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GROWTH CURVES MODELS IN TWO LINES OF JAPANESE QUAIL SELECTED FOR HIGH BODY WEIGHT

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ABSTRACT: This study was carried out at the Poultry farm of the Agricultural Experiments and Research Center, Faculty of Agriculture, Fayoum University. A total number of 598 Japanese quail chicks from the same hatch at the eighth generations of selection for high body weight at 28 days of age (BW_{28}) were used to draw the growth curves for two lines using Gompertz, Richards and Logistic growth functions. Line significantly affected all studied body weights (BWs) except BW at hatch favoring selected line. Males had significantly higher BW_7 and BW_{14} than females which had significantly higher BW_{42}.

The selected line had the highest asymptotic weight parameter (β_0) and relative growth rate (β_2) values than the control line for both sexes. The selection program has affected clearly on increasing body weight and growth pattern in the selected line compared to the control line. The β_2 values were higher in males under all models indicting that male birds have grown faster than females and reached earlier their weight at inflection point (IPW) and β_0. Regardless of growth model, the selected line had higher age at inflection point (IPT) and IPW values than the control line in both sexes. Females had higher IPT and IPW values than males reflecting that females reached mature weight after males. Selection for high BW_{28} modifies all studied growth curves and alter their parameters in both sexes favoring the selected line. Also, sexual dimorphism had a pronounced effect on studied growth curves.

All studied models have considerably high and similar coefficient of determination (R^2) values (close to 1) which ranged from 0.9938 to 0.9995. Gompertz was the best model to describe the growth curve of females and males in both lines which had the lowest AIC, BIC, Mean square error (MSE) values and the highest R^2value.

Key words: Selection, high body weight, growth curves, Gompertz, Richards, Logistic and Japanese quail.

INTRODUCTION

Growth is a complex biological process which is related to alterations in size and shape in a specific time but these processes can be affected by the environment, including nutrition and random events, causing growth to fluctuate and thus making the study of growth at a single age unattractive (Aggrey, 2003).

On the other hand, growth curves were found to be very useful tools representing the evolution of body weight during growth and are particularly important in breeding and management. The benefit from curve modeling is to describe the weight increase with age by simple equations with few parameters (Ricklefs, 1985). The growth model parameters and their biological meaning are very useful to accurate inference and prediction of economic information that related to maturity and the inflection point compared to simple analysis outputs of growth traits such as weights at different ages (Dudusola et al., 2019).

The biological meaning of the parameters is as follows: β_0 is the maturation weight, β_1 is scaling parameter related to initial weight and β_2 is growth parameter indicates the growth rate or the rate of gain (Gotuzzo et al., 2019).

Akbaş and Oguz (1998) and Narinc et al. (2017) reported that the most widely used growth functions are Gompertz and Logistic in poultry. Moreover in the studies on Japanese quail Gompertz and Richards are considered the most famous growth functions used, the best to fit data according to goodness of fit criteria and their biologically interpretable parameters (Karadavut et al., 2017, Rossi et al., 2017 and Kaplan and Gürcan, 2018). In these functions, weight at inflection point is mostly known as 35–40% of β_0 (Teleken et al., 2017 and Kaplan and Gürcan, 2018).

Effects of selection for increasing body weight at 28 days of age differed in modification either in BWs or in growth pattern between the two sexes (Akbaş and Oğuz, 1998, Aggrey et al., 2003, Rezvannejad et al., 2013 and Abou Khadiga et al., 2018). However, many authors conducted studies on growth curves in Japanese quail, there are few studies investigated sexual dimorphism in growth curves as a selection response. Hence, this work aimed to study the growth curve parameters in the selected line (selection for high body weight at 28 days of age) and the control line. Also, it aimed to detect which model best fits the data from each sex by comparing the three sigmoidal models.

MATERIALS AND METHODS

This study was carried out at the Poultry farm of the Agricultural Experiments and Research Center, Faculty of Agriculture, Fayoum University. A total number of 598 Japanese quail (Coturnix coturnix japonica) chicks from the same hatch used to describe the growth pattern of birds in the selected (SL) and control (CL) lines of Japanese quail, considering the effect of sex, after eight generations of selection for high body weight at 28 days of age. Birds were distributed as shown in Table 1. At hatch, chicks were wing banded using small size plastic bands and were brooded on the floor until 42 days of age. According to NRC (1994), all quails were fed ad libitum on a grower diet containing 24% crude protein and 2900 K Cal ME (from hatch to 42 days of age) and clean water. Birds were kept under the same managerial hygienic and environmental conditions.

Studied Traits:

Body weight at hatch, seven, 14, 21, 28, 35 and 42 days of age (BW_0, BW_7, BW_{14}, BW_{21}, $BW_{28,}$ BW_{35} and BW_{42}, respectively) were individually recorded to the nearest 0.01g.

Statistical analyses:

Data of body weights at different ages were analyzed by PROC MIXED (SAS, 2011) to calculate the line and sex specific means by the following model:

$Y_{ijkl} = \mu + a_i + L_j + S_k + (LS)_{jk} + e_{ijkl}$

where: Y_{ijkl}: is the observation for a trait, µ: is the overall mean, a: is the random additive genetic effect of the i^{th} animal, L: the effect of j^{th} line, S: the effect of k^{th} sex, $(LS)_{jk}$: the effect of j^{th} line with the k^{th} sex and e_{ijkl}: is the random error term; the random variable was the birds within line.

Models:

Model parameters were analyzed using the procedure of nonlinear models (PROC NLIN) of SAS software (SAS, 2011). Functions used in this study to describe the growth pattern of the quail were as follows:

Gompertz function:

$W_t = W_0 .e[\beta_1 . (1- e^{-\beta 2.t}) / \beta_2]$

IPT = $\ln (\beta_1) / \beta_2$ IPW = β_0 / e

Richards function:

$W_t = [W_0 .\beta_0] / [W_0^{\beta 3} + (\beta_0^{\beta 3} - W_0^{\beta 3}) e^{-\beta 2.t}]^{1/\beta 3}$

IPT = $[1/\beta_2] .[\ln \left| (\beta_1 . W_0^{\beta 1}) / (\beta_0^{\beta 1} - W_0^{\beta 1}) \right|]$

IPW = $\beta_0 / (\beta_3+1)^{1/\beta 3}$

Logistic function:

$W_t = [W_0 . \beta_0] / [W_0 + (\beta_0 - W_0) .e^{-\beta 2.t}]$

IPT = $\ln (\beta_1) / \beta_2$ IPW = $\beta_0 / 2$

Where W_t is body weight (BW, g) of bird at age t, day; W_0 is predicted body weight at hatch, g; β_0 is predicted final weight or asymptotic weight, g; β_1 is scaling parameter related to initial weight, β_2 is growth parameter indicates the growth rate or the rate of gain, β_3 is shape parameter in Richards model, **e** is Euler's number (~2.71828…), IPT: time at Point of inflection, IPW: weight at Point of inflection.

Goodness of fit criteria:

The goodness of fit criteria to compare the studied functions that explain the growth of Japanese quail are as follows:

- Coefficient of determination,
  $R^2 = 1- (SSE/SST)$
- Mean Square Error, MSE = SSE/(n−k)
- Akaike's(1974) Information Criteria,
  AIC = n .ln (SSE/n) + 2k
- Schwarz Bayesian Information Criterion,
  BIC = n .ln (SSE/n) +k . ln (n)

where SST the total sum of squares, SSE is the sum of square errors, n is the number of observations and k the number of parameters.

RESULTS AND DISCUSSION

Least square means ± standard errors for studied BWs of both sexes for each line are presented in Table 2. In this study, line significantly (P< 0.001) affected all studied BW's, except BW_0 as the SL had heavier BW from seven up to 42 days of age than the CL line. Males had significantly higher BW_7 and BW_{14} than females. On the other hand, females significantly showed higher BW_{42} than males (P< 0.001) as shown in Table 2. There were significant higher BW's favoring the SL as reported by many investigators (Akbaş and Oğuz, 1998, Aggrey et al., 2003, Rezvannejad et al., 2013 and Abou Khadiga et al., 2018) .On the contrary, Abou Khadiga et al. (2018) reported that BW at all ages were significantly lower in males than females in both lines. Similarly**,** Taskin et al. (2017) indicated that sex was a significant source of variation for BW at all ages across selection generations.

The effects of line by sex interaction in this study was not significant for all BWs, except for BW_0.Whereas in Japanese quail, Kızılkaya et al. (2006) found a significant effect on mature weight due to the interaction between line and sex. Effects of selection for increasing BW_{28} resulted in modification either in BWs or in growth pattern between the sexes (Akbaş and Oğuz, 1998, Aggrey et al., 2003, Rezvannejad et al., 2013 and Abou Khadiga et al., 2018).

The highest values of asymptotic weight parameter (β_0) were observed in the

Richards function (288.31g for females and 268.11g for males) in the SL while they were 271.88g for females and 259.00g for males in Gompertz and were 271.31g for females and 265.26g for males with Logistic model. On the other hand, Gompertz model had the highest β_0 values for both sexes in CL being 246.73g for females and 232.41g for males compared to the other growth functions either Richards (240.56g and 210.08g for females and males) or Logistic (217.55g and 202.15g for females and males, respectively).

The selection program has clearly increased live BW as well as β_0 values in the SL compared to the CL. Similarly, many authors reported that there were differences between SL and CL lines in β_0 values (Aggrey et al., 2003, Kızılkaya et al., 2006, Alkan et al., 2009, Narinç and Aksoy, 2014 and Abou Khadiga et al., 2018), these differences could be due to the different genetic background of the growth curve parameters of Japanese quail.

Many investigators conducted selection programs for high BW in Japanese quail, they estimated values of β_0 parameter to be 211.00g to 300g, 182g to 256g for females and males in the SL vs 144g to 256g and 104g to 213g for females and males in the CL (Aggrey et al., 2003, Rezvannejad et al., 2013 and Abou Khadiga et al., 2018). Kaplan and Gurcan (2018) reported higher β_0 parameter values in unselected females of 287.7g, 324g and 219.4g for Gompertz, Richards and Logistic models, respectively. Therefore,β_0 parameter values in this study are in line with the pervious reviewed studies.

According to studied growth functions, β_1 is a constant which reflects the shape of the growth curves. In this work, small distinctions were found between sexes in β_1 values which may be due to the similarity in integration coefficient of both sexes under the same model. Karaman et al. (2013) reported no major differences between sexes in β_1 values with the Logistic model. Abou Khadiga et al. (2018) reported that $\beta_1$parameter is a biological constant which is related to weight development. Also, it can be affected by selection programs for alteration in BW at or near maturation. A wide range of β_1 estimates for studied modelsranging from (0.98 to 6.55, for Gompertz) reported by many authors (Aggrey et al., 2003, Rezvannejad et al., 2013 , Abou Khadiga et al., 2018, Kaplan and Gurcan 2018 and Haqani et al.,2020), ranging from 0.002 to 2.49 for Richard model (Kaplan and Gurcan 2018 and Haqani et al., 2020) and ranging from 14.02 to 24.30 for Logistic model (Rezvannejad et al., 2013) thusthe β_1 values in this study are in agreement with previous studies.

The values of β_2 represented the relative growth rate were in the range of (0.071-0.13, for selected females, 0.072—0.14 for selected males vs 0.069-0.128 for control females and 0.07-0.129 for control males). Generally, males had higher β_2 values than females with all models indicating that male birds have grown faster than females and reached the weight at inflection point (IPW) and β_0 at earlier ages. In addition, the $\beta_2$estimates were higher in the SL than the CL line, these differences could be due to significant differences between lines. Similar results were reported by Akbaş and Oğuz (1998), Rezvannejad et al. (2013) and Abou Khadiga et al. (2018). Moreover, Aggrey et al. (2003) reported that there were negative correlation between β_0 and β_2.

In general, the estimates of β_2 in this work are in agreement with the reports of other authors (Akbas and Oguz, 1998, Kızılkaya et al., 2006 and Abou Khadiga et al., 2018). In this study, the β_2 values of the Richards model did not differ in sexes of both two lines, however, Aggrey et al.

(2003) reported that selection for high BW_{28} increased the β_2 values only in females without males under the Richards function. Similarly, males had significantly higher β_2 values (0.080) than females (0.059) (Rossi et al., 2017).

The IPT and IPW estimates of the SL and CL lines are presented in Table3. In this study, regardless of growth model, the SL line had higher IPT and IPW estimates than the CL in both sexes due to the selection influence on these estimates. Females had higher IPT and IPW values than males reflecting that females reached mature weight after males. According to Gompertz model, the IPW and IPT estimates for the selected females (100.03g, 17.75) and for selected males (95.29 g, 17.31), respectively. Whereas, the Logestic model has the highest estimates of IPW and IPT in both sexes of the SL and CL lines compared to the other models (135.66g, 22.15 for selected females and 132.63g, 20.55 for selected males) vs (108.5g, 20.88 for control females and 101.07g, 20.49 for control males). In the selected line, the corresponding values of IPW under the Richards function were slightly higher (106.12g for selected females, 98.68g for selected males) than under the Gompertz model. Gompertz model in the CL had higher IPW estimates of females and males (90.77g, 85.50g, respectively) compared to Richards model (88.54g, 77.32g, respectively). Regarding Gompertz and Richard models, the inflection point estimates in this study were lower than those estimated by Rossi et al. (2017), Kaplan and Gürcan (2018) and Abou Khadiga et al. (2018), whereas, IPT estimates in this study was higher than those reported by Aggrey et al. (2003) using Richards model. In selection studies there were wide range of IPW and IPT estimates (68.22 - 217g,17.15-23.66 day for Gompertz, 77.52 - 246g, 17.1-22.42 day for Richards,115- 213g,19.87-22.3 day for Logistic) as reported by Aggrey et al. (2003), Rossi et al. (2017), Kaplan and Gürcan (2018) and Abou Khadiga et al. (2018) and Haqani et al. (2020). In unselected lines, Aggrey et al. (2003), Gürcan et al. (2017), Haqani et al. (2020) reported higher IPT values under the Richards function (16.38 to 23.1 days). This wide range of estimates may be due to variants of both environmental conditions and genetic background.

Results presented in Figure 1 clearly shows the selection for high BW_{28}effect in Japanese quail indicating that selection resulted in modifications of all studied growth curves and their estimates in both sexes favoring the selected line. Also, sexual dimorphism had a pronounced effect on the studied sigmoidal growth curves, as shown in Figure 1.

Comparison the criteria of the three tested models was presented in Table 4. The three studied models have considerably high and similar R^2values (close to 1) which ranged from 0.9938 to 0.9995 in the SL and from 0.9941 to 0.9991 in the CL indicating that all models had good performance (fitting) in describing live weight changes related to age in Japanese quail. Figures 2 and 3 depict the fit of three growth models to the real values for female and male birds for each line. From these figures, it can obviously be indicated that all growth functions predicted accurately the actual body weights.

Similar high R^2values have been investigated by several authors (Narinç et al., 2010, Rezvannejad et al., 2013, Karadavut et al., 2017, Kaplan and Gurcan, 2018, Abou Khadiga et al., 2018 and Haqani et al., 2020). According to four goodness of fit criteria (BIC, AIC, MSE and R^2), Gompertz function was the best function to describe the growth pattern of female and male in both lines which had the lowest values of AIC, BIC and MSE and the highest value of R^2(Table 4). The order of the growth models based on the best fit in the SL and CL lines was Gompertz, Richards and Logistic, respectively. A wide range of AIC and BIC estimates reported by many authors ranging from (-21040 to 21170 and -21017 to 21192, respectively) for Gompertz model (Beiki et al., 2013, Firat et al., 2016 , Abou Khadiga et al., 2018, Kaplan and Gurcan 2018, Dudusola et al., 2019, Faraji- Arough et al., 2019 and Haqani et al., 2020), ranging from -21076 to 21145 and -20150 to 21172, respectively for Richard model (Beikiet al., 2013, Firat et al., 2016, Abou Khadiga et al., 2018, Kaplan and Gurcan 2018, Faraji- Arough et al., 2019 and Haqani et al., 2020) and ranging from -747 to 21297 and -736 to 21319, respectively for Logistic model (Aggrey et al., 2003, Beiki et al., 2013, Firat et al., 2016 , 2018, Kaplan and Gurcan 2018, Dudusola et al., 2019 and Faraji- Arough et al., 2019). Similarly, Haqani et al. (2020) reported that the Gompertz function was the best to fit the normal-sized quail strain for both sexes. The results of four goodness of fit criteria in the current study agreed with the results of Akbaş and Oğuz (1998), Narinç et al. (2010) and Rossi et al. (2017) who found that the Gompertz function was the best to fit the growth curves data of Japanese quail. On contrary, Richards function was better than other functions in fitting growth data of Japanese quail (Beiki et al., 2013 and Kaplan and Gürcan, 2018).

CONCLUSION

Selection for high BW_{28} in Japanese quail improves BWs from seven up to 42 days of age. Moreover, the selection program could influence all studied sigmoidal growth curves and alter their estimates in both sexes. Also, sexual dimorphism appeared to be effective in describing the growth curves data of Japanese quail. Depending on goodness of fit criteria, Gompertz function was the best functions to describe the growth pattern of female and male in both lines which had the lowest values of AIC, BIC, and MSE and the highest value of R^2.

Table(1): Number of birds used in the selection experiment.

Item	Selected line (SL)	Control line (CL)	Total
Females	158	130	288
Males	165	145	310
Total	323	275	598

Table (2): Least square means ± SE for the body weight's traits as affected by line and sex.

Item	BW_0	BW_7	BW_{14}	BW_{21}	BW_{28}	BW_{35}	BW_{42}
Line effect:							
CL	8.36±0.09	30.79±0.43^b	72.77±0.81^b	118.53±1.18^b	153.55±1.35^b	183.12±1.51^b	208.57±2.12^b
SL	8.50±0.06	34.06±0.30^a	81.73±0.56^a	132.28±0.82^a	174.76±0.94^a	204.19±1.03^a	232.92±1.28^a
Sex effect:							
Female	8.43±0.08	31.74±0.38^b	76.34±0.71^a	125.66±1.05	164.54±1.19	195.43±1.33	224.48±1.83^a
Male	8.42±0.07	33.11±0.36^a	78.16±0.68^a	125.15±1.00	163.77±1.14	191.89±1.26	217.02±1.68^b
***p*-value**							
Line	0.1343	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sex	0.4520	0.0060	0.0282	0.6896	0.5018	0.1367	0.0004
Line x Sex	0.0148	0.4370	0.3610	0.6141	1.0000	0.1272	0.9864

Means having different superscripts within each effect within the same column are significantly differed at specified probability, SE: stander error, BW_0, BW_7, BW_{14}, BW_{21}, BW_{28}, $BW_{35}$and BW_{42}: body weights at hatch, seven, 14, 21, 28, 35 and 42 days of age, respectively, SL: the selected line for high body weights at 28 days of age, CL: the control line and *p*-value: probability.

Table (3): Estimated parameters ± SE of growth models for both sexes in each line.

Models	parameter	SL		CL	
		Female	Male	Female	Male
Gompertz	β 0	271.88±4.44	259.00±5.21	246.73±7.69	232.41±6.60
	β 1	3.59±0.050	3.54±0.030	3.32±0.054	3.31±0.043
	β 2	0.072±0.002	0.073±0.003	0.069±0.004	0.07±0.004
	IPT	17.75	17.31	17.39	17.18
	IPW	100.03	95.29	90.77	85.50
Richards	β 0	288.31±8.56	268.11±10.22	240.56±13.22	210.08±14.73
	β 1	0.001±0.0001	0.001±0.0001	0.001±0.0001	0.001±0.0001
	β 2	0.072±0.012	0.073±0.012	0.070±0.017	0.070±0.016
	β 3	17.58	16.94	17.27	16.82
	IPT	17.58	16.94	17.27	16.82
	IPW	106.12	98.68	88.54	77.32
Logistic	β 0	271.31±7.92	265.26±8.64	217.55±10.85	202.15±9.74
	β 1	14.43±2.73	13.85±2.85	14.01±3.06	13.42±2.93
	β 2	0.13±0.013	0.14±0.014	0.128±0.015	0.129±0.016
	IPT	22.15	20.55	20.88	20.49
	IPW	135.655	132.63	108.505	101.07

SE: stander error, SL: the selected line for high body weights at 28 days of age, CL: the control line, β0: asymptote weight, β1: scale parameter, β2: relative growth rate, β3: shape parameter, IPT: point of inflection time (days), and IPW: point of inflection weight (g).

Table (4): The goodness of fit criteria for fitted growth functions.

Models	criterion	SL		CL	
		Female	Male	Female	Male
Gompertz	R^2	0.9988	0.9995	0.9991	0.9991
	MSE	3.5426	2.237	2.820	2.6239
	AIC	8415.65	8585.82	3859.75	4328.24
	BIC	8440.41	8607.80	3876.30	4345.30
Richards	R^2	0.9988	0.9995	0.9991	0.9941
	MSE	4.1007	2.595	3.266	7.016
	AIC	8424.45	8587.93	3860.52	4328.47
	BIC	8444.15	8610.91	3881.21	4349.78
Logistic	R^2	0.9938	0.9945	0.9942	0.9991
	MSE	8.3589	7.368	7.2485	3.038
	AIC	8579.43	8778.48	3906.71	4383.49
	BIC	8599.19	8798.47	3923.26	4400.54

SL: the selected line for high body weights at 28 days of age, CL: the control line, $R^{2:}$coefficient of determination, MSE: mean square error, AIC: Akaike information criterion and BIC: Schwarz Bayesian information criterion.

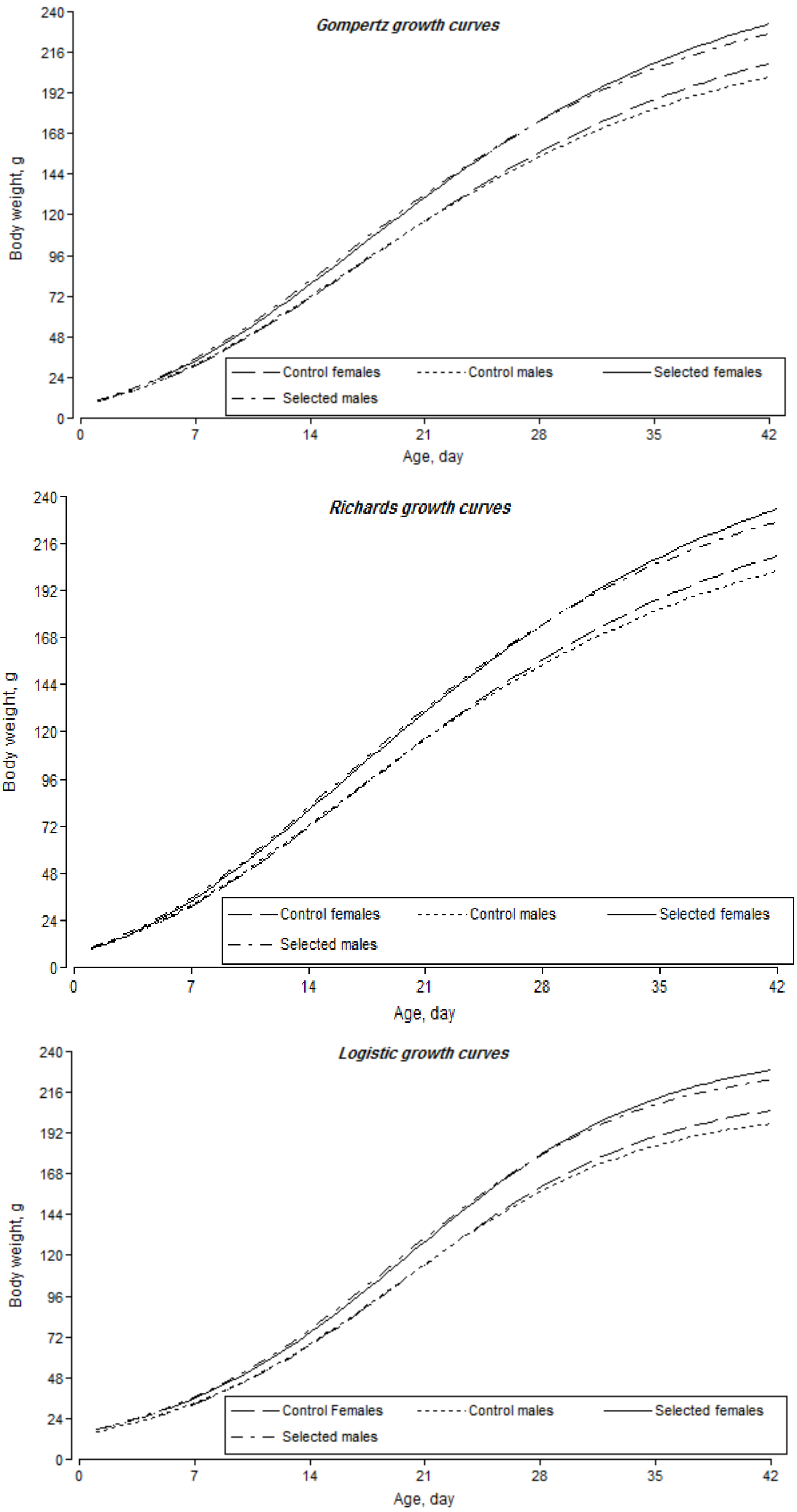
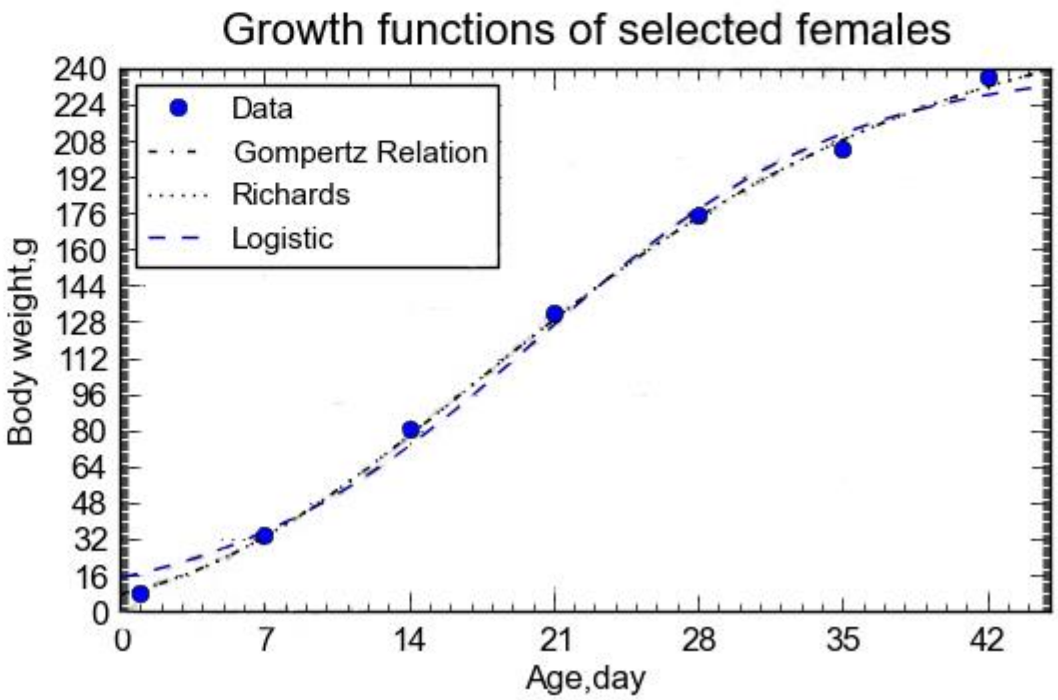


Figure (1): Growth curves of females and males in both lines for different growth functions.



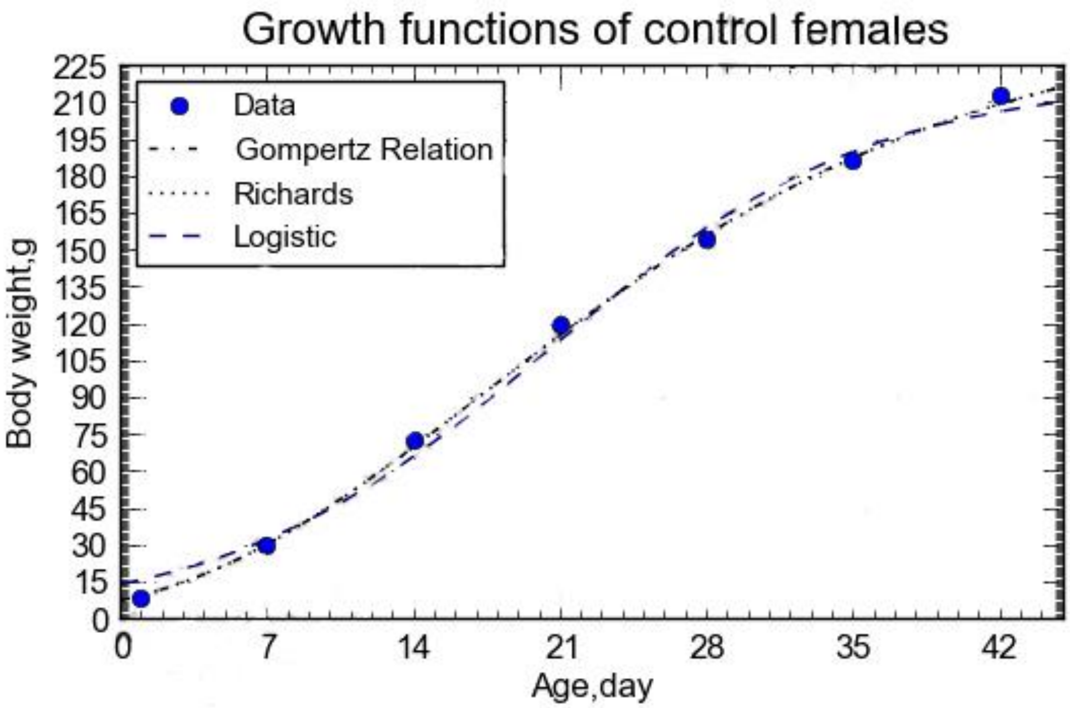


Figure (2): Growth curves of selected and control males for different growth functions.

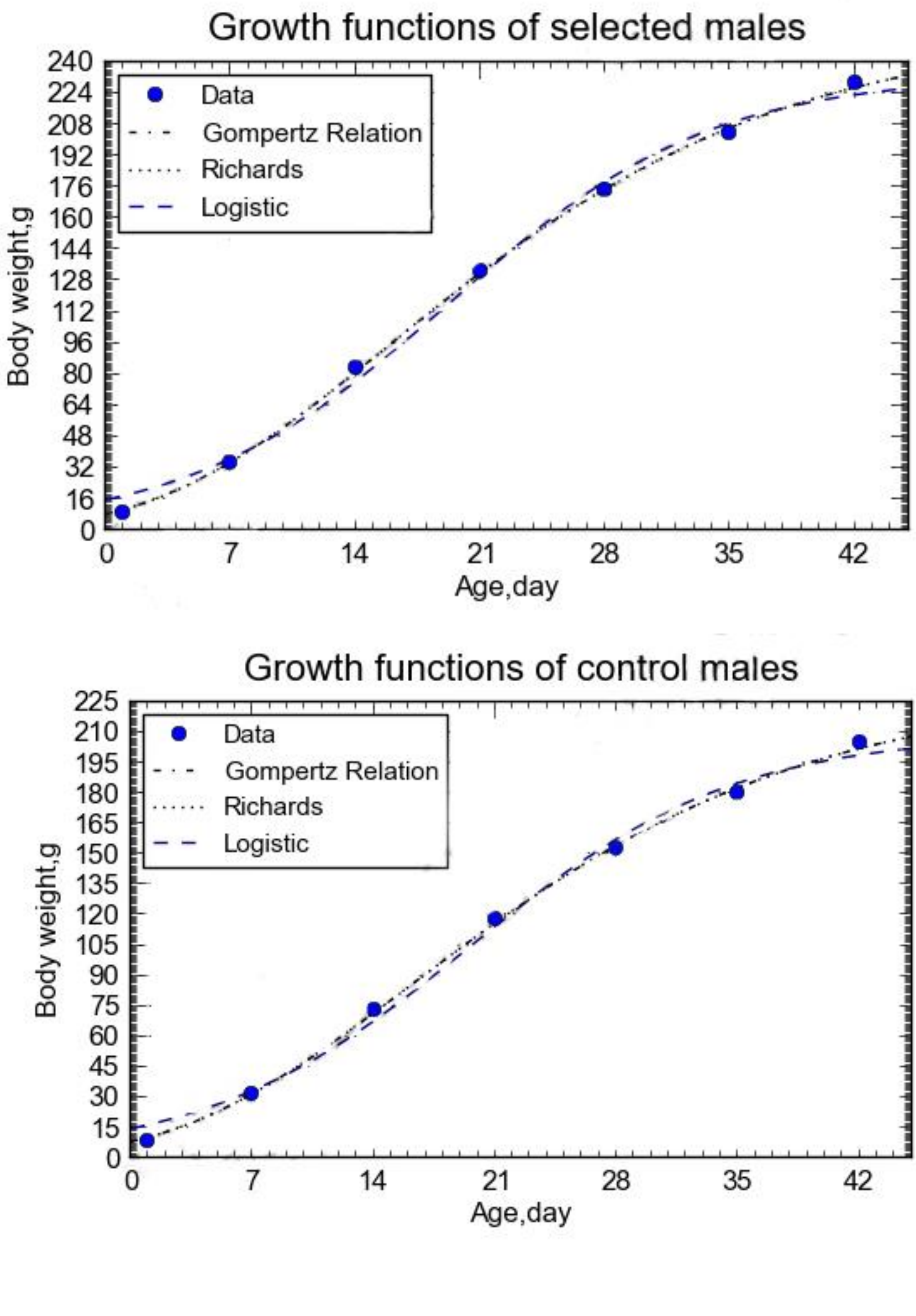


Figure (3): Growth curves of selected and control males for different growth functions.

REFERENCES

Abou Khadiga, G., Mahmoud, B. Y. F. and El-Full, E. A. 2018. Modelling of growth alteration in Japanese quail after a selection experiment for body weight at 4 weeks of age. J. Agric. Sci. 156: 1153–1159.

Aggrey, S. E., Ankra-Badu, G. A. and Marks, H. L. 2003. Effect of long-term divergent selection on growth characteristics in Japanese quail. Poult. Sci. 82: 538-542.

Aggrey, S. E. 2003. Dynamics of relative growth rate in Japanese quail lines divergently selected for growth and their control growth. Develop. Aging. 67: 47-54.

Akaike, H. 1974. A new look at the statistical model identification. IEEE Transactions on Automatic Control. 19: 716–723.

Akbaş, Y. and Oğuz, I. 1998. Growth curve parameters of lines of Japanese quail (Coturnix coturnix japonica), unselected and selected for four-week body weight. Europ. Poult. Sci. (Archiv fur Geflugelkunde). 62: 104 – 109.

Alkan, S., Mendeş, M., Karabağ, K. and Balcıoğlu, M. S. 2009. Effect of short- term divergent selection for 5-week body weight on growth characteristics of Japanese quail. Europ. Poult. Sci. (Archiv fur Geflugelkunde). 73: 124–131.

Beiki, H., Pakdel, A., Moradi-Shahrbabak, M. and Mehrban, H. 2013. Evaluation of growth functions on Japanese quail lines**.** J. Poult. Sci. 50: 20–27.

Dudusola, I. O., Oseni, S. O. and Adeyemi, E. A. 2019. Modeling the growth curve of Japanese Quail under different nutritional environments. Nigerian J. Anim. Sci. 21 (2): 53-58.

Faraji- Arough, H., Rokouei, M., Maghsoudi, A. and Mehri, M. 2019. Evaluation of non- linear growth curves models for native slow-growing Khazak Chickens. Poult. Sci. J. 7(1): 25-32.

Firat, M. Z.; Karaman, E.; Başar, E. K.; Narinc, D. 2016. Bayesian analysis for the comparison of nonlinear regression model parameters: an application to the growth of Japanese quail. Brazilian J. Poult. Sci. 18(1): 19-26.

Gotuzzo, A. G, Piles, M., Della-Flora, R. P., Germano, J. M., Reis, J. S., Tyska, D. U. and Dionello, N. J. L. 2019. Bayesian hierarchical model for comparison of different nonlinear function and genetic parameter estimates of meat quails. Poult. Sci. 98 (4):1601–1609.

Haqani, M. I., Kawamura, K., Takenouchi, A., Kabir, M. H., Nakamura, Y., Ishikawa, A. and Tsudzuki, M. 2020. A Growth Performance and Nonlinear Growth Curve Functions of Large- and Normal-Sized Japanese Quail (Coturnix japonica). The J. Poult. Sci. https://doi.org/10.2141/jpsa.0200020

Kaplan, S. and Gürcan, E. K. 2018. Comparison of growth curves using non- linear regression function in Japanese quail. J. Appl. Anim. Res. 46: 112–117.

Karadavut, U., Taskin, A. and Genc, S. 2017. Comparison of growth curve models in Japanese quail raised in cages enriched with different colored lights. Brazilian J. A. Sci. 46: 839–846.

Karaman, E., Narinc, D., Fırat, M. Z. and Aksoy, T. 2013. Nonlinear mixed effects modeling of growth in Japanese quail. Poult. Sci. 92: 1942–1948.

Kızılkaya, K, Balcıoğlu, M. S., Yolcu, H. İ., Karabağ, K. and Genc, İ. H. 2006. Growth curve analysis using nonlinear mixed model in divergently selected Japanese quails. Archive fur Geflugelkunde.70: 181–186.

Narinc,D., Oksüz, N. and Aygun, A. 2017. Growth curve analyses in poultry science. Worlds Poult. Sci. J. 73:395–408.

Narinç, D., Aksoy, T. and Karaman, E. 2010. Genetic parameters of growth curve parameters and weekly body weights in Japanese quails (Coturnix coturnix japonica)**. J.** Anim. Vet. Adv. 9: 501–507.

Narinç, D. and Aksoy, T. 2014. Effects of multi-trait selection on phenotypic and genetic changes in a meat type dam line of Japanese quail**.** Kafkas Üniversitesi Veteriner Fakültesi Dergisi. 20: 231–238.

N.R.C., 1994. Nutrient Requirements of Domestic Animals. Nutrient Requirements of Poultry, 9th Rev**.** ed. Washington, DC: National Academy Press

Rezvannejad, E., Pakdel, A., Miraee Ashtianee, S. R., Mehrabani Yeganeh, H. and Yaghoobi, M. M. 2013. Analysis of growth characteristics in short-term divergently selected Japanese quail lines and their cross. J. Appl. Poult. Res. 22: 663–670.

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

Rossi, R. M., de Grieser, D. O., de Conselvan, V. A. and Marcato, S. M. 2017. Growth curves in meat-type and laying quail: a Bayesian perspective. Ciências Agrárias. 38 (suppl. 1): 2743–2754.

SAS, Institute Inc. 2011. SAS/STAT® 9.3 User's Guide. Cary, NC: SAS Institute Inc.

Schwarz, G. 1978. Estimating the dimension of a model. Annals of Statistics. 6: 461–464.

Taskin, A., Karadavut, U., Tunca, R. I., Genc, S. and Cayan, H. 2017. Effect of selection for body weight in Japanese quails (Coturnix coturnix Japonica) on some production traits. Indian J. Anim. Res. 51:358–364.

Teleken, J. T., Galvão, A. C. and da Robazza, W. S. 2017. Comparing non-linear mathematical models to describe growth of different animals. Acta Sci., Anim. Sci. 39: 73–81.

الملخص العربى

منحنيات النمو في خطين من السمان الياباني المنتخب لوزن الجسم العالي

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أجريت هذه الدراسة بمزرعة الدواجن التابعة لمركز التجارب الزراعية والابحاث بكلية الزراعة جامعة الفيوم. حيث تم استخدام 598 فرخ سمان ياباني من نفس دفعة التفريخ (الفقسة) والمنتخب لوزن الجسم المرتفع عند 28 يومًا من العمر لمدة ثمانية أجيال، وذلك لرسم منحنيات النمو للخطين باستخدام Gompertz، Richards و Logistic كدوال للنمو. كان للخط تأثير معنوي على جميع أوزان الجسم المدروسة باستثناء وزن الجسم عند الفقس وذلك لصالح الخط المنتخب. كان وزن الذكور عند عمر 7 و 14 يوما أعلى معنويا مقارنة بالإناث التي كان لها وزن أعلى معنويا عند عمر 42 يوما. كان معامل الوزن المقارب (β_0) ومعدل النمو النسبي (β_2) للخط المنتخب أعلى من خط الكنترول لكلا الجنسين. لقد أثر برنامج الانتخاب بشكل واضح على زيادة وزن الجسم الحي ونمط النمو في الخط المنتخب مقارنة بخط الكنترول. كانت قيم β_2 أعلى في الذكور من الإناث في جميع دوال النمو المستخدمة مما يشير إلى أن الذكور نمت بشكل أسرع من الإناث ووصلت في وقت مبكر إلى وزنها عند نقطة الإنقلاب (IPW) والوزن المقارب. بغض النظر عن دالة النمو، كان كل من العمر عند نقطة الإنقلاب (IPT) وقيم IPW أعلى في الخط المنتخب في كلا الجنسين من خط الكونترول. كانت للإناث قيم IPT و IPW أعلى من الذكور مما يدل علي وصول الإناث إلى الوزن الناضج بعد الذكور. الإنتخاب لوزن الجسم عند عمر 28 يوم عدل كل منحنيات النمو المدروسة وغير معاييرها لصالح الخط المنتخب. كذلك كان للفروق بين الجنسين أثرها الواضح على منحنيات النمو المدروسة.

في جميع نماذج النمو المدروسة كانت قيم معامل التقدير (R^2) عالية ومتقاربة إلى حد كبير (قريبة من 1) والتي تراوحت من 0.9938 إلى 0.9995. وكان نموذج Gompertz هو أفضل نموذج لوصف نمط نمو الإناث و الذكور في كلا الخطين حيث سجل أدنى قيم AIC، BIC و متوسط المربعات للخطأ (MSE) وأعلى قيم R^2.

الكلمات الدالة: الانتخاب، وزن الجسم العالي، منحنيات النمو، Gompertz، Richards،Logistic ، السمان الياباني.