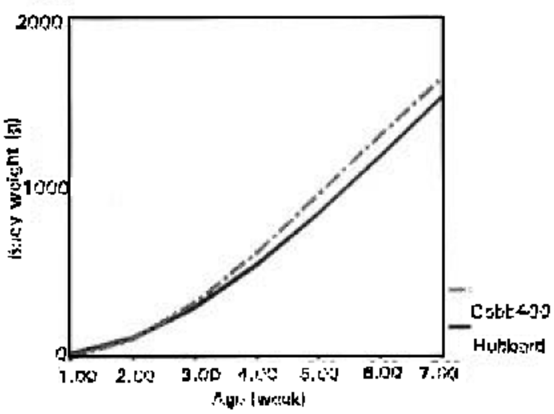

Fig. 2: Predicted Bertalanffy growth curves for genotypes

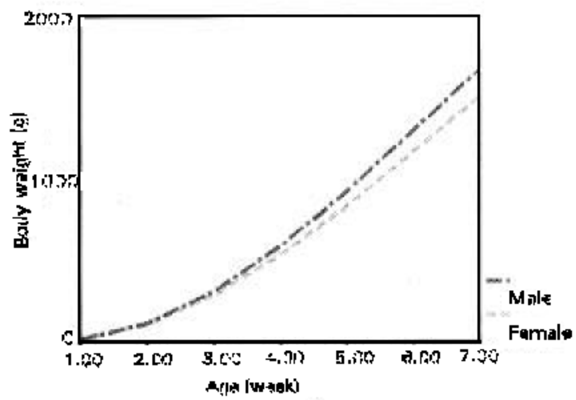

Fig. 4: Predicted Bertalanffy growth curves for sexes

Watson statistic is given by the following formula.

$$d = \frac{\sum_{t=2}^{n} (e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t^2}$$

In many studies involving data collected over time, a special type of correlation among the error terms was found to cause problems; this was serial correlation or autocorrelation. When autocorrelation was present, serious errors could be made in statistical inferences about the regression model due to misinterpretation of statistics. This statistic can be used to detect first order autocorrelation and it has an expectation of 2, and a value less than 2 indicates a positive autocorrelation and a value greater than 2 in dicates a negative autocorrelation (Koops, 1986).

The other criteria were residual variance and A parameter (asymptotic weight) values. The model, with the smallest residual variance is assumed to have best fit to the data. The parameter for asymptotic weight offered the best opportunity to make direct comparisons among all models since the other parameters measure slightly different phenomena (Brown *et al.*, 1976).

Results and Discussion

Predicted Growth Curves: Predicted Gompertz and Bertalanffy growth curve models for two genotypes were given in Fig. 1 and 2. In the Gompertz model, two genotypes have same growing rate upto 4 and 5 weeks of age Fig. 1. On the other hand, in the Bertalanffy model changes in growth have occurred at 3 weeks of age Fig. 2.

Same results obtained from predicted curves for sexes. Sexual dimorphism found between 4 and 5 weeks of age and 3 weeks of age in the Gompertz model and Bertalanffy models respectively, (Fig. 3 and 4).

Coefficient of Determination (R^2): Table 2 summarizes the coefficients of each of the fitted equations for two genotypes and sexes. Except females fitted with Bertalanffy model in Hubbard genotypes, all female broilers have higher determination of coefficient than males. In the general sense, two models yielded quite high coefficient of determination values (≥.998). This result is in good agreement with Akbas and Oguz (1998) worked on quail, Ersoz and Alpan (1994) worked on female broiler, Anthony *et al.*, (1991) worked on Turkeys, quail and broiler.

Gompertz curve is more appropriate to describe rabbit growth (Blasco and Gomez, 1993). Buffington *et al.*, (1973) notified that Laird (1966) had been found the Gompertz equation adequately describes the postnatal growth of many mammals and birds. This result is in good agreement with Akbas and Oguz (1998) worked on quail, Mellett and Randall (1994) worked on ostrich, Anthony *et al.*, (1991) worked on turkeys, quail and broiler.

Autocorrelation Values: Autocorrelation results for two genotype and sexes were given in Table 3. Durbin Watson statistics show a good fit (no autocorrelation) for Co66400 genotype in two models on the otherhand, Durbin Watson statistics show a negative autocorrelation for Hubbard genotype, female and mole in two models ($P<0.05$).

Residual Variances: Residual variances obtained from Gompertz and Bertalanffy models for two genotypes and sexes were given in Table 4.

Males had higher residual variances than females. It can be explained by higher asymptotic weights for males than for females. This result is agreement with Koops (1987), who worked on mice.

A Parameter Values: The residual variance varies accordingly increasing and decreasing asymptotic body weight. That's why the A parameter values would be preferred to be smaller for the decision of best-fit model (Ersöz and Alpan, 1994). A parameter estimations and residual variances for genotype and sex are given in Table 5.

As it can be seen in the Table 5, in Gompertz model, Cobb 400 had the smallest values for A parameters and residual variance and they were 2628.84 g and 191.22, respectively. On the other hand, in Bertalanffy model, male broilers had the highest values for A parameter and residual variance and they were 5156.33 g and 990.18, respectively.

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