Research Article

Morphometrics and Heritability of the Body Of 1-8 Weeks Aged Tolaki Chickens

Rusli Badaruddin*, La Ode Nafiu, Muhammad Amrullah Pagala and Takdir Saili

Faculty of Animal, Science, Halu Oleo, University, Campus, Hijau Bumi Tridharma, Jl. H.E. A., Mokodompit andonohu, Kendari, City, Sulawesi, Tenggara 93232,Indonesia.

Abstract | The Tolaki chicken is a native breed from Southeast Sulawesi, commonly found in areas such as Konawe Regency and South Konawe Regency. This study aims to provide insights into the estimated heritability value of the body weight of Tolaki chickens aged 1-8 weeks. The mating group consisted of 5 males and 25 females, with each male paired with 5 females, resulting in the production of 150 Tolaki chicks. The chickens were fed ad libitum. Data from the research were analyzed using a Complete Randomized Design (CRD) with an analysis of variance and a nested design pattern (hierarchical structure) to calculate the variance components. These components were then used to estimate the heritability value of the Tolaki chickens. The findings revealed that the inheritance of traits (heritability) for Tolaki chickens, based on the male component ($\hat{h}^2$s), the parent variation component ($\hat{h}^{2d}$) and the combined male and parent component ($\hat{h}^2_{s+d}$) at all age levels, was positive. The heritability values obtained are generally in the low to high category.

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***Correspondence** | Rusli Badaruddin, Faculty of Animal Science, Halu Oleo University; **Email:** rusli.badaruddin79@uho.ac.id
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Introduction

Indonesia is a country rich in biodiversity, including various types of chickens, both native Indonesian breeds and local introduced breeds that have long adapted to the country. Several Indonesian chicken strains are considered genetic resources (SDG) that still need to be explored for their potential, whether as sources of meat, eggs, or ornamental purposes (such as for their sound, fighting, or attractive appearance) (Pagala *et al*., 2013; Pagala *et al*., 2015; Birteeb *et al*., 2016). Currently, there are several local chicken breeds that have yet to possess specific distinguishing characteristics, one of which is the Tolaki chicken. The Tolaki chicken is a native breed from Southeast Sulawesi, found in areas such as Konawe Regency, South Konawe Regency, North Konawe Regency and East Kolaka Regency (Pagala *et al*., 2017; Pagala *et al*., 2018; Pagala *et al*., 2019). However, information regarding the characteristics of the Tolaki chicken, as a unique breed of Southeast Sulawesi, is still limited, including both its phenotypic and genotypic traits, as well as its productivity and reproductive potential.

Efforts to identify and characterize local chicken breeds are still considered important because, in addition to being useful for the collection of Indonesia's genetic resources, they also support breeding programs. This identification can be carried out by evaluating phenotypic traits, both qualitatively (such as feather color, skin, shank, beak, comb shape, or wattle) and quantitatively, including body size or morphometric measurements like femur length, tibia length, shank length, head length, head width, neck length and others. Characterization of local chickens can be done by identifying their morphometric traits (Guo *et al*., 2017; Udeh, 2017; Fangele et al., 2021). Morphometry is a quantitative trait that can be used as a selection criterion to improve local chicken productivity (Akramullah *et al*., 2020; Husmaini *et al*., 2021). Quantitative traits of local chickens based on morphometry include body length, neck length, wing length, wing width, chest circumference, chest width, head length, head width, beak length, comb length, comb height, tibia length, metatarsus length, metatarsus circumference, length of the longest toe, femur length, maxilla length, sternum length and body weight (Sophian *et al*., 2021; Tan Nha *et al*., 2021; Widodo *et al*., 2021). These morphometric variables can serve as indicators of the size and shape of local chickens, useful for predicting production potential, improving livestock productivity and as a basis for standardizing local chicken traits comprehensively.

Genetic information is crucial for describing the genetic quality of livestock, which can then be used as a reference in continuous selection and crossbreeding (Wolde *et al*., 2021; El-Henfnawy *et al*., 2022; Jannah *et al*., 2022). The genetics of livestock cannot be directly measured or observed, but it can be studied through their phenotype with the help of statistical tools based on genetic diversity between individuals or groups within a population. This can be seen from the estimation of genetic parameters such as heritability (Rizk *et al*., 2022; Gomez & Mbaga, 2022). Heritability is the proportion of genetic variance relative to the total genetic variance plus environmental variance (Taffa *et al*., 2022; Tan Nha & Thu Thuy, 2022). The heritability value indicates the strength of inheritance from the parents to their offspring. Heritability can serve as foundational information in the selection and breeding process to improve the genetic quality of livestock.

This study presents novelty in the characterization of the Tolaki chicken, which, until now, has limited information. Unlike other local chickens that have been extensively studied, the Tolaki chicken from Southeast Sulawesi has not been widely researched in terms of its morphometric traits and productivity. This information is essential as a basis for the future development of local chickens in Indonesia. Therefore, the aim of this study is to determine the body weight and morphometric characteristics of several local chicken breeds and to provide a new contribution in filling the gap of data related to the genetic and phenotypic potential of the Tolaki chicken. This research also aligns with current trends in studies focused on utilizing the latest technologies and methodologies to enhance the understanding of the genetic diversity of Indonesia's local chicken breeds.

Materials and Methods

The research was conducted from December 2023 to April 2024 at road Haji Lamuse, Lepo Lepo Village, Baruga District, Kendari City. The tools used in this study included 30 battery cages measuring 40 x 35 cm, feeding and drinking containers, a digital scale with a 2 kg capacity and 0.01 accuracy, calipers, a measuring tape and writing materials. The subjects of this study were randomly selected male and female Tolaki chickens with relatively equal body weights, consisting of 10 roosters aged 12 to 15 months with body weights between 1.7 kg to 2 kg at this age the roosters are sexually mature and reach the optimal weight for fertilization and 50 hens aged 8 to 12 months with body weights between 1 kg to 1.3 kg This age the hens have begun to productively lay eggs or are ready for reproduction, but are not too old so that the egg quality is still good and the fertility rate is still optimal.

The Male and female Tolaki chickens were fed a diet consisting of RK24 concentrate (25%), ground corn (55%) and bran (20%) that had a total nutrient content of 12.21% protein, 3587% metabolic energy, 6.75% crude fiber and 3.36% crude fat. These chicks, aged 1 to 8 weeks, were fed the commercial feed BP-11 which has a nutrient content of 21.5-23.8 % protein, 3000-3100 % metabolic energy, 5.00 % crude fiber and 5.00 % crude fat. Drinking water was provided ad libitum. Feeding was done twice a day, at 6:00 am WITA in the morning and 3:00 pm WITA in the afternoon, In the morning, chickens need energy for activities throughout the day, while the afternoon helps maintain energy reserves until the evening and Chickens tend to eat more when the ambient temperature is comfortable, i.e. in the morning and evening which are usually cooler than the hot midday.

During the study, the chickens were placed in colony cages with a liter system, with a total of 10 cages used.

The data collected include morphometric characteristics such as body weight (BW) measured using a digital scale with a capacity of 5 kg with an accuracy of 1 g, chest circumference (LD) measured at the base of the right wing straight down to the sternum bone to the base of the right wing using a measuring tape, wing length (WL) measured from the humerus bone to the phalanges bone on both wings using a measuring tape, Back length (BL) was measured by measuring the distance between the last cervical vertebra and bone, tibia length (TL) was measured from the joint of the tibia bone to the initial joint of the middle finger using a measuring tape, femur length was measured from the illium bone to the border of the tibia bone using a measuring tape and shank length (SL). Data were arranged by sex and then analyzed descriptively to calculate the mean, standard deviation and coefficient of variation. The mean is a value used to represent a set of data and the formula used is as follows:

$$\bar{X} = \frac{\sum_{i=1}^{n} Xi}{n} = \frac{x_i + x_i + x_i + \cdots + x_n}{n}$$

$$Sd^2 = \sqrt{\frac{\sum_{i=1}^{n}(Xi-\bar{X})^2}{n-1}}$$

$$KK = \frac{SD}{X} \text{ x } 100\ \%$$

The research data were analyzed using Analysis of Variance (ANOVA) with a Completely Randomized Design (CRD) in a nested design pattern to obtain the variance components for males and females. The mathematical model used is as follows:

$$Y_{jk} = \mu + J_i + \beta_{ij} + \varepsilon_{ijk}$$

Information:

- Y_{jk} = Observation values of offspring = k, females = j and males
- μ = General average of observations
- J_i = Male influence (i = 1,2,5)
- β_{ij} = Female influence (j = 1,2,10) in male (i = 1,2,5)
- ε_{ijk} = Influence of the ith offspring for each of the i-th male and j-th female (*individual error)*.

Through statistical analysis based on hierarchical structure (nested design) variance components among males, among females within males and among offspring within females and males were calculated. Estimated genetic estimates based on variance components are shown in Table 1.

Heritability value estimates were calculated based on the male variance component ($\hat{h}^2_s$), female variance component ($\hat{h}^2_d$) and the combined male and female variance components ($\hat{h}^2_{s+d}$), can be formulated as follows:

Based on male components ($\hat{h}^2_s$):

$$\hat{h}^2{}_s = \frac{4\sigma s^2}{\sigma s^2 + \sigma d^2 + \sigma^2 \epsilon}$$

Based on the female component ($\hat{h}^2_d$):

$$\hat{h}^2{}_d = \frac{4\sigma d^2}{\sigma s^2 + \sigma d^2 + \sigma^2 \epsilon}$$

Based on male and female components ($\hat{h}^2_{s+d}$):

$$\hat{h}^2{}_{s+d} = \frac{2\sigma(s+d)^2}{\sigma s^2 + \sigma d^2 + \sigma^2 \epsilon}$$

Information:

- $\hat{h}^2_s$ = Heritability estimates based on male components
- $\hat{h}^2_d$ = Estimation of heritability based on female
- component

Table 1: *Structure of hierarchical structure variance analysis (nested design)*

Source variance	Degrees of freedom	Sum of squares	Mean square	Group mean square
Ant σs^2	v-1	$\sum X^2 i. - C$	SSjtn/(v-1)	$\sigma^2\epsilon + k1\sigma^2♀ + k2\sigma^2♂$
Ant σd^2	v(m-1)	$\sum X^2 ij. - \sum X^2 i.$	SSbtn/v (m -1)	$\sigma^2\epsilon + k3\sigma^2♀\sigma^2\epsilon$
Ant $\sigma^2\epsilon$	vm(n-1)	$\sum X^2 ijk - \sum X^2 ij$	SSket/vm (n - 1)	$\sigma^2 T = \sigma^2\epsilon + \sigma^2♀ + \sigma^2♂^2$
Total	Vmn-1		-	

Information: σs^2: Male variance components, σd^2: parent variance components,
$^2\epsilon$: hereditary variance components/individual error;

- $\hat{h}2_{(s+d)}$ = Heritability estimates based on male and female components

Table 2: *Average body weight (g) of Tolaki chickens aged 1-8 weeks*

Age (Week To)	Gender	X± SD	Correlation coefficient %
1	Male	52,88±6,62	12,51
	Female	43,38±3,90	9,00
2	Male	126,87±12,27	9,67
	Female	100,78±5,44	5,40
3	Male	192,66±13,00	6,75
	Female	170,72±4,44	2,60
4	Male	264,69±56,99	11,16
	Female	246,08±12,14	4,93
5	Male	335,16±14,65	4,37
	Female	321,43±25,16	7,83
6	Male	429,90±17,79	4,14
	Female	410,22±19,99	4,87
7	Male	527,72±17,79	2,71
	Female	499,01±14,88	2,98
8	Male	621,54±11,95	1,92
	Female	589,77±11,24	1,91

Results and Discussion

Body weight

Table 2 shows that the average body weight of Tolaki chickens aged 1-8 weeks increased significantly over time. At 1 week of age, the average body weights of male and female Tolaki chickens were 52.88±6.62 and 43.38±3.90, respectively. The body weight of Tolaki chickens continued to increase with age, reaching an average of 621.54±11.95 for males and 589.77±11.24 for females at 8 weeks of age. Body weight increases with age, accompanied by changes in body components such as muscle, bone and fat. This result is higher than the research of Saputra *et al*., (2021) which obtained the average body weight of one-week-old native chickens of 34.68 g/head, the second week of 48.04 g/head, the third week of 70.88 g/head and the fourth week of 107.34 g/head. However, it is lower than the research of Lukmanuddin *et al*., (2018) which reported body weight in local chicken crossbreeds IPB-1 at the age of 3 weeks amounted to 121.27 ± 24.20 g. Sutardi (1997) stated that chickens can grow more optimally in accordance with good genetic potential and get food substances that suit their needs.

The coefficient of variation of body weight based on age showed variation. The highest coefficient was found at 1 week of age, which was 12.51%, while the lowest coefficient was found at 8 weeks of age, which was 1.91%. The coefficient of variation for body weight ranging from 1.91% to 12.51% indicates that the homogeneity of Tolaki chicken breeds is still relatively low. This can be caused by crossbreeding with other local chickens from the region. The standard deviation of body weight for local chickens is about 25%. A group of chickens is considered homogeneous or uniform if the standard deviation of body weight does not exceed 10%. The effect of sex during the 8-week study period showed that male chickens grew faster than female chickens. At 8 weeks of age, roosters had an average body weight of 621.54 grams, while hens had a body weight of 589.77 grams. In male chickens, the growth hormone gene is responsible for producing more of this trait compared to female chickens (Agac *et al*., 2023)

Table 3: *Genetic variance components of body weight of starter phase Tolaki chickens (1-8 weeks old)*

Week To-	Components of genetic variation in body weight			
	σ^2_s	σ^2_d	σ^2_e	σ^2_{total}
1	11,15	0,83	66,46	78,45
2	18,64	8,63	99,83	127,10
3	16,25	12,46	102,05	103,75
4	18,48	13,36	102,38	134,22
5	8,05	15,68	102,38	126,11
6	8,57	13,84	102,63	125,04
7	11,46	17,54	102,09	131,09
8	9,37	14,36	106,31	130,04

Information : σ^s_2: Male variance components, σ^2_e: Components of hereditary variance (individual error), σ^2_d: Parent variance components, σ^2 total : Total variance components

Genetic variance components of body weight in village chickens during the chicken aged (1-8 Weeks)

The genetic variance component of males (σ^2s) shows the genetic contribution of males to the body weight of Tolaki chickens in each observation period. Based on the data in Table 3, the value of σ^2s increased significantly from week 2 to week 4. This indicates that the genetic role of the male becomes more dominant in the early growth phase (2-4 weeks), which also indicates that the male selection period for increasing body weight should ideally be carried out in this age range (Lee *et al*., 2018; Mtileni *et al*., 2017; Sornplang and Karoon, 2022). Data from week 1 then 5 to week 8, the value of σ^2s is relatively low and fluctuating, which can be caused by environmental influences that are more dominant in the early growth phase.

Figure 1: *Information: (a) 1 week old, (b) 2 weeks old, (c) 3 weeks old, (d) 4 weeks old, (e) 5 weeks old, (f) 6 weeks old, (g) 7 weeks old, (d1-h2) 8 weeks old*

The parent genetic variance component (σ^2d) shows the genetic contribution of the female parent to the body weight of the offspring. Based on the data in Table 3, the highest σ^2d value occurred in week 7 with a value of 17.54. In the early phase (weeks I - 8), the σ^2d value tends to increase, indicating that the influence of the female parent is more significant in this phase.

The hereditary variation component or individual error ($\sigma^2\epsilon$) is the variance resulting from the influence of the environment and other uncontrolled factors. Based on the data in Table 3, the value of $\sigma^2\epsilon$ tends to increase with the age of Tolaki chickens. The highest increase occurred at week 8, with a value of 106.31. This value indicates that the influence of the environment is getting greater at the age of 8 weeks. Environmental factors can be in the form of feed quality, maintenance management and chicken health conditions. An increase in the value of $\sigma^2\epsilon$ in the advanced phase can also indicate a greater environmental variation in that period (Lee *et al*., 2018).

The total variance component (σ^2total) shows the sum of contributions from all sources of variance, both from males, females and the environment. The highest σ^2total value occurred in week 4 with a value of 134.22. This indicates that the week 4 growth phase is the period where variation in body weight is greatest, which is largely dominated by the genetic influence of males (σ^2s).

Based on hierarchical analysis of variance, the distribution of genetic variance components for body weight showed positive values in the male variance component (σ(2) s), female variance component (σ(2) d) and offspring variance component (σ(2) ϵ) at each age level. Positive values indicate that the additive genes of the parents can be expressed and have a significant influence on the body weight of the offspring. A positive male variance component indicates that male genetic variance can be passed on to the offspring (Ani *et al*., 2024; Bui *et al*., 2024; Fatmona *et al*., 2024). Conversely, a positive female variance component means that the female genetic variance can also be expressed in the offspring (Fitrimawati and Hellyward, 2024).

Determining the optimal selection time based on total variance is very important to increase the effectiveness of the selection program. Based on these data, genetic selection for increased body weight of Tolaki chickens should be conducted in week 4, where the genetic contribution of males is at its peak.

Table 4: *Heritability values based on body weight of starter phase tolaki chickens (age 1-8 weeks)*

Week To-	Heritability		
	$\hat{h}^2_s$	$\hat{h}^2_d$	$\hat{h}^2_{s+d}$
1	0,57±0,44	0,04±0,14	0,31±0,29
2	0,59±0,46	0,27±0,30	0,43±0,32
3	0,50±0,29	0,38±0,32	0,44±0,33
4	0,55±0,33	0,40±0,23	0,47±0,37
5	0,26±0,27	0,50±0,35	0,38±0,33
6	0,27±0,26	0,44±0,25	0,36±0,30
7	0,35±0,31	0,54±0,36	0,44±0,31
8	0,29±0,24	0,44±0,24	0,36±0,32

Keterangan : $\hat{h}^2_s$: Male component, $\hat{h}^2_{s+d}$: Combined components of the male and female, $\hat{h}^2_d$: Parent component

Heritability of body weight in village chickens during the starter phase (1-8 Weeks)

Based on statistical analysis using a hierarchical approach, the heritability values for body weight were estimated from the male component ($\hat{h}^2_s$), female component ($\hat{h}^2_d$) and the combined male and female component ($\hat{h}^2_{s+d}$), as presented in Table 4.

Body weight heritability values in roosters were low throughout the observation period, ranging from 0.05 to 0.24. The highest values were recorded in weeks 4 and 7 (0.24), while the lowest value was in week 1 (0.05). This indicates that the genetic influence on male body weight is relatively small and environmental factors (feed, cage management, disease) are more dominant. This low heritability also indicates that male selection based on body weight alone may be less efficient and should be combined with other characters or selection indices.

The heritability values of female chickens were relatively higher than males, especially in weeks 5 to 8, with values reaching 1.01 to 1.17. Values above 1.0 may be the result of statistical estimation error or very small environmental variance, making the genetic variance appear very large (Hill and Kirkpatrick, 2010). Nonetheless, this pattern shows that the genetic influence on female body weight is very strong during the growth phase, making this an excellent time for selection. High heritability values are due more to genetic factors than environmental influences, meaning that traits with high heritability are more likely to be passed on to offspring. (Zainudin *et al*., 2024; Zainudin *et al*., 2024; Akporhuarho *et al*., 2025). The high variance caused by additive genetic influences on a trait is reflected in a positive and high heritability value. High heritability values indicate that selection will be more effective and efficient in improving genetic quality (Mukhtar *et al*., 2025; Mushawwir *et al*., 2025).

The combined heritability of males and females showed a fluctuating pattern, with the highest values at week 4 (0.77) and weeks 2 and 3 (0.72-0.73). The moderate to high combined heritability (0.57-0.77) at weeks 2-8 suggests that selection based on body weight would be most effective at these ages, as the proportion of genetic to phenotypic variation is quite large. Variation in values may result from differences in the materials used and environmental variability (Fehri *et al*., 2025; Muhsinin *et al*., 2025).

Conclusions and Recommendations

Based on the results of the discussion it can be concluded that:

- The body weight characteristics of Tolaki chickens in this study have relatively moderate diversity (low homogeneity).
- The heritability value of body weight of Tolaki chickens is in the low to high category, the male component ($\hat{h}2s$) inherits a lower body weight compared to the mother component ($\hat{h}2d$) and the combination of both ($\hat{h}2s + d$).
- The older the chicks, the higher the level of body weight variability. So it is still possible to improve the genetic quality through selection.

Novelty Statement

This study offers novel insights into the heritability and morphometric traits of the Tolaki chicken, a native breed from Southeast Sulawesi. Despite its significance, the breed has been under-researched and this study fills a critical gap in the understanding of its genetic potential. The research focuses on estimating the heritability of body weight in Tolaki chickens during their first 8 weeks of growth, using statistical models such as variance analysis to better understand the genetic components of growth and productivity. This work represents a pioneering effort in documenting the phenotypic and genotypic traits of the Tolaki chicken, contributing to the broader field of livestock breeding and genetic resource management.

Author's Contribution

Rusli Badaruddin: Conceptualization, methodology, data analysis and writing of the original manuscript.
La Ode Nafiu: Data collection, statistical analysis and critical review of the manuscript.
Muhammad Amrullah Pagala: Supervision of the project, writing and revising sections related to the results and discussion.
Takdir Saili: Data collection, drafting of the introduction and analysis of morphometric data.

Generative AI or AI assisted technology statement
The authors declare that no genrative AI was used in the creation of this manuscript.

Conflict of interest
The authors declare no conflict of interest in the execution and publication of this research.

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