Estimation of Body Weight Using Linear Body Measurements in Two Crossbred Beef Cattle

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ABSTRACT
In rural areas where weighing scales are not easily accessible in the farms to monitor cattle performance, live weight is often predicted by using less accurate visual approaches which is highly subjective. This research was conducted to provide an easy method to estimate life weight using body measurements data for two cattle breeds: Simmental-Ongole crossed and Limousine-Ongole crossed (locally named, SimPO and LimPO). The data were collected from cattle owned by butches with 85 possession of slaughter cattle (> 250 kg of live weight). The measured variables including body length, chest depth, chest width, chest circumference, abdominal circumference, height at withers, height at sacrum, hip height, head index, head length, and head width. Data was analysed using simple and multiple linear regression. The results showed that head index was not significantly different between two breeds. The correlation results showed that body length and head index were not significant ($P<0.05$). Overall results of the Quadratic Method showed that abdominal circumference explained most variance on body weight; which R^2 value was the largest (0.657) and the root of mean squared error (RMSE) value was the lowest (41.313). The R^2 value in multiple linear regression is within the interval of 0.611-0.9. We conclude that the prediction for the models were relatively weak, this can be seen from the RMSE value of all models which were in the interval of 20.37-43.67 kg.

Keywords: *Beef cattle, Crossbred, Local Butcher, Linear body measurement, live weight*

1. INTRODUCTION

Beef cattle highly contributes in the fulfillment of nutritional needs, especially for animal-originated protein sources. Most of Indonesia's beef production is provided by smallholder farmers (78%); whereas the rest were obtained through importations (5% for meat products and 17% live cattle [1]. In response to the growing demand for meat, Indonesian government has introduced a crossbreeding program with European beef cattle breeds to increase the national beef production. Indonesia has many breeds of cattle that have been adapted to the existing climate and environment. Bali, Madura, Ongole, Brahman, Brangus (Brahman and Aberdeen Angus), Ongole crossed (locally named *Peranakan* Ongole / PO), Simmental x PO (locally named SimPO), Limmousine x PO (locally named LimPO) and Frisian Holstein (FH) are cattle breeds which widely kept by farmers in Indonesia [2].

An adult male SimPO and LimPO can reach 1150 kg and 1100 kg of weights, respectively; while adult females can reach 800 kg for SimPO and 575 kg for LimPO [3]. Farmers prefer these breeds over local cattle (Ongole Crossed /PO) due to higher birth weights, faster growth, good adaptation to the environment and simple feeding, larger adult body size and attractive appearance.

In rural areas where weighing scales are not easily accessible in the farms to monitor cattle performance, live weight is often predicted by using less accurate visual approaches which is highly subjective. Therefore, a simple and reliable method to estimate life weight using easily obtained measurements is needed. Several studies have found a strong relationship between live weight of livestock and their linear measurements then developed a live weight prediction model using body measurements. Accurate prediction of live weights can be influenced by several parameters including breed, sex and age [4,5]. The objective of the research was to measure the accuracy of the live weight prediction models employing linear body measurements variables; using separate equations for these two groups of cattle breeds.

2. MATERIAL AND METHODS

2.1. Material

The study was conducted from January 2021 to May 2021 at a slaughterhouse and Dimoro Traditional Livestock Market, in Blitar, East Java. Eighty-five slaughter cattle (SimPO and LimPO), belonged to a butcher, with minimum 250 kg of live weights, were observed and measured.

2.2. Methods

2.2.1. General

Measurement of the body size of livestock: an overview of the size and shape of various parts of the livestock body measured based on the methods of [6,7]. Body length (cm) measured by a straight line from the front of the shoulder joint (tubercullum major humeri) to the back edge of the protrusion of the seated bone (tuber ischii). Chest depth (cm) measured from the top of the shoulder to the lower edge of the breastbone (crista sterni of the sterni manubrium). Chest width (cm) was measured from the bulge of the shoulder joint (os scapula) left and right; whereas Chest circumference (cm) measured circular chest just behind the shoulder blade (os scapula). Abdominal circumference (cm) was measured circular abdomen right in the middle of the body, Height at withers (cm) measured from the highest part of the shoulder through the back of the scapula, perpendicular to the ground. Height at sacrum (cm) was measured from the highest distance of the pelvis perpendicular to ground. Hip height (cm) was measured from the highest distance of the hip perpendicular to the ground. Head index (%) was measured by the formula (Head width x 100%), head length (cm) was measured at the distance between the nasal mirror (planum nasolabialis) to the intercornuale border dorsal median line of head; head width (cm) measured at the distance between the *archus zygomathicus* beside the orbit. Rump width was measured from the distance between the posterior points of the back leg pin bone.

2.2.2. Statistic

Statistical analysis was performed using the SAS® Software. The measured individuals were grouped into two breed groups (LimPO and SimPO). Analyses were conducted separately for each breed. For each body measurement variable, the least square mean (LSMEANS) and related standard error (SE) were calculated using a generalized linear model procedure (GLM). If necessary, the Tukey HSD test was applied to compare the paired means. Pearson's correlation coefficients (r) were calculated and tested for significance using the PROC-CORR procedure to assess the linear association between live weight and linear measurements. The live weight was then regressed on each of the independent variable using the AUTOREG procedure. Different predictive models were evaluated and compared using coefficients of determination (R^2), root of mean squared error (RMSE) and Mallows' Cp statistics. R^2 was used to describe the proportion of measurable data variance described by the model; the value ranged from 0 to 1, with a higher value (≥ 0.5) indicating less variations due to error. RMSE is the standard deviation estimate of the error term, and the lower the RMSE, the better the predictive model performance. Therefore, RMSE is associated with ensuring prediction accuracy. For all analyses, the value was considered to differ significantly at < < 0.05.

3. RESULTS AND DISCUSSION

3.1. Breed differences in live weights and linear body measurements

Phenotypes such as body weight and sizes were often used to study the genetic relationships of livestock. Data of body measurements indicate the size and shape of various parts of the body including: body length (cm), chest width (cm), chest depth (cm), chest circumference (cm), abdominal circumference (cm), height at withers (cm), height at sacrum (cm), hip height (cm), and head index (%) [6].

The average weight of the cattle in this study was 394.7 ± 7.91 (LimPO was 399 ± 10.3 and SimPO was 389 ± 12). All these body measurements are not significant and negatively correlated to both breeds of cattle except for the head index data (Table 1). The head index showed the highest variability with an overall value of 40.2 ± 0.59, LimPo head index value of 47.3 ± 0.78 and for SimPO head index 33.1 ± 0.91. LimPO tends to have higher body measurement variables compared to SimPO. Various measurements of body measurements have an important role in identifying various cattle breeds, both between one cattle breed and between cattle farms [8]. Heryanti et al [6] added that there are allegations that the size of the cattle body is influenced by factors of feed, genetic, management of the distribution and inbreeding level.

3.2. Phenotypic Correlation

The shape and size of the body of cattle can be known by measurements or visual observation. The body size of cattle is often used to evaluate growth periodically. Cattle are diverse which can be seen from the observable characteristics, traits expressed by an individual called phenotype [9]. Based on the results of the study, the correlations of life weight and independent variables are shown in Table 2. The life weight is significantly and positively related to each of the observed body measurement variables ($r = 0.59 - 0.791$; $p < 0.001$) except for body length and head index. Overall, the highest correlation was obtained between life weights and abdominal circumference and lowest was between life weights and rump width (Table 2). Different results were obtained in the study of Vanvanhossou et al [7] which stated that life weight is significantly and positively related to each of the body measurements variables ($r = 0.90 - 0.97$; $p< 0.001$). Overall, the highest correlation was obtained between life weight and chest circumference and lowest between life weight and height at sacrum.

The relationship between life weight and body measurements related to height were low ($r = 0.111 – 0.123$). The highest correlation was observed between the chest width of the LimPO ($r = 0.809$) followed by the abdominal circumference of the SimPO ($r = 0.796$), and the lowest was the rump width of the SimPO breed ($r = 0.510$). The correlation of body length and head indexes showed insignificant correlation coefficients with overall values ($r = 0.123$) and ($r = 0.111$), for the correlation of head indexes in limpo ($r = - 0.034$). Pearson's correlation coefficient values from across breed data were relatively lower than when obtained by conducting the same procedure on separated breed data. However, for the same body measurement variable, the correlation coefficients were higher in male than female cattle; further, the younger the animal, the higher the correlation coefficient between their life weight and each linear body measurement [7].

The plot of life weight regression in simple linear models (i), squares (ii) and allometric (iii) is presented in Figure 1. From the plot it Figure 1, it is seen that the linear model between Weight and abdominal circumference gave the largest R^2 value in the linear regression equation and allometric equation. The breed's effect on simple, quadratic, and allometric linear regression on the variable Abdominal Circumference with Weight gain is presented in Table 3. From the results it is seen that for the overall results the Quadratic Method is the best method to determine the effect of variable abdominal circumference on body weight where R^2 has the largest value (0.657) and the smallest RMSE value (41.313) compared to the other two methods. The results of the Quadratic method on the LimPO data also showed that this is the best method to determine the effect of variable abdominal circumference on body weight where the value of R^2 has the largest value (0.664) and the smallest RMSE value (40.138) compared to the other two methods. The results for the SimPO breed allometric method visualization showed that this is the best method to find out the relationship between abdominal circumference variable on body weight when viewed based on the criteria of R^2 value that has a value of 0.655. But when viewed from the value of RMSE (41.702) quadratic method is the best method. Hence, in this case, researchers can use quadratic or allometric methods for estimating the influence of variable abdominal circumference on body weight. Multiple linear regression equations are mathematical equations that aim to find the relationship between a dependent variable and two or more independent variables [10]. The results of the regression models with the stepwise method showed that there are only five variables that are considered important for predicting the weight available in Table 4.

The quadratic regression model provides better results on overall results and for each breed based on both R^2 and RMSE values. The value of the coefficient of determination (R^2) describes how far the model's ability to explain the variation of dependent variables with values between zero and one [11]. The results of the regression model with the stepwise method showed that there are only five variables that are considered important to predict Live Weight; the five variables were Abdominal Circumference, Chest Width, Height at Withers, Chest Depth, and Height at Sacrum based on AIC values. The values of R^2 in multiple linear regressions were at the intervals of 0.621-0.9. In line with research Aguantara et al [10] which stated that the coefficient of determination R^2 was 0.939 where chest circumference and height have the influence on body weight; while body length has no influence on body weight.

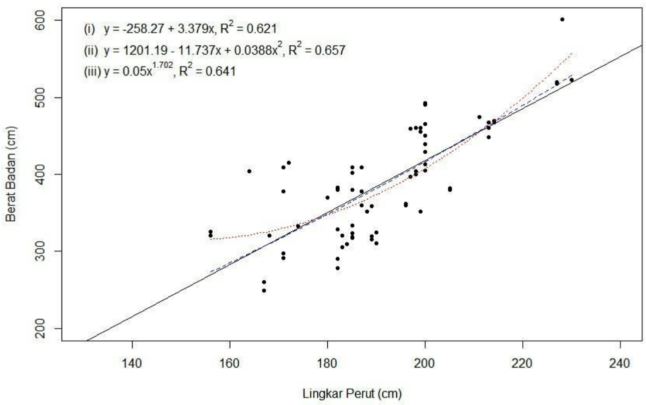

Figure 1 Live weight regression plot live weight and stomach circumference

Table 1. Physical characteristics of cross breeds

Vital Body Data	Cattle Breeds		Average
	LimPO	SimPO	
Body Weight	399 ± 10.3	389 ± 12	394.7 ± 7.91
Body Length	145 ± 2.1	145 ± 2.44	145.1 ± 1.61
Chest Depth	68.1 ± 0.71	67.9 ± 0.85	68 ± 0.56
Chest Width	45.7 ± 1.02	45.7 ± 1.19	45.6 ± 0.78
Chest Circum	179 ± 3.82	177 ± 4.46	178 ± 2.94
Abdominal Circum	194 ± 2.42	192 ± 2.82	193 ± 1.86
Height at Withers	127 ± 0.82	125 ± 0.96	126 ± 0.63
Pelvic Height	133 ± 0.87	131 ± 1.02	132 ± 0.67
Hip Height	132 ± 0.77	130 ± 0.90	131 ± 0.59
Rump Width	44 ± 0.97	42.6 ± 1.13	43.3 ± 0.74
Head Index	47.3 ± 0.78*	33.1 ± 0.91*	40.2 ± 0.59*

Description: *shows a significant difference in the p.value level < 0.05.

Table 2. Output correlation of living weights with independent variables

Vital Body Data	Cattle Breeds		Average
	LimPO	SimPO	
Body Length	0.117^{NS}	0.129^{NS}	0.123^{NS}
Chest Depth	0.628	0.567	0.600
Chest Width	0.809	0.768	0.790
Chest Circum	0.622	0.612	0.617
Abdominal Circum	0.787	0.796	0.791
Height at Withers	0.619	0.690	0.645
Pelvic Height	0.660	0.582	0.623
Hip Height	0.741	0.635	0.695
Rump Width	0.643	0.510	0.590
Head Index	-0.034^{NS}	0.293^{NS}	0.111^{NS}

Description: NS signifies an insignificant correlation coefficient, the rest of the entire correlation coefficient is significant at p.value < 0.001.

Table 3. The breed's effect on simple, quadratic, and allometric linear regression on variable abdominal circumference with body weight

Analisis	b_0	b1	b2	R^2	RMSE
Simple Linier					
LimPO	-250.377	3.350		0.611	43.692
SimPO	-265.964	3.402		0.623	43.426
Average	-258.273	3.379		0.621	43.667
Quadratic					
LimPO	1806.705*	-17.690*	0.053	0.664	40.138
SimPO	870.770	-8.573	0.031	0.642	41.702
Average	1201.194*	-11.736*	0.038	0.657	41.313
Allometric					
LimPO	0.060	1.668		0.638	43.009
SimPO	0.040	1.743		0.655	42.784
Average	0.050	1.702		0.641	43.006

Description: * Indicates a significant coefficient at the rate of 5% / 0.05 (p.value < 0.05)

Table 4. Stepwise regression model five variables to predict weight

Analisis	b_0	b_1	b_2	b_3	b_4	b_5	R^2	RMSE	AIC
LimPO									
LP	-250.373	3.35					0.611	43.692	515.219
LP+LD	-236.208	2.012	5.363				0.79	31.769	485.991
LP+LD+TG	-641.257	1.858	4.309	3.807			0.879	23.783	459.616
LP+LD+TG+DD	-625.493	1.534	4.623	2.901	2.165		0.888	22.682	456.971
LP+LD+TG+DD+TP	-713.811	1.579	4.296	0.489^{NS}	1.979	3.104	0.9	21.176	452.238
$LP^2+LD^2+TG^2+DD^2+TP^2$	-169	0.00395	0.0424	0.0017^{NS}	0.0199	0.0116	0.907	20.377	448.467
SimPO									
LP	-265.964	3.402					0.623	43.426	379.681
LP+LD	-287.473	2.349	4.928				0.806	30.726	356.771
LP+LD+TG	-639.564	1.792	4.448	3.861			0.859	25.763	346.087
LP+LD+TG+DD	-618.346	1.417	5.01	2.477	2.913		0.882	23.187	340.503
LP+LD+TG+DD+TP	-626.797	1.398	4.983	1.380^{NS}	3.157	1.023^{NS}	0.882	22.846	341.436
$LP^2+LD^2+TG^2+DD^2+TP^2$	-132.5	0.00339	0.0502	0.0046^{NS}	0.0308	0.0042^{NS}	0.892	21.765	337.947
Rerata									
LP	-258.273	3.379					0.621	43.667	889.240
LP+LD	-260.323	2.177	5.134				0.799	31.562	836.056
LP+LD+TG	-633.834	1.83	4.389	3.768			0.876	24.669	796.168
LP+LD+TG+DD	-622.121	1.468	4.798	2.719	2.524		0.891	22.949	785.883
LP+LD+TG+DD+TP	-654.885	1.450	4.689	1.210^{NS}	2.683	1.669	0.896	22.284	782.881

Description: NS (Non-Significant) indicates an insignificant variable coefficient (p.value >0.05);

4. CONCLUSION

The value of R^2 in multiple linear regressions were at intervals of 0.611-0.9. Quadratic regression models provide better results on overall and for each breed data based on both R^2 and RMSE values. But the prediction for the model looks quite weak; this was seen from the RMSE value for the models which were at intervals of 20.37 - 43.67 kg.

AUTHORS' CONTRIBUTIONS

All authors contributed to manuscript conceptualization, editing, review for submission, and additional research development.

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