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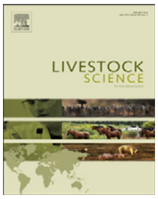

Genetic parameters of body weight and egg traits in meat-type quail

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ABSTRACT

Data from two quail strains, UFV1 and UFV 2, measured weekly from hatch to sixth week in a total of seven live body weight traits were used aiming to estimate genetic correlations and heritabilities. After females were evaluated they were monitored in their egg-laying phase, in which the total egg number, the average weight of the eggs and the average specific gravity of eggs were measured. Multi-trait analysis was performed with the ten traits measured for estimation of heritabilities, genetic and residual correlations. For body weight traits, heritabilities varying from 0.25 to 0.53 for UFV1 and from 0.27 to 0.53 for UFV2 were estimated; genetic correlations increased as the interval between records was reduced. For egg number, the heritability estimate was of low magnitude (0.05 and 0.04), whereas for average egg weight (0.41 and 0.39) and egg specific gravity (0.31 and 0.18), they were of moderate magnitude for UFV1 and UFV2, respectively. The genetic correlations between body weights and egg number were negative in UFV1 and positive in UFV2; for average egg weight, they were positive, and for specific gravity, they were negative for both strains. It can be concluded, then, that selection based on body weight in the growth phase of meat quail must be done preferably at early ages such as weight at the third or fourth week of life, once they are positively correlated with weight at slaughter age and have few effects on the production and quality of eggs.

1. Introduction

Quail have been raised all over the world for production, especially in countries of Europe, for meat, and Far East, for egg production (Minvielle, 2004). In Brazil, the number of birds and egg production in the last few years have almost doubled (IBGE—Instituto Brasileiro de Geografia e Estatística, 2010). Thereby, it is necessary to meet the production needs and consequently to ensure the future of this activity.

The last few decades have seen a transition in poultry genetics from dual-purpose birds to those specialized in meat or eggs (Siegel et al., 2006). In this way the study of correlations between productive traits is of great importance in the development of poultry breeding programs. Selection is often practiced in one or few traits of interest, which may lead to undesirable responses if its correlations are antagonistic. Several methodologies have been described for the measurement of relations between traits in animal breeding. Phenotypic, genetic and residual correlations obtained by the estimation of variance

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components are very common in animal breeding; however, in studies with quail specialized for meat production, they are limited; most of them only concern body weight measured from the growth phase until slaughter, i.e., from hatch to the sixth week of life, as in a review by Vali (2008).

Although several studies performed multi-trait analyses, these are restricted to two-trait analysis with an anchor trait (El-Fiky et al., 1994; Saatci et al., 2006; Varkoohi et al., 2011) or when using more than two traits simultaneously used only performance and carcass traits (Resende et al., 2005; Vali et al., 2005), but seldom with reproductive traits. The advantage of using a multi-trait model is associated with improving reliability in estimation of genetic parameters (Druet et al., 1999) due to better connections between traits measured and that can be more beneficial for sex-limited traits like egg quality and production.

Multi-trait analyses can be complicated due to large numbers of parameters to be estimated; in this way the use of estimation of genetic principal components of covariance matrix has several advantages over full rank estimation, considering sampling variation and computational requirements and is indicated to facilitate routine analyses involving more than a few traits simultaneously (Meyer and Kirkpatrick, 2005).

The initial growth pattern and the weight at sexual maturity have been pointed out as the main factors which affect the performance of birds in the laying phase (Sezer et al., 2006), and these traits must be regarded with special attention in breeding programs. The selection criterion adopted must not cause decrease in the performance of the breeder birds in the adult phase.

There are numerous differences in the estimates of genetic parameters for body weights in quail, which are caused by several factors; among them are the nutritional plan and the genetic background—some of the studies are performed in populations selected for egg production, or with a lower body weight.

Siegel (1963) showed that some genes which influence the juvenile weight at a certain age have a great impact on other ages due to the pleiotropic effect, and that environmental effects act similarly on the weight gain at several ages, so positive correlations are expected when these traits are considered.

Several studies reported the effects of selection on body weight and egg production in poultry species. Nestor (1971) reported results of selection in two randomly bred control populations that were selected for egg production or increased body weight. In both the selection in the first few generations did not result in great responses in the correlated trait; the further selection results in major reduction on correlated trait but this response ceases in latter generations.

Shebl et al. (1996) reported an increase in the correlated response between weight at 42 days and the total number of eggs in strains selected for high body weight; similar results were obtained by Marks (1979, 1991). However, El-Fiky et al. (1994) and Mielenz et al. (2006) obtained negative estimates of genetic correlations between body weight and the total egg number in quail.

The aim of the present study was to identify and quantify the association between body weight in the growth phase with productive traits of meat-type quail breeders to determine an age for selection for higher body weight which has a lower impact on the production and quality of eggs.

2. Material and methods

2.1. Experimental material and management

Data from 8759 meat quail (*Coturnix coturnix*) of the UFV1 strain and another 9128 from the UFV2 strain from the Poultry Breeding Program of Federal University of Viçosa were used. Of the total, 1824 and 1704 birds from strains UFV1 and UFV2, respectively, were female breeders in the reproductive phase.

The two strains originated from two different farms in Brazil and were selected for high body weight; thus they are possibly no related. The average weight and meat yield indicates that these strains are suitable for meat production.

For each generation, at the starting stage of raising, birds individually identified with numbered tag on the leg for pedigree record were housed in stall of concrete floor with wood shavings bed, with protection circle and heating through heat brooders, by utilizing one hood for approximately 750 quails. Starter diet (from 26% to 28% CP and 2900 kcal of ME/kg) and water were supplied ad libitum. Light regimen from hatch to the fourth week was of 24 h. In the fourth week of life, 102 males and the 204 females with the highest body weight in the whole population were selected and transferred to individual steel cages ($15\times20\times23\ \text{cm}^3$) for monitoring animal productive performance. In the entire period females were kept in individual cages, whereas males were changed between two female breeders in this period. Thus, the sex ratio of breeding population was 2:1 and males were changed among the same two females every three days to maintain the fertility of laid eggs. Mates were chosen randomly. At approximately 5% egg production the diet supplied was changed to a breeder ration (19% CP and 2900 kcal energy/kg) with water and food ad libitum and light regimen of 16 h of light (16:8). The rearing procedures were repeated likewise for 13 generations, with a total of 16 hatches. Despite several generations of individual selection, there is no inbreeding depression in both strains because high population effective size.

2.2. Traits measured

Seven records of body weight, taken weekly from hatch to the sixth week of life and three productive traits of female breeders: total egg number in 365 days from the sixth week of age, average egg weight and egg specific gravity both at 180 days of age, were collected. Specific gravity was determined by the method of water displacement (Hamilton, 1982). This measure is of importance, because it is an indirect indication of egg quality, related with shell thickness and egg breakage resistance, and has

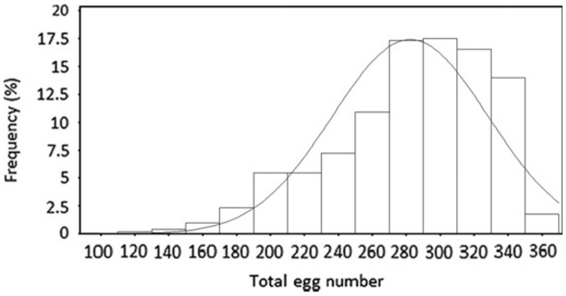

Fig. 1. Distributions of total egg number for UFV1 strain.

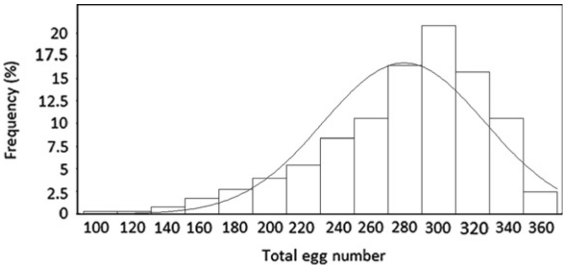

Fig. 2. Distributions of total egg number for UFV2 strain.

a low cost. For egg production, only birds which survived up to the last day of measurements were considered for production records. Thus the information of total egg number has includes the egg persistence and mortality in the full period, since in meat-type female breeders the mortality has a high impact on activity profit due to high rates of mortality (Silva et al., 2011). Figs. 1 and 2 show the distribution of total egg number in both strains, that can be considered little skewed, with the highest value for skewness as −0.74.

2.3. Statistical methods

In the analyses by the animal model, the animals which did not have any relation with the others, or those which did not contribute to the information collected and had any link were excluded from the genetic relationship matrix through a process of pruning, performed in a first phase through software Wombat (Meyer, 2007). In this process individuals that are sire or dam and which do not contribute to the information for variance component estimation, i.e. individuals without records and a pedigree link to at least one other individual, are replaced with an "unknown" code and eliminated from the list of the pedigree records (Meyer, 2010).

Afterwards, single-trait analyses were carried out; for body weights, only fixed effects of sex and of generation/hatch were considered, and for productive traits of female breeders, only fixed effects of generation/hatch. These estimates served to build up the genetic and residual (co)variance matrices used as initial values for estimation of variance components in a multi-trait analysis.

The multi-trait analysis was conducted with 10 traits. To facilitate the convergence process, first a multi-trait analysis using reduced rank was done. In this case, the matrix of additive (co)variances was reduced, by means of principal components, according to methodology described by Meyer and Kirkpatrick (2005), for a rank equals to five. After this process, the resulting matrix was used as a starting value for the full-rank multi-trait analysis to avoid problems with biases by picking up the possible wrong subset of genetic principal components (Meyer and Kirkpatrick, 2008).

For all genetic analyses, the package Wombat (Meyer, 2007) was used, with standard algorithms of the system. The model can be represented in matrix terms by

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{e}$$

where $\mathbf{y}$ is the vector of observations; $\mathbf{X}$ is the incidence matrix of fixed effects; $\mathbf{b}$ is the vector of fixed effects; $\mathbf{Z}$ is the incidence matrix of random effects; $\mathbf{a}$ is the vector of random effects; $\mathbf{e}$ is the vector of residuals.

The model has the following assumptions:

$$E\begin{pmatrix}\mathbf{y}\\ \mathbf{a}\\ \mathbf{e}\end{pmatrix} = \begin{pmatrix}\mathbf{X\beta}\\ \mathbf{0}\\ \mathbf{0}\end{pmatrix} \text{ and } V\begin{pmatrix}\mathbf{a}\\ \mathbf{e}\end{pmatrix} = \begin{pmatrix}\mathbf{A}\otimes\mathbf{G} & \mathbf{0}\\ \mathbf{0} & \mathbf{I_n}\otimes\mathbf{R}\end{pmatrix}$$

where $\mathbf{G}$ is the additive (co)variance matrix, $\mathbf{A}$ being the numerator relationship matrix and $\mathbf{R}$ is the residual variance matrix, $\mathbf{I_n}$ is a identity matrix with the order given by the number of animals ($\mathbf{n}$).

3. Results

3.1. UFV1 strain

Table 1 presents the descriptive statistics of the characteristics measured in the UFV1 strain. After pruning of uninformative animals the proportion of remaining animals was 99.3%. In the body weight dataset, 49% of animals were females and 51% males, with 96.4% of animals with at least one record and 22.4% of animals with offspring.

Body weight traits have a higher number of data for being measured both in selected and non-selected animals. There is a decrease in number of animals with increase in age by mortality and loss of identification, whereas eggs number, egg weight and egg specific gravity

Table 1
Descriptive statistics for UFV1 strain.

	Number of records	Mean	Standard deviation	Minimum	Maximum
HW	8759	9.69	1.08	5.30	13.42
W1	8540	33.31	7.48	10.00	58.03
W2	8368	86.14	16.14	12.79	136.69
W3	8532	149.15	24.70	44.80	228.85
W4	8533	210.06	29.67	81.00	315.06
W5	7867	248.81	31.61	109.01	397.68
W6	7574	274.29	36.72	131.27	448.54
TEN	515	281.95	46.64	81.00	357.00
AEW	1502	13.86	1.17	10.10	18.59
ESG	1178	1.072	0.06	1.060	1.090

From HW to W6—body weights from hatch to sixth week in grams; TEN—total egg number; AEW—average egg weight in grams; ESG—average egg specific gravity in grams per cubic centimeter.

Table 2
Heritabilities (on the diagonal), genetic (above the diagonal) and residual correlations (below the diagonal) among ten traits and standard errors (in parenthesis) for meat-type quail strain UFV1.

	HW	W1	W2	W3	W4	W5	W6	TEN	AEW	ESG
HW	0.53	0.38	0.35	0.35	0.43	0.39	0.43	−0.05	0.92	−0.12
	(0.01)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.07)	(0.04)	(0.06)
W1	0.31	0.30	0.90	0.74	0.57	0.40	0.26	0.29	0.47	−0.19
	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.03)	(0.04)	(0.07)	(0.07)	(0.08)
W2	0.23	0.71	0.29	0.96	0.82	0.64	0.44	0.11	0.41	−0.15
	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.03)	(0.04)	(0.08)	(0.07)	(0.08)
W3	0.21	0.23	0.75	0.30	0.94	0.78	0.59	−0.11	0.47	−0.26
	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.03)	(0.04)	(0.09)	(0.07)	(0.09)
W4	0.21	0.49	0.69	0.80	0.30	0.93	0.80	−0.34	0.54	−0.33
	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)	(0.03)	(0.08)	(0.07)	(0.09)
W5	0.21	0.36	0.54	0.66	0.77	0.29	0.96	−0.30	0.50	−0.19
	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.09)	(0.06)	(0.08)
W6	0.17	0.22	0.35	0.45	0.55	0.69	0.25	−0.32	0.46	−0.20
	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.09)	(0.07)	(0.09)
TEN	−0.03	0.03	−0.06	−0.13	−0.19	−0.18	−0.13	0.05	0.14	0.80
	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.02)	(0.06)	(0.04)	(0.09)	(0.04)
AEW	0.16	0.09	0.11	0.16	0.23	0.25	0.20	−0.03	0.41	0.13
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.07)	(0.04)	(0.09)
ESG	0.00	−0.03	−0.05	−0.08	−0.10	−0.10	−0.08	0.13	−0.02	0.31
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.07)	(0.06)	(0.07)

From HW to W6—body weights from hatch to sixth week; TEN—total egg number; AEW—average egg weight; ESG—average egg specific gravity.

have a reduced number in records as these traits are measured only in selected females (breeders).

The estimates of heritabilities, genetic and residual correlations for strain UFV1 are presented in Table 2.

The correlations between body weights and total number of eggs estimated were in general of low to medium magnitude, tending to negative values at later ages. These results suggest that selection for body weight at earlier ages might have little effect on the number of eggs produced.

As for average egg weight, it presents almost constant genetic correlations in the growth phase, and always of moderate magnitude, except for weight at hatch, which presents high correlation.

For specific gravity of the eggs produced, the genetic correlations with body weights were negative, probably because of the positive correlations between body weights and average egg weight.

The heritability estimates were, overall, of moderate to high magnitude for body weight; the highest was at hatch and the lowest at the sixth week.

3.2. UFV2 strain

Table 3 shows the basic descriptive statistics of the recorded traits, and in Table 4 shows the estimates of heritability, genetic and residual correlations for the UFV2 meat quail strain. In this strain after pruning of uninformative animals 99.9% of data remained and in the body weight dataset there were 53% females and 47% males, with 98.6% of animals having at least one record and 20.5% of animals with offspring.

In the UFV2 strain, there was increase of genetic correlations as the interval between ages decreased. The highest estimate of heritability for body weights was for weight at hatch (0.53) and the estimates for the following ages varied from 0.27 to 0.45.

Table 3
Descriptive statistics for UFV2 strain.

	Number of records	Mean	Standard deviation	Minimum	Maximum
HW	9128	9.82	1.13	5.60	13.55
W1	8925	33.91	6.84	11.80	59.36
W2	8627	87.46	15.95	20.30	214.20
W3	8793	151.20	23.95	39.00	265.00
W4	8811	213.01	28.52	78.00	358.17
W5	8183	255.65	31.17	104.01	396.67
W6	7486	283.50	37.42	123.18	429.62
TEN	407	279.57	47.76	99.00	357.00
AEW	1375	14.05	1.17	8.88	18.59
ESG	1190	1.071	0.05	1.060	1.090

From HW to W6—body weights from hatch to sixth week in grams; TEN—total egg number; AEW—average egg weight in grams; ESG—average egg specific gravity in grams per cubic centimeter.

The correlations between body weights and number of eggs produced were positive, but different from those estimated for the UFV1 strain.

For specific gravity and average egg weight, the estimates of genetic correlations with body weights were similar to those obtained for the UFV1 strain. The genetic correlations between productive characteristics of breeders were similar to those from UFV1, except for the correlation between average weight and number of eggs, which was negative.

4. Discussion

In general, genetic correlations between body weights are of high magnitude, increasing as the distance between them is reduced, except for weight at hatch, which, in general,

Table 4
Heritabilities (on the diagonal), genetic (above the diagonal) and residual correlations (below the diagonal) among ten traits and standard errors (in parenthesis) for meat-type quail strain UFV2.

	HW	W1	W2	W3	W4	W5	W6	TEN	AEW	ESG
HW	0.53 (0.01)	0.46 (0.03)	0.40 (0.03)	0.35 (0.03)	0.33 (0.03)	0.34 (0.03)	0.35 (0.03)	−0.46 (0.07)	0.99 (0.05)	−0.02 (0.05)
W1	0.34 (0.02)	0.27 (0.02)	0.86 (0.01)	0.68 (0.02)	0.53 (0.03)	0.41 (0.04)	0.28 (0.05)	0.30 (0.08)	0.57 (0.07)	−0.05 (0.08)
W2	0.25 (0.02)	0.76 (0.01)	0.28 (0.02)	0.94 (0.01)	0.84 (0.02)	0.71 (0.03)	0.58 (0.04)	0.46 (0.08)	0.49 (0.07)	−0.32 (0.08)
W3	0.23 (0.02)	0.62 (0.01)	0.85 (0.01)	0.35 (0.02)	0.97 (0.01)	0.87 (0.02)	0.75 (0.04)	0.47 (0.09)	0.42 (0.07)	−0.30 (0.08)
W4	0.20 (0.02)	0.48 (0.01)	0.71 (0.01)	0.83 (0.01)	0.42 (0.02)	0.96 (0.02)	0.87 (0.02)	0.45 (0.10)	0.38 (0.07)	−0.27 (0.08)
W5	0.20 (0.02)	0.35 (0.01)	0.56 (0.01)	0.70 (0.01)	0.80 (0.01)	0.45 (0.02)	0.97 (0.03)	0.48 (0.08)	0.37 (0.07)	−0.35 (0.08)
W6	0.15 (0.02)	0.21 (0.02)	0.37 (0.02)	0.48 (0.01)	0.57 (0.01)	0.69 (0.01)	0.33 (0.02)	0.47 (0.09)	0.37 (0.09)	−0.45 (0.08)
TEN	−0.02 (0.06)	0.03 (0.06)	−0.03 (0.06)	−0.09 (0.07)	−0.13 (0.07)	−0.16 (0.07)	−0.05 (0.06)	0.04 (0.03)	−0.37 (0.08)	0.55 (0.04)
AEW	0.19 (0.04)	0.16 (0.04)	0.19 (0.04)	0.19 (0.04)	0.20 (0.04)	0.22 (0.04)	0.20 (0.04)	−0.01 (0.08)	0.39 (0.04)	−0.06 (0.10)
ESG	−0.03 (0.04)	0.00 (0.04)	−0.06 (0.04)	−0.11 (0.05)	−0.09 (0.05)	−0.14 (0.05)	−0.13 (0.04)	0.03 (0.06)	0.02 (0.06)	0.18 (0.08)

From HW to W6—body weights from hatch to sixth week; TEN—total egg number; AEW—average egg weight; ESG—average egg specific gravity.

presents lower correlations with the other measures. This behavior is similar to the observations of Bonafé et al. (2011a) and Dionello et al. (2008), with different populations of meat quail under similar conditions.

The magnitude of correlation between egg production and body weight depends on the stage of improvement of the population as described by Nestor (1971). Thus the genetic correlation among these traits could range from near zero to strongly negative. Nordskog and Briggs (1968) reported that this relation can be attributed to the fact that one of the strains analyzed had not yet reached the ideal body weight for the maximum expression of egg production.

The correlation among body weight and average egg weight was moderate for all, except for the hatch weight. This can be explained by the influence of maternal supply on embryo development, which has already been pointed out between weight at hatch and weight of the incubated egg (Seker et al., 2004). These results were close to those obtained by Saatci et al. (2006), who worked with the same traits in a strain of Japanese quail and analyzed correlations between average egg weight and seven weekly body weights from hatch to the sixth week of age.

Heritabilities for body weight are close from those obtained by Bonafé et al. (2011b), in random regression models considering heterogeneity of residual variances. High heritability on hatch weight can be explained by a small environmental effect, since the management provided by the hatchery was the same in each generation/hatch. The estimation of heritability for hatch weight can be improved by using maternal component or using dam as the permanent environmental effect. Tigli et al. (1997) working with Japanese quail reported estimations outside the parametric space due to the absence of these effects. Aggrey and Cheng (1992) suggest that this inflation on hatch weight heritability estimate in birds can be due to the common preovipositional maternal variance, i.e. egg size. In this study these effects were not considered due to low association verified in the previous studies (Nascimento et al., 2010), although more studies in this subject must be done to clarify this matter.

For total number of eggs, the heritability estimate was lower than that observed in a review conducted by Vali (2008), who summarized the studies of several authors by different methodologies. The results of our study can be due the use of total egg number of one year laying instead of a partial egg number, but Ribeiro et al. (in press) found that heritability estimates are similar in partial and total period while working with the same strains of this study. The total egg number measured in one year of laying reveal the total laying ability despite the small number of records. Problems in genetic parameter estimation with small number of records can be avoided by using a multi-trait model which increases accuracy of estimates resulting from better connections in the data (Thompson and Meyer, 1986), methodology employed in the present study. For egg weight, the estimate was close to the range estimated by Georg et al. (2009) with three strains of Japanese quail in two different environments. The estimate of heritability for specific gravity was similar to that obtained by Sezer (2007) with Japanese quail and the correlations between this trait and body weights were negative and low in both strains. Selection for body weight, as reported by Alkan et al. (2010), does not increase the eggshell quality significantly, although the shell weight was greater in the high body weight line compared with the control line.

As verified by this study, each strain has different correlations between body weights and egg production; therefore, the antagonistic effects of selection of higher body weight in meat quail must be analyzed within each population. Selection based on body weights in the growth phase of meat quail must be done preferentially at early ages, such as weight in the third or fourth week of life, because these are positively correlated with weight at slaughter and have little effect on the production and quality of eggs.

Conflict of interest statement

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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