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Evaluation of selection criteria in laying quail (*Coturnix coturnix japonica*)

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Abstract

The primary aim of the commercial exploration of quail in Brazil is to increase egg production. The characteristics of the genetic groups used are not well known, making it difficult to increase eggs production. The objective of this study is to evaluate selection criteria to increase the number of eggs produced in two lineage of laying quail. In this sense, genetic parameters were estimated and calculated the indirect and direct responses to selection. The genetic gain was calculated based on the selection of partial production in the complete egg production. The indirect response showed to be more efficient in terms of genetic gain compared to the direct selection, indicating that the use of the first 60 days is the ideal period for selection of quail, providing satisfactory gain in egg production compared to the total production period. The use of this period allowed the early identification of superior individuals, increased the total egg production and the genetic gain, reducing the generation interval and making it possible to carry outtwo selections per year.

Keywords: *egg production, genetic gain, genetic parameters, selection efficiency*

Introduction

Brazilian quail production is predominantly focused on eggs.The current situation in Brazil is a growing demand for eggs; however, there is a need to develop breeding programs to obtain better defined strains to produce eggs of good quality.The breeding lineages used in Brazil are the *Coturnix coturnix japonica* (unique to egg production) and *Coturnix coturnix coturnix* (eggs and meat). There are several differences that characterize the species. In general, it appears that up to 60 weeks of age where quail produce more eggs, due to its sexual precocity in its early stage of rearing (Bertechini 2010). However, the lack of suitable genetic material and insufficient data on the performance affects the growth of this activity (Martins 2002).

The main objective of production on a commercial scale is to increase the number of eggs produced, integrated with the egg processing industries. Nevertheless, the average egg weight and body weight of the bird are economic important traits, since an exaggerated increase in egg weight would lead to physiological problems, and an increase in body weight would increase the production costs.

Total egg production is often used as a parameter of performance and as a selection objective (Boukila et al 1987). The egg production is influenced by other traits, which can be considered as selection criteria, such as age of the bird at first egg, laying rate and laying persistence. In order to increase the total egg production and the genetic gain per generation, the selection of laying birds can be made based on partial production periods (Poggenpoel et al 1996). The selection for partial periods decreases the generation interval and may result in greater genetic gain at each selection cycle (Lopes 2005). In addition, egg production varies throughout the production period. When only the total period is evaluated, the variations that may occur during the laying period are not well known. Partial periods analyses improve the selection of animals, since the variations that occur throughout the productive life of the birds are known (Cruz et al 2016).

The knowledge of correlations and genetic parameters is crucial to define selection criterias, and then increase the genetic gain for each trait (Viana et al 2000). Several studies showed that partial production periods can be used as a selection criterion for total egg production in order to increase egg production efficiency for both laying and broilers (Venturini et al 2012; Teixeira et al 2013; Cruz et al 2016; Karami et al 2017; Khadiga et al 2017). However, information is still scarce in laying quail, showing the importance to study the particularities of each population, especially in terms of genetic gain and selection efficiency. The knowledge of this information is crucial for maximizing production and defining the appropriate selection strategy.

In this sense, the aim of this study was to estimate genetic parameters for partial and total egg production, as well as egg and bird weight, and to evaluate selection criteria to be applied into two lineages of laying quail under selection to increase egg production.

Material and methods

The database used in this study was provided by Vicami Codornas breeding program. The study was submitted and approved by the ethics and animal use committee (CEUA) at the Universidade Tecnológica Federal do Paraná - Campus Dois Vizinhos under protocol number 2015-001. Two lineages of laying quail (yellow and black) were used. The breeding stock consisted of 200 females and 100 males for each lineage. The matings were controlled, and one male to two females ratios (1:2) was used for coverage. For the formation of the two populations of this study, the eggs were collected in two periods of ten days and incubated in two periods of 17 days, with identification of the mother, resulting in two births. After hatching, the chicks were identified with numbered and colored rings, according to their lineage, allowing genealogical control. Informations from 928 females belonging to the yellow lineage and 896 from the black lineage were collected.The total egg production (TEP) was analyzed for 150 days, counted from the first egg in each lineage, and the partial egg production (PEP) was measured in four periods denominated: PEP1(1-60 days) corresponding to the first 60 days of laying; PEP2 (61-90 days), PEP3 (91-120 days) and PEP4 (121-150 days) periods corresponded to 30 days of laying to each the previous period, respectively. In addition, body weight (BW) and average egg weight (AEW) in grams traits were also collected.

Four-trait analyses were performed between each partial production period (PEP1, PEP2, PEP3 and PEP4) and TEP, BW and AEW for each lineage (totaling eight 4-trait analyses). The analyses were conducted to estimate the heritabilities and genetic correlations between TEP and PEP, BW, AEW whit in each of the partial periods addressed. The relationship matrix for the yellow lineage was composed by1,215 animals and for the black lineage by 1,183 animals. The birth was considered as a fixed-effect in the model. The variance components and genetic parameters were estimated using the Gibbs sampling method and the animal model, as follows:

$$\mathbf{y = X\boldsymbol{\beta} + Za + e}$$

Where: **y** is a vector of observations for a trait in the analyses**; X** is the incidence matrix associating **β** with **y**; **β** is a vector of fixed effects; **Z** is the incidence matrix associating **a** with **y** ; **β** is vector of randomadditive genetic effect **e** and is the residual effects vector.The normal multivariate joint distribution for **y**, **a**, **e** is:

$$\begin{bmatrix} y \\ a \\ e \end{bmatrix} \sim NMV \left\{ \begin{bmatrix} X\beta \\ 0 \\ 0 \end{bmatrix} ; \begin{bmatrix} ZGZ'+R & ZG & R \\ GZ' & G & 0 \\ R & 0 & R \end{bmatrix} \right\}$$

In the four-trait analyses the **G** matrix is given by $\mathbf{G_0}$ A , where **A** is the relationship matrix between the animals, and $\mathbf{G_0}$is the matrix of genetic variances and covariances between the traits. Also, the **R** matrixis given by $\mathbf{R_0}$ **I**, where **I** is the identity matrix of equal order to the number of observations, and $\mathbf{R_0}$ is the matrix of residual variances and covariance between the traits.

The analyses were performed under a Bayesian approach using the MTGSAM software (Van Tassel and Van Vleck 1995). Gibbs chains of 550,000 iterations were generated, with an initial burn-in of 50,000 samples and sampling interval of 1,000. The convergence was tested using the Geweke and the Heidelberger-Welch diagnostic tests, available at CODA (Convergence Diagnosis and Output Analysis), implemented in R software.

To decide the partial production periods to be indicared as a selection criterion we estimated the correlated response (CR) in the total egg production as a function of selection in the different partial periods.The CR in bird weight and egg weight in the different partial periods were also calculated. The CR was calculated according to Falconer (1989):

$$\mathbf{CR_y} = \frac{\mathbf{r}_g\ \mathbf{h_x h_y}\ \mathbf{i}\ \boldsymbol{\sigma}_\mathbf{y}}{\mathbf{2}}$$

Where: $\mathbf{h_x}$ and $\mathbf{h_y}$ are the square root of the heritability of the **x** and; **y** traits, respectively; $\mathbf{r_g}$ is the genetic correlation between the traits **x** and **y** ; is the selection intensity (1.52); $\boldsymbol{\sigma}_\mathrm{y}$ and is the phenotypic deviation for the trait **y** , where **x** and **y** are the selection criteria and objectives, respectively. The correlated responses estimated were divided by two, due it to the fact that selection was made based on the females.

The relative efficiency of the indirect selection (RE) for total egg production was calculated as a ratio between the genetic gain from the indirect selection (*i.e* each partial production period) on the total production and the genetic gain in the total production obtained by direct selection, as follows:

$$\mathbf{RE_{y}} = \frac{\mathbf{i_{pep} r_g h_{pep}}}{\mathbf{i_{tep}\ h_{tep}}}$$

where: $\mathbf{h_{pep}}$ is the square root of the heritability of the partial period**;** $\mathbf{h_{tep}}$ is the square root of the heritability of the total period; $\mathbf{r_g}$ is the genetic correlation between the partial and total periods, and **i** is the selection intensity for the partial and total periods.

Results and discussion

Heritability estimates and their respective mean confidence intervals are presented in Table 1.

All chains presented convergence and small mean confidence intervals. The heritability for TEP was of low magnitude, and the same estimate was observed in all periods for the yellow (0.05) and black (0.15) lineages. However, we observed an increase in heritability in the black lineage (see table 1). Heritability estimates for TEP indicated that gain in this trait should be small by direct selection in every selection cycle. This indicates that the phenotype of the trait is highly influenced by the environment. Another possible cause of the low heritability in these populations is the reduction of genetic variability as a consequence of inbreeding. Similar to this study low heritability estimates (0.11 and 0.08) for total egg production were reported in two lineage of laying hens by Nurgiartiningsih et al (2005). In three generations of Japanese quail, heritabilities estimates varying from low to high (0.12, 0.33 and 0.48) were reported for the number of eggs, indicating an increase in additive genetic variance over the generations, as reported by Okenyi et al (2013). High heritability estimates (0.43) for monthly egg production in laying quail were reported by Narinc et al (2013).The high heritabilities estimates for total egg production reported by the authors indicate that genetic gain was obtained when selecting the birds by the means of this trait, unlike the results our study, in which the low heritability estimates indicate lower genetic gain, selecting the birds for the total eggs production.

For PEP, the heritability in our study was moderate and similar in both lineages in each period.

PEP1 presented slightly lower values (0.25 and 0.26) when compared to the other periods (Table 1). Heritability estimates for PEP indicated that this trait has potential response to selection. For egg production in partial periods, lower estimates of heritabilities than those presented in this study (0.05 to 0.27) were reported by Venturini et al (2013) in laying hens. In meat quail, for partial production of eggs, lower heritability estimates were found for the genetic groups UFV1 (0.03 to 0.1) and UFV2 (0.20 to 0.25) by Ribeiro et al (2017). These results indicate the phenotypic variation for PEP in the lineages used in this study is influenced by the environment, and the increase in this trait should be more related to the improvement of environmental components than with selection process.

Table 1. Heritability estimates (h^2) for total egg production, partial egg production, body weight and average egg weight

Lineage	Period	h^2_{TEP}	h^2_{PEP}	h^2_{BW}	h^2_{AEW}
Yellow	P1	0.05 (0.05-0.06)[1]	0.26 (0.24-0.27)[1]	0.63 (0.61-0.66)[1]	0.11 (0.11-0.13)[1]
	P2	0.05 (0.04-0.05)[1]	0.35 (0.33-0.37)[1]	0.62 (0.59-0.65)[1]	0.12 (0.11-0.13)[1]
	P3	0.05 (0.04-0.05)[1]	0.35 (0.33-0.37)[1]	0.63 (0.59-0.65)[1]	0.11 (0.10-0.12)[1]
	P4	0.05 (0.04-0.05)[1]	0.35 (0.33-0.37)[1]	0.62 (0.59-0.65)[1]	0.10 (0.08-0.12)[1]
Black	P1	0.15 (0.14-0.17)[1]	0.25 (0.24-0.27)[1]	0.51 (0.48-0.54)[1]	0.25 (0.23-0.25)[1]
	P2	0.15 (0.14-0.16)[1]	0.34 (0.33-0.36)[1]	0.52 (0.49-0.55)[1]	0.25 (0.23-0.27)[1]
	P3	0.15 (0.14-0.16)[1]	0.34 (0.32-0.35)[1]	0.50 (0.48-0.53)[1]	0.24 (0.21-0.23)[1]
	P4	0.15 (0.14-0.16)[1]	0.34 (0.32-0.36)[1]	0.50 (0.48-0.53)[1]	0.19 (0.16-0.23)[1]

[1] Mean confidence intervals at 90%; TEP total egg production; PEP partial egg production; BW body weight and AEW average egg weight

The heritability for BW in the different periods presented high magnitude values (see table 1). Furthermore, for this trait, a greater proportion of genetic variance in relation to phenotype variance was observed for the yellow lineage compared to the black lineage. The heritability values for BW indicated a response to direct selection with the use of this trait. However, the increase in this traitis not advantageous. The increase in the consumption of food by birds affetcts the production costs, so gain in BW must be controlled. Heritabilities of low to high magnitude (0.10 - 0.90) were reported at different ages in three generations of Japanese quail by Magda et al (2010). In meat quail lineages, Silva et al (2013) reported heritabilities ranging from moderate to high magnitude (0.25 to 0.53). Also, Momo et al (2014) reported low to high magnitude heritabilities estimates (0.10 - 0.82) in different periods in Japanese quail. These results are similar to the estimates reported in our study, indicating that when using body weight for bird selection, it would be possible to obtain response to selection.

The heritability for AEW was low to moderate magnitude, (0.11 to 0.25) and the highest proportion of additive genetic variance was observed in the black lineage (see Table 1). These estimates are related to decrease of genetic variability in the studied population, as a result of the selection program which the quail were submitted. Heritability estimates like those described for the black lineage (0.25) were found for AEW in Japanese quail by Saacti et al (2006). Manaa et al (2015) estimated the heritability for egg weight in two generations of Japanese quail. The authors reported values ranging from low to moderate (0.02 - 0.18) and low to high (0.19 - 0.91) indicating the possibility of genetic gain through direct selection. Karami et al (2017) showed an increase in heritability estimates (0.27 - 0.54) when the age of the quail increased, this fact is related to the increase in the genetic variance rate during the egg production period. However, in this study the genetic variance was similar for all periods (Table 2) as well as the heritabilities (Table 1).

In general, the heritability estimates were low for egg production and weight, suggesting that the environment, management and nutrition have a strong influence on the determination of the phenotypic variation of these traits. As a quantitative trait, egg production is influenced by the environment (Silva 2009). In addition, the animals were kept in a selection core in which they were selected over the years for egg production. This factor contributed to the reduction of genetic variability, an increase in the inbreeding and a reduction of heritability in the populations of this study. According to Teixeira et al (2013), japonese quail have been selected for decades for egg production an quality, causing a decrease in genetic variability and heritability, resulting in lower genetic gain.

For all traits, the estimates of additive genetic variance presented slight changes as the age increased (see Table 2). Furthermore, in general, the estimates presented lower values in the yellow lineage than those reported in the black lineages. For BW, an increase of the additive genetic variance was observed in both lineages until PEP3, but PEP4 showed a decrease.

Table 2. Additive genetic variance (σ^2_a)for total egg production, partial egg production, body weight and average egg weight

Lineage	Period	σ^2_{aTEP}	σ^2_{aPEP}	σ^2_{aBW}	σ^2_{aAEW}
Yellow	P1	14.55 (13.57-15.51)[1]	39.50 (36.71-42.20)[1]	132.25 (123.39-143.10)[1]	0.23 (0.22-0.25)[1]
	P2	14.06 (13.14-15.00)[1]	34.55 (32.47-36.92)	136.60 (125.97-148.28)[1]	0.23 (0.22-0.25)[1]
	P3	14.12 (13.14-15.15)[1]	34.65 (32.61-36.89)[1]	140.92 (129.71-152.70)[1]	0.23 (0.22-0.25)[1]
	P4	14.13 (13.12-15.18)[1]	35.24 (33.00-37.55)[1]	134.78 (124.61-147.72)[1]	0.23 (0.22-0.25)[1]
Black	P1	56.58 (52.41-60.98)[1]	50.23 (52.41-66.98)[1]	101.58 (94.04-108.97)[1]	0.37 (0.34-0.39)[1]
	P2	55.36 (51.54-59.44)[1]	44.16 (41.61-46.94)[1]	102.91 (95.64-111.66)[1]	0.36 (0.33-0.38)[1]
	P3	55.53 (51.80-59.97)[1]	44.48 (41.75-47.33)[1]	107.16 (98.93-116.210)[1]	0.35 (0.33-0.38)[1]
	P4	55.44 (51.70-59.16)[1]	44.54 (41.65-47.49)[1]	103.36 (95.09-111.44)[1]	0.36 (0.33-0.38)[1]

[1]Mean confidence intervals at 90%; TEP total egg production; PEP partial egg production; BW body weight and AEW average egg weight

For the lineages studied, the adequacy of the production system would allow to obtain greater gain with the use of the selection. The environmental conditions includes all environmental effects that may influence the analyzes, being the main sources of error that can cause imprecision in the estimate of the true genetic value of animals (Eler 2017).

Genetic correlations between TEP and PEP, BW and AEW traits are presented in table 3. These estimates were moderate to high magnitude. Furthermore, these results indicate that selection based on PEP1 for boths lineages should result in greater responses in other traits than selection in other periods. Also, the results presented in Table 3 indicates the selection for more productive animals should result in heavier animals and eggs.

Genetic correlations where moderate to high positive correlated between TEP and PEP in all periods (see Table 3). In general, PEP1 presented the highest correlations with the other traits for both lineages, when compared to the other periods. In addition, the estimated genetic correlations were similar in both lineages, suggesting that selection can be performed in a joint manner. Santos et al (2003) found higher estimates (0.71 to 0.99) than our study in laying quail. In meat quail, it was also observed genetic correlations of higher magnitude than those described in this study (0.70 to 0.99) (Teixeira et al 2013). Genetic correlations between the total period and partial periods in meat quail ranged from 0.34 to 0.64 for UFV1 and from 0.44 to 0.47 for UFV2 in the study by Ribeiro et al (2017). However, we should compare with caution, since the number of days comprised in partial periods presents differences.

Table 3. Genetic correlations r_g for total egg production, partial egg production, body weightand average egg weight

Line	Period	$r_{gTEP,PEP}$	$r_{gTEP,BW}$	$r_{gTEP,AEW}$
Yellow	P1	0.52 (0.48-0.55)[1]	0.50 (0.46-0.54)[1]	0.49 (0.43-0.52)[1]
	P2	0.48 (0.44-0.51)[1]	0.49 (0.44-0.53)[1]	0.47 (0.44-0.51)[1]
	P3	0.47 (0.43-0.52)[1]	0.49 (0.44-0.53)[1]	0.48 (0.44-0.52)[1]
	P4	0.48 (0.44-0.52)[1]	0.49 (0.44-0.53)[1]	0.49 (0.45-0.53)[1]
Black	P1	0.53 (0.50-0.57)[1]	0.47 (0.43-0.50)[1]	0.48 (0.44-0.52)[1]
	P2	0.47 (0.43-0.51)[1]	0.44 (0.39-0.48)[1]	0.45 (0.41-0.49)[1]
	P3	0.48 (0.44-0.51)[1]	0.44 (0.39-0.44)[1]	0.45 (0.41-0.49)[1]
	P4	0.47 (0.44-0.51)[1]	0.44 (0.40-0.48)[1]	0.46 (0.43-0.50)[1]

[1] *Mean confidence intervals at 90%;TEP total egg production; PEP partial egg production; BW body weight and AEW average egg weight*

The correlation between TEP and BW suggests that the increase in total egg production should lead to an increase in the body weight of the bird. Genetic correlations higher than those described in this study (0.67 and 0.84) for TEP and BW were reported in quail lineages by Mielenz et al (2006). In contrast to theseresults, Okuda et al (2013) found genetic correlations of low magnitude (0.14) in Japanese quail. However, if the increase in egg production is an aim for quail breeding programs, the increase in body weight is a result of the selection of this population for TEP. In this sense, an alternative is the use of selection indexes for multiple traits, in which the true genetic value is defined as a linear combination of the traits of interest (Silva and Torres 2009). For broilers, the use of selection indexes resulted in better estimates of genetic gain than those observed in direct and indirect selection (Vayego et al 2014).

Genetic correlations between TEP and AEW presented values ranging from 0.45 to 0.49 in boths lineages.From a commercial point of view, the increase of AEW is desirable to grant demands of the market; however, an excessive increase could lead to problems such as prolapse, so the improvement of this trait must be controlled. Also in laying quail, Hidalgo et al (2011) showed correlations values for TEP and AEW of 0.58, 0.09, and 0.09 in yellow, blue and red lineages, respectively. For the yellow lineage, the genetic correlation estimate was positive and moderate confirming the results found in this study, while for the other lineages the values were lower than ours. The selection in PEP1 should allow greater genetic progress in TEP, due to the reduction of the generation interval, and the highest heritability and genetic variance estimate for this period, while direct selection by total egg production presented lower estimates for both heritability and genetic variance.

The correlated response to selection in TEP as a function of selection in PEP was 0.69, 0.76, 0.75, 0.76 eggs/cycle for yellow lineage, and 1.33, 1.48, 1.51, 1.48 eggs/cycle for the black lineage, when the selection was performed on PEP1, PEP2, PEP3 and PEP4, respectively. The genetic gain estimates predicted for each selection cycles showed small changes between the production periods, suggesting that PEP1, i.e which corresponds to the first 60 days of production, should be the most advantageous for selection, given the reduced generation interval, enabling the selection of birds to occur as early as possible and consequently obtaining more genetic progress. Higher levels of genetic gain (2.92 - 4.01) were reported by Santos et al (2003) in quail lineages, indicating that the selection in initial periods results in a lower generation interval and greater achievement of genetic progress per unit of time, confirming the results found in this study. By direct selection of the total egg production in 150 days of laying, the genetic gain was 0.99 eggs/year in the yellow lineage and 2.09 eggs/year for the black lineage.These results indicate that the correlated response was more efficient in the selection of laying quail for total egg production using as selection criterion the egg production in PEP1.

The correlated response in the BW, when the selection was made based on PEP1 for the yellow lineage was 0.83, -0.50, -0.68, -0.68 grams/cycle, and for black lineage of -0.52, -0.12, -0.01, -0.44 grams/cycle in periods PEP1, PEP2, PEP3 and PEP4, respectively. For the yellow lineage, the correlated response in BW resulted in an increase in body weight in PEP1, and a decrease for the other periods. For the black lineage, we observed a decrease in the weight of birds in all periods. For AEW, we found values of 0.01, 0.00, 0.02, 0.04 grams/cycle for correlated response in the yellow lineage and 0.05, -0.01, 0.02, -0.05 grams/cycle for black lineage in the periods PEP1, PEP2, PEP3 and PEP4. For this trait, the impact of the correlated response was small, and selection based on the partial production of eggs in PEP1 allowed to obtain small positive changes in this trait for the yellow lineage. For the black lineage, there was a small increase in PEP1 and PEP3, and a decrease was observed in PEP2and PEP4. The results obtained in BW and AEW in the lineages indicated that this is the appropriate selection criterion.This result occurred due to the negative phenotypic deviation of the trait.

The selection time spent in the total and partial production periods were compared.When we select the birds by TEP it took 260 days, while for the partial periods PEP1, PEP2, PEP3 and PEP4, the time required for each cycle corresponded to 170, 200, 230 and 260 days, respectively. The time period evaluations made it possible to execute 2.14, 1.82, 1.58, 1.40 and 1.40 selection cycles per year, in PEP1, PEP2, PEP3, PEP4 and TEP, respectively. The annual genetic gain defined as a function of the number of selection cycles performed per year was also estimated. The correlated response in the total production resulted in gain of 1.47, 1.38, 1.20, 1.06 eggs/cycle for the yellow lineage, and 2.84, 2.69, 2.38, 2.07 eggs/cycle in the black lineage for the selections in PEP1, PEP2, PEP3 and PEP4, respectively. In direct selection of TEP, it was possible to achieve genetic gain of 1.38 eggs/year for yellow lineage and 2.92 eggs/year for the black lineage.

The results presented above indicate that indirect selection for yellow lineage resulted in greater genetic progress in the TEP compared to direct selection. However, for black lineage, direct selection resulted in higher gain in TEP, but we recommend the indirect selection, since the difference between the values were small. Additionally, we recommend using PEP1 as selection criteria, for the identification of the superior animals is performed at the beginning of the posture cycle. This allows an increase in the selection intensity, and make more than one selection cycle per year, consequently increasing the number of females in the breeding stock and the genetic gain.

The relative efficiency of the indirect selection based on the means of genetic gain predicted for total production on PEP1 was 1.87 for the yellow lineage, and 0.90 for the black lineage. In laying quail, Santos et al (2003) reportedselection efficiency estimates of 0.78, 0.92, 0.85, 0.90, 0.96 and 0.98 for six partial periods. These authors indicate the superiority of partial period two use for selection of birds, since the information was collected in only two months, and an increase of 6% in selection efficiency was be achieved in period six.

In meat quail, Ribeiro et al (2017) reported values of relative efficiency of low to moderate selection efficiency (0.16-0.40 for UFV1 and 0.45-0.49 for UFV2) compared to the total production period. In our study, the efficiency of selection indicated the indirect selection was more efficient in promoting increase in TEP in the selection of females for PEP1 on the yellow lineage. While in the black lineage, direct selection by TEP promoted a superior increase compared to the indirect selection by PEP1. However, when the genetic gain was considered, the use of PEP1 was recommended. Although, this period presented lower selection efficiency in the black lineage, the genetic correlation with the total production was higher, and the heritability for total production was low than partial production periods. Additionally, the generation interval was smaller, making it possible to make up to two generations per year and identify genetically superior animals earlier.

Conclusions

- Indirect selection showed greater efficiency in producing genetic gain compared to direct selection.
- It is recommended to adopt the first partial period, corresponding to 60 days of posture as a selection criteria, allowing the reduction of the generation interval, and making it possible to perform selection two times a year, helping to identify earlier superior individuals, while they have high production rates.

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Conflict of interest

The authors declare to have no conflict of interest.

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