Bayesian Hierarchical Modeling of Growth via Gompertz Model: An Application in Poultry

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Abstract

Estimation of growth curves of poultry species is of particular importance in animal science. This study aims at fitting hierarchical Gompertz growth curve to Japanese quails body weight data obtained from hatching to 56 days of age weekly. The model involved a random animal effect as well as sex and line effects in asymptotic weight parameters. Model parameters were estimated via Bayesian methodology. The results of the present study indicated a higher asymptotic weight for selection line quail than that of control line. Moreover, as expected, female quails had a higher asymptotic weight than males.

Keywords: Repeated measures; random effects; non-linear growth model

1 Introduction

To date, the use of mixed models, which include both fixed (e.g. sex, line) and random (individual) effects, is scarce in modeling the growth of poultry [1, 2, 3]. It is also natural to assign a hierarchy to this type of data, such that the response variable body weights can be regarded as nested within individuals [4]. Although Bayesian analysis of hierarchical linear models was considered by various researchers [5, 6], in fitting non-linear models, particularly to growth data of poultry, the use of Bayesian approach is rare [7]. In the present study, widely used Gompertz growth model was fitted to Japanese quail's data using Bayesian approach.

2 Material and Method

Weekly body weight measurements of 206 male and female Japanese quail from hatching to 56 days of age were formed the basis of this study. Data involves the measurements of a selected line, which was obtained by selecting the quail for 4th-week high body weight over 4 generations, and a control line.

Consider the following fixed effects Gompertz growth model:

$y_j = \beta_0 exp[-\beta_1 exp(-\beta_2 t_j)]$

where y_j is the body weight at time t_j, β_0 is the final (asymptotic) weight, β_1, is the time scale parameter and β_2 is the growth rate. In this function, any combination of the parameters can be assumed as random or fixed.

Assume a Gompertz model where only the asymptotic weight, β_0, is allowed to vary among birds in each line and sex group. The model, in terms of fixed and random effects, can now be written as,

$y_{ij} = [\beta_0 + g_1(line)_i + g_2(sex)_i + u_i]exp(-\beta_1 exp(\beta_2 t_{ij}))$

Here, the fixed effect parameters to be estimated are β_0, β_1, β_2, g_1 and g_2 whereas the random effect to be estimated is $u_i \sim N(0, \sigma_u^2)$, the random animal deviation.

Assuming independence among individuals, the conditional distribution of the data vector $\mathbf{y}$ given the other parameters is as follows:

$$f(\mathbf{y}|.) = \prod_{i=1}^{N} \prod_{j=1}^{n_i} \left(\frac{1}{\sqrt{(2\pi)}\sigma_e} \times \right.$$
$$\left. exp\left\{ - \frac{[y_{ij} - [(\beta_0 + g_1(line)_i + g_2(sex)_i + u_i)exp(-\beta_1 exp(-\beta_2 tij))]]^2}{2\sigma_e^2} \right\} \right)$$

Following prior distributions were assigned to obtain the fully conditional distributions of the model parameters:

$\beta_0 \sim N(0, 0.0001)$, $\beta_1 \sim N(0, 0.0001)$, $\beta_2 \sim N(0, 0.0001)$

$g_1 \sim N(0, 0.0001)$, $g_2 \sim N(0, 0.0001)$

$\sigma_u^2 = \frac{1}{\tau_u}$ and $\tau_u \sim U(0, 1000)$

$\sigma_e^2 = \frac{1}{\tau_e}$ and $\tau_e \sim U(0, 1000)$

Three chains of 100,000 cycles were considered with a burn-in period of 10,000 for each. Thinning intervals were set to 270 cycles.

3 Results

Estimates of asymptotic weight parameter for each sex and line group are plotted in Figure. It can be clearly seen from the figure that the asymptotic weight parameter of Gompertz model was affected by sex and line. Asymptotic weight parameter of females was slightly higher than males while the selection line quail also had a higher parameter estimate than that of control line. According to the results of the present study, it can be concluded that selection for the 4th-week high body weight produces quail with an improved asymptotic (maximum, potential) body weights.

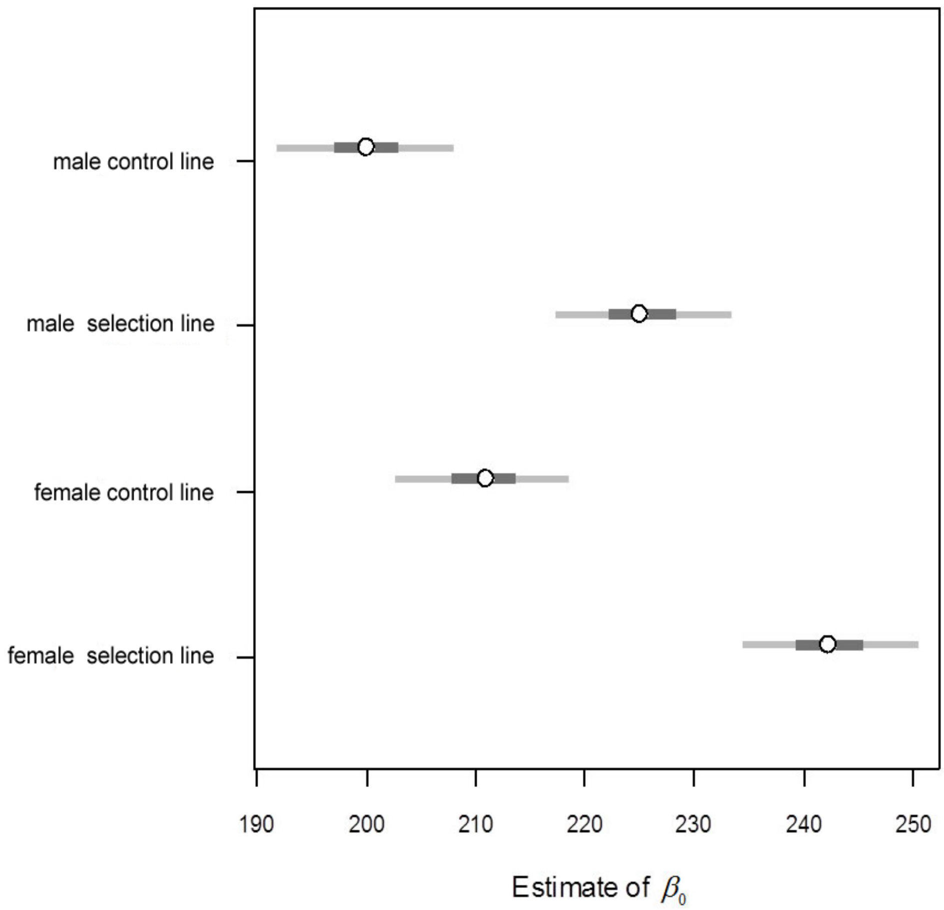

Figure 1: Estimates of asymptotic weight parameter for each sex and line group

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