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Elasticity Of Linear Body Surface Variables To Body Weight In Ipb D1 Chickens And Native Chickens

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Abstract:
The availability of local chicken production is significantly less than that of purebred chicken. Local chickens have the potential to be developed into superior breeds through selective breeding. IPB D1 chickens are a new type of composite local chickens that exhibit better growth compared to native chickens. This research aims to determine the extent to which linear body surface size variables related to natural selection influence body weight gain in IPB D1 chickens and native chickens. The study involved 12 male and 55 female IPB D1 chickens, as well as 57 male and 83 female native chickens during the grower period. The statistical analysis employed was principal component regression analysis (PCRA). The measured linear body surface size variables included femur length (X_1), tibia length (X_2), tarsometatarsus length (X_3), tarsometatarsus circumference (X_4), length of the third finger (X_5), wing length (X_6), maxilla length (X_7), and comb height (X_8). Result showed that the body weight of IPB D1 chickens, which are broiler-type chickens, exhibited a greater degree of responsiveness to alterations in these variables in comparison to native chickens. Furthermore, the study revealed that the degree of responsiveness (sensitivity) of body weight to alterations in wing length was the most pronounced for both IPB D1 chickens and native chickens.

***Key Word**: Body weight; Linear body surface size; Natural selection; Sensitivity.*

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I. Introduction

Poultry farming plays a pivotal role in national development, particularly in Indonesia, where it constitutes the primary source of animal protein consumption. The availability of meat production from superior broiler breeds is 3.99×10^6 tons, while that from local chickens is 280.72×10^3 tons (BPS, 2023). The availability of local chicken meat production is significantly lower than that of purebred chickens. Local chickens have the potential to be developed into superior breeds through crossbreeding, which can improve the genetic quality and overall quality of local chickens. The cross between a PS male chicken (Pelung chicken × Sentul chicken) and KM female chicken (native chicken × meat type Cobb) resulted in the creation of the IPB D1 chicken. The IPB D1 chicken is a novel composite local chicken breed endorsed by the Indonesian Ministry of Agriculture under Decree No. 693/KPTS/PK.230/M/9/2019. This breed exhibits enhanced growth and reproduction performance compared to native chickens (Sumantri and Darwati, 2017). The native chicken is an indigenous Indonesian chicken, exhibiting a high degree of adaptability due to its capacity to adjust to diverse environmental conditions (Mubarak et al., 2018).

The body weight gain of IPB D1 and native chickens in this study is influenced by a number of variables that are closely related to the ability of these chickens to adapt to their environment. Alternatively, it may be a consequence of natural selection. In the context of natural selection, individuals who demonstrate the capacity to adapt effectively to their environment are more likely to survive. The linear body surface size variables include the linear size of long bones (femur length, tibia length, tarsometatarsus length), tarsometatarsus circumference, wing length, maxilla length, cockscomb height, and third finger length (Nishida et al., 1982). The IPB D1 chickens in the grower period (2-5 months old) were utilized in this study. The native chickens were sourced from traditional farmers who lacked records of the chickens' age; thus, the observation of native chickens in the grower period (2-5 months old) was conducted based on body weight classes according to the literature.

This study employed principal component regression analysis (PCRA) as the statistical analysis. This analysis was selected due to the fact that each variable, which is closely associated with the capacity of chickens to adapt to their environment, has a notable impact on body weight. The extent to which these variables contribute to body weight gain as a result of adaptation or natural selection can be determined based on the elasticity of each variable concerning body weight. The objective of this study is to determine the extent to which linear body surface size variables related to natural selection influence the body weight gain of IPB D1 chickens and native chickens, with the aim of facilitating adaptation and identifying the changes in linear body surface size variables that exhibit the highest level of responsiveness (sensitivity) to body weight. This can be determined based on the sensitivity of body weight to changes in each linear body surface size variable observed as a result of chicken adaptation.

II. Material And Methods

Study Area

The IPB D1 chicken was conducted in Jampang Tengah District, Sukabumi Regency, West Java Province, Indonesia. The altitude was 200-800 meters above sea level, the temperature was 20-27°C, the humidity was 70%-90%, and the chickens were reared intensively with twice daily feeding and ad libitum drinking water. The native chickens utilized in this research were traditionally reared by farmers in the Bantarkalong District of Tasikmalaya Regency, situated at an altitude of 873 meters above sea level, the temperature range of 24-28°C, humidity levels of 70%-90%, and a semi-intensive rearing system employing traditional feeding practices and ad libitum drinking water.

Sampling materials and equipment

Research equipment consisted of digital calipers, measuring tapes, digital scales, and stationery. The materials used were IPB D1 chickens (12 males and 55 females) and native chickens (57 males and 83 females) in the grower period when the chickens were 2-5 months old. The age phase grouping in the grower period in native chickens is based on body weight, which is at two months of age of 600-700 g (Aryanti et al., 2013) and 3-5 months of age of 978-1,261 g (Irmaya et al., 2021).

Data collection

Body weight was quantified using a precision weighing device, while linear body surface measures were obtained through direct measurement with a caliper and a measuring tape. The linear body surface measurements were observed in accordance with the methodology proposed by Nishida et al. (1982), which included the measurement of the femur length (X_1) along the femur bone, tibia length (X_2) from the patella to the tip of the tibia, tarsometatarsus length (X_3) along the tarsometatarsus bone, all of which use a caliper. In contrast, tarsometatarsus circumference (X_4) was measured around the center of the tarsometatarsus bone, and subsequently converted to a caliper. The third finger length (X_5) was measured from the base of the third finger to the tip of the finger, wing length (X_6) from the base of the humerus to the tip of the phalanges, maxilla length (X_7) from the base to the tip of the lower beak, and comb height (X_8) from the base of the cockscomb to the tip of the highest cockscomb.

Statistical analysis

Data was analyzed using Minitab software version 21.3.1. Descriptive statistical calculations included mean, standard deviation, and coefficient of variation. The mean, standard deviation, and coefficient of variation are calculated in accordance with the methodology outlined by Walpole (1993).

$$mean\ (\bar{x}) = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n}$$

$$standard\ deviation\ (s) = \left(\frac{\sum_{x=1}^{n}(x_i - \bar{x})^2}{n-1}\right)^{\frac{1}{2}}$$

$$coefficient\ of\ variation = \frac{s}{\bar{x}} * 100\%$$

Data on linear body surface measurements were further analyzed by T^2-hotelling statistics to determine whether differences were found between IPB D1 chickens and native chickens in each sex (Gaspersz, 1992)

$$T^2 = \frac{n_1 n_2}{n_1 + n_2}\left(\overline{x_1}-\overline{x_2}\right)' S_{G^{-1}} \left(\overline{x_1}-\overline{x_2}\right)$$

$$F = \frac{n_1 + n_2 - p - 1}{(n_1 + n_2 - 2)} T^2$$

Furthermore, the magnitudes will be distributed according to the F-distribution, with free degrees of freedom $V_1 = p$ and $V_2 = n_1 + n_2 - p - 1$.

where:

T^2 = T^2-Hotelling value;
F = calculated value for T^2-Hotelling;
n_1 = sample size of the first chicken group;
n_2 = sample size of the second chicken group;
S_G^{-1} = inverse of the joint covariance matrix (inverse of the SG matrix);
$\underline{\overline{x_1}}$ = vector of the first group chickens;
$\underline{\overline{x_2}}$ = vector of the second group chickens; and
p = number of variables measured.

Data analysis continued by determining the equation for estimating body weight based on regression analysis of principal components (PCRA), after proving the real correlation between each observed variable and body weight through the t-student statistical test. PCRA was to estimate the body weight of males and females based on linear body surface size variables of IPB D1 and native chickens through a body size approach. The principal component regression analysis model (PCRA) according to Gaspersz (1992) is formulated in the following description.

$$Y = W_0 + W_1K_1 + \cdots + W_8K_8$$

where:
Y = dependent variable (body weight);
K_1-K_8 = independent variables (1,2,3,…,8);
W_0 = the intercept; and
$W_1, W_2, \ldots, W_8$ = the slopes.

The extent to which linear body surface size variables contribute to body weight can be determined based on the elasticity values obtained. A higher elasticity value indicates a greater contribution of linear body surface variables to body weight. The elasticity model according to Gaspersz (1992) is formulated in the following description.

$$E_i = b_i\left(\frac{X_i}{\bar{y}}\right)$$

where:
E_i = elasticity of body weight of each observed variable;
b_i = regression coefficient of each observed variable;
X_i = mean value of each observed variable; and
$\bar{y}$ = mean value of body weight.

III. Result And Discussion

Descriptive Statistics

Table 1 presents the mean body weights of IPB D1 and native chickens observed. The observed differences in body weight between the IPB D1 and native chickens were attributed to the influence of breed and environmental factors, both external and internal. The IPB D1 chickens exhibited reduced body weights compared to the native chickens, a difference that was observed in both male and female specimens. As reported by Al-Habib et al. (2020), the average body weight of IPB D1 chickens at 12 weeks of age was 1,178 g for males and 957 g for females. The results of the study differed due to differences in the age of the IPB D1 chickens observed, which in this study included 11, 15, and 16 week old chickens, with the largest proportion of chickens at 11 weeks of age. The mean body weight of the native chickens in this study was not significantly different from that reported by Depison et al. (2022), which was 1,080.47 g at 12 weeks of age. The results of the observation demonstrate that the native chicken samples exhibit greater characteristics than those of the IPB D1 chickens. This is due to the fact that the native chicken samples utilized in the observation are not the same as those employed in the formation of the IPB D1 chickens.

Table 1: Means, standard deviations, and coefficients of variation of observed variables in IPB D1 chickens and native chickens in the grower period.

Variables	IPB D1 chicken		Native chicken	
	Male	Female	Male	Female
X_1 (mm)	77.98±7.29	73.03±7.71	91.96±8.18	86.14±6.30

	(9.35%)	(10.56%)	(8.90%)	(7.31%)
X_2 (mm)	108.27±10.20 (9.42%)	98.71±10.07 (10.21%)	131.58±12.96 (9.85%)	120.70±9.32 (7.72%)
X_3 (mm)	82.33±9.58 (11.63%)	74.11±8.52 (11.50%)	96.36±9.11 (9.46%)	85.02±7.58 (8.91%)
X_4 (mm)	32.00±4.26 (13.33%)	29.22±3.21 (11.00%)	35.81±3.56 (9.94%)	32.60±2.29 (7.02%)
X_5 (mm)	53.89±3.95 (7.32%)	47.57±4.64 (9.75%)	57.68±4.95 (8.58%)	52.83±4.52 (8.56%)
X_6 (mm)	210.73±16.70 (7.93%)	197.09±17.34 (8.80%)	232.09±16.72 (7.20%)	215.37±13.20 (6.13%)
X_7 (mm)	30.00±3.13 (10.43%)	28.74±2.26 (7.87%)	33.22±2.88 (8.67%)	31.08±2.38 (7.64%)
X_8 (mm)	18.72±8.73 (46.62%)	7.43±2.85 (38.40%)	22.56±7.99 (35.43%)	8.32±3.42 (41.10%)
BW (g)	755.3±245.5 (32.51%)	595.7±190.3 (31.94%)	1023.0±252.2 (24.65%)	893.2±178.6 (19.99%)

X_1 = femur length, X_2 = tibia length, X_3 = tarsometatarsus length, X_4 = tarsometatarsus circumference, X_5 = third finger length, X_6 = wing length, X_7 = maxilla length, X_8 = comb height; BW = body weight.

T^2-Hotelling Statistical

The results of the T^2-Hotelling test analysis (Table 2) indicated significant differences in linear body surface size between roosters and hens, respectively in IPB D1 and native chickens ($P < 0.01$). According to Ulupi et al. (2018), discrepancies in growth patterns can be attributed to the internal physiological milieu of chickens. Specifically, the testosterone hormone, which is present in roosters during their growth period, exerts a synergistic effect on growth hormones, resulting in a higher growth rate in roosters compared to hens. Furthermore, a significant difference in linear body surface size was observed between IPB D1 chickens and native chickens in both male and female specimens ($P < 0.01$). Genetic factors have a significant impact on the performance of each chicken breed (Djego et al., 2019).

Table 2: Results of the T^2-Hotelling statistical test based on linear body surface measurements in each of the two groups of IPB D1 chickens and native chickens.

Compared group	Test statistic	F	df		P
			Num	Denom	
IPB D1 ♂ vs IPB D1 ♀	1.369	9.928	8	58	0.000
Native ♂ vs native ♀	1.790	29.308	8	131	0.000
Native ♂ vs IPB D1 ♂	0.596	4.471	8	60	0.000
Native ♀ vs IPB D1 ♀	2.025	32.656	8	129	0.000

df = degrees of freedom; F = fisher; P = probability.

Principal Component Regression Analysis (PCRA)

The results of the t-student test demonstrated that all variables pertaining to the linear body surface size of IPB D1 chickens and native chickens, in both male and female specimens, exerted a markedly pronounced influence on body weight ($P < 0.01$). Each linear body surface size, including femur length, tibia length, tarsometatarsus length, tarsometatarsus circumference, third finger length, wing length, maxilla length, and cockscomb height, demonstrated a highly significant correlation with body weight in groups of male IPB D1 chickens, female IPB D1 chickens, male native chickens, and female native chickens. Body measurements have a significant impact on livestock body weight (Zafitra et al., 2020). The equation for estimating body weight based on these eight variables is presented in Table 3. The resulting equation is the result of an adaptation of IPB D1 chickens and native chickens to body weight, involving the measurement of several physical characteristics, including femur length, tibia length, tarsometatarsus length, tarsometatarsus circumference, third finger length, wing length, maxilla length, and cockscomb height.

Table 3 illustrates that femur length, tibia length, tarsometatarsus length, tarsometatarsus circumference, third finger length, wing length, maxilla length, and cockscomb height in IPB D1 chickens exert a considerably greater influence on body The capacity of each linear body surface size variable to account for body weight in native chickens is notably constrained. weight compared to native chickens. In each of these chicken breeds, the eight linear body surface size variables in roosters were found to exert a greater influence on body weight than in hens. This is based on the coefficient of determination in each PCRA equation presented in Table 3. The coefficient of determination (R^2) shows how far the ability of independent variables is in applying variations in the dependent variable (Ghozali, 2011).

The coefficient of determination in the body weight equation for native chickens is less pronounced. This suggests that changes in body weight in native chickens are predominantly influenced by factors other than femur length, tibia length, tarsometatarsus length, tarsometatarsus circumference, wing length, maxilla length, cockscomb height, and third finger length, despite their adaptation to the traditional extensive rearing system. The results of this study demonstrate that factors other than the aforementioned measurements influence body weight in native chickens. These factors contribute to the observed discrepancy in body weight between native and IPB D1 chickens. It is postulated that these factors include the welfare of native chickens in the wild, which encompasses a more diverse range of dietary options, greater access to oxygen, and the capacity to engage in natural behaviors.

Table 3: Equation for estimating body weight of IPB D1 chickens and native chickens male and female based on principal component regression analysis**.**

	Sex	Equality	R^2
IPB D1 chicken	Male	$Y = -2228.98 + 0.411X_1 + 0.424X_2 + 0.426X_3 + 0.408X_4 + 0.308X_5 + 0.432X_6 + 0.288X_7 + 0.196X_8$	96.11%
	Female	$Y = -1415.05 + 0.290X_1 + 0.308X_2 + 0.305X_3 + 0.268X_4 + 0.254X_5 + 0.317X_6 + 0.267X_7 + 0.119X_8$	79.11%
Native chicken	Male	$Y = -1387.37 + 0.278X_1 + 0.287X_2 + 0.286X_3 + 0.196X_4 + 0.235X_5 + 0.293X_6 + 0.220X_7 + 0.114X_8$	47.59%
	Female	$Y = -711.11 + 0.256X_1 + 0.2723X_2 + 0.202X_3 + 0.142X_4 + 0.200X_5 + 0.284X_6 + 0.194X_7 + 0.063X_8$	25.69%

Y = body weight; R2 = coefficient of determination.

The natural behavior of chickens includes activities such as pawing the ground, taking dust baths, and receiving direct sunlight (Fitra et al., 2021). The five principles of animal welfare, or five freedoms, include freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury, and disease, freedom to express normal behavior, and freedom from stress and pressure. These five points can be attributed to both internal and external environmental factors. Additionally, the absence of selective breeding in native chickens is postulated to be a contributing factor to the observed variability in linear body surface size without any corresponding impact on body weight sensitivity. Livestock productivity is influenced by the interplay between selection and adaptation (Swuandana et al., 2022).

The adaptability of livestock through natural selection will affect the production traits of the animals in question (Zulkharnaim et al., 2010). The process of natural selection has resulted in the development of livestock that are capable of withstanding the rigours of their surrounding natural environment. As posited by Lukmanudin, Sumantri, and Darwati (2018), the length of the femur bone is intimately associated with the growth of muscle conformation in chickens. As stated by Pulcini et al. (2021), the tibia bone serves the function of supporting the chicken's body. As posited by Hastuti et al. (2021), the length and circumference of the tarsometatarsus serve to support the weight of the chicken body, which is in turn correlated with the productivity of the animal. As posited by Saleh and Erwan (2016), the length of the wings and the height of the cockscomb are correlated with heat release or thermoregulation. This is achieved through the airflow generated by the extension of the wing bone and the increased peripheral blood flow in the cockscomb. As posited by Matsui et al. (2016), the maxilla serves as an oral cavity for the ingestion of nourishment and is utilized for the grasping of food items. In accordance with the findings of Sada et al. (2018), the length of the third finger is associated with the posture adopted when perching and scavenging food.

Elasticity of Chicken Body Surface Size to Body Weight

The significance test of the regression coefficients was found to be highly significant in each of the principal component regression equations ($P < 0.01$). The responsiveness (sensitivity) of body weight to changes in linear body surface measures of chickens was determined based on their elasticity values. The elasticity value was dependent on the obtained regression coefficients and the means of each variable of linear body surface measures and mean body weight. The highest elasticity value in each principal component regression equation was found in wing length (Table 4), indicating that changes in wing length will result in changes in body weight. The observed changes in wing length in IPB D1 chickens and native chickens can be attributed to the influence of natural selection. In this instance, the natural selection process has resulted in the evolution of wing length that provides the greatest flexibility or change among other linear body surface size variables relative to body weight. The findings of this study suggest a correlation between wing length and body weight, which can be attributed to evolutionary adaptations in response to environmental pressures. Saleh and Erwan (2016) posited that the length of the chicken wing is utilized by the bird to regulate its body temperature through the regulation of airflow, whereby the stretching of the wing bones facilitates the dissipation of heat from and into the body. Winangun (2023) posited that the wings of chickens serve as a balancing mechanism when the birds move.

Table 4: Size elasticity of observed variables on body weight of IPB D1 chickens and male and female native chickens.

Type	Sex	Variables (X_i)	Regression coefficient (b_i)	Mean value ($\bar{X}_i$)	Elasticity (E_i)	Rank
IPB D1 chicken	Male (Y_i = 755.3)	X_1	0.411	77.98	0.0424	4
		X_2	0.424	108.27	0.0608	2
		X_3	0.426	82.33	0.0464	3
		X_4	0.408	32.00	0.0173	6
		X_5	0.308	53.89	0.0220	5
		X_6	0.432	210.73	0.1205	1
		X_7	0.288	30.00	0.0114	7
		X_8	0.196	18.72	0.0048	8
IPB D1 chicken	Female (Y_i = 595.7)	X_1	0.290	73.03	0.0356	4
		X_2	0.308	98.71	0.0510	2
		X_3	0.305	74.11	0.0379	3
		X_4	0.268	29.22	0.0131	6
		X_5	0.254	47.57	0.0203	5
		X_6	0.317	197.09	0.1049	1
		X_7	0.267	28.74	0.0129	7
		X_8	0.119	7.43	0.0015	8
Native chicken	Male (Y_i =1023.0)	X_1	0.278	91.96	0.0250	4
		X_2	0.287	131.58	0.0369	2
		X_3	0.286	96.36	0.0270	3
		X_4	0.196	35.81	0.0069	7
		X_5	0.235	57.68	0.0133	5
		X_6	0.293	232.09	0.0665	1
		X_7	0.220	33.22	0.0071	6
		X_8	0.114	22.56	0.0025	8
Native chicken	Female (Y_i = 893.2)	X_1	0.256	86.14	0.0247	3
		X_2	0.273	120.70	0.0368	2
		X_3	0.202	85.02	0.0192	4
		X_4	0.142	32.60	0.0052	7
		X_5	0.200	52.83	0.0118	5
		X_6	0.284	215.37	0.0686	1
		X_7	0.194	31.08	0.0067	6
		X_8	0.063	8.32	0.0006	8

The IPB D1 chicken was developed as a local breed with the advantage of being a meat-producing chicken with fast growth and good adaptation to the environment (Sumantri and Darwati, 2017; Al-Habib et al., 2020). The responsiveness or sensitivity of body weight to changes in femur length, tibia length, tarsometatarsus length, tarsometatarsus circumference, wing length, maxilla length, cockscomb height, and third finger length in IPB D1 chickens was greater than that of native chickens (Table 4). Table 5 illustrates that alterations in wing length exhibited the highest degree of responsiveness (sensitivity) or body weight sensitivity in IPB D1 and native chickens. The results of this study indicate that the level of responsiveness or sensitivity of body weight is higher in IPB D1 chickens compared to native chickens. Consequently, changes in body weight due to changes in wing length are also higher in IPB D1 chickens compared to native chickens, despite the body weight of IPB D1 chickens in this study being lower than that of native chickens. The greater number of samples of native chickens in this study did not impact the coefficient of determination, as it was lower than that of IPB D1 chickens (Table 3).

The correlation between natural selection on femur length, tibia length, tarsometatarsus length, tarsometatarsus circumference, wing length, maxilla length, cockscomb height, and third finger length and changes in body weight was observed in IPB D1 and native chickens, with the highest sensitivity due to changes in wing length. Artificial selection on body weight indirectly affected a number of morphological variables, including femur length, tibia length, tarsometatarsus length, tarsometatarsus circumference, wing length, maxilla length, cockscomb height, and third finger length. These effects coincided with natural selection on eight linear body surface size variables. This is evidenced by the high coefficient of determination observed in IPB D1 chickens (Table 3). The higher elasticity value observed in IPB D1 chickens (Table 4) reflects the selection of each linear body surface size by nature during the adaptation process. From a genetic standpoint, IPB D1 chickens demonstrate greater potential due to their heightened responsiveness to changes in the linear body surface size that is preferred by nature (i.e., natural selection). Adaptability is inextricably linked to the capacity of chickens to not only survive but also to function adequately in the face of extreme environmental conditions (Pagala et al., 2018).

Table 5: Responsiveness (sensitivity) of body weight based on wing length elasticity IPB D1 chickens and native chickens.

	Sex	Elasticity value wing length (E_i)	Responsiveness (sensitivity) of body weight for every 1 cm increase in wing length (g)
IPB D1 chicken	Male	0.1205	4.301
	Female	0.1049	3.174
Native chicken	Male	0.0665	2.909
	Female	0.0686	2.862

IV. Conclusion

The responsiveness of body weight to changes in femur length, tibia length, tarsometatarsus length, tarsometatarsus circumference, wing length, maxilla length, cockscomb height, and third finger length in this study was found to be higher in IPB D1 chickens as broilers, compared to native chickens. The responsiveness of body weight to changes in wing length was found to be the highest in both IPB D1 and native chickens.

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