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The Growth Curve of Body Weight in Mixed-sex Rock Partridges (*Alectoris graeca*) Kept in captivity

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ABSTRACT

Rock partridge (*Alectoris graeca*) can be domesticated for meat and egg production poultry. This study was carried out to obtain the growth curve model of body weight (BW) in mixed-sex Rockpartridges using non-linear regression of Gompertz (G), Logistic (L)and Richards (R) models. The computer program of CurceExpert 1.4. was used in this study to calculate the growth parameters of asymptotic weight (A), maximum growth rate (MGR), inflection of weight (I_W), inflection of age (I_A), coefficient of determination (R^2) and mean squared error (MSE). Study showed that all models have similar R^2value but the lower MSE value was showed in R model. Hence, the R model can be used to predict the BW in mixed-sex rockpartridges from hatching to adult age accurately. In conclusion, the A, I_W and I_A values in rockpartridges with all models were 442.57 - 513.25 g; 188.69-221.29 g and 5.48-6.69 weeks respectively.

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Introduction

Rock partridge (*Alectoris graeca*) was classified into Galliform birds (Bernard-Laurentet al., 2017) and used for hunting game in their habitat atMediterranean countries (Günlü et al., 2007). The rock partridge was consisted of three sub-species of *A.g. saxatilis*, *A.g. orlandoi* and *A.g. whitakeri* (Corsoö, 2010). According to the D-Loop region (mtDNA), rock partridge was closed to Chukar partridge (*Alectoris chukar*) rather than Red-legged partridge (*Alectoris rufa*) (Lucchini and Randi,1998). In Bulgaria, rock partridge was classified into endangered species with population size of 800-1500 pairs (Nikolovet al., 2007). In Italy, the highly density of rock partridge was recorded in Reatini mountains (Amici et al., 2013).

In Greece, the rock partridge population at Sterea Hellas region recorded under stable trends (Bontzorlos et al., 2012). In the wild nature, the predator animals, over birds haunting game and habitat destruction were affected to the decreasing population in rock partridge. Despite of those factors, the parasite insect of *Tetrathyridium* was recorded as the main factor in reducing rock patridge at Central Greece (Manios et al., 2002).

Recently, rock partridges have genetic potency for meat production. Kırıkçı et al. (2017) reported that the carcass weight in rock partridge at 12 weeks of agekept with captivity was 309.73±14.93 g (female) and 342.00±17.99 g (male). Çetin (2000) reported that the live weight and carcass weight in mixed-sex rock partridge at 12 weeks' age were 425.50±32.89 g and 305.78±28.30 g respectively. Yamak et al. (2016) reported that the carcass weight of Chukar partridge (*Alectoris chukar*) at 14 weeks of age kept with captivity was 454.50 g (male) and 372.20 g (female). Kokoszynski et al. (2013) reported that the carcass weight in grey partridge (*Perdix perdix*) was 218.20±55.70 g (male) and 216.00±56.70 g (female).

As the meat production poultry, the growth of animal is important to evaluate. The growth evaluation in live stocks can be evaluated through the growth curve. The growth curve is represented mathematically as a sigmoid function, defined in a real line, bounded and differentiable with positive derivative. Its graph has a typical S shape showing slow growth at the begining, followed by a fast (exponential) growth that slows down gradually until it reaches an equilibrium value and usually named carrying capacity or level of saturation (Roman et al., 2019). In biology, it is represented as a function of age and live weight, covering all or part of the life of the animal.

Growth can be defined as the weight gain of an animal until it reaches adulthood. In the early stages of life, this growth accelerates and the weight gain is greater than the approach of adulthood, producing a sigmoidal curve. After the inflection point, growth gradually decreases and the growth rate becomes slower and slower.

In livestock and poultry, the fitting and analysis of growth curves of parameters is the basic work for breeding and production. The growth curve parameters determination, effectively, describe issues such as growth, livestock performance and optimum slaughter age, as well as preparing an appropriate feeding process and selection (Sariyel et al., 2017). As for partridges, these parameters facilitate the judgment and analysis the standards of feeding, management and epidemic prevention, and to compare and test the genetic quality of different genders (Wen et al., 2019).

Recently, the growth curve of the animal can be obtained with some non-linear regression models. Gompertz (G), Logistic (L) and Richards (R) models have been used to obtain the growth curve in Chukar partridge (Çetın et al., 2007). Unfortunately, study to obtain the growth curve in rock partridge with non-linear regression has not been reported. Hence, this study was aimed to obtain the growth curve in rock partridge using G, L and R models. The results of the study can be used to develop feeding and breeding systems to rock partridge for preventing from the extinction in the future.

Materials and Methods

The experimental material consisted of rock partridges (*Alectoris graeca*) at 40 weeks old in their first reproductive season, kept on at Veterinary Farm of Selçuk University, Turkey. Eggs obtained from breeder partridges were placed in a refrigerator type incubator (Çimuka T1600 C-Turkey) and incubated at 37.5℃ and 59% relative humidity for during 21 days. The hatching machine was set at 37℃ and 72% relative humidity until the 24th day of incubation. Amount of 77 mixed-sex rock partridges (Figure 1) were used in this study.

Figure 1. Rock partridge (*Alectoris graeca*)

After hatching, partridge chicks at 1 days of age were kept into colony cage (3.5×4.5 m) with temperature of 33℃ and the ground was covered by 8 cm layer of wood shavings used as litter. The temperature was changed to 30℃ one week later. After three weeks, the infra-red heater was not applied to chicks. A 24-h light regime was applied during the experiment. All partridges were fed *ad libitum* using the same diet 0-5 weeks and fed a ratio containing 24% crude protein during 6-12 weeks as *ad libutum* (Table 1).

Table 1. Composition of the starter and grower diets (%)

Ingredient	0-5 week	6-12 week
Soybean meal	41	27
Fish meal	7	5
Corn	36	36.75
Buğday	3	9
Sunflower seed meal	4	15
Vit-trace mineral mix	0.50	0.50
Limestone	-	0.25
Dicalcium phosphate	0.25	0.25
Vegetable fat	8	6
Salt	0.25	0.25

Water was also provided *ad libitum*. The chicks were weighed with electronic scales after hatching until 12 weeks gradually.

The data of body weight (BW) of rock partridges were analysed to obtain their growth model based on non-linear model of Gompertz (G), Logistic (L) and Richards (R) models. The growth curve analysis was performed using Curve Expert 1.4. computer package (Hyams, 2010). The mathematical formula of G, L and R models referring to Selvaggi et al. (2015) as follow:

Gompertz:

$$W_t = A\, e^{-e^{B-kt}} \qquad I_W = A/e \qquad I_A = B/c \qquad MGR = I_w \times k$$

Logistic:

$$W_t = \frac{A}{1 + Be^{-kt}} \qquad Iw = a/2 \qquad I_A = (Ln.B)/k$$

$$MGR = (I_W \times k)/2$$

Richards:

$$W_t = \frac{A}{\left(1 + A^{B-kt}\right)^{1/m}} \qquad I_W = \frac{A}{m\sqrt{m+1}}$$

$$I_A = (1/k) + Ln.(A^m)$$

where, W_t is the predicted weight (g) at t^{ih} week; A is the asymptotic weight; B is the scaling parameter; e is the constanta (2.72); k is the maturing rate; t is the time (week); m is the shape parameter; IW is the inflection of weight (g); IA is the inflection of age (week) and MGR is the maximum growth rate (g/week). Meanwhile, the coefficient of determination (R2) and mean squared error (MSE) were performed to obtain the best regression model using the similar computer package.

Results and Discussion

The average BW of rock partridge at 12 months of age was 421.57±4.88 g (Table 2). The asymptotic weight (A) in Gompertz (G) model was the highest than all model (Table 2). In contrast, the maturing rate (k), inflection of weight (I_w), inflection of age (I_A) and maximum growth rate (MGR) in G model were lowest than all model. The Logistic (L) model has the lowest of A value than all model but highest in k and maximum growth rate (MGR) values. The Richards (R) model showed A and I_A values. The coefficient of determination (R^2) value in all models were similar but the lowest of mean squared error (MSE) value was showed in R model (Table 2).

Table 2. The average of body weight (BW) in mixed-sex rock partridges

Week	BW (g)	Week	BW (g)
0	15.31±0.19	5	151.11±3.37
1	22.22±0.30	6	209.59±2.50
2	40.74±0.86	8	313.48±3.01
3	74.30±1.63	10	388.50±3.86
4	113.49±1.69	12	421.57±4.88

The A value with L model in bird's study showed under similar range to female Chukar partridge (*Alectoris chukar*) as presented in Table 3.

The growth curve line in BW of bird's study from 0 to 12 weeks estimated with all models were similar (Figure 2). Hence, the MGR and I_A values in the growth rate of birds study (Figure 2) were similar to the results estimation with mathematical formula (Table 3).

Günlü et al. (2007) reported that the average BW in mixed-sex rock partridges at 12 weeks' age was ranged from 358.80 g to 376.46 g and showed lower than in the bird's study. In addition, Iqbal et al. (2019) reported that the average BW in Chukar partridges at 12 weeks' age was 383 g (male) and 334 g (female), showed lower than birds study. In the Chukar partridge, the lowest of MSE value was showed in G model rather than L and R models (Çetin et al., 2007; Wen et al., 2019). The asymptotic weight (A) with R model in mixed-sex Chukar patridge was 448.22 g (Wen et al., 2019) and close to the bird's study (453.27 g) with a similar model. The A value with G model in bird's study was higher than mixed-sex Chukar partridge i.e. 513.30 g (Balcıoğlu et al., 2009) and 469.99 g (Wen et al., 2019) with a similar model. In addition, Wen et al. (2019) reported that the A value in mixed-sex Chukar partridge were 469.11 g (G) and 420.62 g (L) showed lower than birds study. Nevertheless, Balcıoğlu et al. (2009) obtained the A value in mixed-sex Chukar partridge of 501.30 g (G) and 481.90 g (L) showed higher than birds study.

Wen et al. (2019) reported that the inflection of weight (I_w) value in mixed-sex Chukar partridge was 172.90 g (G); 210.30 g (L) and 415.70 g (R). Therefore, the I_w value in mixed-sex Chukar partridge according to Balcıoğlu et al. (2009) was 184.89 g (G) and 241.45 g (L). The I_w value with L model in bird's study showed under similar range to female Chukar partridge (Tab. 3) with a similar model. Thus, Wen et al. (2019) obtained the I_w value in male Chukar partridge about 188.60 g with G model and similar to the bird's study. The inflection of age (I_A) value in mixed-sex Chukar partridge was 6.90 (G) and 8.20 (L) weeks (Wen et al., 2019) and higher than birds study. While, Balcıoğlu *et al*. (2009) obtained the I_A value in mixed-sex Chukar partridge of 43.28 (G) and 54.32 (L) weeks and higher than birds study. The I_A value with G model in bird's study showed close to male Chukar partridge (5.28 weeks) that reported by Çetin et al. (2007). The difference of the results study compared to previous studies can be caused by the difference of species, feed nutrition, keeping system, research site (geographic), sex and age.

It can be concluded that the selection in rock partridge can be conducted with body weight at 6 to 7 weeks of age. Hence, the R model can be used to predict the growth curve of body weight in mixed-sex rock partridge from hatching to adult age. In the future, study to determine the growth curve with sex (gender) effect is important to describe the growth characteristic of bird accurately.

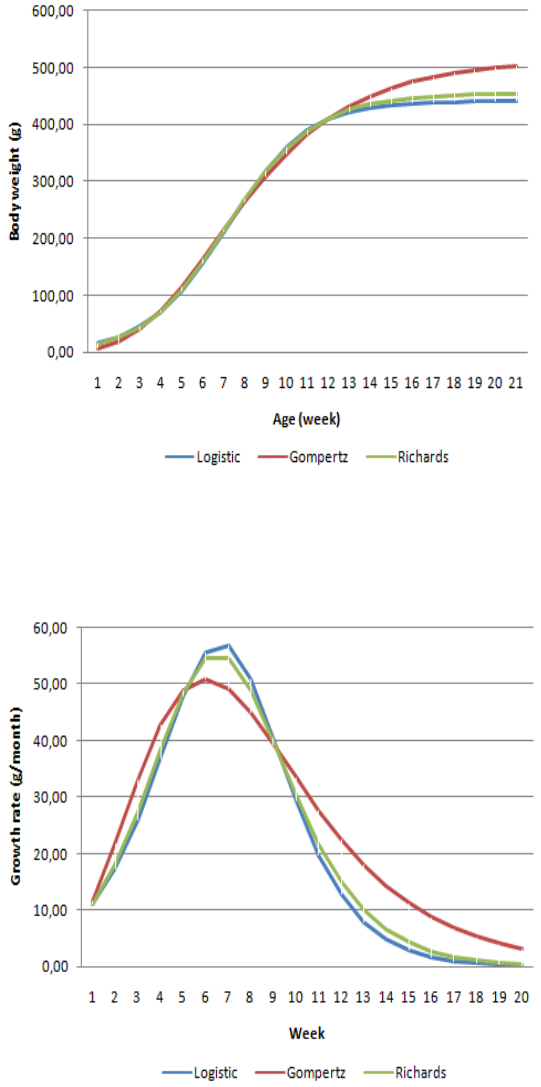

Figure 2. The growth curve and growth rate of body weight in mixed-sex rock partridges

Table 3. The growth parameters in body weight of mixed-sex rock partridges

Model	A	B	k	m	I_W	I_A	MGR	R^2	MSE
Gompertz	513.25	1.48	0.27	-	188.69	5.48	50.95	0.98	7.98
Logistic	442.57	24.70	0.52	-	221.29	6.17	57.54	0.98	4.34
Richards	453.27	2.39	0.45	0.73	213.81	6.69	54.67*	0.98	4.08

A: aymptotic weight (g); B: scaling parameter; k: maturing rate; m: shape parameter; I_w: inflection of weight (g); I_A inflection of age (week); MGR: maximum growth rate (g/week); R^2: coefficient of determination; MSE: mean of squared error. *observed from the growth curve

Table 4. The growth parameters in body weight of male and female Chukar partridge (*Alectoris chukar*) estimated with non-linear regression of Gompertz and Logistic models

Model	Sex	A	B	k	I_W	I_A	R^2	MSE	Reference
Gompertz	Male	570.63	1.29	0.21	209.92	6.03	0.999	5.28	Çetin et al. (2007)
		543.80	4.24	0.23	200.31	44.02	0.994	-	Balcıoğlu et al. (2009)
		565.30	3.59	0.19	208.00	18.70	0.990	274.00	Sariyel et al. (2017)
		512.64	3.85	0.19	188.60	7.10	0.998	43.59	Wen et al. (2019)
		533.00	3.89	0.21	195.96	18.52	0.980	-	Iqbal et al. (2019)
	Female	475.54	1.28	0.23	174.90	5.68	0.998	7.08	Çetın et al. (2007)
		460.20	4.17	0.24	169.98	42.58	0.994	-	Balcıoğlu et al. (2009)
		472.90	3.47	0.21	174.00	16.80	0.991	186.10	Sariyel et al. (2017)
		440.57	3.84	0.21	162.10	6.50	0.998	45.80	Wen et al. (2019)
		457.00	3.65	0.22	168.01	16.59	0.990	-	Iqbal et al. (2019)
Logistic	Male	559.94	12.66	0.32	279.97	7.96	0.995	13.92	Çetın et al. (2007)
		522.10	17.24	0.36	261.33	55.14	0.994	-	Balcıoğlu et al. (2009)
		517.00	14.13	0.32	258.50	8.30	0.987	374.40	Sariyel et al. (2017)
		457.39	17.73	0.34	228.70	8.40	0.999	33.67	Wen et al. (2019)
		502.00	16.00	0.34	251.00	8.15	0.986	-	Iqbal et al. (2019)
	Female	467.55	12.41	0.33	233.78	7.54	0.995	11.70	Çetin et al. (2007)
		443.10	16.60	0.37	222.24	53.52	0.993	-	Balcıoğlu et al. (2009)
		440.20	12.89	0.33	220.10	7.70	0.980	277.80	Sarıyel et al. (2017)
		402.65	17.10	0.36	201.30	7.90	0.999	15.82	Wen et al. (2019)
		432.00	14.30	0.35	216.00	7.60	0.986	-	Iqbal et al. (2019)

A: aymptotic weight (g); B: scaling parameter; k: maturing rate; I_w: inflection of weight (g); I_A inflection of age (week); R^2: coefficient of determination

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