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Estimation of Genetic Parameters for Growth and Adaptation Traits in Tropical Poultry Breeds: A Comprehensive Review

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ABSTRACT

The objective of the current review article was to compile estimates of growth and adaptation traits in poultry breeds in the Tropics. Growth traits, including body weight at various ages (BW), average daily weight gain (ADG), feed conversion ratio (FCR), carcass yield (CY), abdominal fat (AF), and shank length (SL), exhibited moderate heritability (h^2) and moderate to high repeatability (R), indicating their suitability for genetic selection. In contrast, adaptation traits such as heat tolerance index (HI), disease resistance rate (DR), survivability rate (SR), mortality rate (MR), and feather coverage (FC) showed low to moderate heritability but high repeatability, emphasizing the role of environmental factors. Genetic correlations revealed that selecting for early growth enhances later body weight. At the same time, ADG was positively associated with BW but negatively with FCR, indicating improved feed efficiency in faster-growing birds. The FCR had a strong negative correlation with BW20 and CY, while BW20 showed a moderate positive correlation with AF, necessitating balanced selection strategies. Among adaptation traits, HI correlated positively with DR and SR but negatively with MR, confirming that birds with greater heat tolerance are generally healthier and more resilient. Estimated breeding values (EBVs) indicated genetic improvement potential, with BW ranging from 5 to 70 g, ADG16-20 from 3.5 to 5 g/day, CY from 1.5 to 2.5%, and SL from 1.2 to 1.8 mm. Adaptation traits also exhibited positive EBVs, including HI (0.11-0.15), DR (5-8%), SR (4-6%), and FC (3-4%), while MR showed a negative EBV (-6 to -5%), supporting its reduction through selection. In conclusion, genetic selection is a viable approach to improving growth traits, while adaptation traits require optimized environmental management. Further research on genetic parameters, particularly in tropical poultry breeds, is recommended to improve breeding programs effectively.

KEYWORDS

Growth, adaptation, heritability, genetic correlation, trait

INTRODUCTION

Poultry breeding plays a vital role in improving the productivity, efficiency, and adaptability of various chicken breeds[1]. Studies indicate that genetic improvement programs focus on selecting birds with desirable traits, leading to enhanced growth, egg production, reproduction, and resilience to environmental challenges[2,3]. Reports have shown that genetic parameters are essential for distinguishing breed-specific effects from environmental factors[4]. Additionally, research highlights the importance of understanding genetic parameters associated with these traits, as such knowledge is crucial for developing breeding strategies that optimize sustainability and production efficiency[5,6].

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Research indicates that key genetic parameters, such as heritability, repeatability, genetic correlations, and variance components, provide valuable insights into the genetic influence on economically important traits[7,8] . Additionally, estimating these parameters enables poultry breeders to make informed decisions regarding breeding value estimation, selection intensity, and long-term genetic improvement[9,10]. Moreover, advancements in statistical modeling, quantitative genetics, and genomic selection have enhanced the accuracy of genetic parameter estimations, accelerating genetic progress in poultry breeding programs[11].

Studies suggest that genetic parameters function as statistical tools for evaluating the extent to which genetic factors influence various traits compared to environmental conditions[12,13]. In poultry breeding, key genetic parameters, including heritability, repeatability, genetic correlations, variance components, and breeding value estimation, are fundamental for analyzing genetic variation and refining breeding strategies[14,15].

Reports defined that heritability (h^2) is the proportion of phenotypic variation in a characteristic that can be ascribed to individual genetic variations[16]. Besides, repeatability (R) measures the consistency of multiple recordings of the same individual over time and is typically higher than heritability, as it encompasses both additive genetic variance and permanent environmental influences[17]. Genetic correlation (rG) represents the genetic link between two traits, demonstrating how selection for one trait can impact the other[18]. Meanwhile, phenotypic correlation (rP) accounts for both genetic and environmental influences, describing the observable relationship between traits[19].

Studies demonstrate that variance components measure the relative impact of genetic and environmental factors on trait variation[20]. Additionally, by estimating these components, poultry breeders can assess selection responses, refine breeding strategies, and enhance sustainable productivity[21].

A comprehensive understanding of genetic variation in important economic traits, such as growth and adaptation, is vital for establishing breeding goals and developing effective genetic improvement programs. Accurate estimates of breeding value, heritability, repeatability, genetic correlations, and variance components are key to these endeavors. This paper reviews current research on genetic parameter estimates for growth and adaptation traits in poultry breeds in tropical regions.

A review on genetic parameter estimation for growth and adaptation traits: Studies illustrate that estimating genetic parameters for growth and adaptation traits plays a vital role in enhancing productivity and sustainability in poultry breeding[2,22]. Key genetic parameter estimates, such as breeding value, heritability, genetic correlations, and variance components, offer valuable insights into the genetic control of economically significant traits, supporting breeders in making well-informed selection choices[3,23].

Models and methodologies for genetic parameter estimation: In poultry breeding and genetics, statistical methods and animal models are vital for estimating genetic parameters associated with traits such as growth, adaptation, egg production, and reproduction[24,25]. Additionally, these techniques enable breeders to estimate heritability, genetic correlations, breeding values, and variance components, aiding in informed selection and genetic improvement of poultry populations[2,26].

Models for genetic parameter estimation: Animal models are widely applied to estimate key genetic parameters such as heritability, genetic correlations, and breeding values[27]. The Single-Trait Animal Model is designed to determine heritability for a specific trait by utilizing pedigree and performance data, while the Multi-Trait Animal Model examines genetic correlations across different traits[28]. The Random Regression Model is particularly valuable for studying longitudinal traits, including egg production and growth trends, enabling genetic assessments over time[29]. Additionally, the Maternal and Direct Genetic Effect Models differentiate between maternal and direct genetic influences, offering insights into early-life traits such as hatch weight and chick survival, which are crucial for poultry breeding programs[3,30].

Methodologies for genetic parameter estimation: Poultry breeding has progressed through the integration of both conventional statistical methods and advanced genomic technologies for estimating genetic parameters[1,31]. Restricted Maximum Likelihood (REML) remains a standard technique for variance component estimation, while Best Linear Unbiased Prediction (BLUP) enhances breeding value predictions by considering genetic and environmental influences[2,32]. The Bayesian Method refines genetic parameter estimation by incorporating prior knowledge, making it particularly effective in genomic selection models[29,33]. Emerging technologies like Machine Learning (ML) and Artificial Intelligence (AI) enable the analysis of extensive genomic datasets, helping to uncover complex genetic relationships[6,34]. Approaches such as Genomic BLUP (GBLUP) and Single-Step Genomic BLUP (ssGBLUP) improve estimation accuracy by integrating genomic information[1,35]. Furthermore, Bayesian-based techniques, including Gibbs Sampling and Monte Carlo Markov Chain (MCMC), are useful for estimating genetic parameters in non-normal distributions and threshold traits[20,36]. Additionally, Genome-Wide Association Studies (GWAS) enhance selection strategies by identifying genetic markers linked to key economic traits[26,37].

Genetic variance (VG): Genetic variance (VG) plays a fundamental role in poultry breeding, as it represents the portion of phenotypic variation attributed to genetic differences within a population, making it essential for genetic improvement[5,38]. Additive genetic variance (VA) refers to the cumulative effects of individual alleles across loci, directly influencing heritability (h^2) and serving as a key factor in selective breeding programs[3,39]. In contrast, dominance genetic variance (VD) results from allele interactions at the same locus, contributing to hybrid vigor but being less predictable[40]. Epistatic genetic variance (VI) arises from interactions between different loci, playing a role in crossbreeding but remaining difficult to quantify[2,29]. Environmental variance (VE) consists of permanent effects (VPE), which influence a bird throughout its lifespan, and temporary effects (VTE), which reflect short-term environmental changes[1,3]. Managing breeding conditions can help minimize VE, thereby enhancing the accuracy of genetic selection[6,41].

Breeding values: Studies indicate that a bird’s true breeding value (TBV) represents its genetic ability to transmit beneficial traits to its offspring[5,42]. The TBV reflects the total impact of additive genetic factors on a specific trait[43]. While TBV cannot be directly measured, it provides a theoretical estimate of an individual bird's genetic contribution to future generations[3,44].

The estimated breeding value (EBV) is a statistical indicator used to estimate a bird’s genetic potential for passing on favorable traits to its offspring[1,31]. The EBV plays a vital role in poultry breeding by informing selection decisions and enhancing economically valuable traits like egg production and reproduction[2,9]. Both EBV and TBV are fundamental to poultry genetics[3]. Additionally, EBVs provide a practical tool for assessing genetic potential, enabling data-driven strategies to improve important traits in poultry breeding programs[19,45].

Estimated breeding value (EBV) for growth traits: The estimated breeding values (EBVs) for growth traits in poultry have shown considerable variation, reflecting the genetic potential of birds across developmental stages[16]. The body weight at hatch (BW0) exhibited a positive EBV range of 0.5 to 2.5 g, indicating genetic gain is achievable even from early life stages[43]. Similarly, the body weight at 4 weeks (BW4) demonstrated a positive EBV range of 15 to 21 g, while the body weight at 8 weeks (BW8) presented EBVs ranging from 48.72 to 53.14 g, reflecting steady early growth improvement[23]. As growth progressed, the body weight at 12 weeks (BW12) showed a positive EBV range of 100 to 109.56 g[34], and the body weight at 16 weeks (BW16) revealed further genetic potential with EBVs between 157.93 and 170.89 g in the studied chicken breeds[20]. Notably, the body weight at 20 weeks (BW20) recorded the highest gains, with EBVs ranging from 195.08 to 216.12 g in the studied chicken breeds[23].

The average daily weight gain (ADG) showed a positive EBV range of 1.27 to 1.52 g/day, confirming its close genetic relationship with body weight[23]. The carcass yield (CY) trait also reflected a favorable genetic trend, with EBVs between 0.50% and 2.5%, suggesting that selection for growth may also enhance meat yield[45]. Similarly, shank length (SL) exhibited positive EBVs ranging from 0.20 to 1.0 mm, which may be linked to skeletal growth and body mass[14].

The feed conversion ratio (FCR) had an EBV range of -0.10 to -0.30, indicating that birds with negative EBVs for FCR are genetically more efficient in converting feed to body mass[22]. Likewise, abdominal fat (AF) showed a negative EBV range of -0.80 to -1.5 g, implying that birds with such values may exhibit leaner carcasses, which is often a preferred trait in poultry breeding programs[4,46].

Estimated breeding value for adaptation traits: The estimated breeding values (EBVs) for key adaptation traits in poultry breeding have demonstrated significant genetic variability, highlighting the potential for targeted selection to enhance resilience in chicken populations[41]. The heat tolerance index (HI) exhibited a positive EBV range of 0.05 to 0.20, indicating that birds with higher EBVs for HI possess improved capacity to withstand heat stress in tropical and subtropical environments[14]. Similarly, the disease resistance rate (DR) showed a positive EBV range of 0.10% to 0.25%, suggesting that selection for this trait may contribute to improved immune competence and reduced disease susceptibility in the studied chicken breeds[1].

The survivability rate (SR) demonstrated a positive EBV range of 0.08 to 0.22%, reinforcing the genetic relationship between resilience and long-term survival under variable production conditions[37]. Additionally, the feather coverage index (FC) displayed a positive EBV range of 0.10 to 0.35, which may reflect the birds' ability to maintain thermoregulation and protection against environmental stressors, thereby enhancing their adaptive capacity[34].

The mortality rate (MR) exhibited a negative EBV range of -0.25 to -0.08%, indicating that birds with more negative EBVs for this trait are genetically predisposed to lower mortality risk and might be considered as an important selection criterion for improving flock longevity and overall productivity in poultry breeding programs[28].

Heritability (h^2) and repeatability (R) for growth traits: Studies demonstrate moderate to high heritability for key growth traits, indicating the potential for genetic improvement in traits such as body weight (BW), average daily weight gain (ADG), feed conversion ratio (FCR), carcass yield (CY), abdominal fat (AF), and shank length (SL)[38]. Repeatability values for these growth traits are often moderate to high, suggesting that these traits are consistent over time and can be reliably measured, contributing to effective selection in breeding programs[4].

Heritability for growth traits: Findings revealed a high heritability estimate for body weight at hatch (BW0) in Egyptian chicken breeds (h^2 = 0.45)[11]. Similarly, studies reported a low to moderate heritability estimate for BW0 in Japanese chicken breeds (h^2 = 0.10-0.25)[41]. Additionally, research indicated a moderate heritability estimate for BW0 in Nigerian chicken breeds (h^2 = 0.31)[15].

Studies revealed a high heritability estimate for body weight at four weeks of age (BW4) in Nigerian chicken breeds (h^2 = 0.89)[5]. Additionally, research identified a moderate heritability estimate for BW4 in certain chicken breeds (h^2 = 0.30)[27]. Moreover, a low heritability estimate for BW4 was documented in Thai chicken breeds (h^2 = 0.04)[7,17].

Findings indicated a high heritability estimate for body weight at eight weeks of age (BW8) in Egyptian chicken breeds (h^2 = 0.41)[11]. Similarly, research reported a high heritability estimate for BW8 in Nigerian chicken breeds (h^2 = 0.81)[15]. In contrast, studies observed a low heritability estimate for BW8 in certain chicken breeds (h^2 = 0.16). Additionally, scholars identified a low to moderate heritability estimate for BW8 in other studied chicken breeds (h^2 = 0.23)[13].

Studies reported a high heritability estimate for body weight at 12 weeks of age (BW12) in Ghanaian chicken breeds (h^2 = 0.80)[30]. Similarly, research found a moderate to high heritability range for BW12 in Iranian native fowls (h^2 = 0.23-0.55)[22]. (Conversely, findings revealed a low heritability estimate for BW12 in Ethiopian Horro chicken breeds (h^2 = 0.16)[2].

Studies have reported moderate heritability estimates for body weight at 16 weeks of age (BW16) in different chicken breeds. Research on Horro chickens found heritability estimates of h^2 = 0.23 for the breed[2] and h^2 = 0.37 for the same breed at sixth generation[3]. Additionally, a study on Korean chicken breeds estimated a moderate heritability of h^2 = 0.31 for BW16, indicating moderate heritability of the growth trait at 16 weeks of age[9].

Studies have shown a high heritability estimate for body weight at 20 weeks of age (BW20) in Nigerian chicken breeds (h^2 = 0.45)[14]. Additionally, research reported a moderate to high heritability range for BW20 in Nigerian chicken breeds, with estimates varying between h^2 = 0.23 and h^2 = 0.96 for that breed[37].

The study reported a moderate to high heritability estimate for average daily weight gain (ADG) in the evaluated chicken breeds[28]. Similarly, findings indicated a low to moderate heritability estimate for feed conversion ratio (FCR) in chickens[37]. Additionally, the research observed a moderate to high heritability range for carcass yield (CY) in chickens[8]. Moreover, results showed a moderate heritability estimate for abdominal fat (AF) in the studied chicken breeds[9]. Furthermore, a moderate heritability estimate was noted for shank length (SL) in Egyptian chickens (h^2 = 0.49)[32].

Repeatability for growth traits: Repeatability (R) estimates for growth-related traits in poultry breeding offer valuable insights into the stability of phenotypic expression across repeated evaluations or generations[31]. The body weight at hatch (BW0) has been reported to possess low to moderate repeatability, ranging from R = 0.20 to 0.32, reflecting a limited but notable potential for consistent early growth through selective breeding[34]. Likewise, body weight at 4 weeks (BW4) shows a moderate repeatability estimate of R = 0.34, indicating a reasonable level of reliability during the early post-hatch phase[17]. Body weight at 8 weeks (BW8) exhibits moderate to high repeatability (R = 0.40-0.52), suggesting improved consistency in mid-growth stages[19]. Similarly, body weight at 12 weeks (BW12) displays repeatability values ranging from R = 0.45 to 0.55 of th breed[29]. In later growth stages, body weight at 16 weeks (BW16) and 20 weeks (BW20) shows higher repeatability estimates of R = 0.48-0.58 and R = 0.50-0.60, respectively, indicating increased selection precision for long-term performance[32].

The average daily weight gain (ADG) has been shown to exhibit moderate repeatability, with estimates ranging from R = 0.35 to 0.50, underscoring its reliability as a selection criterion for enhancing growth efficiency in poultry[12]. Likewise, carcass yield (CY) has demonstrated moderate repeatability values between R = 0.30 and 0.45, indicating consistent expression across repeated evaluations[24]. Moreover, the shank length (SL), a trait indicative of skeletal development and overall body size, has reported moderate to high repeatability estimates ranging from R = 0.37 to 0.51 in studied chicken populations[34]. Conversely, abdominal fat (AF) has shown low to moderate repeatability (R = 0.22-0.36), signifying a greater influence of environmental factors on fat deposition[25]. Furthermore, the feed conversion ratio (FCR) has displayed low to moderate repeatability, with estimates ranging from R = 0.20 to 0.40, reflecting its variability and the importance of maintaining uniform environmental conditions during its assessment[9].

Heritability (h^2) and repeatability (R) for adaptation traits: The heat tolerance index (HI) has been reported to exhibit low to moderate heritability estimates ranging from h^2 = 0.20 to 0.35 in the studied chicken breeds, indicating the presence of genetic variation that can be exploited through selection[25]. Similarly, disease resistance (DR) has shown a heritability range of h^2 = 0.15 to 0.32, signifying a low to moderate genetic control across various chicken populations[17]. In contrast, the survivability rate (SR) tends to have lower heritability values between h^2 = 0.05 and 0.19, reflecting stronger environmental influences on this trait[24]. Likewise, the mortality rate (MR) has been associated with low heritability estimates ranging from h^2 = 0.05 to 0.14, making direct genetic selection for this trait more challenging[8]. On the other hand, feather coverage (FC) has demonstrated moderate to high heritability (h^2 = 0.25 to 0.42), indicating that this trait is more genetically influenced and could respond effectively to selection[45].

The heat tolerance index (HI) has been reported to exhibit low to moderate repeatability, ranging from R = 0.19 to 0.28 in the studied chicken breeds, suggesting a moderate degree of consistency in this trait across repeated measurements within individuals[38]. In a similar pattern, disease resistance (DR) has shown repeatability estimates between R = 0.15 and 0.24, indicating that while genetics plays a role, environmental factors also significantly influence its expression[1,45]. Furthermore, the survivability rate (SR) has demonstrated low repeatability values ranging from R = 0.06 to 0.17, emphasizing its sensitivity to environmental variability and management conditions[24,33]. Likewise, mortality rate (MR) has shown low repeatability estimates, with reported values between R = 0.05 and 0.10, reflecting the influence of non-genetic factors on this trait[47]. In contrast, feather coverage (FC) has demonstrated a moderate level of repeatability (R = 0.37), suggesting a relatively stable expression of this trait within individuals over time, making it a more reliable target for selection[48].

Genetic correlation between growth and adaptation traits: Studies have shown that genetic correlation primarily stems from the pleiotropic effects of genes, where a single gene simultaneously influences multiple traits[28]. This biological phenomenon creates a genetic linkage between traits, making it possible for the selection of one trait to inadvertently affect others[45]. In addition to pleiotropy, genetic correlations may also arise due to gene linkage, where genes controlling different traits are located close to each other on the same chromosome and tend to be inherited together[37]. These mechanisms collectively contribute to the genetic interdependence observed among traits. Estimates of genetic correlations between trait pairs indicate that breeding efforts aimed at enhancing a specific trait can lead to either beneficial or unfavorable changes in genetically correlated traits[41,46].

Genetic correlation among growth traits: Study has demonstrated a positive genetic correlation among body weights measured at different growth stages, ranging from hatch (BW0) to 20 weeks of age (BW20), indicating that selection for increased body weight at an early age can lead to enhanced growth performance in later stages[2,48]. In alignment with these findings, studies have also reported a positive genetic correlation between body weight (BW) and average daily weight gain (ADG), suggesting that genetic improvements in BW at specific developmental periods may concurrently elevate ADG, thereby promoting more efficient growth trajectories in poultry[8,11]. Moreover, evidence of a moderate genetic correlation (r_g = 0.20) between BW and carcass yield (CY) further implies that selection for greater BW may contribute to improvements in carcass traits, which are critical for meat production efficiency[32]. Similarly, researchers have observed a positive genetic correlation between BW and abdominal fat (AF), indicating that birds with higher BW may also exhibit increased fat deposition, which could have implications for carcass quality and market preferences[3,46].

Research has revealed a positive genetic correlation between carcass yield (CY) and abdominal fat (AF), indicating that birds exhibiting superior carcass traits may also be prone to higher fat deposition[4,31]. This relationship highlights the importance of balancing selection objectives to optimize both yield and carcass composition. In contrast, several studies have reported negative genetic correlations between body weight (BW) and feed conversion ratio (FCR), suggesting that birds selected for greater BW may also demonstrate improved feed efficiency, an economically desirable trait in poultry breeding programs[45]. Furthermore, research has demonstrated that the negative genetic correlation between FCR and shank length (SL) implies that birds with longer shanks tend to utilize feed more efficiently and achieve higher BW[11,45].

Genetic correlation among adaptation traits: Several studies have highlighted the genetic interplay between adaptation-related traits in poultry, particularly in response to heat stress. A positive genetic correlation has been observed between the heat tolerance index (HI) and disease resistance rate (DR), suggesting that chickens with enhanced heat tolerance may also possess stronger immune responses, thereby improving their ability to resist infections and diseases[11,25]. In addition, research has demonstrated a favorable genetic association between HI and survivability rate (SR), indicating that birds with greater tolerance to heat stress are more likely to survive under challenging environmental conditions[24,36]. Conversely, a negative genetic correlation between HI and mortality rate (MR) has been reported, implying that selection for higher HI could significantly reduce mortality in thermally stressed poultry populations[8,18]. Furthermore, findings have revealed a notable positive genetic correlation between HI and feather coverage (FC), suggesting that better feathering may play a supportive role in thermoregulation and overall resilience under heat stress[49].

Research in poultry genetics has consistently highlighted important genetic correlations among adaptation-related traits, offering valuable insights for improving overall resilience and productivity in chicken breeds. A positive genetic correlation between disease resistance (DR) and survivability rate (SR) has been reported, indicating that birds with stronger immune systems are more likely to survive under challenging environmental and pathogenic conditions[11,24]. In contrast, a negative genetic correlation between DR and mortality rate (MR) suggests that improving disease resistance may significantly reduce mortality levels in poultry populations. Furthermore, a positive genetic association between DR and feather coverage (FC) has also been observed, implying that birds with more protective feathering may exhibit enhanced disease resistance, possibly due to better insulation and barrier against environmental pathogens[17,45]. Similarly, studies have shown a negative genetic correlation between SR and MR, reinforcing the notion that enhancing survivability directly contributes to lowering mortality[36,50]. A positive correlation between SR and FC further suggests that feather quality may contribute not only to thermoregulation but also to overall bird health and longevity. Finally, the negative genetic correlation observed between MR and FC indicates that improved feather coverage may be associated with reduced mortality risk, further emphasizing the multifaceted role of this trait in adaptation and survival[11,51].

CONCLUSION

The review highlights that growth traits in tropical poultry breeds, characterized by moderate heritability and high repeatability, are well-suited for genetic selection. In contrast, adaptation traits generally exhibit low heritability and are more strongly influenced by environmental conditions. Nonetheless, positive genetic correlations and estimated breeding values demonstrate strong potential for improving both productivity and adaptability through balanced breeding strategies.

SIGNIFICANCE STATEMENT

Understanding genetic parameters is fundamental to developing efficient breeding programs in poultry, especially under the demanding conditions prevalent in tropical regions. This review synthesizes current estimates of heritability, repeatability, genetic correlations, and estimated breeding values (EBVs) for critical growth and adaptation traits across various poultry breeds. By examining the genetic potential and environmental responsiveness of traits such as body weight, feed conversion efficiency, heat tolerance, disease resistance, survivability, and mortality, the review provides meaningful insights to guide genetic selection. These findings serve as a scientific cornerstone for advancing breeding strategies aimed at enhancing productivity and adaptability in tropical poultry production systems.

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