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Different Selection Strategies for the Improvement of the Growth Performance and Carcass Traits of Japanese Quails

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ABSTRACT

The present study evaluated different selection strategies to improve the growth performance and carcass traits of Japanese quails. To this end, 540 Japanese quails previously selected for high body weight at three ages (10, 12 and 14 weeks) from four close-bred flocks (Major, Kaleem, Saadat and Zahid) were subjected to three selection strategies: pedigree-based, mass selection or random-bred (controls). For pedigree-based selection, 108 birds (4 close-bred flocks × 3 age groups × 9 replicates × 1 bird each) with full pedigree and selected for high body weight were used, whereas in mass selection 324 birds (4 close-bred flocks × 3 age groups × 9 replicates × 3 birds each) with high body weight were selected to be the parents of next generation. Random-bred controls included 108 birds (4 close-bred flocks × 3 age groups × 9 replicates × 1bird each) which were not previously submitted to selection. The effects of selection strategies of Japanese quail parents from four close-bred flocks (CBF) at three ages on the performance growth and carcass traits of their progenies were measured. The parent flocks were selected at three ages (10, 12 and 14 weeks) and reared for 20 weeks, and their progenies were reared for four weeks. The progeny of pedigree-based selected parents presented better feed intake (g), body weight gain (g), feed conversion ratio, live and carcass weights (g), and carcass yield. The progeny of 10- and 14-week-old parents showed better growth performance and carcass traits, respectively. Moreover, there was no influence of CBF on growth and carcass traits. It was concluded that pedigree-based selection had pronounced effect on the growth performance and carcass traits of the progeny compared with mass selection and random breeding. It is suggested that parental ages of 10 and 14 weeks of age promote better progeny growth performance and carcass traits.

INTRODUCTION

Selection is a basic tool to exploit and improve the productive potential of birds. Different selection strategies have been working throughout the world comprising mass selection to fully pedigree selection (Marks, 1991, 1996; Minvielle *et al.,* 1997; Narinç *et al.,* 2016; Durmuş *et al.,* 2017). Selection programs remarkably improve economic traits in broilers with2.4-fold improvements in growth rate and carcass traits; however, feed conversion ratio has improved only 0.025% per year.

In Japanese quails, genetic improvements of 9.6, 8.8 and 8.2g in body weight at four weeks of age (4-wk BW) were observed in generations 2, 3 and 4, respectively (Varkoohi *et al.,* 2010). Over the same period of selection for 4-wk BW, the improvement in feed conversion ratio (FCR) was 0.16 units. These results indicate that selection for reduced FCR increases body weight and weight gain and reduces feed intake and residual feed intake as correlated responses (Varkoohi *et al.,* 2010).

Moreover, a strong genetic correlation between 4-wk BW and carcass traits was recorded (Khaldari *et al*., 2010). Another study reported that slaughter age significantly influenced the carcass traits of Japanese quails (Narinc *et al.,* 2014). The findings of Tukmut *et al.* (1999) revealed that slaughter weight, carcass weight, carcass yield, abdominal fat weight, organ weight and organ yields of female quails were affected by selection. Carcass weight, carcass percent, breast weight and thigh percent were significantly affected by Japanese quail strain (Vali *et al.,* 2005)

Selection experiments provide background knowledge of the inheritance of complex traits and allow the evaluation of the hypothetical predictions by comparing observations against expectations (Szwaczkowski, 2003). The selection objectives may be short-termed, i.e., using genetic additive variance and covariance test to estimate genetic response or long-termed to measure the selection response or additive variance caused by the selection procedure (Hill & Mackay, 2004). Long-term response to selection is more focused on fixing the probabilities of alleles responsible for the trait(s) under consideration and it is generally agreed that to achieve most of the goals of long term selection more than thirty generations will be required (Reddy, 1996). On the other hand, short-term selection response might be attributed to alleles segregating in the population (Fuller *et al.,* 2005).

Japanese quails have called significant attention in recent years due to their high resistance to diseases as well as for its use for meat and egg production. They mature at an early age of 6 weeks and females are usually in full production by about 8 weeks of age (Ashok & Prabakaran, 2012). Due to their faster growth rate and high egg production, quails may be an interesting option to study production, reproduction, egg quality traits, as well as metabolic and immunological traits. Moreover, their generation interval is short, of almost 3-4 generations per year, and present high recombination rate, which makes of Japanese quails a very suitable species for genetic studies (Burt & Pourquie, 2003).

The profitability of quail enterprises largely depends on carcass quality, and many research studies have been conducted to describe quail carcass traits (Odunsi & Kehinde, 2009). Among these, carcass yield is considered as trait of interest and in conventional selection experiments, quail can serve as the best avian model due to several reasons, including that they are relatively easy to handle and have cheap maintenance costs (Daikwao *et al.,* 2013).

Despite having enormous potential, very little research has been conducted on the acclimatization of Japanese quails to Pakistan's environment. Keeping above in view, Japanese quail parents from four close-bred flocks of three ages were subjected to three selection strategies and the growth performance and carcass traits of their progenies were evaluated.

MATERIALS AND METHODS

The present study was conducted at Avian Research and Training (ART) Centre, Department of Poultry Production, University of Veterinary and Animal Sciences, Lahore, Pakistan, to evaluate effect of the selection for higher body weight at 4 weeks of age of 4 close-bred flocks of three age groups of Japanese quails during 4th generation.

A total of 540 quail breeders previously selected for 4-wk BW were subjected to selective breeding. Birds were distributed according to completely randomized design in a 3x4x3 factorial arrangement. The treatments consisted of three selection strategies (pedigree-based, mass-selected, and random-bred), four close-bred flocks (Major, Kaleem, Saadat & Zahid; Jatoi *et al.,* 2013) and three parental age groups (10, 12 and 14 weeks), totaling 36 treatments with nine replicates or 324 experimental units.

The parent flocks were selected at three ages (10, 12 and 14 weeks) and reared for 20 weeks a density of 220 cm^2/bird); however, their progenies were reared under standard managemental conditions during the four experimental weeks [83.61cm^2/bird during brooding (1-14 d of age) and 150 cm^2/bird during the growing phase (15-28 d of age)],as previously described by Narinc *et al.* (2013a).

Selection Procedures

Birds were divided in three main groups according to selection strategies, i.e., pedigree-based, mass-selected and random-bred groups, with 108, 324, and 108 birds, respectively. In first group, quails (4 close-bred flock × 3 age groups × 9 replicates × 1 bird each) having higher body weight with full pedigree record were selected to draw comparison with birds subjected to mass selection and random-bred group. In second group, quails (4 close-bred flock × 3 age groups × 9 replicates × 3 bird each) were subjected to mass selection in which birds with the highest body weight were selected to be the parents of the next generation. In the third group, quails (4 close-bred flock × 3 age groups × 9 replicates × 1 bird each) were randomly selected and were considered the control group (Hussain *et al.,* 2013).

Housing and Management

All experimental birds were maintained in well-ventilated octagonal quail house (21.68 m^2) equipped with multi-deck cages specially designed for separate quail rearing and breeding. The breeder quails were reared for 20 weeks (provided with 16 hours light). Meat-type quails were reared for 4 weeks and provided with 24 hours light. During brooding (first two weeks) 25 lux were provided and light intensity was decreased up to 5-10lux during the rearing period of two weeks (Narinc *et al.,* 2013b). Two feeds were formulated as recommended by the NRC standards (1994): one for breeders (20% CP and 2900 kcal ME/kg) and one for meat-type quails (24% CP and 2900 kcal ME/kg). The nipple drinker system ensured the availability of clean drinking water. In case of pedigreed and random-bred control birds, one individual female was kept per replicate, whereas in mass-selected birds, three females were kept per replicate. The stud-mating system was performed in pedigreed and random-bred control groups, whereas pen-mating system was practiced in mass-selected groups.

Growth performance parameters were determined at 4 weeks of age. Feed intake (g) was record as average feed intake/ bird /day and converted into weekly basis for the calculation of weekly feed conversion ratio. Feed intake (g) was calculated as feed offer (g) – feed residue (g). Body weight gain (g) was calculated by subtracting final from initial body weight. Feed conversion ratio (FCR) was calculated on weekly basis by the following formula:

$$FCR = \frac{\text{Feedintake (g)}}{\text{Body weight gain (g)}}$$

Mortality (%)recorded on daily basis (if any) and converted into weekly basis to calculate mortality % as:

$$\text{Mortality} = \frac{\text{Dead Birds}}{\text{Total Birds}} \times 100$$

At the end of 4th week, three birds per replicate were slaughtered and following parameters were recorded. To record live weight (g), each bird was weighed on a digital scale to the nearest 0.5 g. Birds were slaughtered, and carcass weight (g) was determined after plucking and evisceration on a digital scale to the nearest 0.5 g. Carcass yield, liver, gizzard and heart weights were calculated relative to body weight and expressed in percentages, according to following formula:

$$\frac{\text{Carcass}}{\text{parts}}\text{yield(\%)} = \frac{\frac{\text{carcass}}{\text{parts}}\text{weight (g)}}{\text{Live body weight at slaughter (g)}} \text{x}100$$

Statistical Analysis

Data were analyzed by analysis of variance using the PROC MIXED of SAS software (version 9.1). Means were compared by Tukey's HSD test, assuming the following mathematical model:

$$Y_{ijkl} = \mu + S_i + A_j + C_k + (SA)_{ij} + (SC)_{ik} + (AC)_{jk} + \varepsilon_{ijkl}$$

Where,

Y_{ijkl} = Dependent variable

μ = Overall population mean

S_i = Effect of i^{th} Selection Strategy assumed as fixed effect (i = 1, 2, 3; Pedigree, Mass-selected, Random-bred Control)

A_j = Effect of j^{th} Parental Age group assumed as fixed effect (j = week 1, 2, 3; 10, 12 and 14)

C_k= Effect of k^{th} Close-bred Flock assumed as random effect (k = 1, 2, 3, 4; Major, Kaleem, Sadaat & Zahid)

$(SA)_{ij}$ = Interaction effect between selection strategy and parental age groups

$(SC)_{ik}$= Interaction effect between selection strategy and close-bred flock

$(AC)_{jk}$= Interaction effect between parental age groups and close-bred flock

ε_{ijkl} = Residual error associated with i^{th}, j^{th} and k^{th} treatment NID ~ 0, σ^2

RESULTS AND DISCUSSION

Growth Performance

Means and standard errors of cumulative feed intake (g), weight gain (g), FCR and mortality% are presented in Table 1. Significantly ($p \leq 0.05$) higher feed intake was observed in pedigree birds (433.13±0.77 g) compared with random-bred (429.36±0.80 g) and mass-selected (428.90±0.51 g) birds. However, no significant effects of CBF or parental ages were observed on feed intake in present study; however, a significant interaction of selection strategies interact with CBF and parental age were observed for cumulative feed intake. The significantly higher feed intake of pedigree birds compared with random-bred

Table 1 – Effect of selection strategies of parent Japanese quails from four close-bred flocks of three different age on the growth performance of their progenies.

	Cum. FI	Cum. Gain	Cum. FCR	Mortality
	----------(g)----------			---(%)---
Selection Strategies				
Pedigree	433.13±0.77^{a}	182.19±0.79^{a}	2.38±0.01^{b}	12.12±0.07
Mass Selection	428.90±0.51^{b}	179.96±0.50^{b}	2.39±0.01^{b}	12.19±0.07
Random-bred	429.36±0.80^{b}	175.57±0.76^{c}	2.45±0.01^{a}	12.21±0.06
Close-bred Flocks				
Major	429.59±0.74	179.30±0.96	2.40±0.01	12.30±0.10
Kaleem	431.71±0.65	179.56±0.94	2.41±0.01	12.09±0.06
Saadat	430.32±0.91	178.39±0.72	2.42±0.01	12.16±0.05
Zahid	430.21±1.01	179.70±0.76	2.40±0.01	12.15±0.09
Parental Age Groups				
10 weeks	430.87±0.70	180.81±0.81^{a}	2.39±0.01^{b}	12.17±0.06
12 weeks	429.59±0.80	179.40±0.66^{ab}	2.40±0.01^{b}	12.13±0.06
14 weeks	430.93±0.67	177.52±0.71^{b}	2.43±0.01^{a}	12.21±0.08
Selection Strategies × Close-bred Flocks				
Pedigree × Major	433.41±1.32^{a}	184.74±1.56^{a}	2.35±0.02^{c}	12.17±0.16
Pedigree × Kaleem	433.52±1.29^{a}	183.35±1.70^{ab}	2.37±0.02^{bc}	11.99±0.11
Pedigree × Saadat	432.96±1.95^{a}	179.28±1.56^{bc}	2.42±0.02^{b}	12.06±0.08
Pedigree × Zahid	432.63±1.61^{ab}	181.40±1.32^{abc}	2.39±0.02^{bc}	12.26±0.16
Mass Selection × Major	429.56±0.86^{abcd}	181.16±1.11^{abc}	2.37±0.02^{bc}	12.36±0.22
Mass Selection × Kaleem	430.78±0.76^{abc}	181.05±0.94^{abc}	2.38±0.01^{bc}	12.19±0.11
Mass Selection × Saadat	426.89±1.26^{cd}	178.16±0.87^{cd}	2.40±0.02^{bc}	12.17±0.09
Mass Selection × Zahid	428.37±1.02^{bcd}	179.48±0.98^{bc}	2.39±0.01^{bc}	12.05±0.10
Random-bred × Major	425.81±1.22^{d}	172.00±1.25^{e}	2.48±0.02^{a}	12.36±0.15
Random-bred × Kaleem	430.89±1.20^{abc}	174.29±1.65^{de}	2.48±0.03^{a}	12.08±0.09
Random-bred × Saadat	431.11±1.20^{abc}	177.75±1.28^{cd}	2.43±0.02^{ab}	12.25±0.08
Random-bred × Zahid	429.63±2.32^{abcd}	178.23±1.58^{cd}	2.42±0.02^{b}	12.15±0.18
Selection Strategies × Parental Age Groups				
Pedigree × 10 weeks	434.31±1.55^{a}	185.99±1.44^{a}	2.34±0.02^{c}	12.18±0.12
Pedigree × 12 weeks	432.67±1.24^{ab}	181.37±1.05^{b}	2.39±0.02^{bc}	12.22±0.13
Pedigree × 14 weeks	432.42±1.21^{ab}	179.22±1.34^{bc}	2.42±0.02^{ab}	12.06±0.09
Mass Selection × 10 weeks	428.36±0.84^{c}	180.38±0.90^{b}	2.38±0.01^{bc}	12.25±0.13
Mass Selection × 12 weeks	428.28±0.97^{c}	181.20±0.76^{b}	2.37±0.01^{bc}	12.09±0.08
Mass Selection × 14 weeks	430.06±0.83^{bc}	178.32±0.87^{bcd}	2.41±0.01^{ab}	12.23±0.14
Random-bred × 10 weeks	429.94±0.93^{bc}	176.06±1.31^{cd}	2.45±0.02^{a}	12.09±0.07
Random-bred × 12 weeks	427.83±1.74^{c}	175.63±1.30^{d}	2.44±0.02^{a}	12.19±0.06
Random-bred × 14 weeks	430.31±1.36^{bc}	175.01±1.35^{d}	2.46±0.02^{a}	12.35±0.17
Close-bred Flocks × Parental Age Groups				
Major × 10 weeks	430.93±1.33	181.38±1.67^{ab}	2.38±0.02^{bcd}	12.31±0.20
Major × 12 weeks	429.37±1.34	180.87±1.64^{abc}	2.38±0.02^{cd}	12.17±0.08
Major × 14 weeks	428.48±1.18	175.66±1.51^{d}	2.44±0.02^{ab}	12.41±0.22
Kaleem × 10 weeks	432.19±1.12	184.52±1.64^{a}	2.35±0.02^{d}	12.07±0.10
Kaleem × 12 weeks	431.26±0.91	177.86±1.40^{bcd}	2.43±0.02^{abc}	12.04±0.12
Kaleem × 14 weeks	431.74±1.33	176.31±1.45^{cd}	2.45±0.02^{a}	12.14±0.09
Saadat × 10 weeks	429.67±1.80	178.21±1.12^{bcd}	2.41±0.02^{abc}	12.19±0.08
Saadat × 12 weeks	428.85±1.58	178.99±1.05^{bcd}	2.40±0.02^{abcd}	12.16±0.08
Saadat × 14 weeks	432.44±1.25	177.98±1.58^{bcd}	2.43±0.02^{abc}	12.12±0.09
Zahid × 10 weeks	430.70±1.31	179.14±1.78^{bcd}	2.41±0.02^{abc}	12.11±0.10
Zahid × 12 weeks	428.89±2.31	179.86±1.00^{bcd}	2.39±0.02^{bcd}	12.16±0.15
Zahid × 14 weeks	431.04±1.50	180.11±1.00^{bcd}	2.40±0.02^{abcd}	12.18±0.19

Note: Means with different superscripts in the same column are significantly different ($p \leq 0.05$); CBF: close-bred flocks; Cum: cumulative; FI: feed intake; FCR: feed conversion ratio and mass-selected birds may be attributed to their higher nutrient requirements for growth. Consistently, in another study (Khaldari *et al.,* 2010), higher feed intake was observed in Japanese quails selected for high body weight compared with the controls. In study with Japanese quails, significantly higher weekly feed intake differences were observed in mass-selected birds compared with the control group (Narinc & Aksoy, 2012). In addition, Hussain *et al.* (2013) suggested that a selected line presented better feed efficiency than the control group. However, no significant effect of age on feed intake was also observed among three age groups of indigenous Peshawari Aseel chicken (Sohail *et al.,* 2013).

Pedigree-base selected birds presented the highest body weight gain (182.19±0.79 g), followed by mass-selected birds (179.96±0.50 g) and random-bred controls (175.57±0.76 g). Among different parental age groups, birds from 10-week-old parents had higher weight gain (180.81±0.81 g) than those from 14-week-old parents (177.52±0.71 g). There were significant interactions ($p \leq 0.05$) between selection strategies × parental age groups and selection strategies × CBF for cumulative weight gain. However, no significant effect of CBF on weight gain was observed in present study; however, CBF was compared among ages on overall basis significant ($p \leq 0.05$) body weight differences were observed. Pedigree-base selected birds presented the highest body weight gain followed by mass-selected and random-bred controls, which may be due to the positive response to selection, differences in genetics of sub-strains of pedigree-based selected progenies, and the superior potential of pedigree birds selected for high body weight. The observed higher body weight may be the result of intense selection, which ultimately improves productive potential of birds. Pedigree birds showed better feed utilization, which resulted higher weight gain. Higher body weight in selected birds were also reported in other studies (Khaldari *et al.,* 2010). Similarly, higher body weight gain was observed in Japanese quail lines selected for high body weight (Anthony *et al.,* 1986). Among different parental age groups, the progeny of 10-week-old parents presented higher weight gain compared with the progeny of 14-week-old parents, which may be attributed to the fact that younger birds present higher weight gain potential compared with older ones. At different ages, significant body weight difference among strains and generations were also reported by Varkoohi *et al,* (2011). Similarly, in another study (Ahmad *et al.,* 2013), a significant effect of age on body weight was observed in Mushki Aseel chickens.

In the present experiment, significantly ($p \leq 0.05$) better FCR was observed in pedigree birds (2.38±0.01) compared with mass-selected birds (2.39±0.01) and random-bred controls (2.45±0.01). Birds from 10-week-oldparents showed better FCR (2.39±0.01) compared with those from 12 (2.40±0.01) and 14-week-old (2.43±0.01) parents. In the present experiment, CBF had no effect on FCR; however, FCR was significantly affected ($p \leq 0.05$) by the interactions between CBF and selection strategies and age groups. The interaction of selection strategies with parental age groups significantly influenced ($p \leq 0.05$) cumulative FCR. However, no significant effect of selection methods, CBF or parental age groups on mortality % was observed in the current experiment. In the present experiment, pedigree birds presented significantly better FCR compared with mass-selected and random-bred control birds, which may be due to the lower maintenance requirements and lower fat deposition of pedigree-base selected birds. Usually, there is a favorable correlation between feed conversion ratio and growth because of enhanced pulsative growth hormone release and ultimately live weight gain. The selection for better feed conversion in broiler chickens resulted in direct selection for carcass leanness. Similarly, in another study (Marks, 1980), better FCR was observed in Japanese quails selected for high body weight for 42 generations compared with random-bred controls. Birds from 10-week-old parents showed better FCR compared with the progenies of 12- and 14-w-oldparents, possibly because younger birds have better feed conversion ratio than older ones. However, Sohail *et al.* (2013) did not report any significant effect of age on the FCR of Peshawari Aseel chickens.

No significant cumulative mortality differences ($p >$ 0.05) were observed among the different selection strategies, close-bred flocks, parental age groups or their interactions. However, other study reported significant effect of different selection strategies on the mortality of Japanese quails (Hussain *et al.,* 2013), who argued that the lower mortality of intensively-selected birds resulted in the better exploitation of superior genes, and therefore, increased livability (Hussain *et al.,* 2013).

Carcass traits

Means and standard errors of live body weight (g), carcass weight (g), and carcass yield (%)are presented in Table 2. Significant live body weight (g) differences ($p \leq 0.05$) were observed among the evaluated selection strategies. The progeny from pedigree-based selected

Table 2 – Effect of selection strategies of parent Japanese quails from four close-bred flocks of three different age on the slaughter Parameters (mean ± standard error) of their progenies.

	Live weight ---(g)---	Carcass weight ---(g)---	Carcass yield ---(%)---
Selection Strategies			
Pedigree	192.10±1.02[a]	109.60±0.96[a]	57.07±0.42[a]
Mass Selection	185.35±0.50[b]	106.91±0.50[b]	57.70±0.29[a]
Random-bred	181.45±0.67[c]	97.24±0.53[c]	53.63±0.33[b]
Close-bred Flocks			
Major	186.22±1.05	104.47±1.04	56.08±0.42
Kaleem	185.78±1.32	104.68±1.19	56.35±0.51
Sadaat	188.33±1.13	104.96±1.26	55.71±0.51
Zahid	184.87±0.79	104.23±1.05	56.38±0.49
Parental Age Groups			
10 weeks	185.53±0.87	101.89±0.72[b]	54.93±0.35[b]
12 weeks	186.07±0.91	103.18±0.57[b]	55.49±0.29[b]
14 weeks	187.30±1.06	108.69±1.27[a]	57.97±0.48[a]
Selection Strategies × Close-bred Flocks			
Pedigree × Major	191.47±1.58[ab]	109.13±1.49[a]	57.00±0.67[a]
Pedigree × Kaleem	194.33±2.48[a]	109.71±2.19[a]	56.50±1.01[a]
Pedigree × Sadaat	194.13±2.41[a]	110.56±2.38[a]	56.94±0.91[a]
Pedigree × Zahid	188.47±1.28[bc]	109.01±1.69[a]	57.83±0.74[a]
Mass Selection × Major	186.87±1.17[cd]	107.02±1.05[a]	57.30±0.67[a]
Mass Selection × Kaleem	183.47±0.68[def]	107.08±1.07[a]	58.37±0.57[a]
Mass Selection × Sadaat	186.80±1.08[cd]	107.09±1.10[a]	57.34±0.57[a]
Mass Selection × Zahid	184.27±0.73[cde]	106.45±0.90[a]	57.78±0.54[a]
Random-bred × Major	180.33±1.45[ef]	97.24±1.09[b]	53.94±0.55[b]
Random-bred × Kaleem	179.53±1.16[f]	97.24±109[b]	54.19±0.66[b]
Random-bred × Sadaat	184.07±1.04[cdef]	97.24±1.09b	52.85±0.62[b]
Random-bred × Zahid	181.87±1.44[ef]	97.24±1.09[b]	53.52±0.77[b]
Selection Strategies × Parental Age Groups			
Pedigree × 10 weeks	189.15±1.61[bc]	181.95±1.06[c]	55.72±0.50[bc]
Pedigree × 12 weeks	192.10±1.54[ab]	105.39±0.68[c]	54.93±0.54[cd]
Pedigree × 14 weeks	195.05±1.97[a]	118.12±1.38[a]	60.55±0.30[a]
Mass Selection × 10 weeks	185.95±1.16[cd]	105.24±0.72[c]	56.62±0.43[b]
Mass Selection × 12 weeks	185.20±0.71[de]	104.97±0.63[c]	56.69±0.36[b]
Mass Selection × 14 weeks	184.90±0.66[de]	110.51±0.65[b]	59.78±0.38[a]
Random-bred × 10 weeks	181.50±1.24[ef]	95.12±0.34[e]	52.46±0.41[e]
Random-bred × 12 weeks	180.90±1.19[f]	99.17±0.93[d]	54.84±0.51[cd]
Random-bred × 14 weeks	181.95±1.06[ef]	97.44±1.10[de]	53.58±0.64[de]
Close-bred Flocks × Parental Age Groups			
Major × 10 weeks	187.87±1.78	101.84±1.46[d]	54.19±0.48[d]
Major × 12 weeks	186.20±1.57	103.50±1.23[bcd]	55.57±0.37[d]
Major × 14 weeks	184.60±2.11	108.06±2.27[abc]	58.48±0.80[a]
Kaleem × 10 weeks	183.80±2.46	101.90±1.48[d]	55.52±0.86[bcd]
Kaleem × 12 weeks	185.60±2.11	103.07±1.14[cd]	55.59±0.65[bcd]
Kaleem × 14 weeks	187.93±2.29	109.06±2.77[ab]	57.95±0.98[ab]
Sadaat × 10 weeks	186.33±1.18	101.90±1.48[d]	54.69±0.73[d]
Sadaat × 12 weeks	188.00±1.90	103.07±1.14[cd]	54.87±0.67[d]
Sadaat × 14 weeks	190.67±2.50	109.92±2.95[a]	57.56±1.04[abc]
Zahid × 10 weeks	184.13±1.17	101.90±1.48[d]	55.33±0.66[cd]
Zahid × 12 weeks	184.47±1.71	103.07±1.14[cd]	55.91±0.62[bcd]
Zahid × 14 weeks	186.00±1.19	107.72±2.34[abcd]	57.90±1.11[ab]

Note: - Means with different superscripts in the same column are significantly different ($p \leq 0.05$)

birds were the heaviest (192.10±1.02 g) followed by mass-selected (185.35±0.50 g) and random-bred control (181.45±0.67 g) progenies. The higher body weight of the pedigree-based selected birds might be attributed to the effect of continuous selection and to the positive relationship associated with higher four-week body weight. The superior genes expressed in pedigree-based selected birds increased their live body weight. Higher body weight was reported in Japanese quails selected for high body weight were reported by Baylan *et al.* (2009). Higher pre-slaughter body weight was observed in Japanese quails selected for high four-week body weight for 19 generations (Dhaliwal *et al.,* 2004). Regarding interaction between selection strategies and close-bred flocks and selection strategies and parental age groups significant differences live body weight were determined ($p \leq 0.05$). However, different close-bred flocks and parental age groups as well as their interaction had no significant effect ($p > 0.05$) on progeny live body weight.

Significant differences ($p \leq 0.05$) were observed in carcass weight (g) among progeny form different selection strategies and parental age groups. Pedigree-based selected bird also presented heavier carcasses (109.60±0.96 g) followed by mass-selected (106.91±0.50 g) and random-bred control (97.24±0.53 g) groups. The interactions among selection strategies, close-bred flocks and parental age groups significantly influenced ($p \leq 0.05$) carcass weight. However, different close-bred flocks presented similar ($p > 0.05$) carcass weight. The heavier carcasses of pedigree-based selected birds may be attributed to the positive correlation between body weight and carcass weight. Similarly, another study reported significant effects of selection on the carcass weight of Japanese quails selected for 11 generations (Alkan*et al.,* 2010). Among different parental age groups, birds from 14-week-old parents presented highest carcass weight (108.69±1.27 g) compared with those from 10- (103.18±0.57) and 12- (101.89±0.72) week-old parents. Another study also observed significant effect of age on the carcass weight of Japanese quails (Tarhyel *et al.,* 2012).

Significant carcass yield differences ($p \leq 0.05$) were observed among different selection strategies and parental age groups. The progeny of selected birds (pedigree-based and mass-selected) presented higher (57.07±0.42%, 57.70±0.29%) carcass yield compared with random-bred controls (53.63±0.33%). However, no significant effect of selection on carcass yield was reported in Japanese quails selected for high 5-week body weight (Alkan*et al.,* 2010). Among different parental age groups, the progeny of14-week-old parents presented higher (57.97±0.48) carcass yield compared with those from 12- (55.49±0.29) and 10- (54.93±0.35) week-old parents. A significant effect of age on carcass yield was also observed in Pharaoh quails by Wilkanowska & Kokoszynski (2011). The interaction among selection strategies, close-bred flocks and parental age groups significantly influenced ($p \leq 0.05$) carcass yield. However, non-significant differences ($p > 0.05$) were observed among the different close-bred flocks.

Means and standard errors of cumulative relative weight (%) of the liver, gizzard, and heart has been presented in Table 3. Significant liver relative weight differences ($p \leq 0.05$) were observed among different selection strategies and parental age groups. Random-bred control birds presented the highest liver relative weight (3.67±0.04%) followed by mass-selected (3.19±0.02%) and pedigree-based selected (3.08±0.02%) progenies. However, higher liver yield was observed in Japanese quails selected for high body weight (Ojedapo *et al.,* 2008). Among the different parental age groups, the progeny of14-week-old parents presented higher liver relative weight (3.50±0.05%) followed by the progenies of 12- (3.31±0.04) and 10- (3.14±0.02) week-old parents. A study with Japanese quails also found significant differences in liver relative weight at 3, 4 and 5 weeks of age (Akram *et al.,* 2016). The interactions among selection strategies, close-bred flocks and parental age groups significantly influenced liver relative weight ($p \leq 0.05$).

Significant differences ($p \leq 0.05$) were observed in gizzard relative weight among different close-bred flocks and parental age groups. Random-bred control birds presented higher gizzard relative weight (3.55±0.04%) compared with mass-selected (3.17±0.03%) and pedigree-based selected (3.09±0.03%) birds. This may be due to the negative association between carcass and gizzard weights, as birds selected for high body weight have proportionally lower gizzard relative weight. However, another study indicated higher gizzard weight % in Japanese quails selected for high body weight (Abdel-Azeem *et al.,* 2007). Among the different parental age groups, birds from 14-week-old parents presented higher gizzard relative weight (3.49±0.04%) followed by the birds from 12 (3.27±0.04%) and 10 (3.05±0.02%) week-old parents. Similarly, another study revealed significant effect of age on gizzard relative weight in Japanese quails (Kaye *et al.,* 2016).

Table 3 – Effect of selection strategies of parent Japanese quails from four close-bred flocks of three different age giblet relative weights of their progenies.

	Liver	Gizzard	Heart
	--------------------(Mean% ± Standard Error) --------------------		
Selection Strategies			
Pedigree	3.08±0.02[c]	3.09±0.03[b]	0.97±0.01[c]
Mass Selection	3.19±0.02[b]	3.17±0.03[b]	1.01±0.01[b]
Random-bred	3.67±0.04[a]	3.55±0.04[a]	1.03±0.01[a]
Close-bred Flocks			
Major	3.30±0.05	3.28±0.05	1.01±0.01
Kaleem	3.31±0.05	3.29±0.05	1.00±0.01
Sadaat	3.29±0.05	3.22±0.05	0.99±0.01
Zahid	3.35±0.05	3.30±0.05	1.01±0.01
Parental Age Groups			
10 weeks	3.14±0.02[c]	3.05±0.02[c]	0.95±0.01[c]
12 weeks	3.31±0.04[b]	3.27±0.04[b]	1.00±0.01[b]
14 weeks	3.50±0.05[a]	3.49±0.04[a]	1.05±0.01[a]
Selection Strategies × Close-bred Flocks			
Pedigree × Major	3.08±0.04[bc]	3.09±0.08[b]	0.97±0.02[cde]
Pedigree × Kaleem	3.03±0.05[c]	3.07±0.04[b]	0.96±0.02[de]
Pedigree × Sadaat	3.04±0.03[c]	3.05±0.06[b]	0.96±0.01[e]
Pedigree × Zahid	3.17±0.04[bc]	3.14±0.03[b]	0.99±0.01[bcde]
Mass Selection × Major	3.18±0.04[bc]	3.15±0.04[b]	1.00±0.02[abcde]
Mass Selection × Kaleem	3.21±0.03[b]	3.22±0.07[b]	1.02±0.01[abc]
Mass Selection × Sadaat	3.19±0.04[bc]	3.10±0.04[b]	1.00±0.02[abcde]
Mass Selection × Zahid	3.20±0.04[bc]	3.21±0.08[b]	1.01±0.02[abcd]
Random-bred × Major	3.64±0.09[a]	3.59±0.09[a]	1.05±0.02[a]
Random-bred × Kaleem	3.69±0.06[a]	3.57±0.07[a]	1.03±0.01[ab]
Random-bred × Sadaat	3.66±0.07[a]	3.50±0.08[a]	1.01±0.01[abc]
Random-bred × Zahid	3.70±0.07[a]	3.55±0.08[a]	1.03±0.02[ab]
Selection Strategies × Parental Age Groups			
Pedigree × 10 weeks	2.99±0.03[f]	2.96±0.03[f]	0.93±0.01[e]
Pedigree × 12 weeks	3.05±0.03[ef]	3.06±0.03[ef]	0.97±0.01[cd]
Pedigree × 14 weeks	3.20±0.03[d]	3.24±0.06[d]	1.01±0.01[b]
Mass Selection × 10 weeks	3.08±0.02[e]	2.97±0.02[f]	0.95±0.01[de]
Mass Selection × 12 weeks	3.16±0.01[d]	3.16±0.02[de]	1.01±0.01[b]
Mass Selection × 14 weeks	3.35±0.02[c]	3.39±0.05[c]	1.07±0.01[a]
Random-bred × 10 weeks	3.34±0.02[c]	3.21±0.03[d]	0.98±0.01[c]
Random-bred × 12 weeks	3.72±0.04[b]	3.60±0.04[b]	1.03±0.01[b]
Random-bred × 14 weeks	3.95±0.02[a]	3.84±0.03[a]	1.08±0.01[a]
Close-bred Flocks × Parental Age Groups			
Major × 10 weeks	3.09±0.04[d]	3.01±0.04[e]	0.94±0.01[f]
Major × 12 weeks	3.28±0.08[bcd]	3.28±0.08[bcd]	1.01±0.01[cd]
Major × 14 weeks	3.53±0.10[a]	3.54±0.09[a]	1.07±0.01[a]
Kaleem × 10 weeks	3.14±0.06[cd]	3.10±0.05[de]	0.96±0.01[ef]
Kaleem × 12 weeks	3.31±0.08[abcd]	3.28±0.07[bcd]	1.00±0.01[cd]
Kaleem × 14 weeks	3.48±0.09[ab]	3.48±0.09[ab]	1.05±0.01[ab]
Sadaat × 10 weeks	3.15±0.04[cd]	3.01±0.04[e]	0.95±0.01[f]
Sadaat × 12 weeks	3.29±0.09[bcd]	3.21±0.07[cde]	0.99±0.01[de]
Sadaat × 14 weeks	3.44±0.10[ab]	3.43±0.09[ab]	1.03±0.02[bc]
Zahid × 10 weeks	3.16±0.05[cd]	3.07±0.04[de]	0.96±0.01[ef]
Zahid × 12 weeks	3.36±0.09[abc]	3.33±0.08[abc]	1.01±0.01[cd]
Zahid × 14 weeks	3.54±0.07[a]	3.50±0.07[a]	1.06±0.01[ab]

Note: - Means with different superscripts in the same column are significantly different ($p \leq 0.05$)

Significant differences ($p \leq 0.05$) were observed in heart relative weight among different selection strategies and parental age groups. Random-bred control birds had the highest heart relative weight (1.03±0.01%), followed by mass-selected (1.01±0.01%) and pedigree-based selected (0.97±0.01%) progenies. Lower heart weight was also reported in commercial broilers selected for high body weight (Gaya *et al.,* 2007; Tarhyel *et al.,* 2012). Among different parental age groups, the progeny of14-week-old parents showed the highest heart relative weight (1.05±0.01%) followed by the progenies of 12 (1±0.01%) and 10 (0.95±0.01%) week-old parents. The results may be explained by the fact that, as birds age, body organs also follow the general body growth pattern to meet their anatomical and physiological demands. Consistently, significant differences in heart relative weight were observed among the progenies of different parental age groups of Japanese quails (Akram *et al.,* 2013).

CONCLUSIONS

The results of the present study show that pedigree-based selection had pronounced effect on the growth performance and carcass traits of Japanese quails. In addition, it is suggested that parental ages of 10 and 14 weeks of age promote better progeny growth performance and carcass traits. The progenies of the different close-bred flocks did not present any differences in growth performance or carcass traits.

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CONFLICT OF INTEREST

No potential conflict of interest was found by the authors.

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