International Journal of Poultry Science 5 (6): 517-521, 2006
ISSN 1682-8356

Analysis of Fitting Growth Models in Jinghai Mixed-Sex Yellow Chicken

Y. Yang[1], D.M. Mekki[1, 2], S.J. Lv[1], L.Y. Wang[1]*, J.H. Yu[1] and J.Y. Wang[1]
[1]Department of Animal Genetics, Breeding and Reproduction,
Yangzhou University, Yangzhou 225009, China
[2]Department of Animal Science, Faculty of Natural Resources and Environmental Studies,
University of Kordofan, Elobeid 5111, Sudan

Abstract: The three nonlinear curves of Logistic, Gompertz and Bertalanffy model were used to fit the growth model in Jinghai Yellow chicken of different sex. The results indicated that the three growth models were well fitted the prediction of growth parameters. Females reached inflexion point at earlier age than males; however, their body weight was significantly lighter than males. Inflexion body weight were 1098.99, 1161.86 and 1392.91 g for males and 824.29, 827.99 and 918.67 for female estimated from Logistic, Gompertz and Bertalanffy models, respectively. Fitting degrees (R^2) for the three models were higher than 99%. The lower X^2 values estimated were 9.22 and 7.43 from Bertalanffy model for males and females respectively indicated that, Bertalanffy model was the best model fitted growth prediction parameters of Jinghai Yellow chicken.

Key words: Jinghai yellow chicken, growth curves, fitting model

Introduction

Growth is a fundamental property of biological systems and it can be defined as an increase in body size per time unit (Schulze *et al*., 2001; Lawrence and Fowler, 2002). Growth of fowl is analogous to growth of mammalian; consisting of three or four cycles (Grossman, 1988), two of these cycles, however, occurred after hatching. Indigenous chicken, like improved breeds has a sigmoid growth pattern with differences in growth rate and feed efficiency (Nowsu, 1979), although the indigenous fowl seemed to complete the rapid growth phase earlier than improved breeds (Oluyemi, 1980). Growth is affected by genetic and non-genetic factors (Singh and Singh, 1983; Gupta *et al*., 1988 and Pinchasov, 1991). The assessment of a growth model is of particular importance in animal production, because of its practical implications (possibility of verifying the adherence of a feeding schedule or a rearing system to a reference condition, as it is calculated by a regression equation) (Sabbioni, 1999).

Growth curves are to describe the regular change generated by the live -weight or some part of the animal with the age increasing, which commonly is an S-type curve. When animal growth is described by a growth curve, these parameters can be presented as biologically interpretable constants in a mathematical equation. (Zhang and Yang, 1998; Ersoy *et al*., 2005). Logistic, Gompertz and Bertalanffy equations are often used to fit the growth curve of poultry. Through analysis and study of growth curve of poultry, we can know dynamically its growth course, to forecast the poultry growth law; and instruct the feeding and management programs to improve the selection and breeding effect (Yang *et al*., 2004).

In this study, the main purpose was to estimate growth curve of Jinghai yellow mixed-sex chicken and compare the three mathematical models fitting for this estimation.

Materials and Methods

Experimental animals: Jinghai yellow chicken is an indigenous yellow - brownish breed with prominent yellow shank. The breed is medium-sized and used as dual purpose, distributed in Haimen, Rugao and Rudong the outskirt of Nantong, Jiangsu, China. The experiment was conducted at Haimen Integrated Poultry Company and extended for 16 weeks.300 fertilized eggs were collected randomly, assigned and hatched. 209 chicks (108 male, 101 female) were released, wing banded, weighted and transferred to brooding house.

Management and measurements: The experimental stock was raised in semi-intensive system. Feeding and drinking were *ad. Libitum* according to routine method of layers and routine vaccination program was applied. Chicks were weighted at hatch and subsequently at weekly interval until the age of 16 weeks.

Adopted growth models: Three nonlinear growth models, Logistic (Fan *et al*., 1997), Gompertz (Mignon *et al*., 1999) and Bertalanffy (Zheng, 1995) were applied to analyze the data (Table 1).

Statistical analysis: SPSS v14.0 software was used to

Corresponding author: Wang Jin-yu, College of Animal Science and Technology, Yangzhou University, Yangzhou 225009, Jiangsu, China

Table 1: Three kinds of nonlinear growth models in animal

Mathematics model	Logistic	Gompertz	Bertalanffy
expression	$y_t = A / (1+Be^{-kt})$	$y_t = Ae^{-Bexp\,(-kt)}$	$yt = A\,(1-Be^{-kt})^3$
Absolute growth rate	$dy/dt = ABke^{-kt} / (1+Be^{-kt})^2$	$dy/dt = kABe^{-Bexp\,(-kt)}\,e^{-kt}$	$dy\,/dt = 3kA\,(1-Be^{-kt})^2\,Be^{-kt}$
Relative growth rate	$k\,(1 - y_t / A)$	$K\,(\ln A - \ln y_t)$	$3k\,[(A/y_t)^{1/3} - 1]$
Growth Inflexion (t_i, y_i)	$t_i = (\ln B) / k, y_i = A/2$	$t_i = (\ln B) / k,\ y_i = A/e$	$t_i = (\ln 3B) / k, y_i = 8A / 27$
Maximal week increment weight	$ky_i / 2$	ky_i	$3ky_i / 2$

y_t = weight of the age of t weeks, A = the mature live weight, k = instantaneous relative growth rate (Xing *et al.*, 1998) and B = constant scale.

Table 2: Fitting degree and parameter estimated value of three growth curve models

Sex	Growth model	Model parameter A	B	K	Fitting degree (R^2)	Inflexion body weight	inflexion weeks	Maximal week increment weight
Cock	Logistic	2197.9783	25.5021	0.3008	0.9963	1098.99	10.77	165.29
	Gompertz	3158.2571	4.3084	0.1304	0.9990	1161.86	11.20	151.51
	Bertalanffy	4701.0840	0.8322	0.0714	0.9993	1392.91	12.81	149.18
Hen	Logistic	1648.5768	21.4153	0.2996	0.9952	824.29	10.23	123.48
	Gompertz	2250.7055	4.0384	0.1361	0.9986	827.99	10.26	112.69
	Bertalanffy	3100.5084	0.8055	0.0793	0.9991	918.67	11.13	109.28

estimate optimization values of A, B and K for body weight data to establish and evaluate the growth models according to fitting degree (R^2) (Yang *et al.*, 1996). The fitting optimized degree was examined with measured and estimated values according to the following equation:

$$Chi^2 = \sum_i \frac{(O_i - E_i)^2}{E_i}$$

Where:

O_i = measured value at the *i* moment, E_i = estimated value at the *i* moment.

If $Chi^2 \geq Chi^2_{0.05}$ (P<0.05), the equation is not well fitted, and the estimated value is not consistent with the measured value, and if $Chi^2 < Chi^2_{0.05}$ (P>0.05), the equation is well fitted, and the estimated value is consistent with the measured value (Cui, 2005).

Results

Comparison of growth models: Table 2 showed the estimated values of fitting parameters and fitting degree (R^2) of Logistic, Gompertz and Bertalanffy models for male and female body weight. The three models were all fitted the growth curves of Jinghai yellow chicken very well, and the fitting degrees (R^2) were all above 99%; for the three models, however Bertalanffy model was the best (99.93 %). Estimated parameters A and B showed higher values for male than females for all models; however, K values for females were slightly higher than that of corresponding males.

Analysis of the growth curves: Measured and estimated values of body weight from one-day old to 16 weeks of age for males and females were depicted in Table 3 and Table 4, respectively. The average measured values at 16 weeks of age were 1849.57g and 1444.49g for males and females, respectively. The curve of growth showed smooth slow increasing for both sexes during the first three weeks, and then after steadily elevated (Fig.1).

Table 3 and Table 4 showed absolute and relative growth rate for males and females through the three models. Females reached inflexion point in earlier age than males in all models, however in Bertalanffy curve the inflexion point was later one week (11.13) and two weeks (12.81) than logistic and Gompertz curves for males and females, respectively, where males estimated body weight (1392.91g) was significantly higher (P<0.05) than females estimated body weight (918.67g).

Self-accelerating growth phase estimated by Logistic and Gompertz models reached the maximum at 10 and 11 weeks of age for females and males, respectively. Beyond the inflexion point, growth rate slowed down sharply for both Logistic and Gompertz models compared with Bertalanffy model for both sexes (Fig. 2 and Fig.3).

Chi-square test was applied for measurement and estimated values of males and females for the three models to compare their fitness (Table 5). There were significant differences $Chi^2_{0.05}$ (df = 16) (P<0.05) between estimated and measured values for the three models for both sexes. Chi^2 values for Bertalanffy model were less than that of the two other models.

Discussion

The three nonlinear models Logistic, Gompertz and Bertalanffy were well fitted the prediction of growth parameters of Jinghai Yellow chicken depending on their fitting degree $R^2 \geq 99\%$. Results were in consistent with that reported by Wang *et al*. (2005) for Zang chicken. It was determined that females reached inflexion point earlier than males, with body weight significantly lighter

Table 3: Measured and estimated values and growth rate of three growth curves of males

Weeks	0	1	2	3	4	5	6	7
Measured value y_t (g)	30.74	56.59	106.42	156.41	235.47	349.17	461.23	553.44
Logistic curve								
Estimated value y´ (g)	82.94	110.58	146.79	193.77	253.92	329.66	423.09	535.40
Absolute growth rate (g/week)	24.01	31.59	41.20	53.15	67.55	84.27	102.76	121.85
Relative growth rate (%)	28.94	28.57	28.07	27.43	26.61	25.57	24.29	22.75
Gompertz curve								
Estimated value y´(g)	42.49	71.95	114.24	171.41	244.75	334.58	440.23	560.13
Absolute growth rate (g/week)	23.87	35.48	49.45	65.12	81.62	97.93	113.10	126.32
Relative growth rate (%)	56.18	49.31	43.29	37.99	33.35	29.27	25.70	22.55
Bertalanffy curve								
Estimated value y´ (g)	22.20	53.65	101.63	166.37	247.17	342.72	451.33	571.13
Absolute growth rate (g/week)	23.58	39.56	56.39	72.92	88.42	102.37	114.50	124.75
Relative growth rate (%)	106.25	73.72	55.47	43.82	35.76	29.85	25.36	21.83

Weeks	8	9	10	11	12	13	14	15	16
Measured value y_t (g)	698.83	879.37	968.22	1106.14	1249.00	1435.98	1574.77	1737.66	1849.57
Logistic curve									
Estimated value y´ (g)	666.34	813.62	972.79	1137.50	1300.51	1454.82	1594.91	1717.31	1820.75
Absolute growth rate (g/week)	139.61	154.09	163.15	165.27	159.96	147.73	131.39	113.01	94.00
Relative growth rate (%)	20.96	18.95	16.77	14.51	12.28	10.17	8.25	6.58	5.16
Gompertz curve									
Estimated value y´(g)	692.01	833.13	980.52	1131.24	1282.51	1431.87	1577.24	1716.96	1849.76
Absolute growth rate (g/week)	136.98	144.75	149.53	151.42	150.69	147.67	142.77	136.42	129.00
Relative growth rate (%)	19.80	17.38	15.25	13.39	11.75	10.32	9.05	7.95	6.98
Bertalanffy curve									
Estimated value y´ (g)	700.18	836.59	978.54	1124.37	1272.55	1421.72	1570.68	1718.40	1864.01
Absolute growth rate (g/week)	133.04	139.48	144.16	147.25	148.91	149.27	148.54	146.84	144.33
Relative growth rate (%)	18.99	16.66	14.72	13.09	11.69	10.49	9.45	8.54	7.74

Table 4: Measured and estimated values and growth rate of three growth curves of females

Weeks	0	1	2	3	4	5	6	7
Measured value y_t (g)	30.22	52.93	97.28	141.66	208.13	306.27	390.73	467.64
Logistic curve								
Estimated value y´(g)	73.55	97.72	129.18	169.67	221.00	284.87	362.51	454.26
Absolute growth rate (g/week)	21.05	27.54	35.66	45.60	57.34	70.60	84.73	98.60
Relative growth rate (%)	28.62	28.18	27.61	26.88	25.94	24.78	23.37	21.70
Gompertz curve								
Estimated value y´(g)	39.67	66.32	103.85	153.61	216.16	291.25	377.81	474.13
Absolute growth rate (g/week)	21.80	31.81	43.48	56.13	68.93	81.06	91.77	100.51
Relative growth rate (%)	54.96	47.97	41.87	36.54	31.89	27.83	24.29	21.20
Bertalanffy curve								
Estimated value y´(g)	22.82	52.00	94.82	150.95	219.32	298.46	386.69	482.25
Absolute growth rate (g/week)	22.48	35.97	49.60	62.47	74.03	83.96	92.18	98.67
Relative growth rate (%)	98.51	69.15	52.28	41.36	33.73	28.12	23.83	20.45

Weeks	8	9	10	11	12	13	14	15	16
Measured value y_t (g)	579.86	707.00	827.93	910.37	982.65	1109.05	1222.90	1343.03	1444.49
Logistic curve									
Estimated value y´(g)	559.13	674.54	796.37	919.42	1038.33	1148.39	1246.29	1330.34	1400.33
Absolute growth rate (g/week)	110.71	119.42	123.36	121.86	115.18	104.42	91.15	76.97	63.20
Relative growth rate (%)	19.80	17.70	15.49	13.25	11.09	9.09	7.31	5.78	4.51
Gompertz curve									
Estimated value y´(g)	578.06	687.22	799.20	911.75	1022.86	1130.83	1234.35	1332.40	1424.32
Absolute growth rate (g/week)	106.95	110.97	112.63	112.14	109.80	105.94	100.93	95.08	88.71
Relative growth rate (%)	18.50	16.15	14.09	12.30	10.73	9.37	8.18	7.14	6.23
Bertalanffy curve									
Estimated value y´(g)	583.45	688.69	796.50	905.58	1014.81	1123.20	1229.94	1334.36	1435.92
Absolute growth rate (g/week)	103.48	106.78	108.68	109.36	108.98	107.72	105.72	103.11	100.02
Relative growth rate (%)	17.72	15.49	13.63	12.07	10.73	9.58	8.59	7.72	6.96

than males. During the self-accelerating phase, the absolute growth rate (g/week), increased smoothly for the first three weeks and then rapidly to achieve t he maximum weight gain at the end of the phase. It was observed that males weekly body gain (g/week) was higher than that of females during the whole

Table 5: Chi-square results of measured and estimated values of L, G and B models

	Measured value and L value (%)	Measured value and G value (%)	Measured value and B value (%)	Measured value and L value (&)	Measured value and G value (&)	Measured value and B value (&)
Chi^2 value	95.08	14.93	9.22	73.46	11.99	7.43

*L = estimated value of Logistic model; G = estimated value of Gompertz model and B = estimated value of Bertalanffy model.
** $Chi^2_{0.05}$ = 26.30 (df = 16).

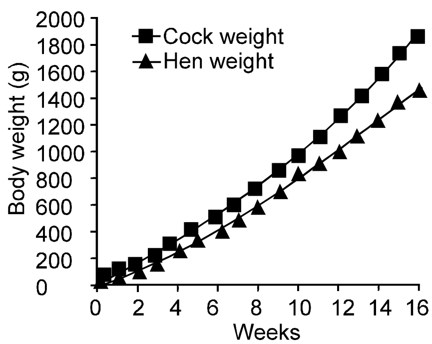

Fig. 1: Cumulate growth curves of body weight of males and females

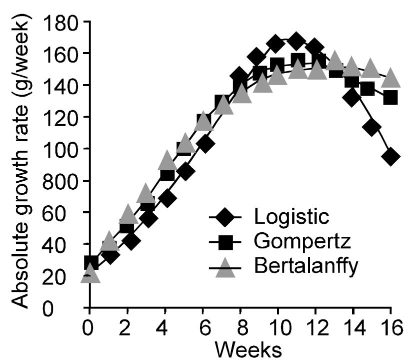

Fig. 2: Males' absolute growth rates of three fitting curves

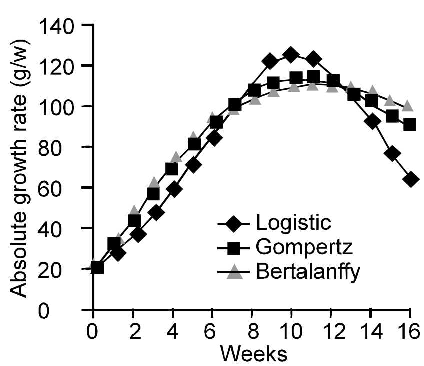

Fig. 3: Females' absolute growth rates of three fitting curves

experimental period. Results were typically consistent with the results early reported by Grossman (1988) and similar to (Zhang and Yang, 1998; Zhang, 2002; Wang *et al*., 2005 and Wei *et al*., 2005) conclusions.

Comparison of the three nonlinear growth curves according to fitting degree (R^2) and X^2 value revealed that Bertalanffy was the best model fitted growth prediction parameters of Jinghai Yellow chicken; similar results were obtained by Zhang (2002) and Wang *et al*. (2002). On the other hand, Yang *et al.* (2004), Zhang *et al*. (2005) and Wang *et al*. (2005) found that Gompertz was the best model to predict growth parameters of the chicken. The fitting analysis results of three growth models for Jinghai yellow chicken indicated that males reached inflexion point in late age compared with females and weekly body gain is greater in males than females. Considerable attention should be made to cover the high nutritional requirements during self-accelerating phase and sex separating feeding could be preferable.

Reference

Cui, D.Q., 2005. Analysis and making good fitting degree test for Logistic curve regression equation. Appl. Stat. Manag., 24: 112-115.

Ersoy, E., M. Mendes and S. Aktan, 2005. Growth curve establishment for American Bronze turkeys. Arch. Tiez., Dummerstorf, 49: 293-299.

Fan, Y.G. and SH. ZH.Ye, 1997. A study on the growth curve and maximum profit from layer-type cockerel chicks. Poult Sci., 38: 445.

Grossman, R.D., 1988. Multiphasic analysis of growth curves in chicken. Poult. Sci., 67: 33-42.

Gupta, R.D., S.K. Joshi, S.S. Alkare and K.K. Bagheel, 1988. Influence of divergent egg weight on performance of progenies from reciprocal cross of dwarf X normal population. Ind. J. Anim. Sci., 58: 130-132.

Lawrence, T.L.J. and V.R. Fowler, 2002. Growth of Farm Animals. 2nd Ed. CAB International, Wallingford. UK., pp: 347.

Mignon, G.S., C.L. Beaumont and D.E. Bihan, 1999. Genetic parameters of growth curve parameters in female chickens. Poult. Sci., 40: 44.

Nwosu, C.C., 1979. Characterization of the local chickens of Nigeria and its potential for egg and meat production. Poult.Prod. Nig., 187-209.

Oluyemi, J.A., 1980. Crossbreeding and upgrading of indigenous fowl of Nigeria with improved breeds. Anim. Breed. Abst., 52: 164.

Pinchasov, Y., 1991. Relationship between the weight of eggs, hatchability and subsequent early performance of broiler chicks. Br. Poult. Sci., 32: 109-115.

Sabbioni, A., P. Superchi, A. Bonomi, A. Summer and G. Boidi, 1999. Growth curves of Ostriches (*Struthio camelus*) in Northern Italy. Paper represented at the 50th EAAP Congress, Zurich, 22-26 Aug., 1999.

Schulze, V., R. Rohe, H. Looft and E. Kalm, 2001. Genetic analysis of the course of individual growth and feed intake of group-penned performance tested boars (In German Language). Arch. Tierz. Dummerstorf, 44: 139-156.

Singh, H.N. and B.P. Singh, 1983. Inheritance of eight week body weight in pure and crossbreds population of two broiler breeds. Ind. Vet. J., 60: 560-563.

Wang, C.F., L. Zhang., J.Y. Li and CH. X. Wu, 2005. Analysis of body conformation and fitting growth model in Tibetan chicken raised in plain. Scientia Agricultura Sinica., 38: 1065-1068.

Wang, ZH. Y., W.L. Chen, Q.A. Bai, J. Wang and H.L. Wang, 2002. The compare research on growth model of new Yangzhou chickens. Heilongjiang J. Anim. Sci. Vet. Med., 12: 4-5.

Wei, F.S., R.L.Han, X.T. Kang, J. ZH. Shi, G.X. Li, G.R. Sun, ZH. Y. Li, ZH. Qin, F.B. Yan and Y.Q. Cui, 2005. Analysis of growth curve in Gushi chicken of different sex. Henan J. Anim. Sci. Vet. Med., 26: 45-51.

Xing, L.F., M.G. Sun and Y.J. Wang, 1998. Richard growth model of living-organism. Journal of Biomathematics. 13: 248-253.

Yang, H.M., Q. Xv and G.J. Dai, 2004. Analysis on three kinds of growth curve in avian. Chin. Poult. Sci., 8: 164-166.

Yang, Y.Q., R.J. Li and S.L. Li, 1996. An estimation method for genetic parameters of dynamic traits. Acta Veterinaria et Zootechnica Sinica., 27: 412-416.

Zhang, D.X. and S. Yang., 1998. Study of growth model difference in broiler of different sex. Heilongjiang Anim. Sci. Vet. Med., 3: 11-12.

Zhang, H., CH. X. Wu, J.Y. Li and Y. Ling, 2005. Analysis of fitting growth curve and heterosis in Tibetan chicken and lowland chicken breeds. China J. Anim. Sci., 41: 34-37.

Zhang, L., 2002. Studies on the growth traits of Minnan turkey. Ecology of Domestic Animal, 23: 27-29.

Zheng, G.M., 1995. Ornithology. Beijing: Beijing Normal University Press. 281-296.