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 Gompertz function of 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 heavier 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 terms 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:

\[ W_t = W_0 \cdot \exp \left[ \left( \frac{L}{K} \right) \left( 1 - \exp(-kt) \right) \right] \]
Where $W_t$ is the weight of bird at time $t$, $W_0$ 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 point 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).
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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 Acres 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 R² 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.
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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 (t=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.
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Figure 1. Growth curve for Fayoumi chickens predicted Gompertz

Figure 2. Growth curve for (Fay×RIR) chickens predicted Gompertz

Figure 3. Growth curve for (RIR×Fay) 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
REFERENCES


تحليل بيانات النمو لأنواع البلدى وخلطائها باستخدام الدوال الغير خطية لجميرز
حسن اسماعيل زكى
مركز بحوث الصحراء

هذ الدراسة جرت بمحطة بحوث راس سدر التابعة لمركز بحوث الصحراء حيث كان الهدف من
الدراسة تحليل بيانات النمو للدجاج المحلي وخلطاتها باستخدام الدوال الغير خطية باستخدام نموذج جميرز.

استخدم في هذه الدراسة نموذج النمو وسجلات الأوزان لمائتين وعشرة من الدجاج الجملة الأولى، وتكمن من
الفيومي والرياني ورائد الأمو، والدجاج المحلي بينهما في الاجهاد والعمل، والذي تتكون من نمو دجاج سيدا و
الدجاج البسيط والدجاج المحلي بينهما في الاتجاهين. تم اختبار أوزان باستعداد المجموعتين و (FayxRIR)
والرياني (RIRxFay) في تمرين من العمر (0.03, 14, 41, 45) يوماً.

بالنسبة للمجموعة الأولى، وجد أن الوزن عند 16 أسبوع لكل من الدجاج (FayxRIR) و (RIRxFay)
مساوى عند هذا العمر. وكان وزنها عند 16 أسبوع أكبر من الفيومي والرياني. سجلت طيور
الرياني أقوى معدلا وزناً وكان (0.03, 14, 41, 45) للذكور. كما سجلت الذكور (FayxRIR) الخليل
العلي المعدل وزن ناضج و (0.03, 14, 41, 45) للذكور (RIRxFay) الخليل.

كانت وزن الناضج للذكور (FayxRIR) الخليل 227.30 جم في مقابل 298 جم للذكور (RIRxFay).
وكان مقياس معدل النمو L (RIxFay) أكبر في الذكور عن الإناث.

الأوفرة لصلابة المجموعة الثلاثية (WLSxS) أكثر وزناً من سيدا والدجاج المحلي (WLSxL)
(12 أسبوع) ساء المعدل وزناً عند (WLSxL) (16 أسبوع) ساء المعدل وزناً عند (WLSxL) (12 أسبوع)
و (WLSxL) (16 أسبوع) ساء المعدل وزناً عند (WLSxL) (12 أسبوع).

وكان الوزن الناضج للكنغر (أ) في الذكور كان أعلى في الذكور (RIxFay) الخليل.

وكان وزن الناضج للذكور كان أعلى في النمط الناضج للكنغر.

وتمكن من خلال استخدام الدجاج الغير خطية النمو الشمسي بسرعة النمو والوزن الناضج المتوقع لدجاج
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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.

<table>
<thead>
<tr>
<th>Age</th>
<th>Fayoumi (n=42)</th>
<th>(Fay x RIR) (n=44)</th>
<th>(RIR x Fay) (n=68)</th>
<th>RIR (n=78)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hatch</td>
<td>38.93</td>
<td>0.080</td>
<td>0.001</td>
<td>35.66</td>
</tr>
<tr>
<td>14 d.</td>
<td>55.84</td>
<td>.0023</td>
<td>.005</td>
<td>55.7</td>
</tr>
<tr>
<td>21 d.</td>
<td>89.11</td>
<td>.1276</td>
<td>.0009</td>
<td>78.46</td>
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<tr>
<td>30 d.</td>
<td>130.21</td>
<td>.0549</td>
<td>.001</td>
<td>123.28</td>
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<tr>
<td>45 d.</td>
<td>233.72</td>
<td>.0100</td>
<td>.0086</td>
<td>231.49</td>
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<tr>
<td>60 d.</td>
<td>441.54</td>
<td>.0100</td>
<td>.0085</td>
<td>437.36</td>
</tr>
<tr>
<td>90 d.</td>
<td>729.91</td>
<td>.0400</td>
<td>.004</td>
<td>702.06</td>
</tr>
<tr>
<td>124 d.</td>
<td>1130.0</td>
<td>.0400</td>
<td>.003</td>
<td>1086.8</td>
</tr>
<tr>
<td>154 d.</td>
<td>1250.2</td>
<td>.0400</td>
<td>.002</td>
<td>1200.3</td>
</tr>
</tbody>
</table>

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, $L$ = the instantaneous growth rate (per day).

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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Female (n=24)</th>
<th>Male (n=18)</th>
<th>Female (n=42)</th>
<th>Male (n=36)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate ±SE</td>
<td>Confidence interval 95%</td>
<td>Estimate ±SE</td>
<td>Confidence interval 95%</td>
</tr>
<tr>
<td></td>
<td>Lower, Upper limit</td>
<td>Lower, Upper limit</td>
<td>Lower, Upper limit</td>
<td>Lower, Upper limit</td>
</tr>
<tr>
<td>$W_a$</td>
<td>1223.7±30.5</td>
<td>1163.6 - 1283.9</td>
<td>2377.2±111.1 - 2158.5</td>
<td>2596.0 - 1273.5±20.2 - 1233.7</td>
</tr>
<tr>
<td>$L$</td>
<td>0.935±0.074</td>
<td>0.7896 - 1.081</td>
<td>0.5857 - 0.4965 - 0.6748</td>
<td>1.152±0.07 - 1.0127 - 1.2931</td>
</tr>
</tbody>
</table>

$W_a$ = asymptotic (mature) body weight, $K$ = is the maturation rate of exponential decay of the initial specific growth, $L$ = 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% |
| | Lower limit | Upper limit | Lower limit | Upper limit | Lower limit | Upper limit |
| W_A | 2471.9±306.5 | 1666.9 | 3076.9 | 370.2±653.5 | 2078.7 | 4661.6 | 2296.3±73.6 | 2151.7 | 2440.8±113.6 | 2455.5 | 2905.4 |
| K | 4.419±0.22 | 3.98 | 4.853 | 4.555±0.3626 | 4.422 | 4.732 | 4.936±0.173 | 4.625 | 4.837 |
| L | 0.3365±0.039 | 0.2598 | 0.4131 | 0.33866±0.06 | 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 = 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 | S x WL (n=90) | | | WL x S (n=122) | | | White Leghorn (n=80) | | |
|-----|---------------|-----------------|-----------------|-----------------|-----------------|
| Hatch | 38.18 | .0082 | .0080 | 37.87 | .312 | 40.74 | .0074 | .0079 | 40.45 | .291 | 42.51 | .0070 | .0080 | 42.22 | .287 |
| 14 d. | 53.89 | .0030 | .0079 | 53.73 | .16 | 130.21 | .0700 | .087 | 121.55 | 8.65 | 129.9 | .0800 | .0010 | 120.0 | 9.97 |
| 21 d. | 102.46 | .1183 | .0009 | 91.06 | 11.4 | 322.03 | .0121 | .009 | 291.11 | 40.9 | 245.1 | .1000 | .0080 | 242.6 | 2.45 |
| 30 d. | 144.46 | .0098 | .0080 | 143.08 | 1.38 | 550.7 | .0100 | .0084 | 545.46 | 5.3 | 629.1 | .0000 | .0010 | 610.6 | 18.5 |
| 45 d. | 257.3 | .0098 | .0080 | 254.88 | 2.41 | 631.5 | .0100 | .0084 | 707.28 | 61.3 | 682.3 | .0100 | .0010 | 674.1 | 88.2 |
| 50 d. | 529.98 | .0080 | .0030 | 789.94 | 40.0 | 729.9 | .0400 | .0070 | 702.5 | 27.5 | 838.2 | .0100 | .0086 | 632.6 | 6.02 |
| 60 d. | 639.68 | .1000 | .0080 | 633.6 | 5.9 | 928.7 | .0900 | .0010 | 757.9 | 70.8 | 1340.0 | .0200 | .0080 | 1211.1 | 22.9 |
| 90 d. | 939.8 | .0100 | .0080 | 931.12 | 8.7 | 1433.1 | .0800 | .0080 | 1330.1 | 103 | 1440.1 | .0210 | .0068 | 1398.4 | 41.7 |
| 124 d. | 1133.6 | .0200 | .0080 | 1112.8 | 20.7 | 1917.4 | .0800 | .0080 | 1902.4 | 15.0 | 1920.3 | .0150 | .0040 | 1840.2 | 80.1 |
| 154 d. | 1133.6 | .0200 | .0080 | 1112.8 | 20.7 | 1917.4 | .0800 | .0080 | 1902.4 | 15.0 | 1920.3 | .0150 | .0040 | 1840.2 | 80.1 |

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 = instantaneous growth rate (per day).
Table 5. Parameter estimate, asymptotic standard error and 95% confidence interval Gompertz model for Sinai and White Leghorn.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sinai</th>
<th>White Leghorn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (n=46)</td>
<td>Male (n=50)</td>
</tr>
<tr>
<td></td>
<td>Estimate ±SE</td>
<td>Confidence interval 95%</td>
</tr>
<tr>
<td></td>
<td>Lower limit</td>
<td>Upper limit</td>
</tr>
<tr>
<td>$W_A$</td>
<td>1288.3±24.6</td>
<td>1239.9</td>
</tr>
<tr>
<td>$K$</td>
<td>11.21±1.672</td>
<td>7.923</td>
</tr>
<tr>
<td>$L$</td>
<td>0.9814±0.063</td>
<td>0.8569</td>
</tr>
</tbody>
</table>

$W_A$ = 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).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>(S x WL)</th>
<th>(WL x S)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (n=40)</td>
<td>Male (n=50)</td>
</tr>
<tr>
<td></td>
<td>Estimate ±SE</td>
<td>Confidence interval 95%</td>
</tr>
<tr>
<td></td>
<td>Lower limit</td>
<td>Upper limit</td>
</tr>
<tr>
<td>$W_A$</td>
<td>2048.6±158.7</td>
<td>1735.2</td>
</tr>
<tr>
<td>$L$</td>
<td>0.438±0.045</td>
<td>0.3504</td>
</tr>
</tbody>
</table>

$W_A$ = 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).