Pak. j. life soc. Sci. (2019), 17(1): 17-23 E-ISSN: 2221-7630; P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences
www.pjlss.edu.pk

RESEARCH ARTICLE

Live Body Weight Assessment Based on Body Measurements in Bali cattle (*Bos javanicus*) at Extensive Rearing System

Jakaria Jakaria[1*], Sutikno[2], Mokhamad Fakhrul Ulum[3] and Rudy Priyanto[1]
[1]Faculty of Animal Science, Bogor Agricultural University, Jalan Agatis Dramaga, Bogor 16680 Indonesia
[2]Doctoral Graduate Student in Animal Production and Technology, Faculty of Animal Science, Bogor Agricultural University 16680 Indonesia
[3]Faculty of Veterinary Medicine, Bogor Agricultural University, Jalan Agatis Dramaga Bogor 16680 Indonesia

ARTICLE INFO
Received: Nov 12, 2018
Accepted: Apr 15, 2019

Keywords
Bali cattle
Body measurements
Body weight
Correlation
Regression

***Corresponding Author:**
jakaria_karman@yahoo.co.id

ABSTRACT

The aim of this study was to assess live body weight by linear body measurement of Bali cattle (*Bos javanicus*) in extensive rearing system. A total of 68 cattle (37male and 31 females, with age ranging from 21-25 months) were extensively reared in Bali cattle Breeding Centre in Bali Province. All the experimental animals were weighed, while their body measurements, i.e. body length (BL), wither height (WH), chest depth (CD), hip height (HH), and chest girth (CG) were recorded. Phenotypic correlation between live body weight and body measurements was analyzed, while estimation of live body weight based on body measurements was performed using simple linear regression and multiple regression analysis in SAS 9.1.3. A strong positive phenotypic correlation was found between live body weight and body measurements from r=0.54 to r=0.93 (P<0.001). The best simple regression model for assessing depth girth was presented as follows: LBW= 2.94 (CG)-227.07 (±67.82) (R^2=0.54, RMSE=26.0) for male and LBW= 3.62 (CG)-326.70 (±35.36) (R^2=0.87, RMSE=9.4) for female. The results of this research indicated that chest girth could be applied as predictor for assessing live body weight of Bali cattle in extensive rearing system.

INTRODUCTION

Bali cattle (*Bos javanicus*) originated from Indonesia and was domesticated from Banteng (Martojo, 2003), were widespread in many parts of Indonesia, even reaching Northern Australia (Calaby, 1975), Southern Philippine of Mindano Island (Molina et al., 2005) and Malaysia (Hafiz et al., 2016). Total population of Bali cattle was estimated to be 5 million heads, which represents 27% of Indonesia's total cattle population (Purwantara et al., 2012) and was extensively reared by smallholder farmers (Martojo, 2012). Bali cattle is considered as beef cattle breed (Jakaria et al., 2017) and demonstrate several desirable characteristics, i.e. high adaptation to the tropical climate conditions and high efficiency in utilizing low quality feeds (Martojo, 2012), high reproductive performance and calving rate of up to one calf per year (Purwantara et al., 2012), thus, are prefered by smallholder farmers in rural area under extensive rearing system, despite a high calf mortality (Priyanti et al., 2012). Due to high calf mortality rate, population growth of Bali cattle has been slowly increased; even their population seemed to be decreased (Talib et al., 2003). Genetic improvement in cattle could be conducted using body measurements such as chest girth and body length used as indirect selection criteria (Kahi and Hirooka, 2005). In term of heritability, linear body measurement was found to be at moderate level (Choy et al., 2017) and showed a strong positive correlation with live weight (Musa et al., 2011; Ige et al., 2015; Lukuyu et al., 2016). Body weight characteristics constitute a major concern in evaluating growth performance of Bali cattle (Supriyantono et al., 2010).

Linear body measurements in livestock are preferred as predictor towards weight including live weight as previously applied for dairy cattle (Tebug et al., 2016), crossbred dairy cattle (Lukuyu et al., 2016), Zebu cattle

(Abdelhadi and Babiker, 2009), South African Herford cattle (Marle-Koster et al., 2000), Sahiwal cattle (Siddiqui et al., 2015) and Bali cattle (Gunawan and Jakaria, 2010). In cattle farming, live body weight is a key variable that is highly useful for breeding practices and other purposes such as direct or indirect selection criteria (Baldi et al., 2012), allowing to evaluate growth performance (Franco et al., 2017), feed requirement, marketing weight, and cash value (Tariq et al., 2013), livestock health control (Depoorter et al., 2015) and transportation (Schwartzkopf-Genswein et al., 2016). Estimation of cattle live body weight is an important issue for many reasons. Weighing the livestock directly is often difficult or not feasible in many cases (Coopman et al., 2009) since it is costly, heavy to transport, and requires technical facilities (Abdelhadi and Babiker, 2009).

Live body weight recording is important as it allows evaluation of growth performance (Franco et al., 2017), feed requirements, marketing weight and cash value (Tariq et al., 2013), although the correlation between body weight and body measurement is strongly affected by breed, age, type, condition, and degree of fatness (Heinrichs et al., 1992; Yanar et al., 1995). The determination of live body weight based on body measurement is often performed using regression analysis (Heinrichs et al., 1992; Ozkaya and Bozkurt, 2009). Siddiqui et al., (2015) reported a strong positive correlation between body weight and body measurement. Previous studies have revealed that chest girth could be used as predictor of live weight (Ozkaya and Bozkurt, 2009; Siddiqui et al., 2015; Tebug et al., 2016). The aim of the present study was to assess the correlation of live body weight and body measurements.

MATERIALS AND METHODS

Cattle and rearing management

Bali cattle (Fig. 1) were randomly selected to obtain 68 cattle heads consisting of 37 male (steers) and 31 females (heifers) with age of 21-25 months old and a range of body weight from 95.5 to 277 kg. The selected cattle (weaned calves, age of 4 month) were reared under extensive cattle system in paddock (not in cattle sheds). Forage was available in paddock, while additional forage of *Pennisitum purpureum* (10% of body weight) and concentrate (1.5% of body weight) were also added and was at *ad libitum*.

Measured variables

Live body weight (LBW) and body measurements (body length= BL, wither height = WH, chest depth = CD, hip height = HH, chest girth = CG) of the Bali cattle were recorded at the morning before feeding (grass supplementation and concentrate) in holding yard. Digital scale was used to measure live body weight (scale of 0-1000 kg). The measurement variables (BL, WH, CD, and HH) were measured using a measuring stick, while CG was measured with a measuring tape. The cattle weighing (expressed as kg) and body measurement (expressed as cm) was performed in cattle crush as presented in Fig. 2.

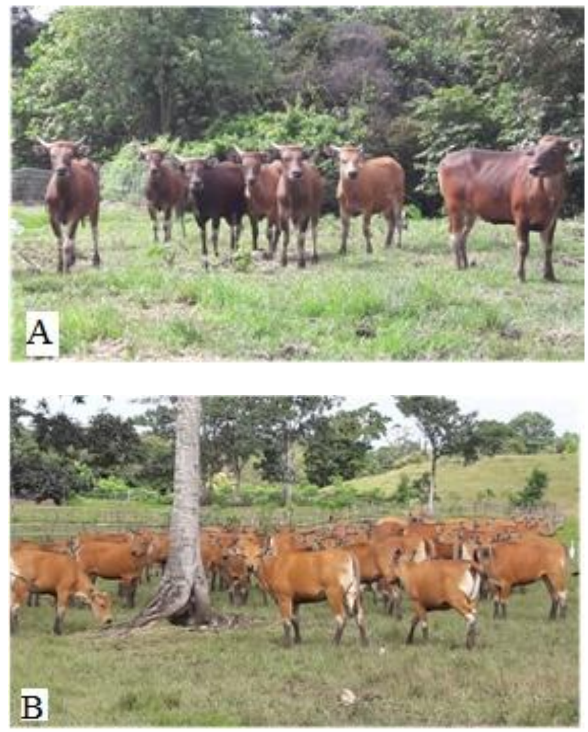

Fig. 1: Bali cattle reared under extensive farming system. (A = steer, B = heifer).

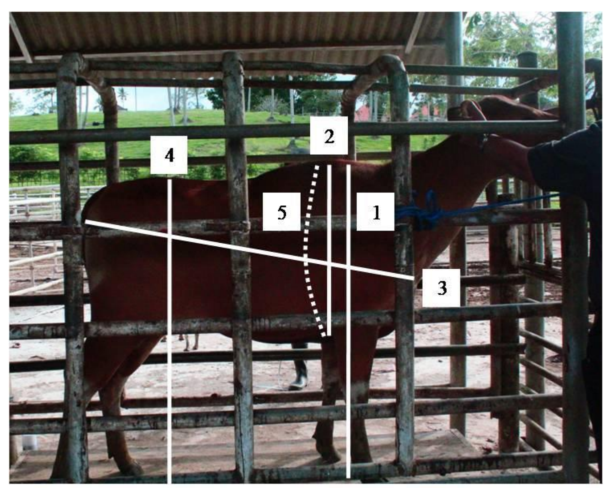

Fig. 2: Collection of live body weight and body measurements in Bali cattle. 1=wither height, 2=chest depth, 3=body length, 4=hip height, 5=chest girth.

Body measurements were collected according to method of Otsuka et al. (1982). Wither height was taken from the wither peak, through scapula, to the standing ground, with a perpendicular position to the surface, while chest depth was a vertical distance from the peak of wither to chest. Body length was a distance between the shoulder joint (*tuberculus humeri*) to the pelvic bone (*tuber ischii*). Hip height was a vertical distance from peak hip to the standing ground, while chest girth was measured as body circumference at exactly behind the forelegs.

Data management

Total collected data (408 set) including 222 set for male and 186 set for female were recorded. The cattle's age was determined according to birth date in livestock's card and date at data collection. In general, both male (steer) (37 heads) and female (heifer) (31 heads) Bali cattle were calved in 2016 (2 years).

Statistical analysis

The recorded data was subjected to statistical analysis to find the correlation coefficients and regression analysis as suggested by Steel et al. (1997). The linear measurements were subjected to simple and multiple linear regression analysis using PROC REG of SAS computer programme (SAS, 2003). The goodness of fit (R^2) was tested to determine the contribution of each of the five independent variables measured to the prediction of the dependent variable the live body weight of Bali cattle. The linear regression equation used Machebe and Ezekwe (2010) was: $Y = a + b_í X_í + E$, Where: Y = LBW, the dependent variable a = constanta; $b_í$ = Regression coefficient of the í th independent variable; $X_í$ = The value of the $í^{th}$ independent variable. Such that: X_1 = BL; X_2 =WH; X_3 = CD, X_4 = HH; and X_5 = CG; E = Standard error of regression. The best model was evaluated from determination coefficient (R^2), adjusted R^2 and RMSE (root mean squares error).

RESULTS AND DISCUSSION

Description of body measurements

Live body weight and linear body measurements of Bali cattle for male (age of 21-25 months) and female (age of 22-25 months) showed a higher average. However, variation coefficient of male was higher than that of female as presented in Table 1 and 2. The average body measurements (WH, CD, BL, HH, CG) of Bali cattle in male and female under extensive rearing system were recorded as follows: 108 cm, 57.4 cm, 111.6 cm, 110.3, 148.0 cm and 100.6 cm, 53.0 cm, 109.7 cm, 109. 8 cm, 136.7 cm, respectively. The values are highly different in comparison with previous report of Otsuka et al., (1982), found that the body measurement of Bali cattle was as follows: 111.4 cm, 60.3 cm, 114.3 cm, 110.1 cm and 151.7 cm. This suggests that there is a decrease in body measurement value in last 36 years. Disagreement may result from negative selection due to trade and slaughtering practices of Bali cattle possessing the most desirable performance; thus, those with less desirable performance are then farmed by local farmers. Additionally, average weight of male and female was 208.7 kg (121-277 kg) and 168 kg (96-249 kg) at age of 22.6 months (21-25 months) and 23.4 months (22-25 months), respectively.

Phenotypic correlation

Phenotypic correlation between live body weight and body measurements showed a strong positive correlation with a very high significance (P<0.001) in both male and female. Furthermore, the phenotypic correlation in female was observed to be higher in comparison with male, particularly between live body weight and chest girth, resulting in correlation coefficient of 0.93. Meanwhile, the lowest correlation coefficient (0.534) was found between live body weight and body length, observed in male cattle (Table 3). The phenotypic correlation of live body weight demonstrated a very strong positive correlation with chest girth in male (r=0.74) and female (r=0.93). The high correlation coefficient is also in agreement with previous studies applied in various cattle, i.e. Brahman cross (r=0.96) (Rashid et al., 2015), Sahiwal (r=0.98) (Siddiqui et al., 2015), crossbred dairy cattle (0.84) (Lukuyu et al., 2016), Kenana Sudanese cattle (r=0.92) (Musa et al., 2011), 1-year old Bali cattle (r=0.87) (Gunawan and Jakaria, 2010) and dairy cattle (r=0.938) (Franco et al., 2017). The strong positive correlation as found in chest girth is not only important for live body weight assessment (Lukuyu et al., 2016), but also for productivity improvement primarily in growth traits of Bali cattle through selecting chest girth (one trait) that enables to improve body weight and other traits.

Table 1: Descriptive live body weight and body measurements of Bali cattle (steer).

Variables	n	Mean	Std Dev	CV%	Min.	Max.
Age (month)	37	22.6	1.0	4.4	21	25
Live Body Weight (LBW)(kg)	37	208.7	37.9	18.2	121	277
Body length (BL)(cm)	37	108.4	9.4	8.7	89	144
Chest depth (CD)(cm)	37	57.4	4.7	8.1	48	68
Wither height (WH)(cm)	37	111.6	5.0	4.5	99	122
Hip height (HH)(cm)	37	110.3	5.5	5.0	94	122
Chest girth (CG)(cm)	37	148.0	9.5	6.4	123	169

n=individual number.

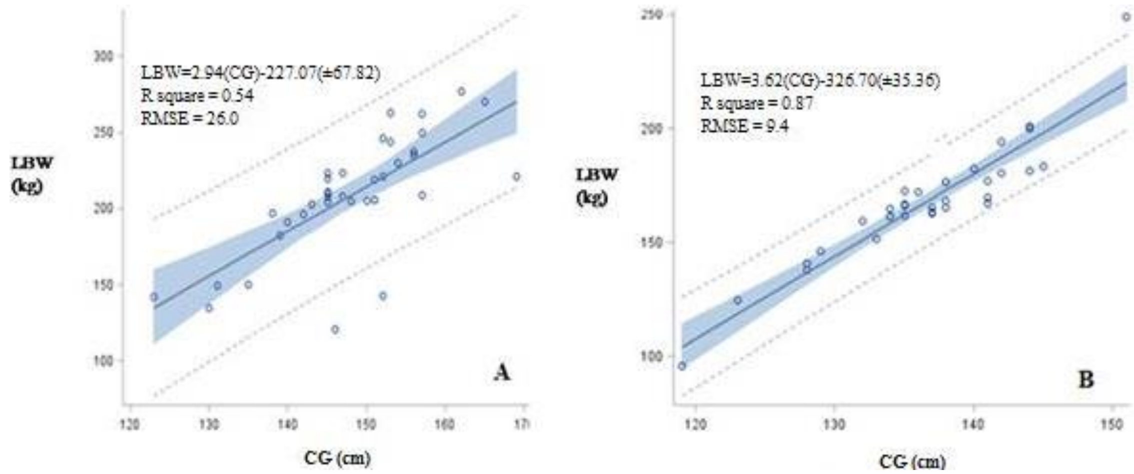

Fig. 3: Relationship between live body weight and chest girth in Bali cattle. Plot A = male group, plot B = female group.

Table 2: Descriptive livebody weight and body measurements of Bali cattle (heifer).

Variables	n	Mean	Std Dev	CV%	Min.	Max.
Age (month)	31	23.4	1.0	4.3	22	25
Live Body Weight (LBW)(kg)	31	168.0	25.9	15.4	96	249
Body length (BL)(cm)	31	100.6	5.5	5.4	90	115
Chest depth (CD)(cm)	31	53.0	2.5	4.8	46	58
Wither height (WH)(cm)	31	109.7	4.1	3.8	102	120
Hip height (HH)(cm)	31	109.8	4.0	3.6	102	122
Chesth girth (CG)(cm)	31	136.7	6.7	4.9	119	151

n=individual number.

Table 3: Regression equations for the prediction of live body weight from body measurements in Bali cattle

Group	n	Regression equation	R^2	Adj. R^2	RMSE
Male	37	LBW = 2.19(BL) -28.54(±62.24)	0.29	0.27	32.3
		LBW = 4.95(CD) -75.56(±62.76)	0.37	0.35	30.5
		LBW = 5.06(WH) -356.73(±107.42)	0.44	0.42	28.7
		LBW = 4.60(HH) -299.52(±96.71)	0.44	0.42	28.7
		LBW= 2.94(CG) -227.07(±67.82)	0.54	0.53	26.0
		LBW= 2.11(CG)+ 2.40(HW)-371.08(±92.66)	0.59	0.57	24.7
		LBW= 2.08(CG)+ 2.23(HW)+ 0.20(HH)-370.94(±94.05)	0.60	0.56	25.1
		LBW=2.08(CG)+ 2.22(HW)+ 0.20(HH)+ 0.01(CD) -370.77(±101.35)	0.60	0.56	25.4
		LBW= 2.23(CG)+ 0.90(HW)+ 0.86(HH) -1.14(CD)+ 1.18(BL)-379.68(±96.75)	0.65	0.59	24.3
Female	31	LBW = 3.29(BL) -162.74(±63.84)	0.48	0.46	18.9
		LBW= 6.23(CD) -162.18(±79.53)	0.37	0.35	20.8
		LBW = 5.05(WH) -386.28(±75.54)	0.65	0.64	15.5
		LBW= 4.29(HH) -302.76(±100.76)	0.43	0.41	19.8
		LBW= 3.62(CG) -326.70	0.87	0.86	9.4
		LBW= 3.00(CG)+ 1.28(HW) -382.96(±43.56)	0.89	0.88	8.9
		LBW= 2.93(CG)+ 0.49(HW)+ 0.94(BL) -381.96(±40.24)	0.91	0.89	8.3
		LBW= 2.90(CG)+ 0.10(HW)+ 0.95(BL)+ 0.60(HH) -401.55(±44.17)	0.91	0.89	8.2
		LBW= 3.22(CG) -0.13(HW)+ 1.14(BL)+ 0.77(HH) -1.40(CD) -384.10(±43.94)	0.92	0.90	8.0
All	68	LBW= 2.99(BL) -123.30(±42.14)	0.46	0.45	28.6
		LBW= 6.20(CD) -153.58(±41.88)	0.51	0.50	27.3
		LBW= 5.75(WH) -446.82(±80.58)	0.49	0.48	27.8
		LBW= 4.74(HH)-331.45(±87.74)	0.35	0.34	31.3
		LBW= 3.28(CG) -278.58(±35.22)	0.73	0.72	20.2
		LBW= 2.94(CG)+ 0.97(CD) -284.54(±35.59)	0.73	0.72	20.2
		LBW= 2.64(CG)+ 0.29(CD)+ 1.71(WH) -391.98(±57.75)	0.75	0.74	19.5
		LBW= 2.67(CG) -0.94(CD)+ 1.03(WH)+ 1.22(BL) -381.61(±53.74)	0.79	0.78	18.1
		LBW= 2.67(CG) -0.10(CD)+ 0.62(WH)+ 1.23(BL)+ 0.45(HH) -388.37(±55.55)	0.79	0.78	18.1

n=individual number, LBW=live body weight, BL=body length, CD=chest depth, WH=wither height, HH=hip height, CG=chest girth, R^2=coefficient of determination, AdjR^2=adjusted R^2, RMSE=root mean squares error.

The enhanced growth traits in Bali cattle are also influential to their genetic improvement, since phenotypic correlation is strongly associated with genetic correlation (Ceacero et al., 2016). Therefore, the high correlation between live body weight and chest girth in Bali cattle constitutes one of the key variables in order to induce phenotypic and genetic improvement primarily for smallholder farmers in Indonesia.

Regression model for estimation of live body weight

As presented in Table 4, simple and multiple regression model for estimating live body weight of Bali cattle in male was found to be lower compared to female, according to value of R^2 and Adj. R^2. Afterwards, this caused the higher RMSE value in male than in female. Practically, chest girth (CG) was best suited to predict live body weight of both male and female using simple regression model, i.e. LBW= 2.94(CG) -227.07(±67.82) for male and LBW= 3.62(CG)-326.70(±35.36) for female with R^2coefficient of 0.54 and 0.87, respectively, as shown in Fig. 3. The coefficient R^2 could reflect RMSE value, in which high value of $R^2$is attributed to low RMSE, vice versa. Simple regression model was deemed most reliable at chest girth of 123-169 cm for male (age of 21-25 months) and 119-151 cm for female (age of 22-25 months).

Simple and multiple regression model could be used to estimate live body weight of Bali cattle according to linear body measurements as predictor. Though, the accuracy of body weight estimation was dissimilar between male and female. In this case, the accuracy in male was lower (R^2=0.65; RMSE=24.3) than that in female (R^2=0.93; RMSE=8.0). The difference is caused by a fact that dissimilarity in variables of live body weight and body measurement for male is higher than that for female. Hence, regression model needs to construct separately between male and female, as well as age (Rashid et al., 2016). Our experimental data found that chest girth represented the best predictor for estimating live body weight in Bali cattle using simple regression model. This finding was also found in preceding reports in Sahiwal cattle (Shidiquie et al., 2015), Brahman cross cattle (Rashid et al., 2016), Bali cattle (Gunawan and Jakaria, 2010), dairy cattle and its crossbred (Tebug et al., 2016), Zebu cattle (Abdelhadi and Babiker, 2009) and South African Herford cattle (Marle-Koster et al., 2000). Live body weight estimation using chest girth is highly useful for many purposes not only for breeding practices but also for smallholder farmers to determine feed requirement, rearing management, and cattle trading. To date, cattle weight in traditional trading practice relies on estimation by traders, without using a scale. Estimation of live body weight based on predictors from body measurements (BL, CD, WH, HH, CG) in Bali cattle is very essential for breeders and smallholder farmers especially in rural location in which they use extensive rearing system.

In conclusion, phenotypic correlation of live body weight according to linear body measurements (WH, CD, BL, HH, CG) in Bali cattle was found to be highly significant and showed positive correlation. Chest girth was also found as the best predictor for assessing live body weight of Bali cattle for male and female. Combination of some linear body measurements could enhance accuracy in estimating the live body weight in both steer and heifer.

Authors' contributions

All authors contributed equally in this manuscript. Also all authors read and approved the final manuscript.

Acknowledgement

The financial support by the Primary Research of Higher Education-Kemenristek Dikti under Grant [1757/IT3.11/PN/2018] for this study is highly acknowledged. The authors acknowledge the Head of Breeding Center for Bali cattle (BPTU-HPT) of Bali province, Indonesia for facilitating in this research.

REFERENCES

Abdelhadi OMA and SA Babiker, 2009. Prediction of zebu cattle live body weight using live animal measurements. Livestock Research for Rural Development, 21: 130-133.

Baldi F, LG de Albuquerque, JN dos SG Cyrillo, RH Branco, BC de O Junior and MEZ Mercadante, 2012. Genetic parameter estimates for live body weight and daily live body weight gain obtained for Nellore bulls in a test station using different models. Livestock Science, 144: 148-156.

Calaby JH, 1975. Introducation of Bali cattle to northern Australia. Australian Veterinary Journal, 51: 108-108.

Ceacero TM, MEZ Mercadante, JNSG Cyrillo, RC Canesin, SFM Bonilha and LG de Albuquerque, 2016. Phenotypic and genetic correlations of feed efficiency traits with growth and carcass traits in Nellore cattle selected for postweaning weight. PLoS ONE, 11: 1-11.

Choy YH, JG Lee, A Mahboob, TJ Choi and SH Rho, 2017. Genetic correlation between live body measurements and beef cutability traits in Hanwoo steers. Asian-Australasian Journal of Animal Science, 30: 1074-1080.

Coopman F, SD Smet, H Laevens, AV Zeveren and L Duchateau, 2009. Live body weight assessment based on easily accessible morphometric characteristics in the double-muscled Belgian Blue beef breed. Livestock Science, 125: 318- 322.

Depoorter P, XV Huffela, H Diricksa, H Imberechts, J Dewulf, D Berkvens and M Uyttendaele, 2015. Measuring general animal health status:

Development of an animal health barometer. Preventive Veterinary Medicine, 118: 341–350.

Franco MO, MI Marcondes, JM de Souza Campos, DR de Freitas, E Detmann and SCV Filho, 2017. Evaluation of body weight prediction equations in growing heifers. Animal Science, 39: 201-206.

Gunawan A and Jakaria, 2010. Application of linear body measurements for predicting weaning and yearling weight of Bali cattle. Animal Production, 12:163-168.

Hafiz MAW, IAJ Bahtiar, MR Hifzan, OM Ariff and ALF Ashraff, 2016. Body weight prediction of Brakmas and Bali cattle using body measurements. Malaysian Journal of Animal Science, 19: 1-7.

Heinrichs AJ, GW Rogers and JB Cooper, 1992. Predicting body weight and wither height in Holstein heifer using body measurements. Journal of Dairy Science, 75: 3576-3581.

Ige AO, TA Adedeji, LO Ojedapo, SO Obafemi and OO Ariyo, 2015. Linear body measurement relationship in white Fulani cattle in derived savannah zone of Nigeria. Journal of Biology Agriculture and Healthcare, 5: 1-6.

Jakaria H Khasanah, R Priyanto, M Baihaqi and MF Ulum, 2017. Prediction of meat quality in Bali cattle using ultrasound imaging. Journal of Indonesian Tropical Animal Agriculture, 42: 59-65.

Kahi AK and H Hirooka, 2005. Genetic and economic evaluation of Japanese black (Wagyu) cattle breeding schemes. Journal of Animal Science, 83: 2021–2032

Lukuyu MN, JP Gibson, DB Savage, AJ Duncan, FDN Mujibi and AM Okeyo, 2016. Use of body linear measurements to estimate live body weight of crossbred dairy cattle in small holder farms in Kenya. Springer Plus, 5: 63.

Machebe NS and AG Ezekwe, 2010. Predicting Body Weight of Growing-Finishing Gilts Raised in the Tropics using Linear Body Measurements. Asian Journal of Experimental Biological Sciences, 1(1): 162-165.

Marle-Koster EV, BE Moster and JVD Westhuizen, 2000. Body measurements as selection criteria for growth in South African here ford cattle. Archivfur Tierzucht, 43: 5-15.

Martojo H, 2003. Indigenous Bali cattle: the best suited cattle breed for sustainable small farm in Indonesia. The Chinese Society of Animal Science. 112 Farm Road, Hsinhua, Tainan, Taiwan.

Martojo H, 2012. Indigenous Bali cattle is most suitable for sustainable small farming in Indonesia. Reproduction in Domestic Animals, 47: 10-14.

Molina EC, EA Gonzaga and LA Lumbayo, 2005. Prevalence of infection with *Fasciola gigantica* and its relationship to carcass and liver weights, fluke and egg counts in slaughter cattle and buffaloes in South Mindanao, Philippines. Tropical Animal Health and Production, 37: 215–221.

Musa AM, KM Elamin, SA Mohammed and HO Abdalla, 2011. Morphometric traits as indicators for body weight in Sudanese Kenana cattle. Online Journal of Animal Feed Research, 1: 218-222.

Otsuka J, T Namikawa, K Kojawa and H Martojo, 1982. Statistical analysis on the body measurements of East Asian Native Cattle and Bantengs. The Research Group of Overseas Scientific Survey, 3: 7-17.

Ozkaya S and Y Bozkurt, 2009. The accuracy of prediction of body weight from body measurements in beef cattle. Archivfur Tierzucht, 52: 371-377.

Priyanti A, VW Hanifah, IGAP Mahendri, F Cahyadi and RA Cramb, 2012. Small-Scale Beef Cattle Production in East Java, Indonesia. Proceedings of 56th Australian Agricultural and Resource Economic Society Annual Conference, pp: 1-22.

Purwantara B, RR Noor, G Andersson and HR Martinez, 2012. Banteng and Bali Cattle in Indonesia: Status and Forecasts. Reproduction in Domestic Animal, 47: 2-6.

Rashid MM, MA Hoque, KS Huque, MAI Talukder Fazlul and H Bhuiyan, 2015. Morphometric characterization of Brahman crossbred cattle and prediction of live body weight using linear body measurements. Asian Journal of Medical and Biological Research, 1: 569-577.

Rashid MM, MA Hoque, KS Huque, AK Fazlul and H Bhuiyan, 2016. Prediction of live body weight for brahman crossbred cattle using linear body measurements in rural area. Advances in Animal and Veterinary Sciences, 4: 99-106.

SAS, 2003. SAS/STAT User’s Guide: Version 9.3.1, SAS Institute Inc, Cary, North Carolina, USA.

Schwartzkopf-Genswein K, J Ahola, L Edwards-Callaway, D Hale and J Paterson, 2016. Transportation issues affecting cattle wellbeing and considerations for the future. The Professional Animal Scientist, 32: 707-716.

Siddiqui MU, M Lateef, MK Bashir, MQ Bilal, G Muhammad, MI Mustafa and SU Rehman, 2015. Estimation of live body weight using different body measurements in Sahiwal cattle. Pakistan Journal of Life and Social Sciences, 13: 12-15.

Steel RGD, JH Torrie and DA Dickey, 1997. Principles and procedure of statistics. A biometric approach (3rd Edition). McGraw Hill Book Comp Inc, New York, USA.

Supriyantono A, L Hakim, Suyadi and Ismudiono, 2010. Breeding programme development of Bali cattle at P3Bali. Proceeding of 5th International Seminar on Tropical Animal Production Community Empowerment and Tropical Animal Industry held at Yogyakarta, Indonesia, pp: 541-546.

Talib C, K Entwistle, A Siregar, SB Turner and D Lindsay, 2003. Survey of population and production dynamics of Bali cattle and existing breeding programs in Indonesia. Strategies to Improve Bali Cattle in Eastern Indonesia. ACIAR Proceedings, 1: 3-9.

Tariq M, M Younas, AB Khan and E Schlecht, 2013. Body measurements and body condition scoring as basis for estimation of live body weight in Nili-Ravi buffaloes. Pakistan Veterinary Journal, 33: 325-329.

Tebug SF, A Missohou, SS Sabi, J Juga, EJ Poole, M Tapio and K Marshall, 2016. Using body measurements to estimate live body weight of dairy cattle in low-input systems in Senegal. Journal of Applied Animal Research, 5: 1-7.

Ulutas Z, M Saatci and RK AÖZLüTü, 2002. Prediction of body weights from body measurements in East Anatolian Red calves. Indian Journal of Animal Sciences, 72: 878–881.

Yanar M, N Tuzemen, M Ozkan, R Aydin and F Ugur, 1995. Prediction of body weights from body measurements in Brown Swiss cattle. Turkish Journal of Veterinary and Animal Sciences, 19: 357-360.