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Abstract. *Dakhlan A, Hamdani MDI, Putri DR, Sulastri, Qisthon A. 2021. Prediction of body weight based on body measurements in female Saburai goat. Biodiversitas.* Saburai goat is a new composite breed in Lampung Province with little information on its performance. This research aimed to predict body weight based on body measurements namely body length (BL), chest girth (CG), and shoulder height (SH) in female Saburai goat. This study used 42 female Saburai goats aged 3-4 years. The method used in this study was a survey, namely all female Saburai goats aged 3-4 years were used for this research. The data obtained were analyzed using correlation and linear and multiple linear regression analysis using R program. Coefficient determination (R^2), adjusted R^2, residual standard error (RSE), Akaike information criterion (AIC), Bayesian information criterion (BIC), and stepwise regression analysis were used to find the best and most parsimonious regression model to predict BW based on body measurements. The results showed that BL, CG, and SH were positively and significantly correlated with BW of female Saburai goat with correlation coefficient of 0.858, 0.956 and 0.862, respectively. Chest girth was the best predictor for BW if using single predictor with regression equation of $\hat{Y} = -31.17 + 0.93X_2$. However, combination of BL and CG was the best and most parsimonious regression model in predicting BW of female Saburai goat with regression equation of $\hat{Y} = -36.09 + 0.31X_1 + 0.72X_2$ with $R^2 = 0.941$, adjusted $R^2 = 0.938$, RSE = 2.842, AIC = 216.73 and BIC = 223.78. In conclusion, all body measurements in this study (particularly combination of BL and CG) could be used as predictor for BW with high accuracy of prediction. The result of this study suggested that CG and BL could be as indirect criterion to improve BW of female Saburai goat.

Keywords: Body length, Chest girth, Correlation, Regression, Shoulder height

Running title: Prediction of body weight of Saburai goat

INTRODUCTION

Saburai goat is new composite goat which is the result of grading-up between female Ettawa Grade (EG) goat and male Boer goat with a genetic composition of 25% EG goat and 75% Boer goat. The Saburai goat has been designated as a Lampung local goat by the Indonesian Ministry of Agriculture in 2015 (Kementan 2015).

In 2018 the population of the Saburai goats amounted to 3,293 individuals (Sulastri et al. 2019). The population growth is still low and need to be increased. To increase the productivity of the Saburai goats, the Lampung Provincial Government established a goat breeding center in Gedong Tataan District, Pesawaran Regency, while the implementation of developing of goat in the field was centered in Tanggamus Regency.

For breeders in Tanggamus Regency, Saburai goats are their livelihood, both goats are kept as a part-time job or as their main source of livelihood. The advantages of Saburai goats are that this goat can adapt to various environmental conditions, its reproductive potential is high, and the number of kids is more than one. In addition, the proportion of meat to bone of Saburai goat is greater than that of EG goat. To develop the future of Saburai goats required knowledge and information on the performance of Saburai goats such as body weight and body measurements of the goat.

To find out the goat's body weight is by weighing the goat. However, the conditions in the field, especially in remote area, the availability of scale is rather difficult. Therefore, we need another way to find out the weight of the goat, one of them is by investigating the correlation between the body measurements of the goat with its body weight. The biometric measurements are used to assess several characteristics of animals. These measurements provide important evidences for the growth of the breed and the properties that change with environmental effects and feeding factors. In addition, body measurements are important data sources in term of reflecting the breed standards which are also important in giving information about the morphological structure and development ability (Cam et al. 2010a; Cam et al. 2010b). According to previous studies that body measurements such as body length, chest girth and shoulder height are highly and positively correlated to body weight in cattle (Vanvanhossou et al. 2014; Paputungan et al. 2013; Haq et al. 2020; Sakar et al. 2020), in sheep (Feyissa et al. 2018; Sabbioni et al. 2020; Khan et al. 2014; Musa et al. 2015; Afolayan et al. 2006; Agamy et al. 2015; Cam et al. 2010b), and in goats (Adeyinka and Mohammed 2006; Khan et al. 2006; Abdallah et al. 2019; Abd-Allah et al. 2019; Dakhlan et al. 2020; Alex et al. 2010; Cam et al. 2010a; Chitra et al. 2012; Tsegaye et al. 2013). The high and positive relationship between body weight and body measurements can be utilized to form a formula of equation, namely regression equation. Therefore, goat body measurements can be used as predictors in the regression equation to estimate goat body weight. On the other hand, research on prediction of body weight of Saburai goat is very

limited, therefore, the current study aimed to predict live body weight of female Saburai goat based on body measurements, namely body length (BL), chest girth (CG) and shoulder height (SH). This research is expected to be very useful for predicting goat weights, especially in situations in the field with small scale farmers where difficulties in getting the scales.

MATERIALS AND METHODS

This research was conducted in May-June 2019 at the goat breeding center, namely in the Regional Technical Implementation Unit of the Negerisakti Goat Breeding Center, Gedong Tataan District, Pesawaran Regency, Lampung Province. The goat used in this study were 42 female Saburai goats aged 3-4 years. The goats were reared intensively with feedstuff given were forages consisted of legume such as "Gamal" *(Gliricidia sepium), Indigofera sp.,* and "Kaliandra" *(Calliandra calothyrsus)* and grass such as "rumput setaria" (*Setaria sphacelata*) which were cut and carried from field. The tools used in this study were 250 kg capacity scales with sensitivity 0.1 kg, 150 cm capacity measuring tapes with sensitivity 0.1 cm, and 150 cm capacity measuring sticks with sensitivity 0.1 cm.

The method used was a survey method, which was observing all goats at the study site in accordance with predetermined goat criteria, which were 3-4 years old. Data on body weight (BW) and body measurements (body length = BL, chest girth = CG, and shoulder height =SH) of the Saburai goat were analyzed for correlation and regression using the program (R Core Team 2020). Correlations between variables were analyzed using Pearson correlation, while regression between body weight and body measurements was analyzed using simple and multiple regression. Simple regression and multiple regression equation can be formulated with the regression equation as follows.

1. $\hat{Y} = a + b_1X_1$
2. $\hat{Y} = a + b_2X_2$
3. $\hat{Y} = a + b_3X_3$
4. $\hat{Y} = a + b_1X_1 + b_2X_2$
5. $\hat{Y} = a + b_1X_1 + b_3X_3$
6. $\hat{Y} = a + b_2X_2 + b_3X_3$
7. $\hat{Y} = a + b_1X_1 + b_2X_2 + b_3X_3$

where $\hat{Y}$ is the dependent variable which is BW, X is the independent variable, a is a constant, b1, b2, and b3 are the regression coefficients for the variable of BL (X_1), CG (X_2) and SH (X_3). Body weight (BW) was measured by weighing the goat using a 250 kg capacity scales (Gea brand), while CG was measured in a circular circumference around the chest cavity just behind the elbow of the forelegs using mater tape. Body length (BL) was measuring the distance between the shoulder joint and a lump of sitting bone using a measuring stick. Shoulder height was measured perpendicular from the highest shoulder over the feet to the ground using a measuring stick (Khan et al. 2006; Nurhayati et al. 2014; Abdallah et al. 2019).

Normality of data distribution was checked using boxplot and Kolmogorov-Smirnov and Shapiro test. To find the best and most parsimonious regression model for predicting goat body weight we used coefficient of determination (R^2), adjusted R^2, residual square error (RSE), Akaike information criterion (AIC) and Bayesian information criterion (BIC) and also stepwise regression analysis (Dakhlan et al. 2020). The model with the highest R^2 and adjusted R^2 and the lowest RSE, AIC and BIC values was the best regression model to be used to predict the body weight of female Saburai goats. We also checked multicollinearity for independent variables in multiple linear regression (Dakhlan 2019).

RESULTS AND DISCUSSION

Body measurements

The results of this research on average body weight and body measurements including BL, CG, and SH are presented in Table 1 and Figure 1.

Table 1. Statistics of body weight and body measurements of female Saburai goats aged 3-4 years

Variables	n	Mean	Sd	Median	Minimum	Maximum	CV%
Body weight (kg)	42	32.10	11.43	32.70	14.60	52.50	35.61
Body length (cm)	42	61.16	10.25	63.00	43.00	79.00	16.13
Chest girth (cm)	42	68.02	13.16	67.00	50.00	86.00	17.28
Shoulder height (cm)	42	58.79	7.04	60.00	45.00	70.00	11.97

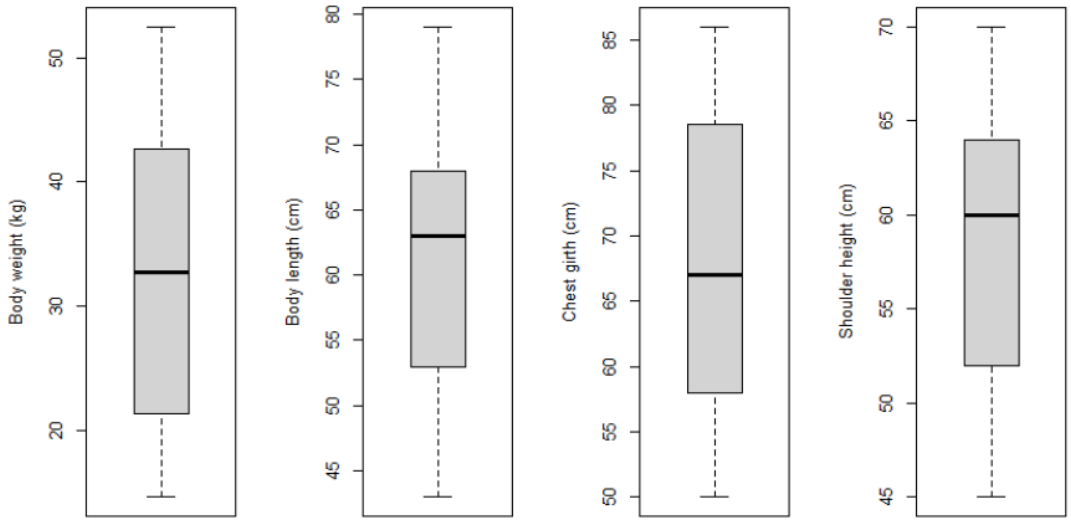

Figure 1. Boxplot of body weight and body measurements of female Saburai goats aged 3-4 years

Based on Table 1 and Figure 1 indicated that the means and medians of body weights and body measurements of female Saburai goats were similar meaning that the data were balance between below and upper the median. Based on Kolmogorov-Smirnov and Shapiro test indicated that the body weight and body measurements data of female Saburai goats were normally distributed.

Correlation and Regression between Body Measurements and Body Weight of Female Saburai Goat

The results of the correlation analysis of BW of Saburai goat with body measurements are presented in Table 2 and described in Figure 2. Based on the results of the analysis of the correlation coefficient value of body measurements on BW of the Saburai goat, CG has the highest correlation value (r) of 0.956 followed by SH of 0.862 and the lowest is BL, namely 0.858. Furthermore, among the body measurements, correlation between BL and SH was the highest (0.921) while correlation between BL and CG was the lowest.

Table 2. Correlations among variables

	Body weight	Body length	Chest girth	Shoulder height
Body weight	1			
Body length	0.858	1		
Chest girth	0.956	0.793	1	
Shoulder height	0.862	0.921	0.804	1

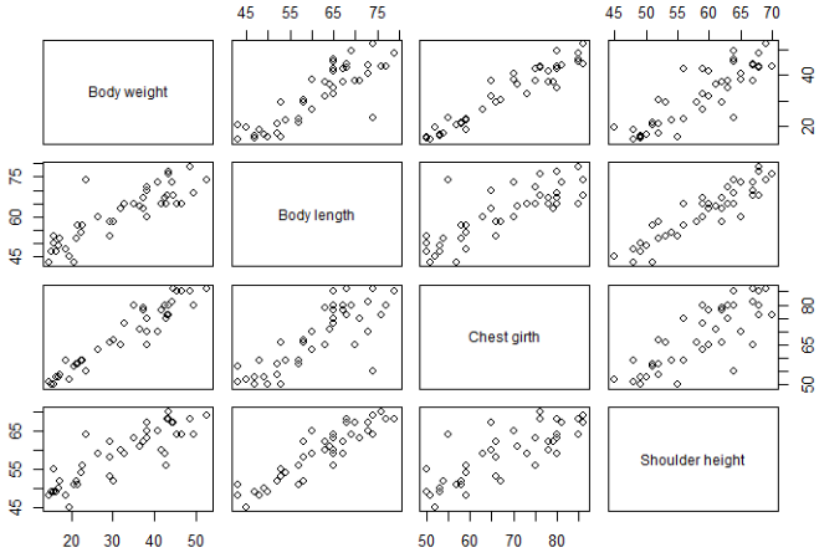

Figure 2. Correlation plot among variables

Correlation between BW and body measurements (either single or combination of body measurements) and regression equation along with selection parameters for body weight prediction of Saburai goat based on body measurements are presented in Table 3. The highest correlation coefficient between BW and combination of body measurements was between BW and combination of CG and SH (0.967), while the lowest correlation coefficient between BW and combination of body measurements was between BW and combination of BL and SH (0.877). Multicollinearity test for regression equation of BW on combination of BL and CG and also BW on combination of CG and SH resulted in multicollinearity value under 5 indicating that there is no multicollinearity among the body measurements. On the contrary, multicollinearity test for regression equation of BW on BL and SH and also BW on BL, CG and SH resulted in multicollinearity value above 5 indicating there was multicollinearity among the body measurements. The existence of multicollinearity of regression equation implies that the information provided by one body measurement about the BW is redundant in the presence of the other body measurements.

Table 3. Regression equation for prediction of body weight of Saburai goat based on body measurements along with their parameters

Regression equation	r	R^2	Adj.R^2	RSE	AIC	BIC
$\hat{Y} = -28.69 + 0.99X_1$	0.858**	0.736	0.729	5.946	279.30	284.58
$\hat{Y} = -31.17 + 0.93X_2$	0.956**	0.915	0.913	3.381	230.74	236.02
$\hat{Y} = -50.24 + 1.40X_3$	0.862**	0.744	0.737	5.855	277.97	283.25
$\hat{Y} = -36.09 + 0.31X_1 + 0.72X_2$	0.962**	0.941	0.938	2.842	216.73	223.78
$\hat{Y} = -43.10 + 0.48X_1 + 0.78X_3$	0.877**	0.770	0.759	5.614	275.29	282.34
$\hat{Y} = -42.33 + 0.72X_2 + 0.43X_3$	0.967**	0.939	0.936	2.888	218.14	225.18
$\hat{Y} = -39.68 + 0.20X_1 + 0.70X_2 + 0.21X_3$	0.954**	0.943	0.939	2.823	217.09	225.90

Note: $\hat{Y}$ = Body weight, X_1 = Body length, X_2 = Chest girth, X_3 = Shoulder height.
**Significant at (P<0.01)

Discussion

Figure 1 shows us that BW and body measurements data were normally distributed. The results showed that body weight of the female Saburai goat was 32.10 kg in average with a standard deviation of 11.43 kg, median 32.70 kg, smallest data (minimum) 14.6 kg, largest data (maximum) 52.5 kg and variation coefficient of 35.61%. Likewise, the body measurements of the Saburai goat can be seen in Table 1. This result indicated that goats body weight variation was high enough although their ages were close each other (3-4 years old). This variation might be caused by the different of their genetic potential for growth, because their environmental factor such as feeding and rearing management was relatively the same. Consequently, this big variation of body weight could be good indicator for successful selection program.

The results of this study showed the lower results compared to the results reported by Dakhlan et al. (2020) that the BW, BL, CG and SH of adult female Ettawa Grade (EG) goats were 37.07 kg, 71.27 cm, 78.33 cm and 73.86 cm,

respectively. Body measurements of female Saburai goat of current study was lower than that of female Jawarandu goats of which the mean body length, chest girth and shoulder height were 70.63 ± 5.99 cm, 75.86 ± 6.02 cm, and 67.99 ± 5.87 cm, respectively (Nurhayati et al. 2014). This difference may be caused by the differences in goat breeds and the environment and also the feed management applied. Body weight and body measurements of goats are greatly affected by environmental factors which produce varied body sizes, even in the same breed (Devendra and Burns 1994).

Table 3 shows that all the seven regression equation could be used to predict BW of Saburai goat with significant correlation between body measurements and BW of Saburai goat. The result of this study indicated that CG was the best predictor for BW of female Saburai goat compared to using BL or SH if using only one body measurement. Addition of body measurement in the regression equation will increase the value of R^2. However, combination of BL and CG (equation 4) was the best and more parsimonious predictor for BW of female Saburai goat with regression equation $\hat{Y} = -36.09 + 0.31X_1 + 0.72X_2$. This is because of the high of r (0.962), R^2 (0.941) and adjusted R^2 (0.938) and also the lowest AIC (216.73) and BIC (223.78) of the equation. In addition, there was no multicollinearity between BL and CG in equation 4. Although the highest r was equation 6 (0.967), but the other parameters were worse than equation 4. Likewise in equation 7 which used all body measurements with the highest R^2, adjusted R^2 and the lowest RSE, but for r and AIC and BIC, equation 4 was better and more parsimonious than equation 7. In addition, there was multicollinearity among independent variables in this equation 7 indicated by the VIF (variance inflation factor) which were higher than 5 (6.98 for BL, 2.99 for CG, and 7.33 for SH).

The best equation for equation 4 was supported by stepwise regression analysis which resulted in equation 4 where combination of BL and CG was the best predictor and parsimonious for predicting the weight of female Saburai goat. The result of current study is in accordance with the result reported by Adeyinka and Mohammed (2006) that combination of CG and BL was the best predictor for live body weight of female Nigerian Red Sokoto goats. The present study also agree with the result reported by Dakhlan et al. (2020) that combination of CG an BL was the best predictor and more parsimonious regression model for predicting BW of female Ettawa Grade goats. Furthermore, regression equation using combination of BL and CG resulted in the lowest MSE (mean square error, 8.181) although its R^2 (0.719) was lower than that using combination of BL, CG and height at withers with R^2 of 0.721 and MSE of 8.297 (Chitra et al. 2012). Three dimension (3D) figure describing regression model between BW and combination BL and CG can be seen in Figure 4.

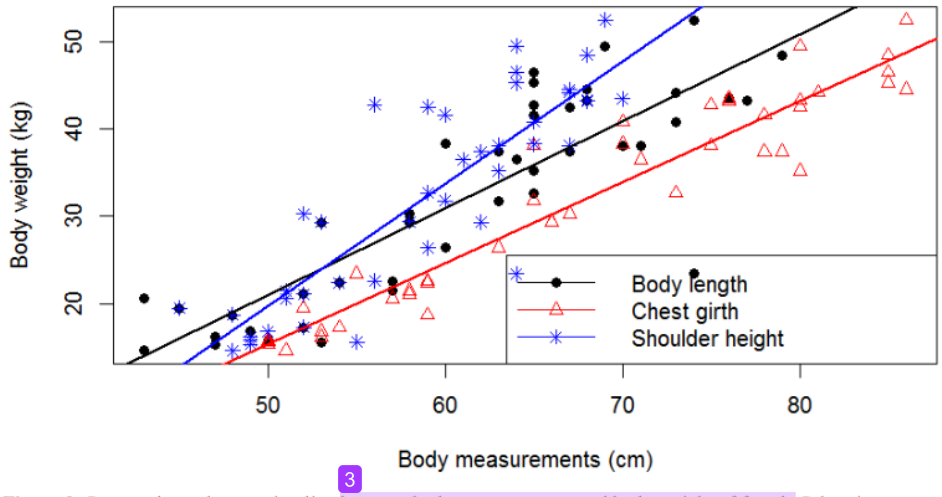

Figure 3. Scatter plot and regression line between body measurements and body weight of female Saburai goat

Scatter plot and regression line if using single body measurements for predicting BW of female Saburai goat is shown in Figure 3. Figure 3 shows us that body weight prediction using different single body measurement resulted in different accuracy indicated by the value of R^2 (0.736, 0.915 and 0.744 if using BL, CG and SH, respectively, as predictor) with different slope (0.99, 0.93 and 1.40, respectively). In addition, if using BL and CG as predictor, the two regression lines were almost parallel with similar slope (0.99 and 0.93, respectively), while regression line if using SH as predictor resulted in not parallel to each other indicated by the higher slope (1.40). The result of this study suggested that we cannot substitute body measurement one to other to predict body weight of female Saburai goat if using single body measurement.

In conclusion, chest girth could be used as predictor of body weight of female Saburai goat if using single body measurement. Regression equation using combination of body length and chest girth resulted in the best prediction of body weight of female Saburai goat with more parsimonious.

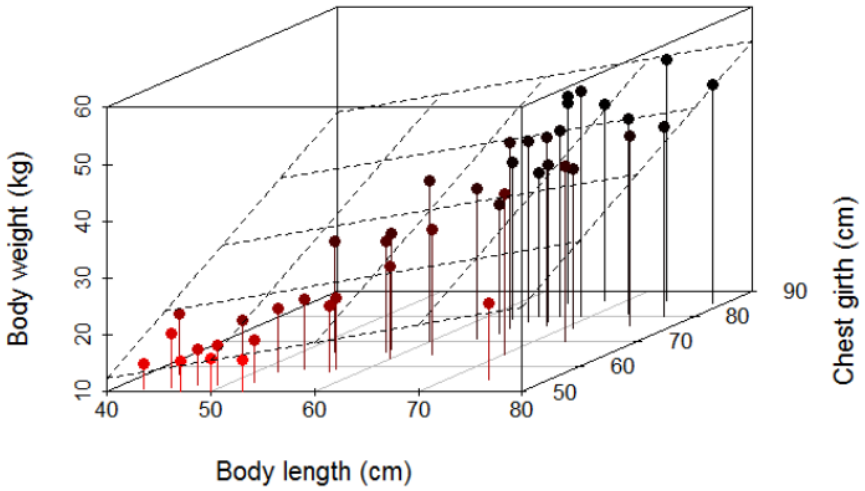

Figure 4. 3D vizualisation for the best and parsimonious regression equation between BW and combination of BL and CG

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DECLARATION OF COMPETING INTEREST

The authors have declared that no competing interest exists.

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