Effect of short-term divergent selection for 5-week body weight on growth characteristics of Japanese quail

Einfluss einer kurzzeitigen, divergierenden Selektion nach dem Fünf-Wochen-Gewicht auf die Kennwerte des Wachstumsverlaufs von japanischen Wachteln

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Introduction

Growth is a complex physiological process from conception until maturity (CHAMBERS, 1990) and is determined as body weight on a longitudinal time frame (AGGREY, 2002). The growth pattern of body weight or body parts is described by growth curve functions, which summarize the information into a few biologically interpretable parameters (GOLIOYMTIS et al., 2003; ERSOY et al., 2007). These curves are universal sigmoid shapes, which can define the growth rate of animals. Any irregular fluctuations in weight caused by random environmental effects are eliminated when the functions are expressed graphically (KNÍZETOVA et al., 1991). ANTHONY et al. (1986) compared the use of Logistic, Gompertz, and Bertalanfy models in the divergent selection for 4-week body weight on the growth patterns of Japanese quail. Also, ANTHONY et al. (1991) studied the growth curves of selected populations in turkey, quail and chicken. AKBAS and OGUZ (2000) used three nonlinear growth models in selected and non-selected quail lines. AKBAS and YAYLAK (2000) tried to estimate heritabilities of growth curve parameters in unselected quails by using Gompertz model. AGGREY (2002) compared three nonlinear models (Richards, Gompertz and Logistic) and spline regression model in unselected chicken populations. AGGREY et al. (2003) examined the effect of long-term divergent selection on growth characteristics in quail using Richard’s model.

The generalized Richards model, which also assesses the shape of a growth curve, has had limited use in poultry (HYANKOVA et al., 2001; AGGREY, 2002). There is a general agreement in literature about the effects of selection for weight or growth on increased fatness (MIGNON-GRASTEAU et al., 2000), however, the effect of selection on altering the shape of the growth curve or growth trajectory has been conflicting. Results from long-term selection experiment in mice indicated that selection for size or growth rate had little effect on shape of the growth curve (EISEN, 1976). HYANKOVA et al. (2001) on the contrary, reported alterations in growth curve shape in quail when selected for relative growth in the short-term. QUEIROZ et al. (2004) compared five growth curve models fitted to weight records of native partridges (Rhynchotus rufescens) from South America and found that the Gompertz and Von Bertallanfy models were the best models according to having the highest coefficient of determination ($R^2 = 96.35\%$). Growth curves of the same or different species are not necessarily best described by the same equation (RICKLEFS, 1967).

BRISBIN et al. (1987) suggested that the shape of a growth curve has a greater propensity to change in response to environmental changes than the asymptotic weight or growth rate and may be used to study the effects of environmental stress on growth. AGGREY (2002) further suggested that shape of the growth curve may reflect the architecture of body composition and could, therefore, be used to manipulate the desired body composition at a given age. Therefore, selection for changes of the shape of a growth curve may be a useful tool for improving the efficiency of lean meat production.

The objective of the present study was to investigate the effect of short-term divergent selection for 5-wk BW on growth characteristics of Japanese quail (Coturnix coturnix japonica) and compare these characteristics with the nonselected randombred control base population.

Material and Methods

Growth data were collected from Japanese quail lines selected for increased (high) or decreased (low) 5-week body weight for 11 generations and their random bred control line (CONT). The high body weight (HBW) and low body weight (LBW) Japanese quail lines were established by applying individual selection with 10% and 40% selection intensity on males and females, respectively. Hatching weights were collected for all chicks. The body weights are measured individually each week with a digital scale grading 0.01 g until 46 weeks of age. Eggs obtained from selected lines were incubated at a temperature of 37.8°C and 55% relative humidity (RH) for 14 days. They were then transferred to hatching trays located in the bottom of the same incubator individually, and maintained at 37.2°C and 75% RH until hatching. Chicks were wing-banded at the first day before transferring to wire-floored growing batteries as mixed-sex where raised under standard brooding temperatures. Each line was raised in separate brooder batteries. The diets contained 240 g protein/kg and 11.9 MJ/kg metabolisable energy (ME) for the first 35 days, and 210 g protein/kg and 11.7 MJ/kg (ME) until the

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end of research (Anonymous, 1994). Food and water were available ad libitum. At fifth week of age, sex identification was carried out according to plumage and color pattern and individual selection was applied. During the first two weeks 24 hour illumination was applied, and then it was gradually decreased to 12 hours per day up to 5 weeks of age. The lightening program was gradually increased to 16 hours again. Birds were housed in individual cages in a house which had windows with curtains at both sides.

Statistical Analyses

Gompertz growth curve model was fitted to body weight-age data of quails in each group. Starting values of the parameters were taken from previous studies. Gompertz growth models were fitted to the body weight and age data of quails in each group, using NCSS statistical package program (Hintze, 2001). Statistical significance of Gompertz model parameters was determined using 95% asymptotic confidence intervals. Differences among parameters were tested by one-way ANOVA. Gompertz growth model was defined as:

\[
W(t) = A \exp(-B \exp(-K t))
\]

(1)

where, \( W(t) \) is the expected body weight (g) at the week of t; \( A \) is the maximum body weight at maturity or mature weight (g); \( B \) is the integration constant which is related to hatching weight, \( K \) is the coefficient of relative growth or maturing index (smaller value of \( K \) indicates later maturity, while the larger \( K \) indicates earlier maturity); \( t \) is time (age) (Ricklefs, 1967; Emmans, 1989). In this study, depending on the parameters estimated by fitting Gompertz function, the following formulae were used to calculate the growth information (Balcioglu et al., 2005; Ersoy et al., 2007).

Time inflection (ti) = 1nb/K, Weight inflection (Yi) = A/e and maximum weight gain at point of inflection (Ui) = A.K/e

Time inflection is defined “as the point on the growth curve when the rate of growth is maximum”; weight inflection is “the body weight corresponding to the time of inflection” (Goonewardene et al., 1998; Goonewardene et al., 2003; Bayram et al., 2004; Ersoy et al., 2006).

Individual growth curves for each quail in each group were determined, and then, F test was applied (Eq. 2) to test homogeneity of individual growth curves. F test indicated that growth curves were parallel for all three groups (\( P > 0.05 \)). It can be concluded that overall growth model cated that growth curves were parallel for all three groups test homogeneity of individual growth curves. F test indi-

\[
F = \frac{S_2/(m-1)}{S_1/\left( \sum n_i - 2m \right)}
\]

(2)

Each parameter for the individual growth curves was then subjected to analysis of variance (PROC GLM, SAS INSTITUTE INC., 1999), using the following model to test effects of group (\( \alpha \)), sex (\( \beta \)), and group (line) by sex (\( \alpha \beta \)) interaction:

\[
Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha \beta_{ij} + \epsilon_{ijk}
\]

(3)

Where \( Y_{ijk} \) is a growth curve parameter, \( \mu \) is the overall mean, \( \alpha_i \) is the fixed effect of group (line) (i=1, 2, 3), \( \beta_j \) is the fixed effect of sex (j=1, 2), \( \alpha \beta_{ij} \) is the interaction effect between group and sex, and \( \epsilon_{ijk} \) is the residual error distributed as Normal (0, \( \sigma^2 \)).

Results and Discussion

Descriptive statistics for 46 weeks of age, parameter estimates based on Gompertz model, goodness-of-fit criteria, degree of maturity values, results of Duncan multiple comparison test to test differences between lines and sex within lines for the Gompertz growth model parameters and asymptotic correlations between the growths parameters for both sexes within each groups are given in Table 1 to 6, respectively. Results of repeated measurement analysis of variance showed that differences in body weight data changed by weeks and sex (group x week x sex interaction effect; \( P < 0.05 \)). Therefore, the effect of short-term divergent selection on body weight had indicated significant variations with respect to ages (week) and sex of the birds. Body weight means for males and females were found to be similar from hatch to four weeks of age within the HBW and LBW groups, and from hatch to three weeks of age within the CONT group. After these ages statistically significant differences were observed between the sexes (\( P < 0.05 \)), and body weight of females was found to be higher than that of males (Table 1). In numerous studies (Anthony et al., 1986; Oguz et al., 1996; Du Preez and Sales, 1997; Hyankova et al., 2001; Aggrey et al., 2003; Balcioglu et al., 2005) similar results were indicated. The effect of short-term divergent selection for 5-week body weights was found to be significant when comparing HBW and LBW groups with the CONT group (\( P < 0.05 \)). Similar results were also reported by Anthony et al. (1991).

Many growth curve models have been developed in order to define the growth in terms of different factors such as animal species, genotype, rearing condition, different character(s) and sex. In this study, however, Gompertz growth curve model was fitted to body weight-age data of Japanese quail.
quails in each group, since Gompertz growth model was found more effective than other models such as Richards, Logistic, Brody, and Von Bertalanffy in the preliminary analysis based on goodness-of-fit criteria, namely $R^2$, mean square error (MSE), asymptotic correlations and Durbin-Watson statistic (DW). Therefore, the shape of growth curve was not affected by short-term divergent selection. Similar results were reported by Anthony et al. (1991). However, Hyankova et al. (2001) reported that the shape of the growth curve was affected by short-term selection in Japanese quail.

All parameter estimates for quails based on Gompertz growth curve model for HBW were statistically significant at 95% confidence interval.

**Table 2. Parameter estimates, asymptotic standard errors, 95% confidence intervals and asymptotic correlations between growth curve parameters based on Gompertz growth curve model for control**

**Table 3. Parameter estimates, asymptotic standard errors, 95% confidence intervals and asymptotic correlations between growth curve parameters based on Gompertz growth curve model for HBW**
similarities are one of the indicators that growth body weight-age data were well described by the Gompertz growth curve model. The Gompertz growth model fitted the body weight-age data very well based on goodness-of-fit criteria such as $R^2$, MSE, DW estimates and asymptotic correlations (Table 2). When asymptotic correlations are high (absolute value greater than 0.95), the precision of the parameter estimates is suspect. Absolute values of all asymptotic correlations were lower than 0.95 (Table 6). Figure 1-3 supported these findings. DW statis-
tic showed that there were negligible positive autocorrelations for females in CONT (1.89) and HBW (1.96) groups, while, there was a negligible negative autocorrelation for LBW group (2.12). For males DW statistics showed that there are negligible negative autocorrelation for all three groups (2.07 for CONT, 2.04 for HBW and 2.19 for LBW group). Therefore, it can be concluded that the residuals were random or no autocorrelation for the groups with respect to body weight existed.

Data in Table 2, 3, 4 and 5 indicated that parameter estimates were generally affected by short term divergent selection and sex of the quails. For instance, estimated parameter A or mature weights showed significantly higher values for females than for males for all groups (P < 0.05; Table 5). Likewise, average mature weights of females (306 g) and males (295 g) in HBW group were higher (P < 0.05) than for both sexes in CONT (224 g and 204 g) and LBW groups (164 g and 151 g). Marks (1978) reported that growth curve parameters were altered by applied selection for body weight. Similar results related to sex differences were also reported in some previous studies (Anthony et al., 1986; Du Preez and Sales, 1997; Akbaş and Yavılar, 2000; Hyankova et al., 2001; Aggrey et al., 2003; Balcioglu et al., 2005). However, because of different lines used (i.e. Du Preez and Sales, 1997) and different numbers of generation taken into consideration in some previous studies (i.e. Özkanc and Kocabaş, 2004; Balcioglu et al., 2005), some differences in the results were observable. Statistically significant differences were observed in this study between HBW and CONT groups, LBW and CONT groups and HBW and LBW groups for both females and males with respect to A-parameters (P < 0.05; Table 5). However, the mature weight of females and males in HBW group were higher than for all birds in CONT group, while, mature weights of both sexes in LBW group were lower than that of the CONT group’s females and males (see Table 5). Results showed that short-term divergent selection for 5-week body weight had a significant effect on mature weight of quails. But, the response of birds in HBW and the LBW groups to selection was not on the same level.

When b-parameter related to hatching weight were examined, it was seen that b-value of females was almost the same as for males in HBW group (Table 5). On the other hand, b-values of females in LBW and CONT groups were found to be significantly higher than for males of the same groups (P < 0.05). The b-parameter estimates of LBW
group males and females were higher than that of the HBW and CONT groups. AKBAS and YAYLAK (2000) reported that there was not any statistically significant difference between males and females for b-parameter in non-selected quails (CONT) group. Also, KIZILKAYA et al. (2005) reported that b-parameter estimate for females was higher than that of for males in non-selected birds. However, BALCIOLU et al. (2005) reported that b-parameter estimate of males was higher than of females in HBW and LBW groups, while, the estimated b-parameter for females was higher than for males of CONT group.

A higher (P < 0.05) parameter K value (smaller K value indicates late maturity and a larger value is standing for earlier maturity) was estimated for males in HBW and LBW groups (0.561 and 0.503) than for females (0.504 and 0.452). Therefore, it can be conclude that females in HBW and LBW groups matured later than the males of same groups. Similarly, quails belonging to both sexes in comparably HBW group matured earlier than birds of LBW and CONT groups (P < 0.05). On the other hand, the K-parameter estimated for females (0.470) and males (0.464) in CONT group was fairly close to each other (P > 0.05). Hence, it is possible to say that linear growth periods of males and females in the CONT group are similar. Short-term divergent selection had a statistically significant effect on K-parameters of males (P < 0.05; Table 5). However, it had no statistically significant effect on K-parameter estimated for females (P > 0.05). Similar results were obtained in different studies (DU PREEZ and SALES, 1997; AKBAS and OGUZ, 1998; AKBAS and YAYLAK, 2000; KIZILKAYA et al., 2005; BALCIOLU et al., 2005). On the other hand, non-significant differences between males and females were reported by ANTHONY et al. (1991).

Effect of short term divergent selection on Yi, Ui and ti parameters indicated that HBW selection group had higher Yi and Ui values than that of CONT and LBW groups (P < 0.05; Table 5). On the contrary, a bit smaller ti value was obtained in HBW group than in the other groups (P > 0.05). Divergent selection effects for Yi and Ui values between both sexes of HBW and CONT groups, both sexes of LBW and CONT groups and both sexes of HBW and LBW groups were statistically significant (P < 0.05). On the other hand ti estimates between HBW-CONT, LBW-CONT and HBW-LBW groups were only significant for males (P < 0.05).

The age when the birds reached maximum growth rate and average body weight at this age were estimated for females as 2.24 weeks and 113 g for HBW, as 2.98 and 60.5 for LBW, 2.61 and 82.3 for CONT groups, while, same parameters were found a 2.52 and 108 for HBW, as 2.58 and 55.9 for LBW, as 2.57 weeks and 75.0 g for CONT groups, respectively. Although males in all group’s reached maximum growth rate at about same age, mean body weight of males in HBW group was significantly higher than for males of CONT and LBW groups. Although, both males and females reached the maximum growth rate when they were approximately at a similar age for each group, estimated body weights at age of inflection point were higher in females than in males.

Average degree of maturity (DM) for quails in HBW (91.3% for females and 91.0% for males) and CONT groups (91.0% for females and 91.2% for males) was slightly higher than for LBW group (90.0% for females and 88.9% for males). Although, during early ages of life degree of maturity was lower for LBW group than HBW and CONTROL groups. All three groups showed a similar degree of maturity at the end of 46th week.

Conclusion
In view of the results of this study, it is possible to conclude that short-term divergent selection for 5-week body weight had generally a significant affect on all growth parameters such as mature weight (A), integration constant (b) which is related to hatching weight, coefficient of relative growth or maturing index (K), weight inflection or body weight at age of point of inflection (Yi), maximum weight gain at point of inflection (Ui) and inflection time (ti) in quails. But, the response of quails in the high body weight (HBW) and low body weight (LBW) lines to the selection was not at the same level. The effect of short term divergent effect was also different for males and females.

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Summary

This study was carried out to investigate the effect of short-term divergent selection for 5-week body weight on growth characteristics of Japanese quail (Coturnix coturnix japonica) and to compare these characteristics with the non-selected randombred control base population. For this aim, Gompertz growth curve model was fitted to body weight-age data of quails in each group.

Results of growth curve analyses showed that the shape of the growth curve was not affected by short-term selection. On the other hand, parameter estimates were significantly changed by short-term selection and sex of the quail (P < 0.05). The estimated parameter A or mature weights showed significantly higher values for females than for males in all groups (P < 0.05). The growth rate (K) in HBW and LBW groups (0.561 and 0.503) was significantly higher in males than in females. On the other hand, the K-parameter estimated for females (0.470) and males (0.464) in CONT group was fairly close to each other.

Key words

Quail, divergent selection, growth rate, growth curve, Gompertz

Zusammenfassung

Einfluss einer kurzzeitigen, divergierenden Selektion nach dem Fünf-Wochen-Gewicht auf die Kennwerte des Wachstumsverlaufs von japanischen Wachteln

Bei japanischen Wachteln (Coturnix coturnix japonica) wurde die Auswirkung einer kurzzeitigen, divergierenden Selektion nach dem Fünf-Wochen-Gewicht auf die Kennwerte des Wachstumsverlaufs untersucht und die ermittelten Kennwerte wurden mit einer unselektionierten Kontrollpopulation verglichen. Hierzu wurde für jede Zuchtlinie die Gompertz Wachstumskurve an die Lebendgewichts- und Altersdaten der Wachteln angepasst.

Es zeigte sich, dass die kurzzeitige Selektion die Form der Wachstumskurven nicht verändert hat. Dagegen wurden die Kennwerte des Wachstumsverlaufs durch die Selektion beeinflusst (P < 0.05), wie auch das Geschlecht von Bedeutung war. In allen Linien wurden bei den Hennen signifikant höhere A-Werte, die das Reifegewicht bezeichnen, ermittelt als bei den Hähnen (P < 0.05). Die Wachstumsrate k war bei den Hähnen der Linien HBW (hohes Körpergewicht; 0,561) und LBW (geringes Körpergewicht; 0,503) signifikant höher als bei den Hennen. Im Gegensatz hierzu unterschieden sich die k-Werte der männlichen (0,464) und der weiblichen (0,470) Wachstumsparameter der Kontrollinie nur wenig.

Stichworte

Wachtel, divergierende Selektion, Wachstumsrate, Wachstumskurve, Gompertz

References


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