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Genetic parameter estimates of fear, growth, and carcass characteristics in Japanese quail

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Abstract: The aim of this study was to estimate the heritability values of tonic immobility duration, several growth traits, and their genetic relationships with some slaughter traits. Fearfulness reaction was examined using tonic immobility (TI) response at 5 and 6 weeks of age. All birds were slaughtered at 6 weeks of age to measure carcass yield (CY), and percentage of breast (BY), leg (LY), wing (WY), abdominal fat (AFY). Heritability estimates for the TI durations and body weights measured at 5 and 6 weeks of age were 0.16, 0.20, and 0.46, 0.44, respectively. Heritability estimates for growth curve parameters and inflection point coordinates of Gompertz model were moderate to high, with values ranging from 0.36 to 0.54. Low heritability estimates for CY, BY, LY, and WY were found as 0.17, 0.19, 0.19, and 0.12, respectively. Genetic and phenotypic correlations between TI and BW-growth traits were determined low and statistically nonsignificant ($P > 0.05$). Similarly, genetic and phenotypic relationships between TI and carcass yield, and between TI and percentages of carcass parts were found low and statistically nonsignificant ($P > 0.05$). As a result, it is possible to say that applying multitrait selection including TI trait will not affect other yield characteristics.

Key words: Tonic immobility, heritability, genetic correlation, carcass yield, abdominal fat

1. Introduction

Fear causes economic losses in poultry and is one of the important factors causing stress. Researchers describe the fear as an alarm situation felt in case of danger, unrest caused by danger, an energy that both harmonizes and disrupts harmony. Fear can also be defined as a psychophysiological response of the brain and nervous secretion system [1]. A bird that has severe fear can react to escape, remain motionless or resist. These reactions normally protect the animal from external threats. If the threat that creates fear is severe and prolonged, it impairs the peace of the birds and affects their performance [2]. Fear, like other stressors, negatively affects many yield characteristics of poultry. Barnett et al. [3] reported that 20%–63% reduction in the egg yields of chickens during the peak period due to fear. Due to chronic fear, thinning and cracks in the egg shells and increase in the number of eggs without shells occur [4]. Similarly, feed efficiency and growth are negatively affected. It has been determined that there is a decrease in hatchability of chickens exposed to fear. The response of fear in breeders causes mating disorders, infertility, and low reproductive productivity [5]. In Japanese quails that have been selected according to their level of fear, quails with high fear levels have been reported to have worse meat quality than those with a low level of fear due to their higher carcass water holding capacity [4].

The duration of tonic immobility, which is one of the most important criteria of the fear situation in poultry, is a reaction that restricts the movement of the bird for a short time [2]. In this test, the animal is placed in a cradle-like wooden tool on its back, held by the chest, and the animal is released after 10–15 s. The standing up time of the poultry can be extended from a few seconds to several hours. The evaluation of the test is made according to the time that the animal remains motionless without standing up [6]. Animals with long tonic immobility period are considered to be more passive and cowardly than those who stand up in a short time. The variability of the tonic immobility period might be due to the animal's ability to stand up as a result of fear temporarily, the slowing of sympathetic nerve conduction, and its inability to react to external stimuli. Another reason for the animal to remain immobile is claimed to be caused by the animal's genes and this behavior is appeared to surprise their hunter.

The importance of animal welfare in poultry production has been more understood in recent years. Particularly in recent years, there are many studies on

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the relationship between yield characteristics and animal welfare in chickens [7,8]. However, there are few studies on the heritability of the level of fear directly affecting animal welfare and the genetic relationships between fear and other production traits. In addition, the number of studies on the level of fear in Japanese quail, the relationship of fear with the yield characteristics, and the genetic background of this trait are almost nonexistent. The methods based on the prediction of variance components for genetic parameter estimation have not been used in few studies on the inheritance of fear level in Japanese quail. In these studies, the realised heritability calculation which is a primitive method have been performed for heritability of fear level and the genetic relationships between the yield characteristics and the fear have not been studied.

In this study, it was aimed to estimate heritabilities for tonic immobility and some production traits, and the genetic and phenotypic relationships between the fear level and other yield characteristics. Japanese quail, which is both commercially important and model animal for other poultry, was used in the study.

2. Material and methods

The experiment was conducted at the Animal Science Department, Akdeniz University, Turkey. The care and use of animals were in accordance with laws and regulations of Turkey and approved by Ministry of Food, Agriculture and Livestock (decision number 22875267-325.04.02-E.3751911) and Animal Experiments Local Ethics Committee of Akdeniz University (decision number 09/69–02.14.2011). Japanese quail (*Coturnix coturnix Japonica*) was used as animal material in the research. A total of 40 male and 120 female breeder were used at the Akdeniz University livestock facilities in order to create a base population which had not been selected before. 400 chicks from 650 hatching eggs obtained from the base population were selected according to chance and used as the animal material of the experiment. The hatched chicks were kept until dry, then the wing numbers were attached, thanks to this process the pedigree records were created, weekly live weights and other measurements were performed by matching the pedigree records during the trial. Quail chicks were housed in brooding cages (90 cm^2/quail) for the first three weeks, after sex determination in the third week, then they were transferred to fattening cages (160 cm^2/quail), and they were housed here until the slaughtering age of 42 day. A grower diet containing 24 % CP and 2900 kcal of ME/kg for the first 21 d, and a fattening diet containing 21 % CP and 2,800 kcal of ME/kg were used. Ad libitum feeding, water and a 23-h/day lighting program were applied from hatch to the end of the study.

Tonic immobility test to measure fear responses was conducted at 5 and 6 weeks of age within a special test room. Tonic immobility testing was carried out as described by Campo and Dávila [6] on all birds. In brief, birds were placed on their backs in a cradle and held there for 10 s. If the bird righted before 10 s, tonic immobility was reinduced up to 3 times. The test was terminated in 300 s if a bird failed to right and that bird was scored as 300. Longer latency to right indicates greater level of fear.

At 6 weeks of age, the BW of all birds were determined 4 h after feed withdrawal and slaughtered in an experimental processing plant. The birds were manually cut, bled out, scalded (55 °C, 2 min), defeathered with equipment, manually eviscerated, and the abdominal fat pad (from the proventriculus surrounding the gizzard down to the cloaca) was taken, chilled in an ice-water tank, and drained [9]. Next day, after carcass dissection, breast with bone and the remaining abdominal fat on cold carcasses were weighed using an electronic digital balance with a sensitivity of 0.01 g. Slaughter and dissection were performed by same experienced operators. Cold carcass, breast, leg, wing, and total fat pad yields were calculated in relation to body weight at 6 weeks of age.

To obtain the estimates of individual growth curve parameters, all quail were weighed weekly from hatching to 6 weeks of age. The Gompertz nonlinear regression model (1) was used to estimate growth curve of each quail.

$$\boldsymbol{y_t} = \boldsymbol{\beta_0 e}^{(-1\beta_1 e\, \beta_2 t)} \quad (1)$$

where $\boldsymbol{y_t}$ is the weight at age t, $\boldsymbol{\beta_0}$ is the asymptotic (mature) weight parameter, $\boldsymbol{\beta_1}$ is the scaling parameter (constant of integration), and $\boldsymbol{\beta_2}$ is the instantaneous growth rate (per day) parameter [10,11]. The Gompertz model is characterized by an inflection point in a manner such that β_0/e of the total growth occurs prior to it and the remainder occurring after. The coordinates of the point of inflection, age and weight at inflection point (IPA and IPW, respectively) were obtained as follows:

$$\mathbf{IPW} = \boldsymbol{\beta_0}/\mathbf{e} \quad (2)$$

$$\mathbf{IPA} = \mathbf{In}(\boldsymbol{\beta_1})\boldsymbol{\beta_2} \quad (3)$$

The descriptive statistics and Kolmogorov-Smirnov normality tests of the traits were obtained using UNIVARIATE procedure of SAS 9.3 statistics software.

The following linear mixed effects model (4) was used in the analysis:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Zu} + \mathbf{e} \quad (4)$$

where **y** is the vector of observations, **β** is a vector of fixed effects and **u** is a vector of random genetic effects. **X** and **Z** are known design matrices relating phenotypic records to **a** and **u**, respectively. **e** is a vector of random errors. It is assumed that **y** follows a multivariate normal distribution which can be denoted as **y~MVN(XP, ZGZ + R).** It is further assumed that, **u** and **e** follow multivariate normal distributions, **u~MVN(0, G)** and **u~MVN(0, R)**, where, **I** is the identity matrix, **A** is the numerator relationship matrix, **G** is the additive genetic variance-

Table 1. The descriptive statistics and effect of sex on studied traits.

Trait	Mean	SE	CV %	Min	Max	Sex effect
TI5 (s)	81.84	2.609	61.68	14.74	300.00	NS[1]
TI6 (s)	87.54	3.321	73.36	13.16	300.00	NS
BW5 (g)	91.04	1.181	25.15	31.34	151.40	*
BW6 (g)	115.24	1.063	17.75	67.02	172.58	*
β_0[1] (g)	265.78	7.811	56.82	98.34	882.09	*
β_1[2]	3.92	0.042	20.36	2.53	9.51	NS
β_2[3]	0.046	0.001	42.85	0.02	0.11	NS
IPT[4] (d)	35.06	0.846	47.09	14.90	91.83	*
IPW[5] (g)	97.78	2.868	56.82	36.18	324.50	*
CY (%)	74.88	0.319	8.19	61.93	88.74	*
BY (%)	28.53	0.201	13.88	20.85	41.14	*
LY (%)	17.17	0.118	13.18	12.37	27.91	*
WY (%)	5.36	0.037	12.96	3.33	9.28	*
AFY (%)	1.09	0.028	53.06	0.08	2.94	*

TI5 and TI6 = Tonic immobility at 5 and 6 wk of age, BW5 and BW6 = Body weight at 5 wk of age; β_0= Asymptotic BW parameter; β_1= Shape parameter; β_2= Instantaneous growth rate parameter; IPT and IPW = age and weight at inflection point, CY= Carcass yield, BY= Breast yield, LY=Leg yield, WY= Wing yield, AFY= Abdominal fat yield.
[1]NS = Nonsignificance, $P > 0.05$. * = Statistically significance, $P < 0.05$.

covariance matrix and **R** is the error variance-covariance matrix. A non-informative prior was assumed for the fixed effects. The prior distribution assumed for **G** and **R** was an inverted Wishart distribution. Bayesian analyses were carried out using R package [12]. A single sampling chain of 550.000 iterations was considered with a 50.000 cycles of burn-in and a thinning interval of 50 cycles to obtain 10.000 samples of the parameters of interest in total.

3. Results and discussion

3.1. Basic statistics

The descriptive statistics of TI5, TI6, BW5, BW6, β_0, β_1, β_2, IPT, IPW, CY, BY, LY, WY, and AFY are presented in Table 1. At 5 and 6 weeks of age, significant effects of sex of the birds were not observed for durations of TI. The mean values of TI at 5 and 6 weeks of age (81.84 and 87.54 s) were in agreement with those reported by Benoff and Siegel [13] and Calandreau et al. [14] which range from 80.8 to 113.9 s. In current study, the tonic immobility durations of birds were lower than those published by Satterlee et al. [15], Mignon-Grasteau and Minvielle [16], Minvielle et al. [17] who reported TI of 183.1-201.8 s in Japanese quail. Besides, Sabuncuoğlu et al. [7] and Flores et al. [8] found shorter TI durations (26.06-38.40 s) than our findings. The duration of TI can vary widely from bird to bird and flock to flock as it is affected by both numerous environmental and genetic factors.

The mean values of BW at 5 and 6 weeks of age were found 91.04 and 115.24 g, respectively. Similar results (from 91.63 to 114.76 g) have been reported by Aggrey et al. [18], Raji et al. [19] and Rocha et al. [20]. Contrary to these findings, in their study, Toelle et al. [21] and Sarı et al. [22] reported that the average values of BW at 5 weeks of age were 156.1 and 176.0 g. In other studies [23-25], the mean values for BW at 6 weeks of age were reported as between 160 and 231.6 g. Minvielle [26] reported that the reasons for the weekly live weight values of Japanese quail to be very different are the result of the adaptation of these birds to cage conditions from immigrant life and effects of genetic improvement studies. Sex differences for BW5 and BW6 in Japanese quail have been reported previously by Aggrey et al. [18] and Narinç et al. [27] who reported that the body weights of females were heavier. There were significant differences for β_0 parameter, IPT, and IPT between males and females. Females showed higher mean values of mentioned traits than males. Beiki et al. [28] who analyzed the growth of three different Japanese quail lines with the Gompertz function, reported that the β_0 parameter estimates were 317.23, 271.46, and 291.63 g. β_0 parameter values of the growth curve in Japanese quails were estimated in the range of 242-276 g by Karabağ et al. [29], as 222.1 g by Hyankova et al. [30], in the range of 221.74-225.50 g by Kizilkaya et al. [31], in the range of 204-224 g by Alkan et al. [32], as 210.7 and 222.1 g by Narinç et al. [27]. In this study, the mean value of β_0 parameter (265.78 g) are in agreement with the values reported by Beiki et al. [28] and Karabağ et al. [29]. The estimations of integration coefficient parameter (β_1) of the Gompertz model for growth samples of Japanese quail were found to be 3.89 and 3.82 by Akbaş and Oğuz [33], and Kızılkaya et al. [31], which is in agreement with the mean value (3.92) of β_1 parameter in this study. The mean value of instantaneous growth rate parameter (β_2) was found to be 0.046 and this value is in agreement with the values (from 0.032 to 0.075) reported by Akbaş and Yaylak [10], Narinç et al. [9], and Kaplan and Gürcan [34]. The age at inflection point estimations of Japanese quails were found those previously reported by other researchers [32-35] that ranged from 15 to 35 days of age. Similar results for IPW have been reported by Alkan et al. [32], Kızılkaya et al. [35], and Kaplan and Gürcan [34] that ranged from 88.13 to 105.84 g.

The percentages of carcass, breast, leg, wing and abdominal fat were 74.88, 28.53, 17.17, 5.36, 1.09 %, respectively, which were higher than those previously reported by Narinç et al. [36], Lotfi et al. [37], Narinç et al. [38], and Raji et al. [39]. At 42 days of age, significant effects of the sex of the birds were observed for all slaughter-carcass traits. The average percentages of slaughter-carcass traits (BY, LY, and WY), except AFY, were higher in males compared with females. Similar sex differences for slaughter-carcass characteristic in Japanese quail have already been reported for BY, LY, and WY [36,40,41].

3.2. Heritability estimates

The estimates of genetic parameter for TI and growth traits are presented in Table 2. The posterior density graphs for TI and growth traits are shown in Figure 1 and Figure 2, respectively. Heritability estimates for the TI duration trait measured at 5 and 6 weeks of age were found to be 0.16 and 0.20, respectively. There are very few studies on the genetic structure of tonic immobility trait. In one of these studies, Mills and Faure [4] performed selection for 8 generations according to the short and long duration of tonic immobility in Japanese quail, and then determined the heritabilities for the tonic immobility trait using realized heritability method. In the aforementioned study, it was reported that the heritabilities of the TI duration ranged from -0.63 to 1.69 within the generations. Researchers

Table 2. Heritability estimates (on diagonal), genetic correlation estimates (below diagonal) and SE (in parentheses), phenotypic correlations (above diagonal), and P values (in parentheses) of TI and growth traits.

	TI5	TI6	BW35	BW42	β_0	β_1	β_2	IPT	IPW
TI5	**0.16** (0.028)	0.50*[1] (0.000)	0.05 (0.293)	0.07 (0.160)	−0.06 (0.274)	0.09 (0.068)	0.13 (0.013)	−0.10* (0.046)	−0.06 (0.274)
TI6	0.68 (0.013)	**0.20** (0.019)	0.08 (0.127)	0.08 (0.106)	−0.11* (0.032)	0.02 (0.688)	0.15* (0.004)	−0.15* (0.003)	−0.11* (0.032)
BW35	0.20 (0.072)	0.21 (0.042)	**0.46** (0.006)	0.91* (0.000)	−0.15* (0.000)	0.33* (0.000)	0.60* (0.000)	−0.53* (0.000)	−0.15* (0.000)
BW42	0.13 (0.061)	0.17 (0.032)	0.95 (0.009)	**0.44** (0.009)	−0.01 (0.853)	0.40* (0.000)	0.52* (0.000)	−0.43* (0.000)	−0.01 (0.852)
β_0	−0.20 (0.052)	−0.20 (0.051)	−0.41 (0.018)	−0.19 (0.025)	**0.50** (0.011)	0.30* (0.000)	−0.77* (0.000)	0.84* (0.000)	1.00* (0.000)
β_1	0.20 (0.027)	−0.02 (0.053)	0.44 (0.027)	0.61 (0.010)	0.25 (0.008)	**0.37** (0.012)	0.16* (0.001)	0.14* (0.006)	0.30* (0.000)
β_2	0.24 (0.055)	0.25 (0.014)	0.82 (0.009)	0.73 (0.011)	−0.77 (0.007)	0.35 (0.017)	**0.36** (0.008)	−0.93* (0.000)	−0.77* (0.000)
IPT	−0.34 (0.106)	−0.28 (0.056)	−0.77 (0.008)	−0.63 (0.011)	0.85 (0.008)	−0.08 (0.006)	−0.95 (0.008)	**0.54** (0.006)	0.84* (0.000)
IPW	−0.20 (0.078)	−0.20 (0.027)	−0.41 (0.026)	−0.19 (0.048)	0.16 (0.055)	0.25 (0.025)	−0.77 (0.009)	0.85 (0.011)	**0.46** (0.007)

TI5 and TI6 = Tonic immobility at 5 and 6 wk of age, BW5 and BW6 = Body weight at 5 wk of age; β_0 = Asymptotic BW parameter; β_1 = Shape parameter; β_2 = Instantaneous growth rate parameter; IPT and IPW = age and weight at inflection point.
*=Statistically significance, $P < 0.05$.

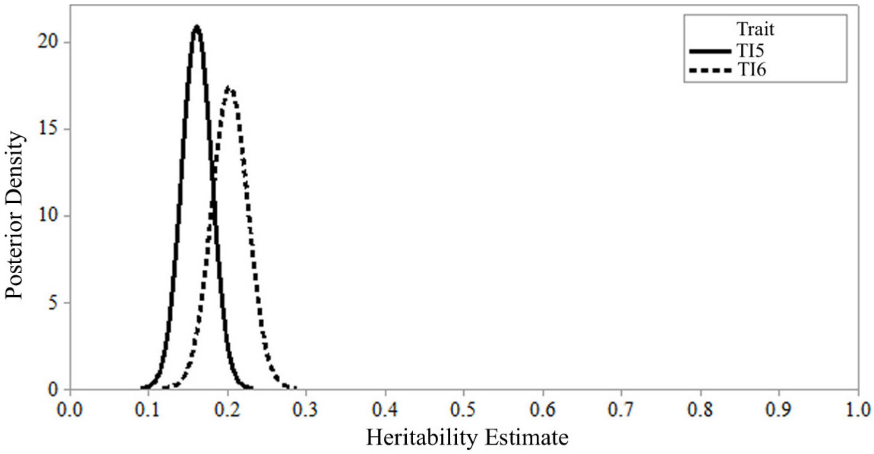

Figure 1. The posterior distributions of heritability estimates for tonic immobility traits.

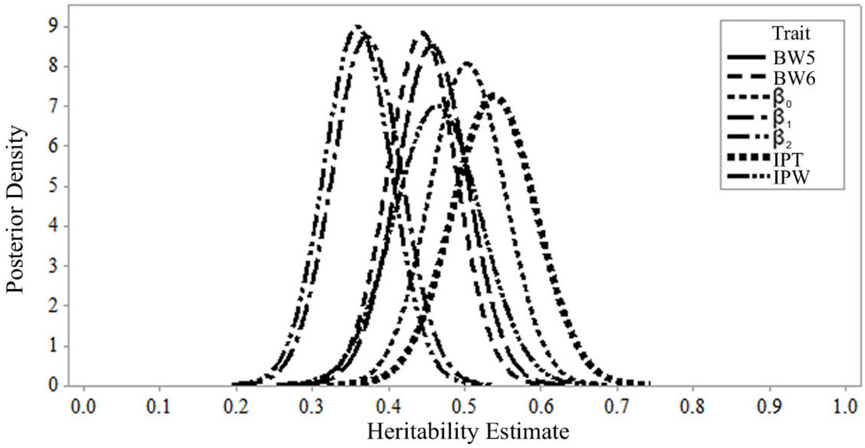

Figure 2. The posterior distributions of heritability estimates for growth traits.

explained that the out-of-theory value estimates were because the data did not show normal distribution. When all generations were evaluated together, it was reported that the heritabilities of TI were in the range of 0.24-0.28. Similarly, Benoff and Siegel [13] estimated low to moderate heritability estimates for TI duration of birds in different quail flocks selected for high and low mating ability over ten generations. In a selection study, Campo and Carnicer [42] estimated the heritability of 0.18 for the tonic immobility trait in the randombred control flock of Leghorn chickens. In a study investigating the genetic structure of developmental stability and fear behavior in chickens by Campo et al. [43], a low heritability (0.06) for tonic immobility duration was estimated. Altan et al. [44] reported that the heritability estimates for tonic immobility characteristics measured in a sire line were 0.07 (using original data) and 0.10 (using transformed data) in a study using laying hens. In current study, the low heritability estimates (0.16-0.20) for tonic immobility duration were found to be compatible with the low-to-moderate heritability estimates (0.07-0.28) reported by Benoff and Siegel [13], Mills and Faure [4], Campo and Carnicer [42], Campo et al. [43], Altan et al. [44]. In contrast to all the estimates, there were researchers [44, 45] who claimed that the heritability of tonic immobility was moderate to high (0.35-0.57). Differences in heritability estimates could be attributed to different species, genotypes, environmental conditions, estimation methods, and experimental-sampling error.

Heritabilities for BW at 5 and 6 weeks of age were estimated 0.46 and 0.44, respectively (Table 2). The selection criteria for many breeding studies in Japanese quail were live weights at 5 and 6 weeks of age. Due to the fact that there are many studies on estimating the heritabilities of these traits. Consistent with the findings in current study, many researchers found high heritabilities (0.40-0.69) for both traits [10, 11, 21, 46-48]. The estimates of heritability for Gompertz model parameter β_0 (0.50), β_1

(0.37), β_2 (0.36), and live weight (0.54) and age (0.46) at inflection point of growth function were close to those reported in previously published studies in Japanese quail [9, 10, 27, 33].

The posterior density graphs and genetic parameter estimates for slaughter-carcass traits were presented in Figure 3 and Table 3, respectively. The current estimate (0.17) of the heritability of carcass percentage (Table 3) was close to previously reported estimates for Japanese quail which range from 0.12 to 0.21 [21,37,48-50]. In present study, low heritabilities for BY, LY, and WY were found as 0.19, 0.19, and 0.12, respectively (Tablo 3). These estimates were in agreement with estimates reported by Toelle et al. [21], Vali et al. [51], and Akşit et al. [52], Lotfi et al. [37], and ranged from 0.09 to 0.19. Estimated heritability for AFY (0.21) was low to moderate. In other studies involving quail, low to moderate heritabilities (0.23-0.29) were also reported for the trait [11,37,52]. However, Narinç et al. [38] and Le Bihan Duval [53] reported higher heritability estimates for AFY in Japanese quail and chickens which range from 0.35 to 0.84.

3.3. Genetic and phenotypic relationships

In the study, the genetic correlation estimates among all characteristics were found higher than the phenotypic correlation coefficients (Table 2 and Table 3). Cheverud [54] reported that genetic correlation estimates were slightly larger than their phenotypic counterparts, and the correlation patterns were strikingly similar in all studies using data sets based on appropriate effective sample sizes. Hence, Cheverud [54] claimed that most of the difference between phenotypic and genetic correlation estimates was due to the imprecise estimates of genetic correlations.

The coefficients of phenotypic and genetic correlation between the tonic immobility durations measured at 5 and 6 weeks of age were 0.50 and 0.68, respectively. The positive and strong relationships between tonic immobility values determined in successive weeks was evidence that these measurements were performed consistently and accurately. In a study, the related trait sets in Japanese quail were determined using a multivariate statistical method by Mignon-Grasteau and Minvielle [16] which constituted a significant part of the total variation for many characteristics, including the tonic immobility duration. According to the results of the study, the set of variables including tonic immobility constituted a very small part of the total variance, and it was determined that the relationship between tonic immobility duration and yield characteristics was nonsignificant. In current study, the genetic and phenotypic relationships between tonic immobility and live weights were determined as low and statistically nonsignificant ($P > 0.05$) to support the situation determined by Mignon-Grasteau and Minvielle [16]. These genetic correlations were found between -0.18 and 0.26, and phenotypic correlations were found between -0.07 and 0.14 (Table 2). Genetic and phenotypic relationships between TI5, TI6 characteristics and Gompertz model parameters and the age and weight at the inflection point were generally found to be low and statistically nonsignificant (Table 2). However, genetic and phenotypic relationships between TI6 and mature weight parameter (-0.20 and -0.11, respectively), and between TI6 and growth rate parameter (0.25 and 0.15, respectively) were remarkable. These findings supported the claim "the birds with short tonic immobility duration had high growth rate" by Wang et al. [55] and Minvielle et al. [56], although there were no statistically significant correlations between tonic immobility durations and weekly live weights in Japanese quail in the study. Genetic and phenotypic relationships between TI traits and carcass yield, and between TI traits and percentages

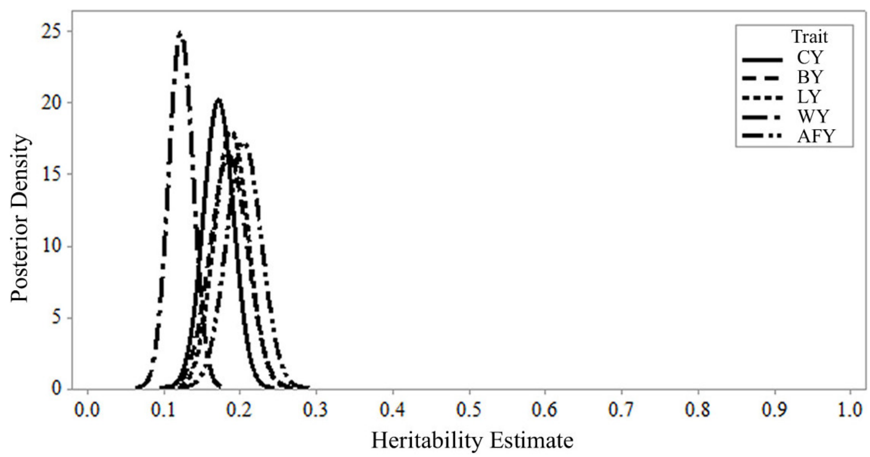

Figure 3. The posterior distributions of heritability estimates for slaughter-carcass traits.

Table 3. Heritability estimates (on diagonal), genetic correlation estimates (below diagonal) and SE (in parentheses), phenotypic correlations (above diagonal), and P values (in parentheses) of TI and slaughter traits.

	TI5	TI6	CY	BY	LY	WY	AFY
TI5	**0.16** (0.028)	0.50 (0.000)	–0.02 (0.737)	0.04 (0.490)	–0.05 (0.343)	–0.02 (0.674)	–0.10 (0.062)
TI6	0.66 (0.013)	**0.20** (0.019)	–0.06 (0.255)	0.01 (0.843)	–0.04 (0.400)	0.04 (0.481)	–0.05 (0.373)
CY	0.08 (0.017)	0.11 (0.007)	**0.17** (0.008)	0.21* (0.000)	0.21* (0.000)	0.28* (0.000)	0.29* (0.000)
BY	–0.14 (0.027)	–0.08 (0.014)	0.23 (0.012)	**0.19** (0.009)	0.30* (0.000)	0.12* (0.016)	–0.04 (0.444)
LY	0.08 (0.031)	0.13 (0.002)	0.24 (0.013)	0.32 (0.012)	**0.19** (0.014)	0.33* (0.000)	0.18* (0.001)
WY	0.04 (0.041)	0.06 (0.008)	0.28 (0.012)	0.22 (0.014)	0.37 (0.012)	**0.12** (0.014)	0.14* (0.006)
AFY	0.04 (0.032)	0.17 (0.027)	0.33 (0.042)	0.18 (0.013)	0.33 (0.013)	0.27 (0.013)	**0.21** (0.007)

TI5 and TI6 = Tonic immobility at 5 and 6 wk of age, CY = Carcass yield, BY = Breast yield, LY = Leg yield, WY = Wing yield, AFY = Abdominal fat yield.

of carcass parts were found to be low and statistically nonsignificant (P > 0.05).

Positive and strong genetic and phenotypic correlations between weekly live weights were estimated to be 0.95 and 0.91, respectively (Table 2). These estimates were in agreement with estimates reported by Sezer [46], Akbaş et al. [57], and Sarı et al. [48] and ranged from 0.80 to 0.96. The genetic and phenotypic correlation coefficients between the β_0-β_1 and β_0-β_2 parameters of the Gompertz model were negatively estimated, and they were positively estimated between β_1 and β_2 parameters of the Gompertz model. Small parameter β_2 and long growing period resulted in high mature weight in birds as a consequence of correlation between parameters β_0-β_2. These results were in agreement with similar research findings [10,11,33]. Genetic correlations between parameter β_0 and weekly live weights were positive, and genetic correlations between $\beta_{1,}$ β_2 and weekly live weights were negative. These estimates were similar to those reported by Akbaş and Oğuz [33], Akbaş and Yaylak [10], and Narinç et al. [9]. This is the fact that an increase in the asymptotic (mature) body weight results in a desrease in the parameter β_2, which denotes the average rate of maturing. According to Table 2, there were negative genetic correlations (-0.77 and -0.63) between body weight traits and IPT. These results were in agreement with the estimates of Mignon-Grasteau et al. [58] who found a strong negative relationship (-0.60) between BW and IPT traits. Genetic and phenotypic correlations between IPT and IPW characteristics were estimated to be positive and strong (0.86 and 0.85). Similar findings for these genetic correlations Narinç et al. [11] has also been reported.

Phenotypic and genetic correlations between CY, BY, LY, WY, and AFY traits were positive and generally moderate (Table 3). Lotfi et al. [37] reported similarly that the genetic relationships between cold carcass yield and percentage of breast and, between cold carcass yield and the percentage of abdominal fat were 0.46 and 0.43, respectively.

Considering the results obtained from the study, it is not possible to say that tonic immobility duration in Japanese quail has important genetic and phenotypic relationships with most yield characteristics. Since the TI duration is both low heritable trait and low genetic correlated trait with other yield characteristics, there is no inconveniency to be included directly in the selection index in a poultry breeding study, where improvement of the fear behavior is also taken into account.

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