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ANALYSIS OF FITTING GROWTH CURVE IN EGYPTIAN LOCAL BREED CHICKENS AND THEIR CROSSES USING NONLINEAR MIXED GOMPERTZ MODEL

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ABSTRACT

Parameters of the Gomperz function pf growth fit to individual body weight curves of two crossbred groups. Six hundreds and twenty chicks from two groups were used. The first group involved Fayoumi (Fay), Rhode Island Red (RIR) and their reciprocal crosses (FayxRIR) and (RIRxFay). The second group involved Sinai (S), White Leghorn (WL) and their reciprocal crosses (WLxS) and (SxWL). The objective of this research was to evaluate the growth pattern of local and crossbreds chickens and to evaluate growth curve parameters using non-linear model for Gompertz. Chickens were weighed at hatch, 14, 21, 30, 45, 60, 90, 124 and 154 days of age. Feeds and water were supplied *ad libitum*.

In the first group: weights at 16 week of age relative to asymptotic was the same for (FayxRIR) and (RIRxFay) and highest for Fay and RIR. Birds in (FayxRIR) showed the lowest maturing rate 0.3365 for female and 0.3386 for male. High estimates for mature weight were observed in (FayxRIR) males and (FayxRIR) females. The mature live weights of hybrid (FayxRIR) males was 3.370 Kg compared to 2.680 kg for (RIRxFay). The rate of maturing parameters (L) of the males used in this evaluation was greater than for the females.

In the second group: (WLxS) chicks were hieavier the Sinai and (SxWL) chick at hatch. (WLxS) hybrid was heavier at 12 week of age than (SxWL), S and WL. Both hybrids reached the same asymptotic body weight at 20 week of age. The predicted mature body weights differ among sexes. The rate of maturation K was higher in males than in females. The mature body weight estimated for males were higher than those for females.

Keywords: Growth curve, Fayoumi, Sinai chickens, non-linear Gompertz model.

INTRODUCTION

Chicken meat is one of the most popular meat sources in Egypt. The local chickens could not produce high or acceptable meat yield. The crossbred progenies were superior to purebreds in term of growth rate, meat quality, and feed conversion. Growth curves for live weight and feather yield vary between strain-crosses and between sexes, so the adequate estimation of parameters is necessary Stilborn, et al., 1994, Hancock, et al., 1995; Gous et al., 1999). In literature, growth of avian species is often described by means of non-linear models. These non-linear models, such as Gompertz and Logistic equations, were developed under the assumption that birds are fed *ad libitum* and are capable of maximum growth (Tzeng and Becker, 1981). Many of these models are mechanistic models that describe the growth process based on physiological and biochemical laws, resulting often in complex models with many equations and model parameters (Oltjen et al., 1986), although the Gompertz equation is often used in empirical models, Emmans (1981) concluded that the Gompertz function is frequently chosen in mechanistic models for its mathematical properties, biological meaning of parameters and its reasonable fit. Gompertz model was the best model to predict growth parameters of chicken (Yang et al., 2004; Zhang et al., 2005; and Wang et al., 2005). Barbato (1991) and Mignon-Grasteau et al., (1999) showed that parameters of the Gompertz curve describing age-weight relationships in chickens were heritable. It was observed that the genes controlling these parameters seemed partly to differ between sexes (Mignon-Grasteau et al., 1999). Growth curves differed, but it was not possible to test the significance of these differences as distributions of the growth curve parameters remained unknown. Growth curves can describe the entire growth process in terms of a few parameters having biological interpretation. Selection for growth rate can modify these parameters, but there are some technical difficulties for comparing curves before and after selection. Typically, growth curves are fitted by nonlinear regression or by linear regression if the model can be linearized by transformation.

The purpose of the present work was to study the growth pattern of local and crossbred chickens, to compare growth curve parameters estimation when fitted to data age-weight measurements using Gompertz model, to compare the predicted and observed weights among genotypes from hatch to maturity for purebreds and crossbreds and to estimate growth parameters for females and males for each genotype.

MATERIAL AND METHODES

The experiment was conducted with two crossbred groups. Sex hundred twenty chickens, of two groups. The first group involved the Fayoumi (Fay) and Rhode Island Red (RIR) purebreds and their reciprocal crossbreds (Fay x RIR) and (RIR x Fay). The second group involved the Sinai Bedouin (S) and White Leghorn (WL) purebreds and their reciprocal crossbreds (WLxS) and (SxWL). The numbers of birds measured per group were 232 in the first and 388 in the second group. The experiment was carried out in south Sinai Research Station- Desert Research Center during period from January 2002 and December 2004. The chicks were pedigreed at hatching and vaccinated against Mark's disease and Newcastle disease at 7 days. Birds were individually identified with a wing-band at hatching. The chicks were randomly assigned, within genetic group and sex to experimental pens in an open-sided house. Birds were sexed at 4 weeks of age by sex characters, then verified again at completion of the study. Chickens were reared on litter floor pens with feed and water available *ad libitum*. Continuous light was provided to 10 days post-hatch after which lighting was reduced to 12 h. At 8 wk of age, the birds were exposed to normal day lengths. All surviving birds were individually weighed, at hatch, 30, 60, 90, 124 and 154 days of age.

Statistical analysis:

Gompertz function and parameters were fitted to data using the SAS software (SAS, 2000). The growth equation used was that of Gompertz (1925), which has the following form:

$$W_t = W_0 \,.\, EXP\ [(L/K)\ (1\text{-}EXP\ \text{-}kt]$$

Where $\mathbf{W_t}$ is the weight of bird at time t, $\mathbf{W_0}$ is the initial (hatch) body weight, L is the instantaneous growth rate (per day), K is the maturation rate of exponential decay of the initial specific growth rate, L(which measures the rate of decline in the growth rate).

The Gompertz function was fitted to the data separately for each genetic group by sex combination using SAS program.

RESULTS AND DISCUSSION

Growth parameters of Fay, RIR, and crosses

Observed and predicted body weight and residual values for Fay, RIR, (Fay x RIR) and (RIR x Fay) are presented in (Table 1). The fitted parameters for each genotype for both sexes are presented in Tables 2&3.

All genotypes have considerably high R^2 values. The model may be ranked according to their R^2 values (0.9975).

Relative hatch weight of (Fay x RIR) was the same as observed for Fay hatch weights. Both genotypes were lower than of RIR and was higher than (RIR x Fay). Weights at 16 weeks of age relative to asymptote was the same for (Fay x RIR) and (RIRxFay) and highest for Fay and RIR. Relative growth patterns of the (Fay x RIR), (RIR x Fay), RIR and Fay populations (Figure 1,2,3 and 4) indicated relatively heavier RIR and Fay.

The slope from hatch to 16 weeks of age followed the same pattern as the relative weight for (Fay x RIR) and (RIR x Fay) hybrids. Although this general pattern of growth was consistent there were specific differences among the species Anthony et al., (1991). Most differences in the shape of the growth curve among species occurred between hatch and mature body weight. The extended growth curve of the chicken was probably related to the deposition of body fat with approaching sexual maturity (Cherry et al., 1984 and Scanes, 1987). Hens in (FayxRIR) showed the lowest maturing rate 0.3365 for female and 0.3386 for male (Table 3).

The parameters estimated using the Gompertz function (Table 2,3) showed higher growth potential for males than females in Fay, (RIR x Fay) and (Fay x RIR). High estimates for mature weight were observed in (Fay x RIR) male and (FayxRIR) females. Genotypes may differ in a number of respects that affect their potential growth curve. Wilson (1977) suggested that more could be learned of the evaluation of growth curves than by measuring weights at only one or possibly two ages. Different values for the growth parameters were measured for six different strains in the study by Gous et al., (1999). Knizetova et al., (1991) using the Richards function to evaluate 9 broiler lines, concluded that the estimation of the asymptotic final weight for different lines enabled the degree of maturity to be determined at any fixed paint of the curve. The ratio of inflection asymptotic weight (0.370-0.388) indicated that in same cases chicken growth can be described approximately by the Gompertz function (0.368). Results were typically consistent with the results reported earlier by Grossman (1988) and similar to those of Zhang and yang (1998), Zhang, (2002); Wang et al., (2005) and Wei, et al., (2005).

T1-2

The males were always heavier than the females and (Fay x RIR) were heavier than Fay and (RIR x Fay). Yang et al., (2006) observed that males weekly body gain was higher than of females during the whole experimental period. The absolute growth rate increased smoothly for the first three weeks and then increased rapidly to achieve the maximum weight gain at end of the phase. The mature live weights of hybrid (Fay x RIR) males was 3.370 kg compared to 2.680 kg for (RIRxFay). The males of both crossbreds in the present study have higher estimated mature body weights than the males for purebreds. The estimated mature live weights of the hybrid (FayxRIR) females are higher than any of the three genotypes. The difference between male and female may be related to the sexual dimorphism on growth trend as reported for chickens (Barbato and Vasilatos-Younken, 1991). Differences between growth rates of male and female quails have also been observed by Du Preez and Sales (1997).

The results obtained here can be compared with those of Hancock et al., (1995) on broiler genotypes. The mature live weights estimated by these authors for the males used crossbreds (Ross male x Arbor Acress females), of 5.8 to 6.1 kg. fall within the upper range of mature body weights of the six strain-crosses of broilers.

The rate of maturing parameter (L) of the males used in this evaluation was greater than for the females. The same results obtained by Hancock et al., (1995) and Knizetova et al., (1991). The values estimated in the present study for the parameters of the Gompertz equation for the four genotypes are shown in (Tables 2&3). Differences between the minimum and maximum body mass in the female and the male chicken groups reached more fourfold value of the standard error both sides around the average value.

In practice, the extract inflexion points are not important, but the length of time during which the growth rate is constant, since the highest deposition of meat in broilers occurs at this point. The convex segment of the curve coincides with the period during which there is a progressive reduction in protein deposition rate, but the body fat growth still occurs until certain age. Afterwards, fat growth also declines and the curve reaches zero, which means that the adult weight has been attained (Santos et al., 2005).

Growth parameters of Sinai, White Leghorn and crosses

The modeling technique was used to model the chicken growth response to crossing in this study. The predicted growth responses of bird to crossing with their respective asymptotic weights for S, WL, (SxWL) and (WLxS) are depicted in Figure 5,6,7 and 8 respectively. Table 4, shows the observed and predicted body weight and residual values (both sexes). Convergence was reached in all cases with R^2 values ranging from 0.955 to 0.998. (WLxS) chicks were heavier than Sinai and (SxWL) chicks at hatch. (SxWL) hybrids were always heavier at 12 weeks of age than (WLxS), Sinai and WL. Both hybrids reached the same asymptotic body weight at 20 week of age (Table 4).

In general terms, the results herein described show that hybrids with Sinai genotype tend to weighed more as the parental lines.

T3-4

As a consequence, both hybrids combinations showed very similar figures for body weight, despite the clear differences in body weight between the two parental genotypes. Residual values between observed and estimated body weights for four genotypes in Gompertz model are presented in (Table 4). It can be noticed the parental lines had small residuals in Gompertz model. Large residuals were present at 16 and 20 weeks of age.

The Gompertz model predicted the hatching weight for (WLxS) hybrid better than (SxWL) and Sinai. Ricklefs (1985) suggested that early growth may be the key response to selection for later body mass, as growth rate is evidently more flexible when it is the greatest. Hence effects to improve poultry meat might best be directed toward the first 2 week after hatching (Aggrey, 2002).

Using Gompertz model, the greatest growth was attained between week 12 and 20 for (WLxS) and (SxWL) and between week 12 and 16 for Sinai. Wo predicted for hybrid (WLxS) was 2140.6 g shown in Table 6. It was higher than the measured symptotic weight for Sinai, White Leghorn and hybrid (SxWL). The predicted mature body weight differes among sexes. Males are heavier than females through growing period.

In this study, females showed a lower (L) compared with males. The average value of (L) for both sexes 0.932 for Sinai, 0.562 for (SxWL) and 0.193 for (WLxS) which was higher than those obtained by Barbato (1991) and Mignon-Grastea et al., (1999). The rate of maturation (K), was higher in males than in females (Table 5,6). Grossman et al., (1985) also obtained a higher (K) value for males than for females using the Logistic model. Among the growth parameters predicted by the Gompertz model L, and K are highly positively correlated for both sexes (r_p=0.99). the mature body weight estimated for males was higher than that for females. Differences between the minimum and maximum body mass in the female and the male chicken groups reached more than fourfold the value of the standard error on both sides around the average value.

Growth curve models cannot explain exactly because of the complex structure of growth (Yakupoglu and Atil, 2001) However, it can be recommended that long period age-weight data set should be used to generalize growth curve parameters estimation findings. Non-linear estimation techniques may contribute to determining of the economic information and marketing strategies in animal based enterprises. Mignon-Grateau et al.,(1999) showed that genes controlling these parameters seemed partly to differ between sexes.

Growth curve differed but it was not possible to test the significance of these differences as distributions of the distributions of the growth curve parameters remained unknown. Barbato (1991) and Mignon-Grateau et al.,(1999) showed that parameters of the Gompertz curve describing age-weight relationships in chickens were heritable. Sizmore and Barbato (2002) suggested that it is possible to simultaneously select for high body weight at near the inflection point of the growth curve without increasing fat deposition or obesity by taking a devautage of lack of a genetic correlation between exponential growth rate at 14 days and body fat percentage at later ages.

T5-6

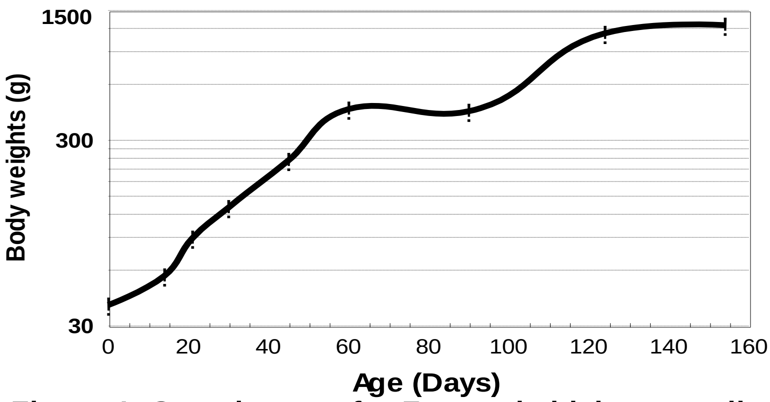

Figure 1. Growth curve for Fayoumi chickens predicted Gompertz

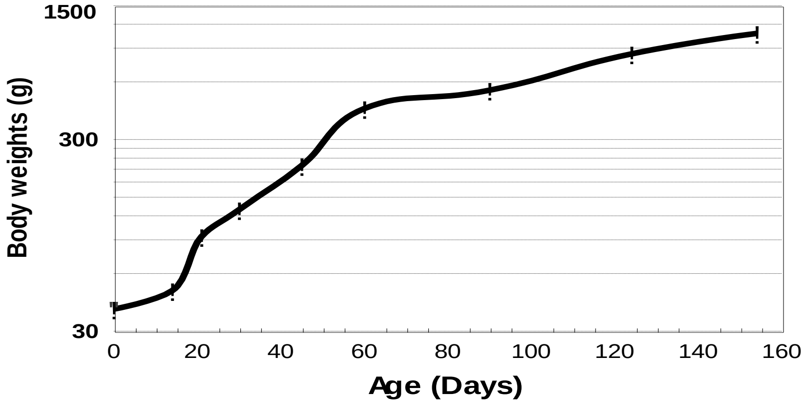

Figure 2. Growth curve for (FayxRIR) chickens predicted Gompertz

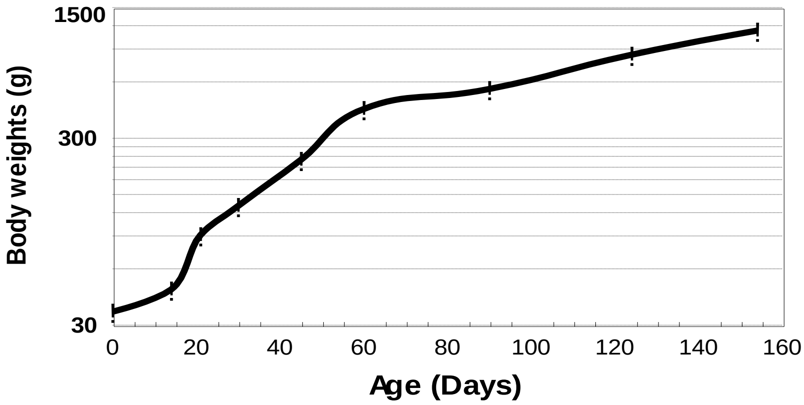

Figure 3 Growth curve for (RIRxFay) chickens predicted Gompertz

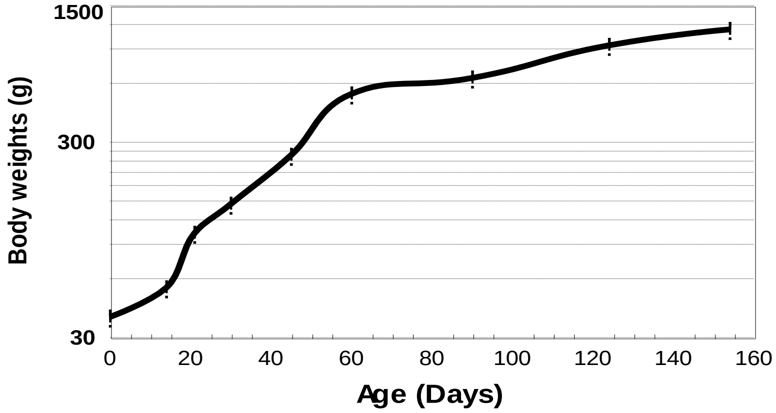

Figure 4 Growth curve for (RIR) chickens predicted Gompertz

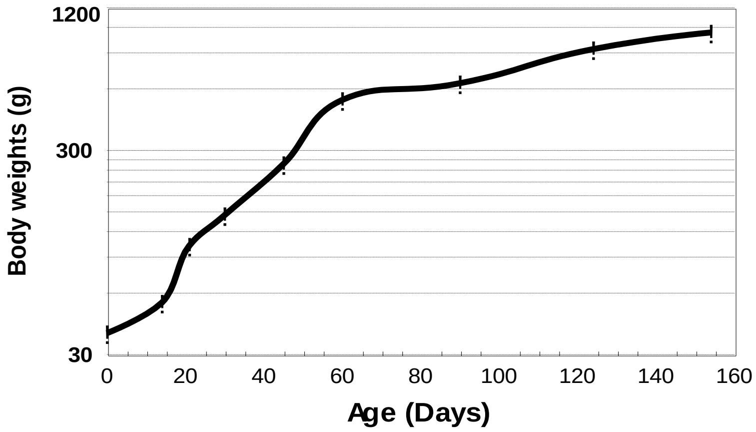

Figure 5 Growth curve for Sinai chickens predicted Gompertz

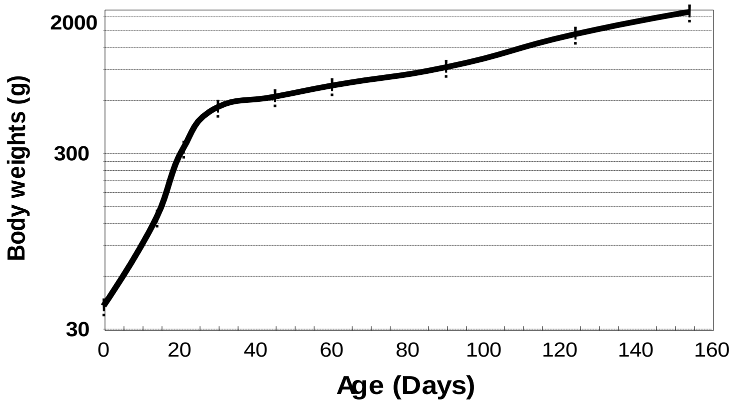

Figure 6 Growth curve for(SxWL) chickens predicted Gompertz

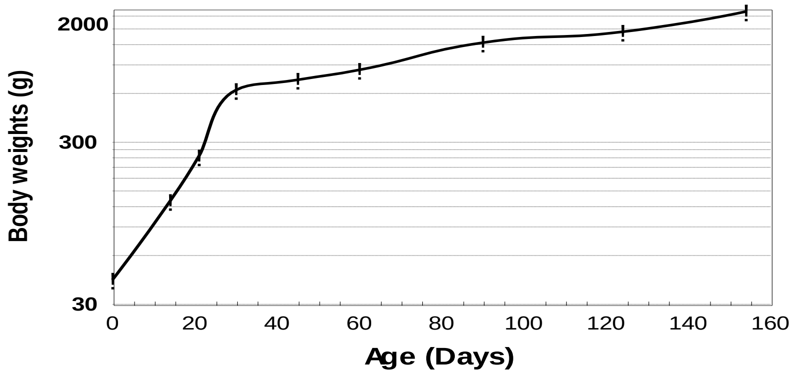

Figure 7 Growth curve for(WLxS) chickens predicted Gompertz

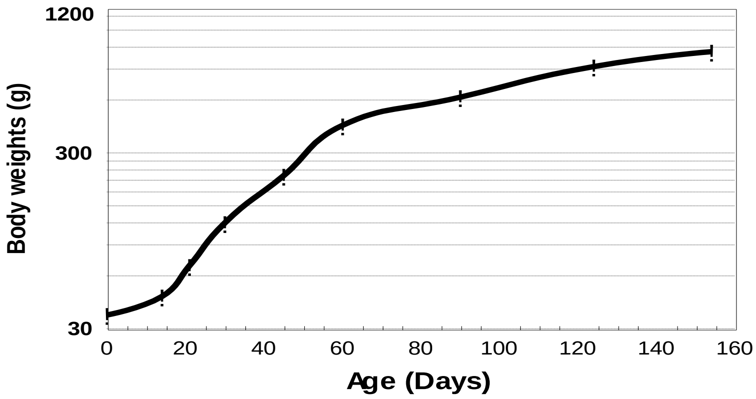

Figure 8 Growth curve for (WL) chickens predicted Gompertz

REFERENCES

Aggrey, S.E. (2002) Comparison of three nonlinear and spline regression models for describing chicken growth curves. Poult. Sci. 81:1782-1788.

Anthony, N.B., Emmerson, D.A., Nestor, K.E., Bacon, W.L. Siegel, P.B. and Dunnington, E.A. (1991). Comparison of growth curves of weight selected populations of turkeys, quail, and chickens. Poult. Sci. 70: 13-19.

Barbato, G.F. "(1991) Genetic architecture of growth curve parameters in chickens.Theor. Appl. Genet. 83: 24-32.

Barbato, F. and Vasilatos-Younken, R.(1991) Sex-linked and maternal effects on growth in chickens. Poult. Sci. 70: 709-718.

Cherry, J.A., Swartworth, W.J. and Siegel, P.B.(1984) Adipose cellularity studies in commercial broiler chicks. Poult. Sci. 63:97-108.

Du Preez, J.J. and Sales, J. (1997) Growth rate of different sexes of the European quail (*coturnix coturnix*). Br. Poult. Sci. 38: 314-315.

Emmans, G.C. (1981). A model of growth and feed intake of ad libitum fed animals, particularly poultry. Pages 103-110 in: Computers in animal production. Animal Production, Occasional Publication No 5. G.M. Hillyer, C.T. Whittemore, and R.G. Gunn, ed. British Society of Animal Production, London, U.K.

Gompertz, B. (1825) On the nature of the function expressive of the law of human mortality, and on a new method of determining the value of life contingencies. Phil. Trans. Royal. Soc 115: 513-585.

Gous, R.M., Moran, E.T. Stilborn, H.R., Bradford, G.D. and Emmans, G.C. (1999) Evaluation of the parameters needed to describe the overall growth, the chemical growth, and the growth of feathers and breast muscles of broilers. Poult. Sci. 78:812-821.

Hancock, C.E., Bradford, G.D., Emmans, G.C. and Gous, r.M. (1995) the evaluation of the growth parameters of six strains of commercial broiler chickens. Br. Poult. Sci. 36:247-264.

Knizetova, H., Hyanek, J. Knize, B. and Roubicek, J. (1991). Analysis of growth curves of fowl. I. Chickens. Br. Poult. Sci. 32: 1027-1038.

Masic, B. and Khalifah, M. (1965) The conformation of chick of various breeds and crosses for broiler production. Anim. Breeding Abst. 34:114.

Mignon-Grasteau, S., Beaumont, C., Le Bihan-Duval, E. Poivey, J.P., De

Rochambeau, H. and Ricard, F.H. (1999) Genetic parameters of growth curve parameters in male and female chickens. Br. Poult. Sci. 40: 44-51.

Oltjen, J.W., Bywater, A.C., and Baldwin, R.L. (1986). Development of a dynamic model of beef cattle growth and composition. J. Anim. Sci. 62:86-97.

Ricklefs, R.E. (1985) Modification of groeth and development of muscles of poultry.Poult. Sci. 64: 1563-1576.

SAS Institute, (2000) SAS/STAT User's Guide, SAS Institute Inc., Cary, NC.

Santos, A.L., Sakomura, U.K., Freitas, E.R., Fortes, C.M.S. and Carrilho, E.N.V.M. (2005) Comparison of free range broiler chicken strains raised in confined or semi-confined systems. Brazilian J. of Poult. Sci. V.7/n.2/85-92.

Scanes, C.G., (1987) The Physiology of growth, growth hormone and other growth factors in poultry. CRC Crit. Rev. Poult. Biol. 1:51-105.

Sizmore, F.G. and Barbato, G.F. (2002) Correlated responses in body composition to divergent selection for exponential growth rate to 14 or 42 days of age in chickens. Poult. Sci. 18:932-938.

Stilborn, H.L., Moran, E.T., Gous, R.M. and Harrison, M.D. (1994) Experimental data for evaluating broiler models. J. Appl. Poult. Res. 3:379-390.

Tzeng, R.Y. and Becker, W.A.(1981) Growth patterns of body and abdominal fat weight in male broiler chickens. Poult. Sci. 60: 1101-1106.

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

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

Wilson, B.J. (1977) Growth curves: Their analysis and use. N. Boorman, and B.J. Wilson, ed. British Poultry Sci. Ltd., Edinburgh, U.K.

Yang, H.M., Vx, Q. and Dai, G.J. (2004) Analysis on three kinds of growth curve in avain. Cin. Poult. Sci. 8: 164-166.

Yang, Y., Mekki, D.M. Lv, S.J., Wang, L.Y., Yu, J.H., and Wang, J.Y. (2006). Analysis of fitting growth models in Jinghai mixed-sex yellow chicken. International Journal of Poult. Sci. 5: 517-521.

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

Zhang, H. Wu, CH. X., Li, J.Y. and Ling, Y. (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.

Yakupoglu, C. and Atil, H.(2001) Comparison of growth curve models on broilers growth curve I: Parameters estimation. Online Journal of Biological Sci. 1 (7) 680-681.

تحليل بيانات النمو لانواع البلدى وخلطانها باستخدام الدوال الغير خطية لجمبيرز

حسن اسماعيل زكى
مركز بحوث الصحراء

هذه الدراسة اجريت بمحطة بحوث راس سدر التابعة لمركز بحوث الصحراء حيث كان الهدف من الدراسة تحليل بيانات النمو للدجاج المحلى وخلطانه باستخدام الدوال الغير خطية باستخدام نموذج جمبيرز استخدم فى هذه الدراسة بيانات النمو وسجلات الاوزان لمجموعتين من الدجاج المجموعة الاولى تتكون من الفيومى و الرود ايلاند الاحمر والخليط بينهما فى الاتجاهين والمجموعة الثانية تتكون من دجاج سينا و اللجهورن الابيض والخليط بينهما فى الاتجاهين. تم اخذ اوزان الجسم عند الفقس و ١٤, ٢١, ٣٠, ٤٥, ٦٠, ٩٠, ١٢٤, ١٥٤ يوم من العمر. تمت التغذية لهذه الطيور للشبع. وكانت اهم النتائج:

بالنسبة للمجموعة الاولى: وجد ان الوزن عند ١٦ اسبوع لكل من الخليط (RIRxFay) , (FayxRIR) متساوى عند هذا العمر. وكان وزنهما عند ١٦ اسبوع اكبر من الفيومى و الرود ايلاند ريد. سجلت طيور الخليط (FayxRIR) اقل معدل وزن ناضج وكان ٣٣٦٥ للاناث و ٣٣٨٦ للذكور. كما سجلت ذكور (FayxRIR) ااعلى معدل وزن ناضج وكذلك اناث (RIRxFay) . قدر الوزن الناضج لذكور (FayxRIR) فكانت ٣٣٧٠ جم فى مقابل ٢٦٨٠ جم للاناث (RIRxFay). وكان مقياس معدل النمو L اكبر فى الذكور عن الاناث.

بالنسبة للمجموعة الثانية: كانت كتاكيت الخليط((WLxS) اكثر وزنا من سينا والخليط (WLxS),) عند الفقس. كذلك وجد ان الخليط (WLxS) اثقل وزنا غند عمر ١٢ اسبوع من (SxWL) و سينا وللجهون الابيض. ووجد ان كل من الخليط (SxWL) و (WLxS) تصل الى نفس الوزن الناضج عند عمر ٢٠ اسبوع . وكان الوزن الناضج المتوقع يختلف باختلاف الجنس ووجد ان معدل K اعلى فى الذكور عن الاناث. كذلك الوزن الناضج للذكور كان اعلى من الوزن الناضج للاناث.

يمكن من خلال استخدام الدوال الغير خطية التنبوء بسرعة النمو و الوزن الناضج المتوقع لاى نوع من الدجاج الذى على اساسه يمكن وضع البرنامج الانتخابى المناسب وتحديد احتياجات التغذية المناسبة بما يتوافق مع سرعة النمو فى كل مرحلة عمرية كذلك امكن تحليل بيانات النمو للانواع الخليطة و النقية لايجاد تفسير لتزايد سرعة النمو مع كل مرحلة عمرية

Table 1. Observed and predicted body weights and residual values and parameter values of non-linear model relating growth by age for Fayoumi, (Fay x RIR), (RIR x Fay) and RIR.

Age	Fayoumi (n=42)					(Fay x RIR) (n=44)					(RIR xFay) (n=68)					RIR (n=78)				
	Pred.	K	L	Obs.	Res.	Pred.	K	L	Obs.	Res.	Pred.	K	L	Obs.	Res.	Pred.	K	L	Obs.	Res.
Hatch	38.93	0.080	0.001	35.66	2.98	39.07	.0548	.001	36.98	2.1	35.54	.0090	.0080	35.23	0.32	43.34	.0065	.0079	43.05	.28
14 d.	55.84	.0023	.008	55.7	.131	48.84	.0100	.0086	48.36	.48	46.50	.0055	.0079	46.25	.25	51.92	.0036	.0079	51.73	.187
21 d.	89.11	.1276	.0009	78.46	10.6	93.35	.0985	.0010	84.61	8.7	90.85	.1264	.0009	80.09	10.8	93.98	.1242	.0009	83.04	10.95
30 d.	130.21	.0549	.001	123.28	6.93	129.01	.0700	.0087	120.58	8.4	130.05	.0900	.0087	119.24	10.8	129.78	.0110	.0009	128.37	1.41
45 d.	233.72	.0100	.0086	231.49	2.23	219.29	.0329	.0010	212.22	7.1	229.97	.0200	.0010	225.44	4.52	564.09	.0095	.0080	261.69	2.40
60 d.	441.54	.0100	.0085	437.36	4.18	435.06	.0900	.0060	398.89	36.2	430.01	.0500	.0080	410.0	20.0	542.34	.0100	.0086	537.22	5.12
90 d.	729.91	.0400	.004	702.06	27.8	542.96	.0300	.0080	527.78	15.2	550.23	.0100	.0085	545.07	5.16	741.04	.0100	.0086	734.10	6.94
124 d.	1130.0	.0400	.003	1086.8	43.2	840.04	.0500	.0070	801.25	38.8	839.62	.0100	.0087	831.82	7.79	1036.2	.0100	.0087	1026.5	9.61
154 d.	1250.2	.0400	.002	1200.3	50.1	1073.9	.0900	.0030	983.89	90.1	1129.6	.0900	.0080	1038.9	90.7	1230.6	.0219	.0010	1204.1	26.53

Obs. = observed weight, Pred. = Predicted weight, Res. =Residual = (predicted weight-observed weight)

W_A =asymptotic (mature) body weight, K = is the maturation rate of exponential decay of the initial specific growth, L= is the instantaneous growth rate (per day).

Table 2. Parameter estimate, asymptotic standard error and 95% confidence interval Gompertz model for Fayoumi and RIR

Parameters	Fayoumi						RIR					
	Female (n=24)			Male (n=18)			Female (n=42)			Male (n=36)		
	Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%	
		Lower limit	Upper limit		Lower limit	upper limit		Lower limit	Upper limit		Lower limit	Upper limit
W_A	1223.7±30.5	1163.6	1283.9	2377.2±111.1	2158.5	2596.0	1273.5±20.2	1233.7	1313.3	1965.0±73.4	1820.1	2109.9
K	10.699±1.88	6.98	14.41	7.153±0.753	5.669	8.636	16.46±2.7	10.969	12.96	8.853±1.55	5.7843	11.92
L	0.935±0.074	0.7896	1.081	0.5857	0.4965	0.6748	1.152±0.07	1.0127	1.2913	0.7796±0.07	0.6364	0.9228

W_A =asymptotic (mature) body weight, K = is the maturation rate of exponential decay of the initial specific growth, L= is the instantaneous growth rate (per day).

Table 3. Parameter estimate, asymptotic standard error and 95% confidence interval Gompertz model for (Fay x RIR) and (RIR x Fay).

Parameters	(Fay x RIR)						(RIR x Fay)					
	Female (n=24)			Male (n=20)			Female (n=38)			Male (n=30)		
	Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%	
		Lower limit	Upper limit		Lower limit	upper limit		Lower limit	Upper limit		Lower limit	Upper limit
W_A	2471.9±306.5	1666.9	3076.9	3370.2±653.5	2078.7	4661.6	2296.3±73.6	2151.7	2440.8	2680.5±113.6	2455.5	2905.4
K	4.419±0.22	3.98	4.853	4.555±0.3626	3.8387	5.2721	4.577±0.078	4.422	4.732	4.936±0.173	4.6258	5.307
L	0.3365±0.039	0.2598	0.4131	0.33866±0.06	0.21928	0.458	0.3648±0.01	0.3415	0.3879	0.4099±0.020	0.3729	0.4529

W_A =asymptotic (mature) body weight, K = is the maturation rate of exponential decay of the initial specific growth, L= is the instantaneous growth rate (per day).

Table 4. Observed and predicted body weights and residual values and parameter values of non-linear model relating growth by age for Sinai, (S x WL), (WL x S) and White Leghorn.

Age	Sinai (n=96)					(S x WL) (n=90)					(WL xS) (n=122)					White Leghorn (n=80)				
	Pred.	K	L	Obs.	Res.	Pred.	K	L	Obs.	Res.	Pred.	K	L	Obs.	Res.	Pred.	K	L	Obs.	Res.
Hatch	38.18	.0082	.0080	37.87	.312	40.74	.0074	.0079	40.45	.291	42.51	.0070	.0080	42.22	.287	35.89	.0090	.0080	35.57	.14
14 d.	53.89	.0030	.0079	53.73	.16	130.21	.0700	.0087	121.55	8.65	129.9	.0800	.0010	120.0	9.97	45.74	.0057	.0079	45.48	.258
21 d.	102.46	.1183	.0009	91.06	11.4	322.03	.1012	.0009	291.11	40.9	245.1	.0100	.0080	242.6	2.45	68.23	.0017	.0070	68.34	-.118
30 d.	144.46	.0098	.0080	143.08	1.38	550.7	.0100	.0084	545.46	5.3	629.1	.0300	.0010	610.6	18.5	119.56	.1063	.0009	107.55	12.02
45 d.	257.3	.0098	.0080	254.88	2.41	631.5	.0800	.0084	770.28	61.3	728.1	.0992	.0009	659.6	68.5	222.28	.1021	.0009	200.81	21.47
60 d.	529.98	.0800	.0030	789.94	40.0	729.9	.0400	.0070	702.5	27.5	838.2	.0100	.0086	632.2	6.02	430.0	.0329	.0010	416.16	13.87
90 d.	639.68	.0100	.0080	633.6	5.9	928.7	.0900	.0010	757.9	70.8	1234.0	.0200	.0080	1211.1	22.9	622.8	.1000	.0009	563.9	58.9
124 d.	939.8	.0100	.0080	931.12	8.7	1433.1	.0800	.0080	1330.1	103	1440.1	.0210	.0068	1398.4	41.7	929.6	.0800	.0010	858.64	70.91
154 d.	1133.6	.0200	.0080	1112.8	20.7	1917.4	.0080	.0080	1902.4	15.0	1920.3	.0150	.0040	1840.2	80.1	1129.7	.0600	.0010	1064.5	65.22

Obs. = observed weight, Pred. = Predicted weight, Res. =Residual = (predicted weight-observed weight)
W_A =asymptotic (mature) body weight, K = is the maturation rate of exponential decay of the initial specific growth, L= is the instantaneous growth rate (per day).

Table 5. Parameter estimate, asymptotic standard error and 95% confidence interval Gompertz model for Sinai and White Leghorn.

Parameters	Sinai						White Leghorn					
	Female (n=46)			Male (n=50)			Female (n=37)			Male (n=43)		
	Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%	
		Lower limit	Upper limit		Lower limit	upper limit		Lower limit	Upper limit		Lower limit	Upper limit
W_A	1288.3±24.6	1239.9	1336.7	2420.1±133.3	2157.0	2683.1	1196.1±30.0	1136.9	1255.2	1894.1±61.4	1773.0	2015.12
K	11.21±1.672	7.923	14.504	6.675±0.8217	5.054	8.297	12.566±2.554	7.531	17.60	9.178±1.335	6.545	11.81
L	0.9814±0.0633	0.8569	1.1059	0.8843±0.054	0.4769	0.6917	0.9973±0.0837	0.8323	1.162	0.7642±0.059	0.6479	0.8805

W_A =asymptotic (mature) body weight, K = is the maturation rate of exponential decay of the initial specific growth, L= is the instantaneous growth rate (per day).

Table 6. Parameter estimate, asymptotic standard error and 95% confidence interval Gompertz model for (S x WL) and (WL x S).

Parameters	(S x WL)						(WL x S)					
	Female (n=40)			Male (n=50)			Female (n=54)			Male (n=68)		
	Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%		Estimate ±SE	Confidence interval 95%	
		Lower limit	Upper limit		Lower limit	upper limit		Lower limit	Upper limit		Lower limit	Upper limit
W_A	2048.6±158.7	1735.2	2361.9	3120.1±195.3	2703.4	3450.3	2140.6±238.0	1672.8	2608.3	2923.5±205.6	2320.2	3150.5
K	4.563±0.350	3.871	5.254	6.321±0.345	5.214	7.321	4.45±0.204	3.950	4.752	6.32±0.301	4.321	7.63
L	0.4388±0.045	0.3504	0.5273	0.6842±0.032	0.4213	0.699	0.3036±0.035	0.2929	0.434	0.0821±0.212	0.2002	0.1234

W_A =asymptotic (mature) body weight, K = is the maturation rate of exponential decay of the initial specific growth, L= is the instantaneous growth rate (per day).