**Research Article**

# Comparative evaluation of carcass characteristics and meat quality attributes of Japanese quail among different lines

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**Abstract:** The present study evaluated the carcass and meat quality traits of three groups of Japanese quails. These groups {i.e. selected for 4-week body-weight group (WBS), selected for egg number (EBS), and random-bred control (RBC)}, were selected for three consecutive generations from a base population of 1125 quails. In total, 2700 four-week-old quails from three selected lines (225 birds per group per generation) were slaughtered in a total of four generations (G0 to G3). The effects of selection were evaluated on the carcass and meat quality traits in four generations. WBS in G3 presented significantly highest dressing yield, breast yield, thigh yield, percentage of liver, heart, and gizzard than RBC and EBS groups. The ultimate pH of breast meat was higher in G2 of the WBS group. Breast meat lightness was also significantly higher in G2 of the WBS group, while redness was higher in G0 (at 20 min post-slaughter) and G3 (at 24 h post-slaughter) of the RBC group. The quails from G3 of WBS had more tender meat than all EBS and RBC groups. Percentage of drip loss and cooking loss were significantly higher in quails of G3 from the WBS group. It was concluded that body weight and egg based selection practices in Japanese quail had a positive influence on meat yield and quality.

**Key words:** Carcass traits, egg base selection, meat quality, weight base selection

## 1. Introduction

Poultry production is one of the rapidly growing sub-sectors of agriculture producing a range of commodities for the global population. Poultry meat and eggs are commodities being consumed in millions of numbers on daily basis [1,2]. Broiler chickens, commercial layers, turkeys, ducks, and quails are generally used for meat and egg production [3]. These fast-yielding birds are genetically selected for a specific purpose and have higher growth and egg-laying rates [1,2]. The aim of developing such strains was to fulfill the dietary needs, especially, of proteins of the global population [3]. Among these, quail production is the most advantageous enterprise because of the short production cycle and early maturity [4,5]. Due to short generation intervals, the Japanese quail is the best model species for breeding and selection experiments. Japanese quails are small birds and can gain more than 170 grams of weight in just 28 days [5,6]. On the other hand, it can lay more or less 300 eggs per year [4,7,8]. In the past, this species was extensively used to improve meat yield and egg production in various parts of the world.

There is immense potential for meat and egg production from Japanese quail. However, the existing potential of Japanese quail is low for meat and egg production than those from imported flocks [9,10] and there is a need to enhance the growth of these birds by selection programs. Pedigree selection, mass selection, and family selection are generally used to enhance the traits of economic importance. In a previous study, Ahmad et al. [5] improved the weight of Japanese quail from 181 grams to 192 grams by pedigree selection. However, the authors were unable to improve the carcass yield in different close-bred flocks [5]. Jatoi et al. [11] reported ranges of 134 grams to 139 grams of pre-slaughter weight and 53 to 59% carcass yield in four local Pakistani flocks of Japanese quail. This shows that there is potential for improvement in the carcass yield. This study aimed to improve meat and egg production by developing a separate line for these traits. Here, we compared the carcass characteristics and meat quality of Japanese quail selected for body weight, egg production, and the non-selected group.

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## 2. Materials and methods

### 2.1. Experimental site

The study was conducted at Avian Research and Training Centre (ARTC), the University of Veterinary and Animal Sciences (UVAS), Lahore, Pakistan, and involved three genetic groups of Japanese quails. The first group consisted of the birds selected for body weight (WBS). The second group had quails selected for egg number (EBS). The third group consisted of non-selected random-bred (RBC) Japanese quails. Each group of selection strategies had 75 families with a 1:4 male to female ratio.

### 2.2. Ethics

The care and use of bird were in accordance with the institutional guidelines and the laws and regulations of Pakistan were approved by Ethical Review Committee (No. DR/495), University of Veterinary and Animal Sciences (UVAS).

### 2.3. Selection protocol

Initially, 3000 day-old chicks (DOC) of Japanese quail were procured from the hatchery of ARTC and were subjected to rearing for 04 weeks. From the 5th week, 900 females and 225 male birds were randomly selected as base population (G0) and divided into three groups based on different selection procedures, i.e. weight-based selected (WBS), egg number-base selected (EBS), and random-bred control (RBC). The base population (G0) of each group comprised 75 families containing 300 females and 75 males where each family consisted of one male and four females.

In WBS, in total, 2050 chicks were obtained from the baseline population, and their growth performance was assessed until the 4th week of age. Only those families fulfilling the criteria (average bodyweight + 0.5 standard deviation) were selected to be the parents of the next generation. Similar to WBS, 2050 chicks from the G0 population of the EBS line were obtained and grown until egg production started. All the female quails were equally divided into 225 families with a ratio of 01 male: 04 females. Egg production records of these families were maintained till the end of the 12th week of age. At the end of the 12th week, out of 225 families, only those families were selected who fulfill the criteria (average egg number + 0.5 standard deviation) to be the parents of the next generation. RBC was maintained without practicing any selection. Among selected families, the same selection process was repeated in the second (G2) and third (G3) generations.

### 2.4. Housing and management

Experimental birds were placed in cages specially made for quail rearing [83.61 cm$^2$ / quail during brooding (1–14 days) and 150 cm$^2$ / quail during growing (15–28 days)] and breeding (220 cm$^2$ / bird). Eggs were tagged and collected according to the particular family identification numbers. For hatching, eggs were placed in an automatic multi-stage incubator (Victoria Inc., Quaglie I-36 and H-24, Italy). After hatching, the chicks were placed in customized Ventury Welders battery cages placed in well ventilated octagonal shape quail sheds with 33 × 12 × 9 ft dimension. An uninterrupted supply of water was ensured with the help of nipple drinkers. A broiler starter ration (CP = 24% and ME = 2900 kcal/kg) was provided to broiler quails up to 05 weeks and a breeder ration (CP = 19.5% and ME = 2900 kcal/kg) was offered from 6th to 12th week of age [5,9].

### 2.5. Traits evaluated

#### 2.5.1. Carcass traits

At four weeks of age, two birds from each family were randomly selected for slaughtering purposes. The slaughtering was performed following the Halal Islamic method [12] with the help of a sharp knife. Briefly, the jugular vein of the bird was cut with a sharp knife while holding the bird in a lateral position. After bleeding, the carcasses were de-feathered and eviscerated. Carcass weights (without viscera) and internal organs (liver, heart, and gizzard) were recorded using an electronic scale of 0.01g accuracy level. The dressing percentage was derived from the following formula:

Thereafter, carcasses were cut into different part cuts (breast with bones and thigh). Carcass cut-up parts and internal organs were evaluated on a percentage basis of the live weight.

#### 2.5.2. Meat quality

Meat quality traits regarding color were measured at 02 and 24 h post-slaughter. For color measurement, the Minolta CR-410 colorimeter was used. Calibrations for different colors were performed at lightness (L*) = 94.93, redness (a*) = –0.13, yellowness (b*) = 2.55. Ultimate pH (24 h post-slaughter) was measured at three places of the breast portion using a pH meter (WTW, pH 3210 SET 2), and an average of these three points was used for data analysis. One breast sample from each slaughtered bird was used to evaluate the drip loss in the meat. For this, the breast sample was placed in a plastic bag after weighing and later hanged at 04 °C in refrigerated storage as recommended by Kaić et al. [13]. For cooking loss, the method recommended by Zaid et al. [14] was adopted. Briefly, breast samples were placed in plastic bags and subjected to cooking in water bath at 82–85 °C until the core temperature of the meat samples reached 72 °C. After cooking, the sample was allowed to cool and subsequently weighed, and cooking loss was derived by subtracting the final weight from the initial weight. The results were presented in percentage of the initial weight of the breast sample before cooking. The meat texture was analyzed in terms of shear force. For shear force measurement,

cooked breast samples were placed in polystyrene trays and allowed to cool down in a horizontal display chiller at 04 °C. After cooling, the breast samples were cut parallel to muscle fibers' orientation with a scalpel handle blade in a rectangular shape measuring approximately $1 \times 1 \times 2$ cm (height × width × length). Finally, Warner–Bratzler shear force ($N/cm^2$) was measured by a Texture analyzer (TAXT plus texture analyzer, UK) using a V slot blade.

## 2.6. Statistical analysis
Collected data were analyzed through factorial ANOVA using PROC GLM in SAS software (SAS 9.1 for windows) assuming Lines and Generations as main effects, and their interaction were tested, too. For the comparison of significant treatment means, Tukey's HSD test was applied; statistical significance level was considered as $p < 0.05$.

## 3. Results and discussion

### 3.1. Carcass characteristics
Genetic selection has been used as a tool to improve the traits of economic importance in food animals. Selection for growth is believed to be negatively associated with egg production traits. This means the birds selected for meat production may have more carcass yield but lower egg production and vice versa for those birds selected for higher egg production. Similar observations were noted in the current experiment. There was an increasing trend of carcass yield with the advancement in generations ($p < 0.05$). Quails from the WBS line in G3 presented the highest carcass yield, while the lowest was in EBS during G3. Higher dressing yield noted in BWS birds compared to EBS line (Table 1) and RBC birds are in line with the findings of El-Bayomi et al. [15] who reported higher carcass weight in the birds selected for higher four-

week body weight compared to those selected for low body weight. In another study, the selection response in Japanese quail resulted in an increase in body weight from 164 g to 210 g from G0 to G3 [16]. Higher heritability of carcass weight and its relationship with live weight (0.9) [15] is likely attributed to the higher carcass yield in the WBS line. However, another study did not agree with our findings and showed no difference in carcass yield of four close-bred flocks of Japanese quails [5].

In the current study, significantly higher ($p < 0.05$) breast yield was noted in WBS compared to the EBS group (Table 1). The breast and thigh yield depends upon various factors including slaughter age, line, and sex [17]. In previous studies, the effect of genetic selection on carcass cut-up parts including breasts and thighs was highly significant [5,18]. However, Alkan et al. [19] found no difference in genetic lines of Japanese quails selected for high and low body weight. According to the findings of the present experiment, breast meat yield in successive generations was comparable and not differed significantly (Table 1). The support also came from Reddish et al. [20] who reported a non-significant correlation (0.317) between a higher growth rate and the breast percentage. Genetic lines and generations interacted significantly for breast yield (Table 2). The quails from the WBS line during G3 presented the highest breast yield ($p < 0.05$), whereas the lowest breast yield was observed in EBS birds during G3. Physiologically, breast meat consists of skeletal muscles mainly of the *pectoralis major* and *pectoralis minor*. Muscle mass in avian and mammals' species relies on the regulation between protein synthesis and degradation, which is controlled by several factors including nutrition, physical activity, and hormones [21]. Higher breast yield

**Table 1.** Effect of family-based selection for improved body weight and egg production on carcass traits at 04 weeks age.[1]

| Trait | Lines | | | Generation | | | | SEM | p-value | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | WBS | EBS | RBC | G0 | G1 | G2 | G3 | | Lines | Generations |
| DY % | 56.95[a] | 54.74[b] | 54.49[b] | 54.84[c] | 55.35[b] | 55.41[b] | 55.97[a] | 0.11 | <.0001 | <.0001 |
| Thigh % | 12.58[a] | 11.44[b] | 11.61[b] | 11.94 | 12.08 | 11.78 | 11.72 | 0.08 | <.0001 | 0.2628 |
| Breast % | 19.64[a] | 18.28[c] | 18.75[b] | 18.61 | 18.92 | 18.99 | 19.04 | 0.10 | <.0001 | 0.3837 |
| Liver % | 2.74 | 2.65 | 2.69 | 2.49[c] | 2.61[bc] | 2.69[b] | 2.97[a] | 0.03 | 0.3111 | <.0001 |
| Heart % | 0.68[a] | 0.51[b] | 0.52[b] | 0.49[d] | 0.55[c] | 0.60[b] | 0.63[a] | 0.01 | <.0001 | <.0001 |
| Giz % | 2.84[a] | 2.48[b] | 2.57[b] | 2.35[c] | 2.57[b] | 2.56[b] | 3.04[a] | 0.03 | <.0001 | <.0001 |

[a,b,c]: Means in a row with no common superscript differ significantly at $p < 0.05$.
[1]Values are least square mean ± standard error.
WBS = Body weight base selection; EBS = Egg production base selection; RBC = Random-bred control; G0 = Generation zero; G1 = Generation 1; G2 = Generation 2; G3 = Generation 3; DY % = Dressing yield %; Giz % = Gizzard %.

**Table 2.** Interaction effects (Lines × Generation) on carcass traits at 04 weeks age.[2]

| Trait | WBS | | | | EBS | | | | RBC | | | | SEM | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G0 | G1 | G2 | G3 | G0 | G1 | G2 | G3 | G0 | G1 | G2 | G3 | | |
| DY | 54.66[def] | 55.83[c] | 57.42[b] | 59.00[a] | 55.10[cde] | 55.38[cd] | 54.47[def] | 54.00[f] | 54.76[def] | 54.85[def] | 54.35[ef] | 54.01[f] | 0.11 | <.0001 |
| Thigh % | 11.94[bc] | 12.44[ab] | 12.94[a] | 12.99[a] | 11.98[bcd] | 11.70[bcd] | 11.26[cd] | 10.84[e] | 11.89[bcd] | 12.10[b] | 11.15[de] | 11.32[cde] | 0.08 | <.0001 |
| Breast % | 18.35[d] | 19.57[bc] | 20.09[ab] | 20.57[a] | 18.60[cd] | 18.40[d] | 18.17[d] | 17.95[e] | 18.88[cd] | 18.80[cd] | 18.72[cd] | 18.61[cd] | 0.10 | <.0001 |
| Liver % | 2.55[de] | 2.76[bcd] | 2.33[e] | 3.30[a] | 2.45[e] | 2.51[e] | 2.84[b] | 2.80[bc] | 2.48[e] | 2.56[cde] | 2.89[b] | 2.80[bc] | 0.03 | <.0001 |
| Heart % | 0.48[e] | 0.63[c] | 0.77[b] | 0.82[a] | 0.49[e] | 0.50[de] | 0.51[de] | 0.53[d] | 0.49[de] | 0.52[de] | 0.53[d] | 0.53[d] | 0.01 | <.0001 |
| Giz % | 2.32[de] | 3.00[b] | 2.37[de] | 3.66[a] | 2.32[e] | 2.32[de] | 2.58[cd] | 2.69[c] | 2.41[de] | 2.38[de] | 2.73[c] | 2.76[c] | 0.03 | <.0001 |

a,b,c,d,e,f: Means in a row with no common superscript differ significantly at P < 0.05.

[2]Values are least square mean ± standard error.

WBS = Body weight base selection; EBS = Egg production base selection; RBC = Random-bred control; G0 = Generation zero; G1 = Generation 1; G2 = Generation 2; G3 = Generation 3; LW = Live weight (gm); CW = Carcass weight (gm); DY % = Dressing yield %; Giz % = Gizzard %.

in the WBS line might be due to an increase in muscle mass possibly due to the changes at the metabolic and cellular levels in successive generations. In an earlier study, breast weight was found to increase in selected birds from 36.9 to 46.4 g when the selection was performed for three consecutive generations [22]. However, in a proportion of the body weight, breast yield was reported not to differ significantly in birds selected for higher body weight to random bred control group [20]. This suggested that there was uniform body development in subsequent generations of the experimental birds that did not allow them to increase their breast proportion. However, WBS quails developed more mass on their breast muscles as there was a significant increase in breast% in the present study compared to that reported by Reddish et al. [22].

Higher thigh yield (p < 0.05) was noted in WBS compared to EBS (Table 1). As far as the interaction is concerned, the genetic lines and generations interacted well (p < 0.05) for the thigh yield with the highest values noted in WBS × G3, while the lowest value was observed in G2 of the RBC line. Similar to these findings, Gontijo et al. [23] reported a significantly higher leg weight in quails from LF1 strain selected for higher body weight than LAY genotype of quail selected for egg production; however, on a percentage basis, thigh yield was higher in LAY quails than LF1. Thigh growth was earlier reported to get an increment when the selection was performed to enhance the breast yield in Japanese quail [24]. In our study, thigh yield was found to increase in the BWS group along with the progress in generations. We assumed that the increase in thigh yield was due to an increase in other body muscles, especially in the breast.

Liver% was similar among the selection groups (p > 0.05), which is in accordance with the findings of Oğuz

et al. [24] who reported no effect of genetic lines on liver yield. Higher liver% was found in WBS quails of G3 than EBS and RBC quails of any generation. In a previous study, El-Bayomi et al. [14] reported significantly higher liver weight in the line of Japanese quail selected for higher body weight compared to random-bred and low-body weight lines. Contrarily, Ahmad et al. [5] compared mass and pedigree based selection programs and reported a negative impact of genetic selection on liver yield in Japanese quail. This could be due to the different selection strategies adopted during the trial.

The birds from WBS during G3 had the highest heart% (p < 0.05), while WBS birds during G0 presented the lowest value as the quails of WBS at G0 were the same as the random-bred quails (p > 0.05). This showed that body weight base selected quails had improved their relative heart weight compared to non-selected random-bred quails. This is in accordance with the findings of El-Bayomi et al. [14] who reported significantly higher heart weight in Japanese quails selected for higher body weight compared to random-bred and low-body weight lines. However, there had been reports of the negative impact of pedigree base selection and mass selection strategies on heart weight in Japanese quail [5]. The difference between the findings of ours and Ahmad et al. [5] could be due to different selection methods adopted during the trial. These findings suggested that the family-based selection is more important and more accurate to increase the body weight in Japanese quail. WBS × G3 had the highest gizzard%, and the lowest gizzard% was found in EBS × G1. Our findings were comparable with earlier reports where significantly higher gizzard weight was observed in the quails selected for higher body weight than random-bred birds [14]. The increase in gizzard weight is likely related

to the physiological and complementary role it plays in conditioning the feed for nutrient absorption in the gastrointestinal tract [25, 26]. On the contrary, Ahmad et al. [5] described the negative impact of pedigree selection and mass selection on gizzard% of Japanese quails.

## 3.2. Meat quality

Genetic lines differed significantly in pH at 24 h post-slaughter (pH24) of their breast meat (Table 3). The meat from the quails of WBS during G2 presented the highest ultimate pH (pH 24) than the quails of RBC and EBS at G0. The higher pH in the meat of Japanese quail might be due to muscle difference as the muscle of Japanese quail are constructed of oxidative fibers (red) that have an immense store of creatine phosphate, which provides the energy for re-production of ATP with the higher mitochondria level supplies oxygen for the aerobic glycolysis deceleration. Therefore, this type of muscle is described with slower progress of rigor mortis and consequently higher pH levels. pH24 of ultimate pH is an important and very complex trait that is a product of genotype and environment interaction that affect the final quality of meat product [27, 28]. It has been reported that the ultimate pH is correlated at a moderate to a high level with the body weight in Japanese quail. Nasr et al. [29] reported a significantly higher ultimate pH in the breast meat of White quails that weighed more than Golden, Black, and Brown quails having a lower ultimate pH. In the case of broiler chickens, the ultimate pH ranges from 5.7 to 6.1, which does not show any quality hazards [29]. In our study, WBS quails had a slightly higher (6.16) ultimate pH. In this case, muscle type differences could be the reason for higher ultimate pH in Japanese quails [30]. In broilers,

muscle fibers are of the glycolytic type that is described by excessive glycogen and minimal creatinine contents [31]. However, in Japanese quail, there is an abundance of oxidative muscle fibers that have immense contents of creatinine phosphate, which ultimately provides energy for the re-production of ATPs with higher numbers of mitochondria and supplies oxygen for aerobic glycolysis deceleration [29]. Hence, these muscles are described with slower progress of rigor mortis and consequently higher ultimate pH [32].

The quails from the WBS line showed a significantly higher lightness (L*) value than EBS at both time intervals (20 min and 24 h). Redness (a*) of the meat at 20 min and 24 h post-slaughter was significantly different among the genetic lines (Table 3). Although the quails from the RBC line showed the highest values, EBS quails were higher than those from the WBS line. This is in accordance with the findings of Gontijo et al. [23] who reported a higher L* in seven bodyweight lines of Japanese quail than an egg type line, whereas redness (a*) of the meat was significantly higher in egg-type compared to meat-type birds selected for higher body weight. The change in meat color is strongly correlated with ultimate pH and is influenced by several factors such as genotype, production systems, diet, processing environment, and storage conditions [33]. In the current experiment, all these factors were almost the same for the selected groups. Only the genotypes were of variable growth rate. Thus, it showed that higher lightness and lower redness in the WBS group might be due to selection performed for higher growth. The better luminance in meat is crucial for consumer acceptance especially during the purchase, and, in this case, WBS meat

**Table 3.** Effect of family-based selection for improved body weight and egg production on meat quality at 04 weeks age.[3]

| Trait | Lines | | | Generation | | | | SEM | p- value | |
|---|---|---|---|---|---|---|---|---|---|---|
| | WBS | EBS | RBC | G0 | G1 | G2 | G3 | | Lines | Generations |
| pH 24 hours | 6.16[a] | 6.02[b] | 6.05[b] | 5.99[b] | 6.10[a] | 6.12[a] | 6.11[a] | 0.02 | 0.0023 | 0.0290 |
| L* 20 min | 60.96[a] | 58.63[b] | 58.53[b] | 57.38[b] | 59.72[a] | 60.35[a] | 60.04[a] | 0.20 | <.0001 | <.0001 |
| L* 24 hours | 47.77[a] | 46.59[b] | 46.04[b] | 45.87[c] | 46.78[b] | 47.70[a] | 46.84[b] | 0.16 | <.0001 | 0.0005 |
| a* 20 min | 10.21[c] | 11.45[b] | 11.98[a] | 11.92[a] | 10.82[b] | 11.10[b] | 11.03[b] | 0.07 | <.0001 | <.0001 |
| a* 24 hours | 12.47[c] | 13.47[b] | 13.79[a] | 13.67[a] | 12.83[c] | 13.20[b] | 13.27[b] | 0.06 | <.0001 | <.0001 |
| SF N/cm² | 11.87[b] | 12.26[b] | 13.54[a] | 13.46[a] | 12.23[b] | 12.27[b] | 12.27[b] | 0.13 | <.0001 | 0.0004 |
| DL % | 6.12[a] | 5.46[b] | 5.71[b] | 5.61 | 5.79 | 5.84 | 5.82 | 0.06 | 0.0001 | 0.5567 |
| CL % | 22.89[a] | 21.35[b] | 21.86[b] | 21.81 | 21.78 | 22.23 | 22.30 | 0.13 | <.0001 | 0.3677 |

a,b,c: Means in a row with no common superscript differ significantly at P < 0.05.
[3]Values are least square mean ± standard error.
WBS = Body weight base selection; EBS = Egg production base selection; RBC = Random-bred control; G0 = Generation zero; G1 = Generation 1; G2 = Generation 2; G3 = Generation 3; SF = Shear force; DL = Drip loss; CL = Cooking loss.

seems to be very important for consumer satisfaction. A similar trend of higher ultimate pH and meat lightness and lower redness was also noted in the pectoral and thigh muscles of quails with different plumage colors [29].

The shear force of the quails' meat differed significantly among the genetic lines. RBC quails had the highest shear force, while the WBS line showed the lowest meat shear force. With respect to generations, the higher shear force was noted in G0 as compared to G1, G2, and G3, which did not differ significantly (Table 3). Regarding interaction, RBC × G0 treatment was found to produce meat with the highest shear force, while the birds from G1 of the WBS line presented the lowest shear force (Table 4), and this toughness could be due to higher pH. Similar to our results, the toughness of the Pharaoh quails selected for body weight was lower than non-selected quails' meat. This can be explained by the fact that the egg-type poultry birds are relatively slow-growing with slow protein accretion compared to meat-type birds, which are fast-growing ones and had higher protein accretion rates [34,35]. These egg-laying birds have more proteolytic activities for Calpain and Cathepsins in comparison to meat-type fast-growing genotypes [36]. However, contrary to our results, Gontijo et al. [23] reported no difference in shear force of meat type and egg type quail lines.

The meat from the quails of G3 of the WBS line presented the highest drip loss (p < 0.05), while the lowest drip loss was noted in G3 of EBS quails (Table 4). Drip loss is an important parameter to assess the water holding capacity. The higher the drip loss, the lower would be water holding capacity. Lower water holding capacity in terms of drip loss coincides with those of pH value. A high ultimate pH, above the isoelectric point of the myofibrillar protein,

enhances the water holding capacity of meat. Similar findings were also reported by Sabow et al. [37] who found lower water holding capacity in leg muscle of black quails having higher ultimate pH. Similar to our results, Gontijo et al. [23] showed a higher water holding capacity in the meat of egg-type quails than in the meat from quails selected for higher body weight. Lower drip loss in egg-type quails could be due to more strengthening cellular proteins that describe its importance for the maintenance of quality and nutritional status of that meat.

Cooking and drip losses are the indicators of water holding capacity in fresh and cooked meat, respectively. Cooking losses represent the stability of cellular proteins, predominantly the myofibrillar proteins during the cooking process [38]. Statistical analysis showed that cooking loss was influenced by selection strategies (p < 0.05). However, generations had no significant impact on cooking loss (p > 0.05). Cooking loss was significantly higher in WBS quails of G3. Accordingly, selection for growth was found to increase the cooking losses from the meat of Japanese quail [39]. A negative correlation was reported between body weight and cooking loss [40]. This could be due to decreased glycogen storage, which might have led to reduced postmortem acidification and water-holding capacity as reported in an experiment on selection for high breast muscle development [41]. However, in a previous study, the cooking loss was found to be higher in egg-type quails' meat than in the meat of body weight selected quails [23].

## 4. Conclusion
From the above discussion, it can be concluded that meat quality traits can be improved through family-based

Table 4. Interaction effects (Lines × Generation) on meat quality at 04 weeks age.[4]

| Trait | WBS | | | | EBS | | | | RBC | | | | SEM | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G0 | G1 | G2 | G3 | G0 | G1 | G2 | G3 | G0 | G1 | G2 | G3 | | |
| pH $_{24\ hours}$ | 6.09[ab] | 6.18[a] | 6.20[a] | 6.20[a] | 5.91[b] | 6.06[ab] | 6.08[ab] | 6.05[ab] | 5.97[b] | 6.06[ab] | 6.09[ab] | 6.08[ab] | 0.02 | 0.0279 |
| L* $_{20\ min}$ | 57.47[bc] | 61.57[a] | 62.43[a] | 62.38[a] | 57.89[b] | 59.02[b] | 59.18[b] | 58.43[bc] | 56.80[c] | 58.57[bc] | 59.43[b] | 59.31[b] | 0.20 | <.0001 |
| L* $_{24\ hours}$ | 45.44[e] | 48.03[abc] | 49.17[a] | 48.42[ab] | 46.57[cde] | 46.41[cde] | 47.32[bcd] | 46.05[de] | 45.61[e] | 45.90[de] | 46.60[cde] | 46.05[de] | 0.16 | <.0001 |
| a* $_{20\ min}$ | 11.36[bcd] | 9.65[e] | 9.95[e] | 9.88[e] | 11.95[ab] | 11.15[d] | 11.39[cd] | 11.32[cd] | 12.43[a] | 11.65[bcd] | 11.95[ab] | 11.88[abc] | 0.07 | <.0001 |
| a* $_{24\ hours}$ | 13.74[abc] | 11.89[e] | 12.13[e] | 12.10[e] | 13.50[bcd] | 13.21[d] | 13.56[bcd] | 13.62[abcd] | 13.76[abc] | 13.39[cd] | 13.92[ab] | 14.08[a] | 0.06 | <.0001 |
| SF N/cm² | 13.32[b] | 11.20[c] | 11.67[c] | 11.29[c] | 12.26[bc] | 12.32[bc] | 12.12[bc] | 12.33[bc] | 14.80[a] | 13.18[b] | 13.00[b] | 13.18[b] | 0.13 | <.0001 |
| DL % | 5.75[ab] | 6.07[ab] | 6.36[a] | 6.30[a] | 5.39[b] | 5.56[b] | 5.45[b] | 5.44[b] | 5.68[ab] | 5.73[ab] | 5.70[ab] | 5.73[ab] | 0.06 | 0.0163 |
| CL % | 21.70[c] | 22.35[bc] | 23.50[ab] | 23.99[a] | 21.79[c] | 21.34[c] | 21.21[c] | 21.05[c] | 21.96[c] | 21.65[c] | 21.97[c] | 21.85[c] | 0.13 | <.0001 |

[a,b,c,d,e]: Means in a row with no common superscript differ significantly at P < 0.05.
[4]Values are least square mean ± standard error.
WBS = Body weight base selection; EBS = Egg production base selection; RBC = Random-bred control; G0 = Generation zero; G1 = Generation 1; G2 = Generation 2; G3 = Generation 3; SF = Shear force; DL = Drip loss; CL = Cooking loss.

selection for higher body weight as well as egg weight in Japanese quail. However, the impact of improvement in body weight based selected group was higher than egg based selected quails.

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