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Monitoring changes in genetic parameters for growth traits over generations of selection in local chickens in Egypt

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Abstract Estimating the genetic parameters for growth traits is a crucial step before designing breeding programs to enhance the productivity in local chicken breeds. The current study estimated the genetic parameters of two local chicken lines selected for meat production (Normally Feathered, CE1, and naked-neck, CE3) and tracked the changes in these parameters over three generations of selection. Heritability estimates for the hatch weight were moderate, ranging between 0.30 and 0.31. Lower estimates ranged from 0.28 to 0.33, and were obtained for BW2 and BW4, respectively. The genetic correlations were moderate to high, and varied from 0.43 (BW12 and BW18) to 0.88 (initial BW and BW2) in the seventh generation of selection. The values in the eighth generation had the same trend and varied from 0.41 (initial BW and BW18) to 0.86 (BW2 and BW4). Similar values were obtained for body weight gain (BWG) and growth rate (GR) traits, where the highest genetic correlation (0.86) was between BWG (0-6) and GR (0-6) in the seventh and ninth generations, respectively, and the lowest was 0.62 that found between BWG (6-12) and GR (12-18) in the eighth generation. However, the highest phenotypic correlation (0.71) was also obtained between BWG (0-6) and GR (0-6) in the eighth generation, and the lowest value (0.42) was obtained between BWG (6-12) and GR (12-18) in the ninth generation of selection. The results suggested that there is enough genetic variation for further improvement in body weight at the juvenile stage.

Keywords: genetic correlation, genetic parameters, heritability, local chicken, phenotypic correlation, selection

Introduction

Worldwide, animal production has faced great pressure from the increased demand for animal protein, compelling producers to deliver high-quality and high-quantity animal products. Consequently, breeding programs have been directed to improve a limited number of commercial breeds, and neglecting the local breeds (Orabi et al., 2025). However, one of the key requirements for sustainable animal production is the wise use and conservation of local breeds. Local breeds are important for sustainability purposes (El-Sabry et al., 2021). However, sensitivity of exotic breeds to temperature and humidity stress under tropical environments suggested that a breeding policy in which the introduction of genes of local breeds into the exotic stocks be initiated (El-Gendy, 2009). Beyond productivity, conserving native chicken breeds is critical for preserving genetic biodiversity and enhancing climate resilience. Indigenous breeds possess unique adaptations to regional stressors increasingly vital under climate change. The erosion of these irreplaceable genetic resources through homogenization toward commercial stocks threatens long-term agricultural sustainability. Therefore, greater emphasis should be given to breeding programs for local breeds, mainly aiming to improve growth traits (Mebratie et al., 2019).

The phenotypic characterization of native breeds is essential for improving their performance. Moreover, estimating genetic parameters is crucial for the practice of selection and the design of breeding programs (Ragab et al., 2022). Exploring genetic variance components and genetic parameters is essential for estimating breeding values, optimizing breeding schemes, and improving estimation of response to selection (Prado-González et al., 2003; Norris and Ngambi, 2006). Genetic parameters might also vary among populations and environments, and should therefore be estimated in different populations and environments (Helal and El-Gendy, 2013; El-Henfnawy et al., 2022). Moreover, the presence of particular genes can affect performance under certain environmental conditions; among these genes is the naked-neck (Na) gene, which reduces feather coverage by 20-40% (Yunis and Cahaner, 1999). The advantages of naked-neck chickens over the normally feathered are observed under high ambient temperatures (Helal and El-Gendy, 2014).

Therefore, the current study aimed to study the changes in genetic parameters over several generations in two local chicken lines selected for high 6-week body weight.

Materials and methods

Populations and breeding history

The selection program was initiated in the early 2000s at the Experimental Poultry Farm of the Faculty of Agriculture, Cairo University (Giza, Egypt; 30°01'N, 31°13'E). Base populations were established by crossing commercial grandsires with two indigenous Baladi chicken lines (El-Gendy, 2009). The primary selection criterion was high 6-week body weight. Each generation included four lines with different genetic backgrounds, two selected lines, and two control lines. These lines were the fully-feathered selected line (CE1), the fully-feathered control line (CE2), naked-neck selected line (CE3), and naked-neck control line (CE4). Lines CE1 and CE3 were selected for, while CE2 and CE4 served as genetic control lines for the two selected lines (El-Gendy, 2009). The current study includes data from four subsequent generations. The sixth generation of selection was considered the base generation, and data from generations 7, 8, and 9 were used as three generations of selection. The number of chickens included in the data set was 1122, 1234, 1054, and 1354 for the base, seventh, eighth, and ninth generations, respectively.

Management

Chicks of all genetic combinations were housed in floor chambers in a semi-closed conventional house, and wood shaving was used as the litter. The ambient temperature was 33 °C during the first week and was gradually decreased to 22-24 °C from the fifth week of age. The relative humidity was maintained at 50-65%. During the brooding and rearing periods, water and mash feed were provided *ad libitum*.The chicks were fed a broiler starter ration (22% crude protein and 2800 kcal metabolizable (ME) energy/kg) during weeks 1-4 of age, followed by a broiler growing ration (19-20% crude protein and 3100 kcal ME energy/kg) during weeks 4-8 of age, followed by a finisher ration (15% crude protein and 2700 Kcal ME energy/kg, 150 g/bird/d) during weeks 8-10, and a pre-layer ration (16% crude protein and 2750 Kcal ME energy/kg, 120 g/bird/d) from weeks 10 to 20 of age. The chickens were routinely vaccinated against Newcastle disease (at 7, 14, 50, 80, and 110 days of age, Lasota strain Poulvac®, USA), Avian Flu (at 1 day of age, Poulvac®, USA), and Gumboro (at 12 days of age, IBD2, Bursine®, USA) diseases.

Phenotypic measurements

Individual body weights (BW) were recorded at hatch and then every two weeks until 18 weeks of age. Body weight gain (BWG) was calculated for 6-week periods as $BWG_{XY} = BW_y - BW_x$, and growth rate (GR) calculated for 6-week periods as $GRxy = (BW_y - BW_x)/1/2\ (BW_x + BW_y)$ as decribed by Brody (1945).

Statistical analysis

Variance and covariance components were calculated using the restricted maximum-likelihood (REML) of the VARCOMP procedure (SAS, 1999) in the following model:

$$y_{ijklm} = \mu + L_i + S_j + M_k + D_l + (LS)_{ij} + e_{ijklm}$$

where, y_{ijklm} is an individual observation for the trait. μ denotes the overall mean, L_i signifies the fixed effect of the ith selected line within a generation (i = 1, 2), S_j refers to the fixed effect of the jth sex (j=1, 2), M_k is the random effect of the kth sire. D_l stands for the random effect of the lst dam. LS_{ij} is the interaction of L_i and S_j, and e_{ijklm} shows the residual random effect distributed as N (0, $I\sigma e^2$). However, the hatch effect was excluded from the model due to insignificance.

Heritability estimates (narrow sense) were calculated (Falconer and Mackay, 1983) as:

$$h^2_s = 4\sigma^2_s / (\sigma^2_s + \sigma^2_d + \sigma^2_e)$$

where, σ^2_s, σ^2_d, σ^2_e are sire, dam, and error variance components, respectively. The calculated variance and covariance components were used to determine the phenotypic and genetic correlations as follows:

$$\sigma_{xy} = (\sigma^2_{x+y} - \sigma^2_x - \sigma^2_y)/2$$

where, σ_x^2 and σ_y^2 are the variances of x and y traits, and σ_{x+y}^2 is the variance of the individual sums of the two traits. Sire variance components were multiplied by four to calculate the genetic covariances. The phenotypic and genetic correlations (r_p and r_g) were calculated according to Falconer and Mackay (1983).

Results and discussion

Heritability estimates

The heritability estimates for growth parameters of the two selected lines in subsequent generations are presented in Table 1. According to Falconer and Mackay (1983), heritability is moderate when the estimate ranges from 0.2 to 0.4, and low when it is less than 0.2. Heritability estimates for body weight (BW) at hatch were moderate, ranging between 0.30±0.05 and 0.31±0.05 in line CE1 and between 0.34±0.05 and 0.35±0.06 in line CE3. The estimates obtained for BW at 2 (BW2) and 4 weeks (BW4) were lower than those for the hatching weight and ranged from 0.28±0.04 to 0.33±0.06. For BW at 6 weeks (BW6), moderate values were estimated in the two selected lines across the three generations; the values ranged from 0.29±0.03 to 0.34±0.05 in the fully-feathered line (CE1) from between 0.31±0.05 to 0.32±0.05 in the naked-neck line (CE3). A declining trend was observed in the estimated heritability values for body weights at subsequent ages. The estimated body weight gain and growth rate values were low and further decreased with increase in age, being higher in the naked-neck line (CE3) compared to the fully-feathered line (CE1).

Table 1. Heritability estimates (± standard error) for growth traits of the two selected lines (CE1 and CE3) in the subsequent generations of selection for high 6-week body weight

Trait	Generation					
	Seventh		Eighth		Ninth	
	Line CE1	Line CE3	Line CE1	Line CE3	Line CE1	Line CE3
BW0	0.30 ± 0.05	0.34 ± 0.05	0.31 ± 0.04	0.35 ± 0.06	0.31± 0.05	0.34 ± 0.06
BW2	0.28 ± 0.04	0.20 ± 0.03	0.29 ± 0.06	0.23 ± 0.04	0.29 ± 0.04	0.28 ± 0.04
BW4	0.29 ± 0.03	0.32 ± 0.04	0.33 ± 0.06	0.32 ± 0.05	0.34 ± 0.05	0.33 ± 0.04
BW6	0.29 ± 0.03	0.31 ± 0.05	0.33 ± 0.05	0.32 ± 0.05	0.32 ± 0.05	0.32 ± 0.02
BW8	0.24 ± 0.03	0.21 ± 0.03	0.22 ± 0.04	0.26 ± 0.04	0.33 ± 0.04	0.30 ± 0.06
BW10	0.22 ± 0.04	0.18 ± 0.02	0.23 ± 0.03	0.24 ± 0.04	0.25 ± 0.03	0.22 ± 0.02
BW12	0.16 ± 0.03	0.22 ± 0.02	0.15 ± 0.04	0.23 ± 0.03	0.22 ± 0.02	0.22 ± 0.04
BW14	0.14 ± 0.02	0.18 ± 0.02	0.16 ± 0.03	0.17 ± 0.03	0.20 ± 0.02	0.17 ± 0.06
BW16	0.11 ± 0.01	0.14 ± 0.02	0.13 ± 0.02	0.14 ± 0.02	0.12 ± 0.04	0.17 ± 0.01
BW18	0.14 ± 0.02	0.14 ± 0.02	0.16 ± 0.02	0.16 ± 0.03	0.17 ± 0.01	0.14± 0.04
BWG(0-6)	0.18 ± 0.02	0.19 ± 0.03	0.19 ± 0.03	0.19 ± 0.04	0.18 ± 0.03	0.17 ± 0.01
BWG(6-12)	0.16 ± 0.04	0.19 ± 0.03	0.15 ± 0.02	0.10 ± 0.02	0.20 ±0.04	0.20 ± 0.02
BWG(12-18)	0.09 ± 0.01	0.11 ± 0.01	0.11 ± 0.02	0.12 ± 0.01	0.14 ± 0.01	0.14 ± 0.04
GR(0-6)	0.18 ± 0.02	0.19 ± 0.03	0.19 ± 0.02	0.19 ± 0.02	0.13 ± 0.03	0.19 ± 0.02
GR(6-12)	0.12 ± 0.02	0.18 ± 0.02	0.14 ± 0.02	0.19 ± 0.02	0.15 ± 0.04	0.17 ± 0.01
GR(12-18)	0.14 ± 0.01	0.19 ± 0.02	0.16 ± 0.03	0.17 ± 0.01	0.14 ± 0.04	0.17 ± 0.04

BW: Body weight; BWG: Body weight gain; GR: Growth rate; CE1: Normally-feathered selected line; CE3: Naked-neck selected line

The heritability estimates for body weight traits were relatively low to moderate and did not greatly differ between the fully-feathered and naked-neck selected lines or among generations. These values suggest that body weight traits in the two selected lines (CE1 and CE3) would still respond to selection. Notably, the estimates were higher for body weights at early ages and tended to decrease with the increasing age. A similar trend was observed in naked-neck broiler chickens (Adeyinka et al., 2006) and fully- feathered Korean native chickens (Manjula et al., 2018). Similarly, Tongsiri et al. (2019) estimated heritability for early growth traits in Thai native chickens and noticed that heritability estimates decreased with the increasing age. In quails, Saatci et al. (2006) reported a reduction in heritability estimates with age. In contrast, Chambers (1993) reported that heritability estimates for body weight traits tend to increase with age. However, the estimated heritability for hatch weight (BW_0) was lower than that estimated by Yousefi Zonuz et al. (2013), who reported a heritability estimate of 0.42 for hatch weight in Esfahan native chickens. Similarly, Norris and Ngambi (2006) reported a heritability estimate of 0.36 for hatch weight in Venda local chickens. In general, previous studies have considered juvenile body weight in chickens to be a highly to moderately heritable trait (Lwelamira *et al.*, 2009; Tongsiri *et al.*, 2019). However, Prado-González et al. (2003) reported lower values (from 0.07 to 0.21) for the heritability of body weights at various early ages compared to the current results. The direct heritability estimates in Thai local chickens ranged from 0.10 to 0.47 (Tongsiri et al., 2019).

Phenotypic and genotypic correlations

Phenotypic and genetic correlations, across all lines, are presented in Tables 2, 3, and 4 for the seventh, eighth, and ninth generations. In general, the genetic correlations for body weight traits were moderate to high, and ranging from 0.43 (BW12 and BW18) to 0.88 (BW0 and BW2) in the seventh generation of selection. These values followed the same trend in the eighth generation and ranged from 0.41 (BW0 and BW18) to 0.86 (BW2 and BW4). Similarly, genetic correlation values ranged from 0.42 (BW4 and BW16) to 0.87 (BW0 and BW2) in the ninth generation of selection. The phenotypic correlation (r_p) values were also high and ranged from 0.38 (BW8 and BW18) to 0.72 (BW4 and BW6) in the seventh generation, from 0.41 (BW6 and BW18) to 0.73 (BW4 and BW6) in the eighth generation, and from 0.40

(BW10 and BW18) to 0.73 (BW2 and BW6) in the ninth generation. Similar values were obtained for body weight gain and growth rate traits, where the highest genetic correlation (0.86) was found between BWG (0-6) and GR (0-6) in the seventh and ninth generations, and the lowest (0.62) was found between BWG (6-12) and GR (12-18) in the eighth generation. Similarly, the highest phenotypic correlation (0.71) was obtained between BWG (0-6) and GR (0-6) in the eighth generation, and the lowest (0.42) was obtained between BWG (6-12) and GR (12-18) in the ninth generation of selection. Similar results were reported for genetic correlations between growth traits at 8, 12, 16, and 20 weeks of age in Tanzanian local broiler chickens (Lwelamira et al., 2009). Likewise, Dana et al. (2011) reported similar findings for Ethiopian broiler chickens. Niknafs et al. (2013) reported high genetic correlations between body weights at hatch, 8, and 12 weeks of age in Mazandaran indigenous broiler chickens.

Table 2. Phenotypic (r_p, above the diagonal) and genetic (r_g, below the diagonal) correlation, overall lines, among growth traits in the seventh generation of selection for meat production (high 6-week body weight) in local Egyptian chickens

Trait	BW0	BW2	BW4	BW6	BW8	BW10	BW12	BW14	BW16	BW18	BWG0-6	BWG6-12	BWG12-18	GR0-6	GR6-12	GR12-18
BW0		0.71	0.73	0.71	0.68	0.67	0.56	0.67	0.45	0.5	0.75	0.53	0.56	0.56	0.5	0.53
BW2	0.88		0.67	0.71	0.56	0.68	0.45	0.42	0.56	0.55	0.43	0.65	0.67	0.62	0.54	0.64
BW4	0.86	0.87		0.72	0.66	0.65	0.53	0.64	0.56	0.54	0.76	0.56	0.65	0.76	0.45	0.65
BW6	0.8	0.83	0.87		0.7	0.65	0.54	0.65	0.64	0.56	0.53	0.63	0.53	0.67	0.69	0.64
BW8	0.82	0.83	0.84	0.84		0.67	0.64	0.63	0.56	0.38	0.5	0.56	0.44	0.57	0.56	0.66
BW10	0.72	0.74	0.82	0.74	0.83		0.78	0.65	0.59	0.41	0.63	0.51	0.65	0.5	0.65	0.45
BW12	0.81	0.64	0.75	0.75	0.64	0.84		0.67	0.66	0.53	0.5	0.64	0.56	0.54	0.54	0.59
BW14	0.67	0.65	0.72	0.73	0.64	0.75	0.78		0.56	0.56	0.5	0.67	0.56	0.43	0.64	0.56
BW16	0.64	0.63	0.62	0.65	0.54	0.74	0.77	0.86		0.64	0.56	0.65	0.54	0.43	0.53	0.65
BW18	0.51	0.54	0.53	0.64	0.75	0.65	0.43	0.84	0.75		0.53	0.65	0.67	0.57	0.64	0.43
BWG0-6	0.83	0.85	0.74	0.86	0.65	0.64	0.65	0.56	0.45	0.75		0.62	0.54	0.53	0.65	0.56
BWG6-12	0.75	0.84	0.82	0.75	0.79	0.85	0.76	0.73	0.56	0.76	0.56		0.56	0.42	0.53	0.54
BWG12-18	0.7	0.76	0.64	0.73	0.67	0.65	0.76	0.63	0.76	0.86	0.67	0.54		0.56	0.5	0.51
GR0-6	0.87	0.85	0.85	0.86	0.56	0.56	0.64	0.63	0.56	0.56	0.86	0.67	0.78		0.64	0.56
GR6-12	0.65	0.83	0.53	0.84	0.86	0.78	0.71	0.75	0.45	0.67	0.75	0.85	0.64	0.73		0.75
GR12-18	0.56	0.74	0.64	0.64	0.75	0.65	0.64	0.78	0.74	0.86	0.76	0.76	0.82	0.78	0.64	

BW: Body weight; BWG: Body weight gain; GR: Growth rate

Table 3. Phenotypic (r_p, above the diagonal) and genetic (r_g, below the diagonal) correlation, overall lines, among growth traits in the eighth generation of selection for meat production (high 6-week body weight) in local Egyptian chickens

Trait	BW0	BW2	BW4	BW6	BW8	BW10	BW12	BW14	BW16	BW18	BWG0-6	BWG6-12	BWG12-18	GR06	GR6-12	GR12-18
BW0		0.70	0.67	0.64	0.61	0.54	0.61	0.56	0.56	0.45	0.64	0.67	0.51	0.65	0.64	0.54
BW2	0.8		0.71	0.64	0.65	0.63	0.61	0.58	0.45	0.5	0.56	0.51	0.45	0.68	0.60	0.45
BW4	0.77	0.86		0.73	0.61	0.65	0.67	0.6	0.54	0.46	0.63	0.64	0.48	0.6	0.48	0.43
BW6	0.79	0.85	0.85		0.81	0.66	0.65	0.7	0.62	0.41	0.56	0.71	0.53	0.64	0.7	0.41
BW8	0.64	0.73	0.76	0.79		0.66	0.56	0.55	0.53	0.48	0.54	0.67	0.63	0.61	0.65	0.45
BW10	0.70	0.53	0.54	0.77	0.76		0.66	0.46	0.45	0.54	0.63	0.64	0.52	0.54	0.67	0.43
BW12	0.64	0.67	0.44	0.61	0.74	0.76		0.71	0.57	0.51	0.53	0.63	0.67	0.65	0.66	0.64
BW14	0.54	0.65	0.5	0.63	0.67	0.56	0.75		0.65	0.61	0.54	0.54	0.68	0.67	0.67	0.55
BW16	0.45	0.53	0.56	0.54	0.63	0.67	0.7	0.81		65	0.46	0.62	0.71	0.56	0.64	0.56
BW18	0.41	0.52	0.57	0.6	0.58	0.66	0.65	0.78	0.67		0.35	0.56	0.59	0.5	0.67	0.66
BWG0-6	0.85	0.82	0.79	0.88	0.65	0.62	0.6	0.54	0.55	0.45		0.53	0.63	0.71	0.56	0.64
BWG6-	0.62	0.7	0.71	0.76	0.76	0.77	0.87	0.80	0.65	0.56	0.76		0.53	0.63	0.70	0.67
BWG12-	0.56	0.45	0.56	0.65	0.78	0.67	0.76	0.72	0.65	0.67	0.7	0.74		0.70	0.65	0.71
GR0-6	0.85	0.76	0.55	0.78	0.67	0.658	0.65	0.56	0.51	0.54	0.75	0.64	0.74		0.67	0.61
GR6-12	0.76	0.64	0.53	0.77	0.78	0.71	0.74	0.61	0.64	0.65	0.65	0.87	0.9	0.84		0.67
GR12-	0.68	0.67	0.45	0.56	0.51	0.46	0.64	0.68	0.71	0.75	0.54	0.65	0.74	0.75	0.84	

BW: Body weight; BWG: Body weight gain; GR: Growth rate

Similar high genetic and phenotypic correlation values among body weight traits in local broiler chickens were previously reported (Haunshi et al., 2021). The high genetic correlations among body weights suggest that selection for increased body weight is an effective approach for achieving permanent genetic change in local chickens (El-Attrouny et al., 2021). Manjula et al. (2018) estimated the genetic correlation for growth rate at two-week intervals and reported higher estimates compared to the results of the current study. However, Manjula et al. (2018) also reported some negative genetic and phenotypic correlations between early and late growth rate periods.

Conclusion

The results suggested that there is sufficient genetic variation for growth traits, with favorable correlations among them. Therefore, there is an opportunity for further improvement in body weight at the juvenile stage, and the ongoing selection can be continued in weight.

subsequent generations to achieve higher 6-week body Furthermore, the overall highly positive genetic and phenotypic correlations between growth traits suggested that these correlations are typically synergistic. Therefore, the mass selection strategy based on 6-week body weight traits is favorable, and it is recommended to estimate the variance component from one generation to the next to maximize genetic gain.

Table 4. Phenotypic (r_p, above the diagonal) and genetic (r_g, below the diagonal) correlation, overall lines, among growth traits in the ninth generation of selection for meat production (high 6-week body weight) in local Egyptian chickens

Trait	BW0	BW2	BW4	BW6	BW8	BW10	BW12	BW14	BW16	BW18	BWG0-6	BWG6-12	BWG12-18	GR06	GR6-12	GR12-18
BW0		0.69	0.56	0.62	0.55	0.63	0.66	0.54	0.53	0.43	0.67	0.62	0.56	0.53	0.43	0.53
BW2	0.87		0.65	0.73	0.65	0.53	0.52	0.43	0.49	0.53	0.56	0.54	0.53	0.56	0.63	0.61
BW4	0.8	0.86		0.64	0.64	0.56	0.53	0.55	0.43	0.46	0.45	0.66	0.63	0.66	0.52	0.45
BW6	0.84	0.85	0.86		0.84	0.64	0.63	0.67	0.62	0.67	0.66	0.54	0.45	0.67	0.45	0.56
BW8	0.79	0.75	0.78	0.78		0.67	0.54	0.63	0.52	0.46	0.43	0.67	0.54	0.64	0.56	0.41
BW10	0.73	0.73	0.61	0.74	0.76		0.66	0.56	0.65	0.4	0.51	0.66	0.67	0.59	0.56	0.45
BW12	0.7	0.65	0.5	0.71	0.72	0.73		0.56	0.63	0.53	0.56	0.65	0.42	0.5	0.67	0.54
BW14	0.67	0.76	0.48	0.56	0.68	0.69	0.8		0.65	0.41	0.43	0.45	0.67	0.52	0.64	0.45
BW16	0.69	0.67	0.42	0.43	0.78	0.67	0.71	0.75		0.54	0.57	0.54	0.54	0.44	0.56	0.56
BW18	0.66	0.62	0.63	0.54	0.42	0.62	0.67	0.64	0.72		0.56	0.45	0.42	0.41	0.43	0.64
BWG0-6	0.88	0.82	0.78	0.78	0.73	0.63	0.57	0.51	0.45	0.53		0.63	0.55	0.73	0.61	0.43
BWG6-12	0.83	0.74	0.56	0.78	0.68	0.44	0.45	0.54	0.52	0.45	0.73		0.68	0.66	0.54	0.42
BWG12-18	0.74	0.71	0.57	0.71	0.56	0.52	0.61	0.67	0.47	0.78	0.65	0.78		0.53	0.56	0.64
GR0-6	0.85	0.8	0.81	0.73	0.63	0.61	0.52	0.43	0.41	0.4	0.86	0.54	0.67		0.52	0.56
GR6-12	0.76	0.72	0.69	0.71	0.81	0.82	0.79	0.63	0.63	0.45	0.56	0.77	0.65	0.74		0.56
GR12-18	0.67	0.66	0.56	0.67	0.53	0.5	0.77	0.73	0.73	0.67	0.67	0.62	0.78	0.71	0.72	

BW: Body weight; BWG: Body weight gain; GR: Growth rate

Statement of animal ethics

All the experimental procedures were approved by the institutional animal care and use committee at Cairo University (CU-IACUC), approval number: CU/II/F/10/22.

Conflict of interest statement

The authors report they have no competing interests to declare.

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