Estimation of genetic parameters of important economic traits in Aravali chicken

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Journal of Livestock Science (ISSN online 2277-6214) 17: 932-936
Received on 25/2/26; Accepted on 28/10/26; Published on 1/11/26
doi. 10.33259/JLivestSci.2026.932-936

Abstract

The present investigation utilized performance records of Aravali birds spanning one generation to estimate genetic parameters of economically important traits. A mixed linear model was employed for the analysis, incorporating sire as a random effect and mean as fixed effect. The performance traits including age at first egg (AFE), egg weight at 28 weeks of age (BW28) and 40 week of age (EW40), body weight at 16 weeks of age (BW16) and 40 weeks of age (BW40) and egg number up to 40 weeks (TEN40). Highly significant ($P \leq 0.01$) effect of sire was observed on AFE trait. The least squares means for performance traits AFE, EW28, EW40, BW16, BW40, TEN40 were 157.78±1.63 days, 37.87±0.30 g, 42.47±0.26 g, 900.46±11.99 g, 1498.24±16.12 g and 47.24±1.21 days, respectively. The heritability estimates were low to moderate for all the traits. Age at first egg (AFE) showed a strong positive association with total egg number up to 40 weeks of age (TEN40). Body weight at 16 weeks (BW16) exhibited a moderate positive correlation with body weight at 40 weeks (BW40). In contrast, egg weight at 40 weeks (EW40) was negatively correlated with total egg production up to 40 weeks (TEN40). Thus, it suggests a modest yet significant potential for genetic improvement. The observed correlations among key traits provide a useful basis for formulating effective selection strategies to enhance overall productivity.

Keywords: Body weight, Egg weight, Egg production, Heritability, Aravali

Introduction

Indigenous chicken genetic resources play a vital role in sustainable rural poultry production, particularly in low-input systems where adaptability, disease resistance and survivability are critical (Singh et al., 2025). Estimation of genetic parameters such as heritability, genetic and phenotypic correlations is fundamental for designing effective breeding programs because these parameters quantify the proportion of trait variability attributable to additive genetic effects and describe the genetic relationships between traits (Szwaczkowski, 2003; Bekele et al., 2024). Accurate estimates enable breeders to predict selection response and prioritize traits that can achieve long-term genetic improvement under local production conditions (Manjula *et al.*, 2017; Fekede & Tadesse, 2021).

The reliability of genetic parameter estimates is breed-specific, as indigenous populations differ from commercial chicken strains in terms of genetic structure, adaptive traits and environmental interactions. Studies on native chickens worldwide have reported moderate heritability for growth and body-weight traits, suggesting considerable scope for genetic improvement through selection (Chandan *et al*., 2019). Egg production-related traits such as age at first egg, egg number, and egg weight typically show low to moderate heritability but often exhibit favourable genetic correlations, indicating the potential for correlated responses in selection programs (Lin *et al.*, 2025).

The Aravali chicken is a recognized indigenous dual-purpose breed from Gujarat registered by ICAR–NBAGR as India's 20th chicken breed (Accession No. INDIA_CHICKEN_0400_ARAVALI_12020) confirming its genetic and phenotypic distinctiveness. The breed is predominantly distributed in the districts of Banaskantha, Sabarkantha, Aravalli and Mahisagar, where it is traditionally reared under low-input rural and backyard farming systems. Recent evaluations have indicated that Aravali hens reach sexual maturity at 6.25 months under field conditions and 5.67 months under farm conditions, while the annual egg production up to 56 weeks of age averages 72.36 eggs in field flocks and 95.04 eggs under farm management (Savaliya *et al*., 2024). Despite its regional importance, adaptability and potential for backyard and semi-intensive systems, scientific information on its genetic parameters remains scarce. Understanding the genetic architecture of growth, reproductive and production traits in Aravali chicken is essential for establishing a structured breeding plan aimed at enhancing its productivity while preserving its unique genetic identity.

Therefore, the present study was undertaken to estimate heritability, genetic and phenotypic correlations for key economic traits in Aravali chicken. These estimates are crucial for developing effective selection plans, enhancing the productivity of this indigenous breed and ensuring its long-term conservation and utilization within regional poultry improvement programmes.

Material and methods

Data

The study utilized data from Aravali birds maintained at Poultry Research Station, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Anand. The dataset of S_1 generation comprised of 218 observations from 25 sire classes of Aravali chicken. Individual birds were housed in separate cages and identified using wing bands, sire and dam identification information was included in the data records. Standardized feeding and management practices were followed, along with the routine vaccination schedule implemented at the farm.

Traits Recorded

The traits evaluated in the study included age at first egg (AFE)**,** measured as the number of days from hatching until the pullet laid its first egg**.** Egg weight at 28 weeks (EW28) and 40 weeks (EW40) was obtained as the mean weight of five consecutive eggs laid by each bird at the respective ages. Body weight at 16 weeks (BW16) and 40 weeks (BW40) was recorded individually using a digital weighing balance. In addition, total eggs laid up to 40 weeks of age (TEN40) was calculated for laying performance and productivity.

Statistical Analysis

Data recorded on growth and egg production traits were analyzed using mixed model least squares analysis of variance and maximum likelihood program (Harvey, 1977). Heritability was estimated using the paternal half-sib correlation method based on the sire component of variance. This approach was adopted to obtain preliminary estimates of genetic parameters from the available sire-family structure. Genetic and phenotypic correlations were estimated using the corresponding variance and covariance components obtained from the fitted statistical model. The estimates were interpreted cautiously because the analysis was based on a single generation and did not incorporate a comprehensive animal model accounting for relevant environmental effects.

$$Yik=\mu+Si+eik$$

Where, Yik = Value of a trait measured on the k^{th} individual belonging to the i^{th} sire, μ = Population mean (fixed effect), Si = Random effect of the i^{th} sire, eik= Random error associated with each and every observation and assumed to be normally distributed with mean zero and variance σ2e.

Results and Discussion

Although birds were maintained under standardized feeding and management practices, variation in egg production and growth traits may also have been influenced by environmental factors such as seasonal variation, nutrition and individual micro-environment. These effects were not explicitly represented in the statistical model used for the present analysis. Therefore, the residual variation may include both unaccounted environmental effects and other sources of variation. Future analyses should consider relevant environmental effects where reliable records are available. In Aravali females, the least squares means of various traits viz., AFE, EW28, EW40, BW16, BW40 and TEN40 were 157.78±1.63 days, 37.87±0.30g, 42.47±0.26g, 900.46±11.99g, 1498.24±16.12g and 47.24±1.21 eggs, respectively. However, Sire was found to have a significant (P≤0.05) effect for AFE but not on other traits. The significant sire effect observed for AFE provides additional evidence of variation among sire groups, although further evaluation across generations is required to establish the reliability of this estimate.

The Age at First Egg (AFE) of the Aravali was comparable to Aseel of Bangladesh (Sarker *et al.*, 2012), backyard poultry breed Vanraja and Pallishree (Satpathy *et al.*, 2020), Ankaleshwar of Gujarat (Patel *et al*., 2020). It is substantially lower compared to Aseel and Kadaknath reared under northern Indian conditions (Dalal *et al.*, 2019), Indian native breeds viz., Aseel and Kadaknath (Haunshi *et al.,* 2011), Nicobari chickens (Chatterjee *et al*., 2004), Aseel and Kadaknath (Pandey *et al.*, 2022), Aseel (Rathi *et al.*, 2024).

The EW40 of the present population was comparable to Ankaleshwar (Patel *et al.,* 2020) and Kadaknath (Dalal *et al.,* 2019), while for Aseel it was found to be high (*Dalal et al., 2019*) and low (Rathi *et al.*, 2024). Egg weights at both 28 and 40 weeks were generally higher in Aseel and lower in Kadaknath compared with Aravali chicken (Haunshi *et al.,* 2011, Pandey *et al.*, 2022).

The BW16 of the present population was reported to be lower than Aseel (Sarker *et al.,* (2012), whereas it remained comparable to Aseel (Dalal *et al.,* 2019). The BW40 was also found to be higher in Aseel (Dalal *et al.,* 2019). In Kadaknath, BW16 was lower, while BW40 was comparable to the present estimate (Dalal *et al.,* 2019). Further, BW40 was comparable in Aseel and lower in Kadaknath (Pandey *et al.,* 2022), which aligns with the present findings. Similarly, higher BW40 was reported in Aseel and lower in Kadaknath (Haunshi *et al.,* 2011) relative to the current population. In contrast, both BW16 and BW40 were comparable to Ankaleshwar chicken (Patel *et al.,* 2020).

The Total Egg Number (TEN40) of the Aravali was lower than that of Kadaknath and higher than Aseel (Haunshi *et al.*, 2011). However, both Aseel and Kadaknath exhibited lower TEN40 values (Pandey *et al*.,2022; Dalal *et al*., 2019) as well as Ankaleshwar (Patel *et al.*, 2020).

Heritability

The heritability estimate of AFE, EW28, EW40, BW16, BW40 and TEN40 were as 0.41±.22, 0.18±0.18, 0.17±0.18, 0.11±0.16, 0.08±0.16 and 0.12±0.16, respectively (Table 2).

AFE exhibited the highest heritability point estimate (0.41 ± 0.22) among the traits studied. This suggests that additive genetic variation may contribute relatively more to differences in sexual maturity than to variation in the other traits within the evaluated population. Consequently, AFE may be a candidate trait for genetic improvement through selection. Earlier sexual maturity may also have practical value in improving the timing of entry into egg production. The heritability estimate for Age at First Egg (AFE) in the Aravali chicken was higher than the values reported for Aseel and Kadaknath (Dalal *et al*., 2019) as well as for Aseel (Rathi *et al.*, 2024). Similarly, it exceeded for Kadaknath, while in confirmation with Aseel (Pandey *et al*., 2022). Further, it was also slightly higher than Vanaraja (Rajkumar *et al.*, 2020[a]).

Table 1. Overall means, standard errors and tests of sire effects for economic traits in Aravali chicken

Traits	Least Square Mean ± SE	P-value for sire effect
AFE (days)	157.78 ± 1.63	0.0059
EW28 (g)	37.87 ± 0.30	0.1134
EW40 (g)	42.47 ± 0.26	0.1159
BW16 (g)	900.46 ± 11.99	0.2047
BW40 (g)	1498.24 ± 16.12	0.2643
TEN40 (eggs)	47.24 ± 1.21	0.1930

Table 2: Heritability (at the diagonal), Genetic (above the diagonal) and phonotypic (below) correlation coefficients for various economic traits

Traits	AFE	EW28	EW40	BW16	BW40	TEN40
AFE	**0.41±0.22**	-0.44	-0.21	-0.33	0.63	-0.78
EW28	-0.11	**0.18±0.18**	0.21	0.56	-0.30	0.57
EW40	0.05	-0.08	**0.17±0.18**	0.48	-0.16	-0.10
BW16	-0.44	0.04	-0.08	**0.11±0.16**	0.61	0.55
BW40	.029	-0.06	0.05	0.35	**0.08±0.16**	-0.37
TEN40	-0.41	0.18	-0.16	0.16	0.02	**0.12±0.16**

The heritability estimates for EW28 and EW40 were found to be 0.18 ± 0.18 and 0.17 ± 0.18, indicating a low proportion of phenotypic variance attributable to additive genetic effects. This suggests that selection based solely on individual egg weight records may produce an uncertain response in the present population. Egg weight is also influenced by age, nutrition and management conditions. Further evaluation across generations would help determine whether sufficient additive genetic variation is available for effective improvement of this trait. Genetic improvement of egg weight should therefore be planned using more reliable estimates and, where appropriate, evaluated alongside egg production and other economically important traits. Further, present estimate also considerably lower than most values reported in earlier studies on indigenous chickens viz. Vanaraja, Gramapariya, Aseel and Kadaknath (Dalal *et al*., 2019; Rajkumar *et al.*, 2020[a]; Rajkumar *et al.*, 2020[b]; Rathi *et al.*, 2024; Pandey *et al*., 2022).

The heritability estimate for BW16 was 0.11 ± 0.16. This suggests that differences in early body weight may not be reliably explained by additive genetic variation alone. Nutrition, health, rearing conditions and other environmental influences may also contribute to observed differences. Although early body weight could be considered as a candidate trait for selection, the current estimate does not establish the magnitude of the expected response. Also, BW40 showed the lowest heritability among all the six traits (0.08 ± 0.16). This suggests a relatively small estimated proportion of phenotypic variance attributable to additive genetic effects in the studied population. The current estimates fall markedly below most of the heritability values documented in previous research on indigenous chickens, including Vanaraja, Aseel, Kadaknath, Uttara, Gramapariya and Nigerian chicken (Rajkumar *et al.*, 2020[a]; Rajkumar *et al.*, 2020[b]; Rathi *et al.*, 2024; Pandey *et al*., 2022; Dalal *et al*., 2019; Singh *et al.*, 2018; Adeleke *et al.*, 2011).

TEN40 exhibited a heritability estimate of 0.12 ± 0.16, indicating a low point estimate of additive genetic contribution to phenotypic variance. Egg number is an economically important reproductive trait that can also be influenced by sexual maturity, nutrition, health and management. The current estimate suggests that the response to direct selection may be difficult to predict reliably from the available data. Multi-generation evaluation, together with better accounting for environmental effects, would help establish the genetic potential for improving egg production in Aravali chicken. The present estimate is slightly lower than Vanraja, Gramapriya and Kadaknath (Rajkumar *et al.*, 2020[a]; Rajkumar *et al.*, 2020[b]; Dalal *et al*., 2019). However, substantially lower than Aseel and Kadaknath (Rathi *et al.*, 2024; Pandey *et al*., 2022; Dalal *et al*., 2019).

Overall, additive genetic variance may account for a relatively greater proportion of the phenotypic variance in AFE than in the other traits within the studied population. Nevertheless, the relatively large standard error as well as smaller population size indicates considerable uncertainty in this estimate. Therefore, further evaluation using additional generations and larger datasets is required to establish the reliability of these estimates.

Genetic and Phenotypic Correlations

A favorable, strong negative genetic correlation was observed between AFE and TEN40 (r=-0.78), implying that selection for earlier sexual maturity will enhance overall egg production, a pattern widely documented in indigenous germplasm. The direction of the genetic and phenotypic relationships observed in the present study is largely consistent with earlier reports in Aseel and Kadaknath (Dalal *et al.*, 2019; Rathi *et al.*, 2024). Also, moderately strong positive association was observed between BW16 and BW40 (r=0.613) indicating an effective early selection criterion for improving mature body weight. However, a substantial genetic antagonism between EW40 and TEN40 (r=-0.10), reinforcing the classic physiological trade-off where selection for increased egg weight may compromise laying intensity of Aravali chicken. However, such genetic association between egg weight and egg number aligns with the physiological constraints in Vanaraja and Gramapriya lines (Rajkumar *et al.*, 2020[a,b]).

Conclusion

The present study provides preliminary estimates of genetic parameters for important economic traits in Aravali chicken using records from a single generation. AFE exhibited a moderate heritability, whereas egg weight, body weight and total egg number showed lower estimates. Further analyses incorporating additional generations and relevant environmental effects need to explore. Though, the findings provide an initial basis for future genetic evaluation and the development of a balanced breeding strategy aimed at improving productivity while conserving the genetic identity of Aravali chicken.

Acknowledgement

The authors sincerely acknowledge Principal, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Anand for providing the necessary facilities and support to carry out this research.

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