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Effect of Genetic and Non-genetic Parameters on Growth and Production Traits in Punjab Brown, PB1 and PB2 Lines

Z. M. Vishwambar[1], Gurjot Kaur Mavi[1], S. K. Sahoo[1], P. P. Dubey[1], Narinder Singh[2], R. S. Grewal[3] and Puneet Malhotra[1]

[1]Dept. of Animal Genetics and Breeding, [2]Dept. of Animal Reproduction, Gynaecology and Obstetrics, [3]Dept. of Animal Nutrition, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab (141 004), India

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Corresponding gurjot.mavi89@gmail.com

0000-0003-4259-7362

ABSTRACT

The present study was undertaken during (August, 2023–January, 2025) at the Poultry Research Farm, Directorate of Livestock Farms, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana, Punjab, India, to evaluate the genetic performance of three dual-purpose chicken lines, PB1, PB2 and Punjab Brown, with respect to growth and reproduction traits to support future selection and breeding programmes. A total of 1328 birds comprising PB1 (n=549), PB2 (n=490) and Punjab Brown (n=289) were maintained under standard management conditions and evaluated from 5 to 52 weeks of age. Body weights were recorded at 5, 20 and 40 weeks, while reproductive traits included age at sexual maturity (ASM), egg number up to 40 weeks (EN40) and egg weight at 40 and 52 weeks (EW40, EW52). Variance components were estimated using REML under a multi-trait animal model, including hatch and sex as fixed effects. Significant differences ($p \leq 0.01$) were observed among the lines for growth traits, with PB1 showing the highest mean body weights followed by PB2 and Punjab Brown. Heritability estimates for body weight traits were moderate to high (0.28–0.55), indicating good scope for genetic improvement, while egg production traits exhibited low heritability (<0.20). It was concluded that PB1 and PB2 possessed strong genetic potential for growth improvement, whereas Punjab Brown remained valuable for adaptability. Selection during early growth stages was recommended to maximize genetic gains, while reproductive traits might require integration of genetic selection with improved management.

KEYWORDS: Punjab brown, heritability, growth traits, reproductive traits, REML

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1. INTRODUCTION

Poultry genetic improvement programs are central to enhancing the productive performance, adaptability and long-term sustainability of chicken populations across varied production systems. In rural and low-input environments, where climatic stress, feed scarcity and minimal management prevail, dual-purpose chicken lines capable of supplying both meat and eggs provide significant livelihood support. India has invested extensively in developing improved colored strains and strengthening indigenous germplasm to achieve a balance between resilience and productivity (Vij et al., 2006). Among the developed and native lines, Punjab Brown, PB1 and PB2 are widely recognized for their suitability in backyard and organized sectors. Punjab Brown is a hardy indigenous line known for its ability to thrive under harsh climatic and nutritional conditions (Haunshi et al., 2011). Its strong survival ability, scavenging behavior and disease tolerance support stable production even with limited inputs. PB1, developed through structured breeding, emphasizes balanced improvement in growth and egg production (Padhi, 2016). PB2, in contrast, was developed with early growth and meat traits as primary goals, while retaining moderate reproductive performance (Chomchuen et al., 2022). Evaluating these three lines together provides a clear understanding of their potential roles in commercial systems, backyard settings and conservation programs. Growth traits remain fundamental economic indicators in poultry breeding. Early body weight, pre-laying body weight and the commonly assessed 20-week body weight serve as reliable predictors of later growth and carcass performance (Parte et al., 2024). Genetic studies in dual-purpose and indigenous birds demonstrate that substantial variability exists for intermediate-age weights, enabling improvement without compromising adaptability (Singh et al., 2023). Genome-wide investigations have identified key loci affecting growth, muscle traits and body development, supporting the integration of genomic tools into dual-purpose breeding strategies (Yang et al., 2021). Additional evidence shows that structural variations can influence early-life growth, highlighting the importance of molecular-level evaluation (Li et al., 2021). Performance comparisons among broiler strains further demonstrate the broad genetic diversity that can be harnessed for future improvement programs (Singh et al., 2021). Studies evaluating slow- and fast-growing strains also underscore differences in efficiency and carcass attributes relevant to dual-purpose breeding (Torrey et al., 2021). Reproductive traits such as age at sexual maturity, hen-day egg production and egg weight considerably influence flock productivity. However, reproductive traits tend to show lower heritability and stronger environmental sensitivity, making selection more complex (Tunsisa and Reda, 2022). Even so, studies on synthetic and indigenous lines have demonstrated moderate genetic variability for egg traits, allowing gradual improvement through selective breeding (Ni et al., 2023). Research on Ethiopian Tilili chickens confirms the scope for genetic progress in both growth and reproductive traits under tropical conditions (Kassa et al., 2025). Similar findings have been observed in Indian Aseel chickens, where moderate heritability and distinct morphometric characteristics support their involvement in structured selection efforts (Rajkumar et al., 2017). Trait expression is also shaped by environmental influences such as hatch conditions, brooding environment and management practices. Hatch differences can arise from temperature or humidity variations, while sex-based differences emerge after the onset of sexual dimorphism, with males consistently exhibiting higher body weights (Haunshi et al., 2022). Evaluating these non-genetic influences is necessary to separate environmental variance from true genetic merit. Reproductive efficiency traits particularly fertility, hatchability and immune competence are essential for sustaining dual-purpose breeding programs. Studies on native chickens have shown heritable variation in immune response and survival following Newcastle disease infection, indicating potential to improve disease resilience genetically (Touko et al., 2021b). Integrating phenotypic and genetic evaluations thus supported the development of line-specific breeding plans and contributed to the long-term conservation of Native poultry genetic resources (Chaikuad et al., 2022).

2. MATERIALS AND METHODS

2.1. *Experimental location and animal resources*

The present investigation was carried out during (August, 2023–January, 2025) at the Poultry Research Farm, Directorate of Livestock Farms, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana, Punjab, India on three chicken genetic groups (PB1, PB2 and Punjab Brown) maintained. A total of 1328 birds consisting of PB1 (n=549), PB2 (n=490) and Punjab Brown (n=289) were used for the study.

2.2. *Experimental design and management*

The birds were reared from hatch up to 52 weeks of age under standard management conditions. Day-old chicks were wing-banded for identification and brooded under uniform temperature. All birds were housed in an open-sided deep litter housing system and were provided with standard feed as per BIS recommendations along with routine vaccination and health care. Male and female chicks were reared together up to 16 weeks of age and separated thereafter. Artificial lighting of 16 h light and 8 h dark (16L:8D) was provided after 20 weeks to stimulate egg production in laying females.

2.2.1. Growth traits

Body weights were recorded individually at 5 weeks (BWT5), 20 weeks (BWT20) and 40 weeks (BWT40) of age.

2.2.2. Reproductive traits

Reproductive performance traits included age at sexual maturity (ASM), egg number up to 40 weeks (EN40), and egg weight at 40 weeks (EW40) and 52 weeks (EW52). Fertility (%) and hatchability on total egg set (%) were estimated from pedigree hatches maintained within each line.

2.3. Statistical and genetic analysis

Least squares means were estimated considering line, sex and hatch as fixed effects. Genetic parameters were estimated by Restricted Maximum Likelihood (REML) using WOMBAT software.

The following linear model was used:

$Y=Xb+Za+e$

where,

Y=Vector of observations

b=Vector of fixed effects (line, sex, hatch)

a=Vector of random additive genetic effects

X and Z=Incidence matrices

e=Random residual error

Heritability (h^2) was estimated using:

$h^2=(\sigma^2_a)/(\sigma^2_a+\sigma^2_e)$

where h^2 was heritability, σ^2_a was additive genetic variance and σ^2_e was residual variance. All analyses were performed by REML using WOMBAT software.

3. RESULTS AND DISCUSSION

3.1. Growth traits

The evaluation of PB1, PB2 and Punjab Brown revealed significant differences in growth performance, indicating clear genetic variability among the three lines. PB1 recorded the highest body weights at all ages, followed by PB2, while Punjab Brown showed lower growth but better adaptability. At 5 weeks of age, PB1 had the highest mean body weight (1153.16±7.83 g) (Table 1) compared to PB2 (988.42±9.26 g) (Table 2) and Punjab Brown (759.65±13.01 g) (Table 3) ($p\leq0.01$). Comparable observations have been reported in indigenous and dual-purpose coloured chicken lines, where males consistently outweighed females during early growth phases (Singh et al., 2023). Similar trends were observed at 20 and 40 weeks, confirming that PB1 and PB2 maintained superior growth potential throughout the observation period. These findings were in agreement with earlier studies on improved coloured poultry lines where synthetic strains outperformed native breeds in growth traits (Padhi, 2016; Parte et al., 2024). Punjab Brown, although lighter, showed growth values within the expected range for indigenous chickens, reflecting its better adaptability, survivability and genetic stability under low-input farm conditions.

3.2. Reproductive traits

Significant variation was also observed in reproductive traits among the three genetic groups. Age at sexual maturity (ASM) ranged from 157 to 160 days, with PB1 (158.68 ±0.39) and PB2 (146.73±0.536) maturing slightly earlier compared to Punjab Brown (161.51±0.96). Indigenous and improved dual-purpose chickens typically reach sexual maturity between 150–180 days (Rajkumar et al., 2017). Egg number up to 40 weeks (EN40) was highest in PB1

Table 1: Least square means along with their standard errors of different growth and and production traits of PB1 birds

Traits	Overall (N=549)	Sex		Hatch		
		Male (N=90)	Female (N=459)	Hatch 1 (N=255)	Hatch 2 (N=184)	Hatch 3 (N=110)
BWT 5 (g)	1153.16±7.83	1282.26*±13.98	1024.06±7.08	1057.30c±10.63	1148.94b±11.20	1253.24a±13.73
BWT 20 (g)	2764.39±18.90	3141.43*±33.73	2387.35±17.09	2761.16b±25.65	2838.87a±27.02	2693.14b±33.14
BWT 40 (g)	3464.73±13.62	3873.19*±24.31	3056.26±12.31	3401.48b±18.48	3528.48a±19.47	3464.23a±23.89
ASM (days)	158.68± 0.39	-	158.68±0.39	157.12b±0.50	159.20a±0.63	159.72a± 0.85
ENO 40	52.67±0.44	-	52.67±0.442	61.15a±0.56	49.31b±0.71	47.55b±0.96
EWT 40 (g)	55.16±0.18	-	55.16±0.18	55.20±0.24	55.32±0.30	54.96±0.41
EWT 52 (g)	55.58±0.10	-	55.58±0.10	55.47±0.13	55.59±0.17	55.67±0.23
Fertility (%)	81.37±0.98	-	81.37±0.98	81.47±0.12	81.33±0.15	81.30±0.21
Hatchability (%)	74.47±0.08	-	74.47±0.08	74.41±0.10	74.54±0.13	74.46±0.17

Significant at 5% level ($p\leq0.05$), Superscripts indicate significant difference within the columns (a, b, c)

Table 2: Least square means along with their standard errors of different growth and production traits in PB2

Traits	Overall (N=490)	Sex		Hatch		
		Male (N=90)	Female (N=400)	Hatch 1 (N=141)	Hatch 2 (N=292)	Hatch 3 (N=57)
BWT 5 (g)	988.42±9.26	1078.20*±15.27	898.65±8.17	1000.03±9.33	973.81±12.82	991.43±18.92
BWT 20 (g)	2565.44±28.18	2887.02*±46.49	2243.87±24.88	2594.27±28.51	2564.20±39.00	2537.86±57.59
BWT 40 (g)	3364.84±14.48	3967.01*±23.89	2762.67±12.79	3362.47±14.67	3365.04±20.04	3367.02±29.59
ASM (days)	146.73±0.536	---	146.73±0.536	148.23^{a}±0.57	146.30^{b}±0.80	145.66^{b}±1.27
ENO 40	53.44±0.85	---	53.44±0.85	52.93^{a}±0.90	57.73^{b}±1.27	49.68^{b}±2.02
EWT 40 (g)	50.02±0.20	---	50.02±0.20	50.28±0.22	50.35±0.31	49.42±0.49
EWT 52 (g)	58.51±0.16	---	58.51±0.16	58.43±0.17	58.49±0.24	58.61±0.38
Fertility (%)	80.16±0.71	---	80.16±0.71	80.40±0.75	80.46±1.06	79.61±1.69
Hatchability (%)	74.26±0.63	---	74.26±0.63	74.33±0.67	74.58±0.94	73.87±1.49

Significant at 5% level ($p \leq 0.05$), Superscripts indicate significant difference with in the columns (a, b, c)

Table 3: Least square means along with their standard errors of different growth and production traits of Punjab brown

Traits	Overall (N=490)	Sex		Hatch		
		Male (N=90)	Female (N=400)	Hatch 1 (N=141)	Hatch 2 (N=292)	Hatch 3 (N=57)
BWT 5 (g)	759.65±13.01	786.45*±19.71	732.85±13.95	886.57^{a}±25.94	750.41b±23.66	641.97^{c}±13.32
BWT 20 (g)	1553.83±18.62	1736.88*±28.19	1370.78±19.96	1616.62^{a}±37.10	1546.30^{ab}±33.84	1498.55^{b}±19.06
BWT 40 (g)	2262.82±17.46	2602.69*±26.44	1922.95±18.72	2285.90±34.80	2267.26±31.74	2235.30±17.87
ASM (days)	161.51±0.96	-	161.51±0.96	165.18^{a}±2.01	160.62ab±1.80	158.73b*±1.00
ENO 40	59.70±1.07	-	59.70±1.07	64.78^{a}±2.25	56.90b±2.01	57.44^{b}±1.12
EWT 40 (g)	47.86±0.28	-	47.86±0.28	47.40±0.59	47.87±0.54	48.30±0.30
EWT 52 (g)	49.12±0.21	-	49.12±0.21	49.65±0.45	48.85±0.40	48.86±0.22
Fertility (%)	80.78±0.93	-	80.78±0.93	80.28±1.96	81.42±1.75	80.64±0.98
Hatchability (%)	74.473±0.82	-	74.473±0.82	73.09±1.73	75.47±1.55	74.85±0.86

Significant at 5% level ($p \leq 0.05$), Superscripts indicate significant difference with in the columns (a, b, c)

(61.15 eggs), followed by PB2 (49.31 eggs) and Punjab Brown (47.56 eggs) ($p \leq 0.01$), indicating better persistency of lay in PB1. In Tilili chickens, egg weight showed only modest correlations with body weight, suggesting that egg size was largely independent of growth (Kassa et al., 2025). Egg weight remained nearly uniform (~55 g) across all lines ($p > 0.05$), which was desirable for market preference and hatchery operations. Long-term egg production in native breeds often correlates moderately with earlier egg numbers but weakly with growth (Padhi, 2016; Chomchuen et al., 2022). Fertility (≈81%) and hatchability (74–75%) did not differ significantly among lines, suggesting that reproductive efficiency was well maintained across all genetic groups under intensive breeding conditions. Tunsisa and Reda (2022) reported 78.17% fertility and 84.1% hatchability (fertile-egg basis) in indigenous chickens of the Sidama region of Ethiopia which was consistent with PB2 performance. Hatchability values between 70–80% were typical in coloured dual-purpose breeds (Vij et al., 2006).

3.3. Non-genetic factors

Non-genetic factors such as sex and hatch significantly influenced growth and production traits. Strain effect was highly significant ($p \leq 0.01$) for growth traits, confirming genetic divergence among PB1, PB2 and Punjab Brown. Similar strain effects have been reported by Singh et al. (2023). Gender had no significant effect during early growth (5 weeks) but was highly significant ($p \leq 0.01$) at 20 and 40 weeks. In all three lines, males were consistently heavier than females, confirming sexual dimorphism in growth performance. These findings are consistent with a recent study by Morris et al. (2024) which demonstrated that both sex and environmental factors significantly influenced growth performance, with male birds consistently attaining higher body weights than females. A significant hatch effect was observed for early growth ($p \leq 0.01$) and egg production, with Hatch 1 birds consistently outperforming Hatch 2 and Hatch 3 across lines, reflecting environmental and management influence at brooding and rearing stages. However, its effect diminished as birds matured, suggesting that genetic influence became more pronounced with age. Similar findings were reported by Xie et al. (2026), where hatch-related management significantly affected early growth performance, but its influence declined with advancing age,

3.4. Genetic factors

Heritability estimates for body weight traits were moderate to high in PB1 and PB2, indicating strong additive genetic control and good response to selection. Punjab Brown exhibited lower heritability at early growth stages but moderate heritability at 20 weeks of age suggesting that mid-growth selection would be more effective in this line. These findings are supported by Kaur et al. (2024), who reported moderate to high heritability and positive genetic correlations for body weight traits in indigenous chickens, indicating good response to selection. Early body weight (BWT5) showed positive genetic correlations with later weights across lines, higher in PB1 (0.30±0.03) (Table 4) and PB2 (0.30±0.02) (Table 5) than Punjab Brown (0.13±0.05) (Table 6). Phenotypically, BWT5 correlated moderately with BWT20 and BWT40 in PB1 (0.17, 0.13), PB2 (0.18, 0.05) and Punjab Brown (0.24, 0.18), supporting early selection in PB1 and PB2. At 20 weeks, genetic correlations remained moderate in all lines (PB1: 0.28±0.03; PB2: 0.28±0.03; Punjab Brown: 0.38±0.04). Phenotypic continuity from BWT20 to BWT40 was strongest in PB1 (0.40), followed by Punjab Brown (0.38) and PB2 (0.09). Later body weights showed weaker genetic associations with reproduction, indicating reduced growth influence at maturity. Genetic correlations were low in PB1 (0.10), PB2 (0.039) and Punjab Brown (0.35), indicating selection for egg weight could be done separately from growth. Egg number to 52 weeks (EN52) showed strong phenotypic correlations with EN40 in all lines (PB1: 0.57; PB2: 0.76;

Table 4: Heritability estimates (diagonal), genetic (below diagonal) and phenotypic (above diagonal) correlations among different traits in PB1

Traits	BWT5	BWT20	BWT40	BWT52	ASM	ENO40	EWT40	ENO52
BWT5	0.3±0.03	0.17*	0.13*	0.05	0.04	0.02	0.05	0.03
BWT20	0.98	0.28±0.03	0.40*	0.05	0.048	0.04	0.05	0.03
BWT40	0.82	0.89	0.11±0.02	0.13*	0.01	0.03	0.10*	0.05
BWT52	0.56	0.60	0.60	0.06±0.02	0.01	0.2*	0.11*	0.18*
ASM	0.19	0.26	0.50	0.28	0.06±0.03	0.08	0.006	0.06
ENO40	0.49	0.53	0.50	0.29	0.38	0.32±0.03	0.08	0.88*
EWT40	0.27	0.27	0.26	0.50	0.02	0.22	0.09±0.03	0.1
ENO52	0.55	0.57	0.54	0.30	0.30	0.98	0.21	0.35±0.04

*: Significant at 5% level (p=0.05)

Table 5: Heritability estimates (diagonal), genetic (below diagonal) and phenotypic (above diagonal) correlations among different traits in PB2

Traits	BWT5	BWT20	BWT40	BWT52	ASM	ENO40	EWT40	ENO52
BWT5	0.3±0.02	0.18*	0.05	0.02	0.03	0.10	0.08	0.04
BWT20	0.15	0.28±0.03	0.09*	0.06	0.09*	0.03	0.003	0.063
BWT40	0.40	0.25	0.3±0.02	0.08	0.02	0.04	0.05	0.001
BWT52	0.27	0.20	0.42	0.19±0.03	0.04	0.07	0.04	0.09
ASM	0.41	0.90*	0.25	0.14	0.07±0.04	0.08	0.048	0.05
ENO40	0.17	0.81	0.11	0.37	0.66	0.31±0.03	0.06	0.76*
EWT40	0.74	0.15	0.48	0.02	0.41	0.05	0.039±0.03	0.003
ENO52	0.35	0.66	0.45	0.13	0.53	0.91	0.21	0.27±0.03

*: Significant at 5% level (p=0.05)

Table 6: Heritability estimates (diagonal), genetic (below diagonal) and phenotypic (above diagonal) correlations among different traits in Punjab Brown

Traits	BWT5	BWT20	BWT40	BWT52	ASM	ENO40	EWT40	ENO52
BWT5	0.13±0.05	0.24*	0.18*	0.06	0.08	0.12*	0.04	0.12*
BWT20	0.80	0.38±0.04	0.38*	0.03	0.03	0.09	0.05	0.09
BWT40	0.57	0.67	0.13±0.04	0.066	0.005	0.05	0.007	0.05
BWT52	0.007	0.19	0.30	0.1±0.04	0.08	0.023	0.001	0.02
ASM	0.29	0.26	0.06	0.50	0.06±0.04	0.008	0.14*	0.003
ENO40	0.53	0.70	0.24	0.33	0.11	0.17±0.07	0.10	0.99
EWT40	0.05	0.43	0.36	0.59	0.71	0.37	0.35±0.05	0.09
ENO52	0.55	0.70	0.22	0.35	0.09	0.99*	0.35	0.17±0.07

*: Significant at 5% level ($p \leq 0.05$)

Punjab Brown: 0.99*), confirming early egg number was a strong predictor of total annual egg production. Genetic correlations among body weight traits were positive across all three lines, indicating that selection for early growth would result in proportional improvement in later growth stages. Similar findings were reported by Chomchuen et al. (2022), who observed predominantly low to moderate genetic correlations between body weight and egg production traits, suggesting that growth and reproductive traits can be improved largely independently through selection. However, correlations between growth traits and reproductive traits were low, suggesting that improvement in growth would not adversely affect reproductive efficiency.

3.5. Genetic evaluation

Rachman et al. (2024) highlighted that indigenous chicken populations possess substantial genetic diversity that can be exploited for the genetic improvement of locally adapted birds. Line-wise evaluation revealed that PB1 exhibited the strongest genetic continuity in growth traits from 5 to 52 weeks, making it the most suitable line for selection-based improvement programs. PB2 also showed strong growth potential but with relatively weaker genetic consistency than PB1, indicating that PB2 was more inclined toward meat production than balanced growth and reproduction. Punjab Brown exhibited moderate genetic progress with lower correlations among growth traits, as generally expected in indigenous germplasm, yet retained good reproductive efficiency and adaptability. These findings are in line with Miyumo et al. (2024), who demonstrated that selection strategies should be modified to specific breeding objectives to maximize genetic gain in indigenous chicken breeding programmes.

4. CONCLUSION

The evaluation of PB1, PB2 and Punjab Brown chicken lines revealed clear genetic differences in growth and reproduction. PB1 exhibited superior body weight and consistent egg production, suggesting that it was the most suitable line for dual-purpose breeding. PB2 showed strong juvenile growth and moderate laying ability, supporting improvement programs. Punjab Brown, though slower growing, demonstrated resilient adaptability and stable reproduction, useful for backyard systems. High heritability for growth and moderate for reproduction indicated good potential for genetic improvement.

5. REFERENCES

Chaikuad, N., Loengbudnark, W., Chankitisakul, V., Boonkum, W., 2022. Genetic comparisons of body weight, average daily gain, and breast circumference between slow-growing thai native chickens (Pradu Hang dum) raised on-site farm and on-station. Veterinary Sciences 10(1), 11. DOI: https://doi.org/10.3390/vetsci10010011.

Chomchuen, K., Tuntiyasawasdikul, V., Chankitisakul, V., Boonkum, W., 2022. Genetic evaluation of body weights and egg production traits using a multi-trait animal model and selection index in thai native synthetic chickens (Kaimook e-san2). Animals 12(3), 335. DOI: https://doi.org/10.3390/ani12030335.

Haunshi, S., Niranjan, M., Shanmugam, M., Padhi, M., Reddy, Sunitha, R., Rajkumar, U., Panda, A., 2011. Characterization of two Indian native chicken breeds for production, egg and semen quality, and welfare traits. Poultry Science 90(2), 314–320. DOI: https://doi.org/10.3382/ps.2010-01013.

Haunshi, S., Ullengala, R., Prince, L.L., Ramasamy, K., Gurunathan, K., Devatkal, S., Chatterjee, R.N., 2022. Genetic parameters of growth traits, trend of production and reproduction traits, and meat quality status of Ghagus, an indigenous chicken of India. Tropical Animal Health and Production 54(3), 170. DOI: https://doi.org/10.1007/s11250-022-03166-y.

Kassa, B., Taye, M., Esatu, W., Kebede, A., Girma, M., Kebede, F. G., Banos, G., Watson, K., Hanotte, O., Dessie, T., 2025. Genetic and phenotypic parameter estimates of body weight and egg production traits of tilili chicken in Ethiopia. Animals 15(18), 2656. DOI: https://doi.org/10.3390/ani15182656.

Kaur, S., Ratwan, P., Kumar, M., Singh, A., 2024. Overview of performance and genetic parameters of economic traits in Indian native chicken breeds. World S Poultry Science Journal 80(2), 547–563. DOI: https://doi.org/10.1080/00439339.2024.2309528.

Li, T., Chen, B., Wei, C., Hou, D., Qin, P., Jing, Z., Ma, H., Niu, X., Wang, C., Han, R., Li, H., Liu, X., Xu, H., Kang, X., Li, Z., 2021. A 104-BP structural variation of the ADPRHL1 gene is associated with growth traits in chickens. Frontiers in Genetics 12, 691272. DOI: https://doi.org/10.3389/fgene.2021.691272.

Miyumo, S., Wasike, C.B., Ilatsia, E.D., Bennewitz, J., Chagunda, M.G., 2024. Evaluation of selection strategies in dual-purpose and specialized breeding of indigenous chicken. Poultry Science 103(8), 103916. DOI: https://doi.org/10.1016/j.psj.2024.103916.

Morris, K. M., Sutton, K., Girma, M., Sánchez-Molano, E., Solomon, B., Esatu, W., Dessie, T., Vervelde, L., Psifidi, A., Hanotte, O., Banos, G., 2024. Phenotypic and genomic characterisation of performance of tropically adapted chickens raised in smallholder farm conditions in Ethiopia. Frontiers in Genetics 15, 1383609. DOI: https://doi.org/10.3389/fgene.2024.1383609.

Ni, A., Calus, M. P. L., Bovenhuis, H., Yuan, J., Wang, Y., Sun, Y., Chen, J., 2023. Genetic parameters, reciprocal cross differences, and age-related heterosis of egg-laying performance in chickens. Genetics Selection Evolution 55(1), 87. DOI: https://doi.org/10.1186/s12711-023-00862-7.

Padhi, M.K., 2016. Importance of Indigenous breeds of chicken for rural economy and their improvements for higher production performance. Scientifica 2016, 1–9. DOI: https://doi.org/10.1155/2016/2604685.

Parte, P., Sahoo, S., Dubey, P., Kaur, S., Mukhopadhyay, C., 2024. Effect of genetic groups and gender on body weight and different morphometric traits in poultry birds. Agricultural Science Digest-A Research Journal, 1–7. DOI: https://doi.org/10.18805/ag.d-5981.

Rachman, M.P., Bamidele, O., Dessie, T., Smith, J., Hanotte, O., Gheyas, A.A., 2024. Genomic analysis of Nigerian indigenous chickens reveals their genetic diversity and adaptation to heat-stress. Scientific Reports 14(1), 2209. DOI: https://doi.org/10.1038/s41598-024-52569-4.

Rajkumar, U., Haunshi, S., Paswan, C., Raju, M., Rao, S. R., Chatterjee, R., 2017. Characterization of indigenous Aseel chicken breed for morphological, growth, production, and meat composition traits from India. Poultry Science 96(7), 2120–2126. DOI: https://doi.org/10.3382/ps/pew492.

Singh, M.K., Kumar, S., Singh, S.K., Sharma, R.K., Prakash, A., Prasad, S., Singh, Y., Singh, D.N., 2023. Body weights and growth rates in indigenous chicken breeds of India. World's Poultry Science Journal 79(4), 867–878. DOI: https://doi.org/10.1080/00439339.2023.2239775.

Singh, M., Lim, A., Muir, W., Groves, P., 2020. Comparison of performance and carcass composition of a novel slow-growing crossbred broiler with fast-growing broiler for chicken meat in Australia. Poultry Science 100(3), 100966. DOI: https://doi.org/10.1016/j.psj.2020.12.063.

Torrey, S., Mohammadigheisar, M., Santos, M.N.D., Rothschild, D., Dawson, L.C., Liu, Z., Kiarie, E.G., Edwards, A.M., Mandell, I., Karrow, N., Tulpan, D., Widowski, T.M., 2020. In pursuit of a better broiler: growth, efficiency, and mortality of 16 strains of broiler chickens. Poultry Science 100(3), 100955. DOI: https://doi.org/10.1016/j.psj.2020.12.052.

Touko, B.A.H., Mbiydzenyuy, A.T.K., Tumasang, T.T., Awah-Ndukum, J., 2021. Heritability estimate for antibody response to vaccination and survival to a newcastle disease infection of native chicken in a low-input production system. Frontiers in Genetics 12, 666947. DOI: https://doi.org/10.3389/fgene.2021.666947.

Tunsisa, L.Y., Reda, K.B., 2022. Evaluation of fertility, hatchability and egg quality of indigenous chickens in different agro-ecologies of the Sidama Region, Ethiopia. Veterinary Integrative Sciences 21(1), 201–219. DOI: https://doi.org/10.12982/vis.2023.016.

Vij, P., Tantia, Vijh, R., 2006. Characterization of Punjab Brown chicken. Animal Genetic Resources Information 39, 65–76. DOI: https://doi.org/10.1017/s1014233900002145.

Xie, C., Macelline, S.P., Melwani, R.R., Toghyani, M., Leary, A., Liu, S.Y., 2026. Hatching method correlates to early growth in chickens but not later performance. Poultry Science 105(4), 106478. DOI: https://doi.org/10.1016/j.psj.2026.106478.

Yang, X., Sun, J., Zhao, G., Li, W., Tan, X., Zheng, M., Feng, F., Liu, D., Wen, J., Liu, R., 2021. Identification of major LOCi and candidate genes for Meat Production-Related traits in broilers. Frontiers in Genetics 12, 645107. DOI: https://doi.org/10.3389/fgene.2021.645107.