Research Article

Prediction of Body Weight from Body Measurements in Bali Cattle of Indonesia Using Regression Analysis

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Abstract | Live body weight (BW) is an economically important trait in a production system which helps in the selection of animals for breeding. This study aimed to estimate the relationship between BW and some body measurements (BMs) such as hip height (HH), body length (BL), and chest girth (CG) at weaning, and to detect the best-fitted regression model for the prediction of BW in Bali cattle. Data from 535 (275 males and 260 females; aged six months) of Bali cattle were collected from the Bali Cattle Breeding Center during the period 2018-2020. The Pearson correlation (r) between BW and BMs was determined, and the simple and multiple regression analysis were performed in a Matlab R2021a. The quality of fit of the models was evaluated using the coefficient of determination (R^2) and root mean squared error (RMSE). The results showed that BW had a positively high significant correlation ($P < 0.01$) with HH ($r = 0.756$), BL ($r = 0.754$), and CG ($r = 0.877$). The stepwise regression results showed that the model using three predictors (BW = -159.57+0.44HH+0.69BL+1.38CG) was the best-fitted model ($R^2 = 0.814$; RMSE = 0.834) for the prediction of BW, followed by using BL+CG, HH+CG, CG, HH+BL, HH, and BL. The correlation results imply that BW might be improved by the enhancement of HH, BL, and CG. In conclusion, the BW could be predicted accurately using the combination of HH, BL, and CG. The findings might benefit farmers in Bali cattle breeding through the estimation of BW from BMs.

Keywords | Bali Cattle, Body weight, Body measurement, Correlation, Regression

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INTRODUCTION

Bali cattle is one of Indonesia's native genetic resources that requires development and conservation. This breed is also one of the recognized breeds of cattle that have been registered as local breeds by the Ministry of Agriculture of the Republic of Indonesia (Hariyono, 2022). The Bali Cattle Breeding Center (BPTU-HPT Denpasar) is currently responsible for the development of Bali cattle with the aim of improving the genetic quality and ensuring the sustainability of the breed. Bali cattle have high growth potential and are currently found in almost all regions of Indonesia (Jakaria et al., 2019; Azis et al., 2022). To protect the purity of the breed, government regulations have been enacted prohibiting the introduction of other breeds of cattle into the Bali region. The Bali cattle are superior because they are adaptable to tropical environments, reproduce well, and are resistant to disease (Suwiti et al., 2017). In terms of performance, growth traits like live body weight (BW) and body measurements (BMs) such as hip height (HH), body length (BL), and chest girth (CG) have been important in the selection of the breed based on the Indonesian National Standard (SNI). Moreover, the growth traits are economically important traits in practical breeding because they contribute to farm profitability and are considered for inclusion in a breeding objective (Prihandini et al., 2021).

Live BW has been reported to be positively associated with the growth dimension of linear BMs in ruminants, in which an increase in BW is accompanied by an increase in BMs (Lukuyu et al., 2016). The positive relationship between BW and BMs in cattle (Irshad et al., 2013; Jakaria et al., 2019; Nurgiartiningsih, 2017), goats (Dakhlan et al., 2021; Iqbal et al., 2013; Putra and Ilham, 2019), and sheep (Ravimurugan et al., 2013; Shirzeyli et al., 2013) have been reported to benefit livestock breeding program for improved meat production. Several authors have found strong associations between BW and BMs in animals and have developed mathematical equations for the prediction of BW from BMs by simple and multiple regression analysis (Agung et al., 2018; Vanvanhossou et al., 2018). Several formulas are available for the estimation of BW in cattle, such as the Schrool and Smith formula, but these show a high bias in Indonesian cattle, particularly in Bali cattle. Samosir and Daulay (2016) reported a high deviation, 34.04% and 29.23% using the Schrool and Smith formula, respectively, for the estimation of BW in Brahman Cross, Aceh, and Bali cattle.

Although live BW can be accurately measured using a scale, there are several circumstances and scenarios that require a more practical approach to estimate BW. Approaches to determine BW from BMs in various ruminants vary in accuracy and adequacy (Ashwini et al., 2019; Widyas et al., 2021), which depends on breeds, ages, sexes, and production systems. BW is closely related to BMs, and chest girth is one of the BMs that is generally considered to be the most satisfactory single predictor of live BW in cattle (Agung et al., 2018; Lukuyu et al., 2016). This method is cheap, accurate and consistent. Therefore, many predictive regression equations are based on this BM alone or in combination with other BMs. To date, there is limited information on the prediction of BW using BMs with the regression method in Bali cattle. Therefore, this study aimed to estimate the relationship between BW and BMs (hip height, body length, and chest girth) at weaning, and to detect the best-fitted regression model for the prediction of Bali cattle BW.

MATERIALS AND METHODS

Ethical approval

The design of this study has been approved by the Research Ethics Commission, Universitas Brawijaya (018-KEP-UB-2022).

Location of the study

The study was conducted at the Bali Cattle Breeding Center, a facility focused on breeding and raising Bali cattle in Indonesia. Bali cattle (males and females) were not placed in separate paddocks, but were grouped in one paddock containing 30 individuals. The number of cattle in the paddock was determined by pasture availability. They were available to graze at any time and were fed supplementary diets (concentrate as much as 2.5% of body weight with crude protein content 18%) in the morning (7:00-8:00 am) and afternoon (3:00-4:00 pm) based on average weight. Each ranch was provided with drinking water and mineral blocks, with free access for all cattle.

Data collection

A total of 535 (275 males and 260 females, aged 6 months) of Bali cattle, recorded from 2018 to 2020 at the Bali Cattle Breeding Center were used in this study. Live body weight (BW), hip height (HH), body length (BL), and chest girth (CG) were measured at weaning age. The BW and BMs at weaning are of primary economical importance in Bali cattle production system. The BW was measured with an accuracy of 1% using a digital scale ID3000 (truetest Limited, New Zealand) calibrated every six months. A standard measuring tape was used to measure the CG (behind the exact forelegs), HH (from the ground to the hip bone) and BL (from the shoulder blades to the collar bone). To reduce measurement inaccuracies, each measurement was performed by a single operator, an expert in cattle measurement.

Data analysis

The Pearson correlation was used to estimate the relationship between BW and BMs (HH, BL, and CG) with the probability of 5% significant difference and 1% highly significant difference, as explained by Nurgiartiningsih (2017).

$$r = \frac{\sum(x_i - \bar{x})\,(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}}$$

Where r was Pearson correlation coefficient, x_i was x variable samples, $\bar{x}$ was mean of values in x variable, y_i was y variable samples, and $\bar{y}$ was mean of values in y variable.

The simple and multiple linear regression was performed in a MATLAB R2021a (9.10.0.1602886) as explained by Vanvanhossou et al. (2018), as follows:

$BW = \alpha + \beta X_i + \varepsilon$ (a)
$BW = \alpha + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$ (b)
$BW = \alpha + \beta_1 X_1 + \beta_2 X_{2+} \beta_3 X_3 + \varepsilon$ (c)

Where: BW was the live body weight, α was intercept, β was coefficient regression, X was body measurement, ε was an error. The quality of fit of the models was evaluated using coefficient of determination (R^2), standard error of mean (SEM), and root mean squared error (RMSE) with the mathematical model as follow:

Coefficient of determination (R^2):

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(y_i - y_{ip}\right)^2}{\sum_{i=1}^{n}\left(y_i - \bar{y}_{ip}\right)^2}$$

Standard error of mean (SEM):

$$\sigma = \frac{\sqrt{\frac{1}{2}\sum_{i=1}^{n}(y_i - \bar{y})^2}}{n-1}$$

Root mean square error (RMSE):

$$RMSE = \sqrt{\frac{1}{2}\sum_{i=1}^{n}\left(y_i - y_{ip}\right)^2}$$

Where, n was the number of data sets, y_i was the observed value of weight at weaning, y_{ip} was the predicted weights at weaning. The R^2 was used to evaluate the proportion of the variance for a dependent variable that is explained by an independent variable. The value normally ranges from zero to 1 (Nakagawa and Schielzeth, 2013). The SEM and RMSE were used in prediction accuracy; a low RMSE value indicates that the simulated and observed data are close to each other showing a better accuracy (Barde and Barde, 2012).

RESULTS

Descriptive statistics

Table 1 summarizes descriptive statistics on live BW and BMs of Bali cattle. The data were pooled over the sex groups. The mean values for BW, HH, BL, and CG were 90.97 kg, 92.53 cm, 86.66 cm, and 108.69 cm, respectively, with the coefficient of variation ranging from 0.06 (HH) to 0.21 (BW).

Correlation and regression analysis

The results of the Pearson correlation and regression analysis are presented in Table 2. BW had a positively high significant correlation ($P < 0.01$) with HH ($r = 0.756$), BL ($r = 0.754$), and CG ($r = 0.877$). The HH, BL, and CG (as independent variables) were used to detect the best-fitted regression model for the prediction of BW (as a dependent variable) in Bali cattle. As shown in Figure 1, the first trait entered into the model was HH which contributed 57.10% ($R^2 = 0.571$) to the variation of BW with a RMSE value being 12.62. The BL and CG, each as a single predictor for the BW showed R^2 of 0.568 and 0.769, respectively and RMSE of 12.73 and 9.28, respectively. The regression model using two predictors showed higher R^2 ranging from 0.632 (HH+BL; RMSE= 11.70) to 0.809 (BL+CG; RMSE= 8.44) (Figure 2). In general, the stepwise regression results showed that the model using three predictors (BW = -159.57+0.44HH+0.69BL+1.38CG) was the best-fitted model ($R^2 = 0.814$; RMSE = 0.834) for the prediction of BW, followed by using BL+CG, HH+CG, CG, HH+BL, HH, and BL.

DISCUSSION

Live BW is an important trait in animal productivity, providing an informative indicator for feeding, health, breeding, and selection of livestock (Ruchay et al., 2022). Monitoring, recording, and predicting livestock BW allows for timely intervention in diets and health, greater efficiency in genetic selection, and identification of optimal times to market animals because animals that have already reached the point of slaughter represent a burden for the feedlot (Wang et al., 2021). The findings of this study indicated that BW had a positively high significant correlation with hip height, body length, and chest girth. The similar outcomes were observed on Nguni cattle (Hlokoe and Tyasi, 2022), on Bali cattle (Agung et al., 2018; Gunawan and Jakaria, 2010), on Holstein-Friesian bulls (Tutkun, 2019), on West African Shorthorn Somba cattle (Vanvanhossou et al., 2018), and on Girolando cattle (Weber et al., 2020). The results suggested that the improvement of hip height, body length, and chest girth might enhance body weight in Bali cattle. The results also implied that body measurements are perfect instruments used to assess the BW of the animals.

The stepwise regression was further used to find out models for the estimation of BW in Bali cattle. The stepwise method was performed with all predictors of measurements, in which BW entered into a dependent variable, whereas hip height, body length, and chest girth served as independent variables. The quality of fit of the models was evaluated

Table 1: Descriptive statistics of body weight and body measurements in Bali cattle

Trait	n	Mean	SD	CV	Min	Max
BW (kg)	535	90.97	19.28	0.21	57	167
HH (cm)	535	92.53	5.52	0.06	70	111
BL (cm)	535	86.66	5.74	0.07	70	103
CG (cm)	535	108.69	8.98	0.08	81	134

BW: body weight, HH: hip height, BL: body length, CG: chest girth, n: number of records, SD: standard deviation, CV: coefficient of variation.

Table 2: Regression equations for the prediction of BW from body measurements in Bali cattle

Trait	Model	P value	RMSE	SEM	r	R^2
BW-HH	BW= -153.23+2.64HH	0.000	12.62	12.84	0.756	0.571
BW-BL	BW= -128.6+2.53BL	0.000	12.73	12.52	0.754	0.568
BW-CG	BW= -113.53+1.88CG	0.000	9.28	9.52	0.877	0.769
BW-HH+BL	BW= -166.25+1.48HH+1.39BL	0.000	11.70	12.68	0.795	0.632
BW-HH+CG	BW= -153.09+0.89HH+1.49CG	0.000	8.63	11.05	0.894	0.800
BW-BL+CG	BW= -149.58+0.94BL+1.46CG	0.000	8.44	10.89	0.899	0.809
BW-HH+BL+CG	BW= -159.57+0.44HH+0.69BL+1.38CG	0.000	8.34	8.39	0.902	0.814

BW: body weight, HH: hip height, BL: body length, CG: chest girth, *r*: Pearson correlation coefficient, R^2: coefficient of determination, RMSE: root mean square error, SEM: standard error of mean.

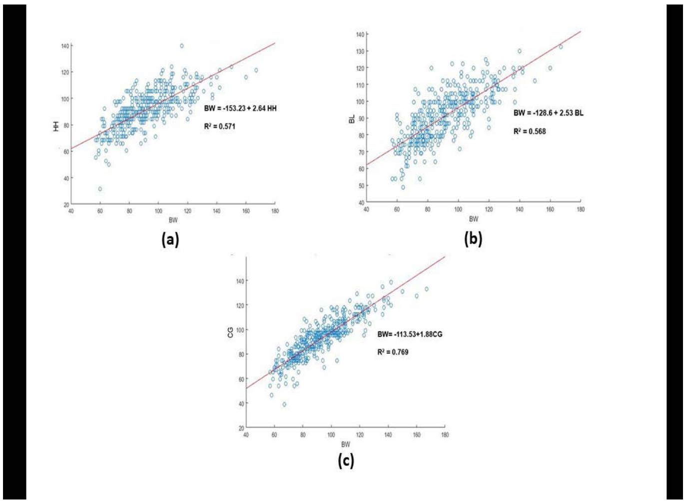

Figure 1: Simple regression equation between BW and linear body measurements in Bali cattle

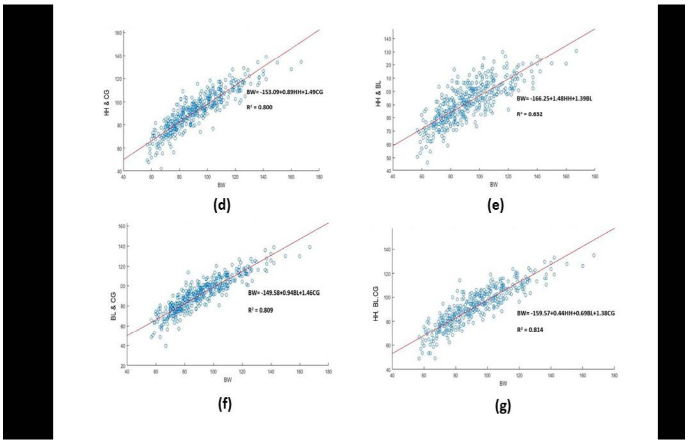

Figure 2: Multiple regression model equation between BW and linear body measurement at weaning in Bali cattle

using the coefficient of determination and RMSE. Chest girth as a sole independent variable gave the highest correlation coefficient with body weight and fitted best Bali cattle BW predicting model compared to other traits as a single predictor. The findings are in accordance with those by Vanvanhossou et al. (2018), which showed that chest girth was highly correlated with BW. There is a slight increase in R^2 and a decrease in RMSE by including more independent variables in the model. In general, the outcomes revealed that the model using three predictors that incorporated hip height, body length, and chest girth was the best model for the prediction of BW in Bali cattle, as depicted by the highest coefficient of determination and lowest RMSE. Similarly, Vanvanhossou et al. (2018) have obtained better-fitted models by including body length and chest girth in multiple regression equations. Agung et al. (2018) also revealed similar findings in Bali cattle raised in Banyumulek Techno Park of West Nusa Tenggara, where body length and heart girth had a high contribution to the variation of BW. Shankar et al. (2016) in their report showed that a combination of height at withers, body length, and heart girth can be used to predict the BW of Sahiwal adult female cattle. Al-Hillo et al. (2020) also reported similar findings in Iraqi Buffalo, where body length was also the biggest contributor to the variation of body weight. Tutkun (2019) reported heart girth as the best trait to predict BW in Holstein-Friesian bulls. In general, our results indicated that the more independent variables included in the live weight prediction model, the more accurate the weight predictions by these variables.

CONCLUSION

Live body weight were highly associated with hip height, body length, and chest girth. The model using three predictors (hip height, body length, and chest girth) was the best-fitted model for the prediction of body weight. Therefore, in situation when weighing animals is not feasible, a combination of those traits as independent variables could be the alternative for prediction of body weight through regression analysis. The findings might benefit farmers in choosing the best traits for improvement of body weight in Bali cattle.

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CONFLICT OF INTEREST

No authors have disclosed any conflicts of interest.

NOVELTY STATEMENT

To our best knowledge, the study provided information on the relationship between live body weight and body measurements (hip height, body length, and chest girth) and found the best-fitted regression model for the prediction of body weight of Bali cattle, which would benefit farmers for the selection in Bali cattle breeding.

AUTHORS CONTRIBUTION

RA: conceptualization, writing original draft, and statistical analyses. VMAN, GC, and SW: methodology and supervision. DNHH and YAT: review and manuscript editing. All authors accepted for the final version of the manuscript.

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