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Comparison of Growth Curve Models on Broilers Growth Curve I: Parameters Estimation

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Abstract: Comparison was carried out between Gompertz and Bertalanffy growth curve models. Growth curve parameters were estimated in the first stage. 141 broilers of two commercial lines, were considered as experimental material. Chickens were fed on *ad libitum* and individual body weights were recorded weekly, 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. It is concluded that long period age- weight data set should be used to generalize growth curve parameters estimation findings.

Key words: Growth, growth curve models, broiler, gompertz, bertalanffy

Introduction

Knowledge concerning genetic differences in growth among individuals and among lines serves as a frame of reference for developing selection schemes that will yield desirable growth characteristics in livestock (Eisen, 1976). Many studies have been published in which growth was analyzed to quantify change in body weight, height etc. In the weight mathematical functions to describe growth, most of the time growth is considered to be a homogeneous process that results in a smooth S-shaped curve (Koops, 1986). Such curves start at some fixed point and increase their growth rate monotonically to reach an inflection point; after this the growth rate decreases to approach asymtotically some final value (Ratkowsky, 1983). These are of value not only for engineers, but also to nutritionists, geneticists, physiologists, economists, and managers (Buffington *et al.*, 1973). For the describing size-age relationships for growing animals, there are an extensive number of growth models available. Names such as Brody, von Bertalanffy, Gompertz, Richards or Logistic are associated with asymptotic growth models (Koops, 1986). The aim of this study was to compare growth curve parameters estimation when fitted to data of broiler age-weight measurements using Gompertz and Bertalanffy models.

Materials and Methods

Data were collected from Cobb 400 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 ±0.01 g, through an age of 6 weeks. Afterwards, data set originated mean weights of all broilers for each week. Equations and properties for special cases of Gompertz and Bertalanffy models are given in Table 1.

Statistical Analysis: Three-parameter models; Gompertz and Bertalanffy were fitted on mean weights of all broilers for each week. 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 1.OE-08 was used in this experiment.

Results and Discussion

Parameters Estimation: A parameters of Gompertz and Bertalanffy models for female broilers were estimated 2904.27±304.94 and 4922.80±1336.62, respectively. Also, B and K parameters were 5.91±0.32 and 0.31±0.03 for the Gompertz model and 0.97±0.04 and 0.16±0.03 for the Bertalanffy model. Likewise, for male broilers the A parameters of Gompertz and Bertalanffy models were estimated 3135.36±368.48 and 5156.34±1526.24. At the same time, B and K parameters were 6.14±0.43 and 0.33±0.03 for the Gompertz model and 0.99±0.06 and 0.17±0.04 for the Bertalanffy model (Table 2).
Considering two genotypes for A,B and K parameter estimations in Cobb400 were found 2936.05±485.36, 6.14±0.65 and 0.33±0.05 for the Gompertz model and 4632.82±1566.32, 1.00±0.07 and 0.17±0.04 for the Bertalanffy model. Similarly, in Hubbard the parameter estimates were 3179.42±543.34, 5.90±0.46 and 0.30±0.042 for the Gompertz model and 5746.19±2160.22, 0.96±0.05 and 0.14±0.04 for the Bertalanffy model. With respect to sex and genotype, Bertalanffy model gives higher estimate than the Gompertz model for the A parameter and Gompertz model gives higher estimate than Bertalanffy model for the B and K parameters (Table 2). These results can be explained by structure of the models.

Age and Body Weight at Point of Inflection: Two genotypes are different to reach at the point of inflection (U_i) (Table 3). Body weights and age of Cobb400 and Hubbard genotype broilers for the Gompertz model were 967.10 and 1113.27,5.07 and 5.78 respectively. Similarly, 1097.43 and 1572.78, 5.42 and 7.13 were found for the Bertalanffy model. The respect of sex, body weight at point of inflection was found female and male 1068.42 and 1153.44 for the Gompertz, 1458.60 and 1527.80 for the Bertalanffy model. In the Gompertz model, two sex of broilers reached to inflection point at 5.67 w. Otherwise in the Bertalanffy model female and male broilers 6.85 and 6.60 w, respectively (Table 3). It is clear that Hubbard genotype broilers were reached at higher body weights and older age than Cobb400. At the same time male broilers were higher body weight than female broilers for the two models (Table 3).
From these results it can be clarified that Hubbard genotype broilers and also male broilers have differences in body weight due to high asymptotic weight. Although there is no difference between two sexes for the Gompertz model according to age at the point of inflection, in the Bertalanffy model male broilers reached to point of inflection at younger age than female broilers (Table 3).

Residual Values: Residual values that are examined between observed and estimated body weights for two genotype and sex in Gompertz and Bertalanffy models are presented in Table 4,5. It can be noticed that the broilers of Cobb400 genotype

Table 1: Equations and properties for special cases of Gompertz and Bertalanffy models

Model	Equation	M	U_I	Asymptote	Maturing Index	t_I	Y_I
Gompertz	Y= A.exp(-B.exp(-K.t))	$M\to\infty$	e^{-1}	A	K	ln (B)/K	A/e
Bertalanffy	$Y= A(1-B.exp(-K.t))^3$	3	8/27	A	K	(lnB + ln3)/K	8/27.A

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 the ratio of maximum growth rate to mature size (maturing index), t: time, M: the inflection parameter,
U_I: point of inflection, t_I: age at the inflection point, Y_I: production at age of point of inflection.

Table 2: Estimate of parameters, standard errors and confidence intervals for two models

	Female						Male					
	Gompertz			Bertalanffy			Gompertz			Bertalanffy		
	Estimation	Standard Errors	Confidence Intervals	Estimation	Standard Errors	Confidence	Estimation	Standard Errors	Confidence Intervals	Estimation	Standard Errors	Confidence intervals
A	2904.27	304.94	(2057.61; 3750.92)	4922.80	1336.62	(1211.74; 8633.85)	3135.36	368.48	(2112.29; 4158.43)	5156.34	1526.24	(918.82; 9393.86)
B	5.91	0.32	(5.01;6.80)	0.97	0.04	(0.85;1.09)	6.14	0.43	(4.96;7.33)	0.99	0.06	(0.83;1.15)
C	0.31	0.03	(0.24;0.39)	0.16	0.03	(0.07;0.24)	0.33	0.03	(0.23;0.42)	0.17	0.04	(0.06;0.27)
	COBB 400						Hubbard					
	Gompertz			Bertalanffy			Gompertz			Bertalanffy		
	Estimation	Standard Errors	Confidence Intervals	Estimation Errors	Standard	Confidence Intervals	Estimation Errors	Standard	Confidence Intervals	Estimation Errors	Standard	Confidence Intervals
A	2936.05	485.36	(1867.79; 4004.31)	4632.82	1566.82	(1185.37; 8080.26)	3179.42	543.34	(1983.54; 4375.30)	5746.19	2160.22	(991.57; 10500.81)
B	6.14	0.65	(4.70;7.59)	1.00	0.07	(0.83;1.16)	5.90	0.46	(4.90;6.91)	0.96	0.05	(0.86;1.07)
C	0.33	0.05	(0.22;0.45)	0.17	0.04	(0.07;0.28)	0.30	0.042	(0.21;0.39)	0.14	0.04	(0.06;0.23)

Table 3: Body weights and age at point of inflection for two models

	Gompertz Model			Bertalanffy Model	
	Weight at U_I (g) Age at U_I (w)	Age at U_I (w)		Weight at U_I (g)	
Cobb 400	967.10	5.07	Cobb 400	1097.43	5.42
Hubbard	1113.27	5.78	Hubbard	1572.78	7.13
Female	1068.42	5.67	Female	1458.60	6.85
Male	1153.44	5.67	Male	1527.80	6.60

Table 4: Observed mean body weights, predicted and residual values relating to genotypes for two models

	Cobb 400					Hubbard				
		Gompertz		Bertalanffy			Gompertz		Bertalanffy	
Age (w)	Observed	Predicted	Residual	Predicted	Residual	Observed	Predicted	Residual	Predicted	Residual
0	46.85	29.34	17.50	12.21	34.63	45.09	39.43	5.66	25.16	19.93
1	125.84	119.09	6.75	112.06	13.78	120.24	124.24	-3.93	120.74	-0.43
2	306.60	312.37	-5.77	322.53	-15.93	290.78	289.00	1.78	297.52	-6.74
3	596.30	606.67	-10.37	615.25	-18.95	546.67	537.78	8.89	545.09	1.58
4	960.10	958.08	2.02	952.02	8.08	824.15	849.16	-25.01	845.18	21.03
5	1326.30	1312.23	14.07	1300.26	25.94	1212.00	1188.28	23.72	1178.39	33.61
6	1621.10	1629.46	-8.36	1637.35	-16.25	1513.60	1521.47	-7.87	1527.44	-13.84

Residual Value = (Observed body weight) - (Predicted body weight)

Table 5: Observed mean body weights, predicted and residual values that are relating to sex for two models

	Female					Male				
		Gompertz		Bertalanffy			Gompertz		Bertalanffy	
Age (w)	Observed	Predicted	Residual	Predicted	Residual	Observed	Predicted	Residual	Predicted	Residual
0	45.49	38.68	6.82	24.33	21.16	46.28	37.09	9.19	20.87	25.41
1	120.97	123.64	-2.67	120.15	0.82	125.06	127.22	-2.16	122.23	2.83
2	287.82	289.09	-1.27	297.72	-9.90	312.41	309.86	2.55	319.49	-7.08
3	548.69	537.85	10.84	545.07	3.62	595.80	589.35	6.45	597.95	-2.15
4	821.10	846.71	-25.61	842.51	-21.41	906.20	937.61	-31.41	932.99	-26.79
5	1203.90	1179.71	24.19	1169.81	34.09	1346.20	1311.16	35.04	1299.78	46.42
6	1495.20	1503.35	-8.15	1509.43	-14.23	1657.80	1670.46	-12.66	1677.28	-19.48

has small residuals in the Gompertz model. Whereas, large residuals were became at 5-6 weeks of age in two models. In Hubbard genotype of broilers, the same interpretation is not valid (Table 4). The respect of sex, residuals have similar quantity at the same ages between male and female broilers. Also, male broilers are heavier than female broilers through growing period (Table 5). With respect to the aim of this study, we compared growth curve parameters estimation when fitted to data of broiler age-weight measurements using Gompertz and Bertalanffy models. Growth curve models cannot be explained exactly, because of the complex structure of growth. However, it can be recommended that long period age-weight data set should be used to generalise growth curve parameters estimation findings.

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