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Application of body volume formula for predicting live weight in Ongole crossbred cows

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Study was conducted to estimate the live weight in Ongole crossbred cow using chest girth, body length and body volume model represented by chest girth and body length dimensions in North Sulawesi province. Data on animal live weight (LW), body length (BL), chest girth (CG) and body volume were collected from cows (n=363) kept by traditional household farmers. Animal body volume was calculated using cylinder volume formula with CG and BL as the components of model. Regression analysis was carried out for LW with all linear body measurements. Data were classified based on age of animals which resulted from five age groups (2.5-3.5, 3.6-4.5, 4.6-5.5, 5.6-6.5, 6.6-7.5, 2.5-7.5). Age significantly (P<0.05) influenced all body measurements. Correlations between all pairs of measurements were highly significant (P<0.001) for all age groups, except between BL and CG as well as LW at ages of 3.5 to 7.5 years old. Regression analysis showed that live weight could be predicted accurately from body volume (R^2=0.96). Simple regression model being recommended to predict live weight of Ongole crossbred cows based on body volume with their age groups ranging from 2.5 to ≥7.5 years old is as follows: Live weight (kg) = 1.26016 * body volume (liters) - 3.06084.

Key words: Ongole crossbred cows, live weight estimation, body linear measurements.

INTRODUCTION

Most of the Ongole crossbred cattle in rural areas of Indonesia were owned by rural households farmers. Often, the marketing of animals was based on visual assesment, while drugs were administrated mostly by estimation based on visual body.size. Regularly, the right use of live weight criteria in feeding, marketing and drug administration required sophisticated facilities such as weighing scales (monitor digital electrical scale), which was expensive and not readily affordable to many rural households. Positive correlation between the live weight and most of the body measurements was found in several research reports (Afolayan et al., 2006; Bene et al., 2007; Ozkaya and Bozkurt, 2009; Sawanon et al., 2011; Udeh et al., 2011). This fact repeatedly point out the importance of taking body measurement and offers opportunity for estimating parameters in relation to the various body measurements. Several scientific reports suggested that body measurements have been of recurring interest in beef cattle and small ruminant selection and breeding programs (Bene et al., 2007; Fajemilehin and Salako, 2008; Jimmy et al., 2010). Body weight of animals is an important factor associated with

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several management practices including selection for slaughter or breeding, determining feeding levels and being a good indicator of animal condition (Ulatus et al., 2001).

Beef cattle production of local household farmers was difficult to be practically predicted due to limited availability of animal weighing scale machine on the field. Animal growth in developed farm system was generally measured by average daily weight gain, and body size was generally detected by increase of chest girth and body length (Willeke and Dursch, 2002; Bozkurt, 2006; Ozkaya and Bozkurt, 2009). Dimensions of animal chest and girth (Bozkurt, 2006; Ozkaya and Bozkurt, 2009). Dimensions of animal chest girth and body length in centimetre (cm) unit have been very simple and easy in measurement for estimating animal live weight although it was unlikely to be more accurate than direct measurement of live weight by scale due to errors in location reference points. Cattle body weight had positive correlation with body dimensions including body length, hip height and chest girth (Ozkaya and Bozkurt, 2009; Puspitaningrum, 2009). The correlation coefficient between body weight and linear traits such as body length and chest girth in Holstein breed were 0.69 and 0.78, respectively (Ozkaya and Boskurt, 2009). Body weight was moderately correlated with chest girth and body length (r = 0.77 and 0.66), respectively in Brahman crossbred beef cattle (Puspitaningrum, 2009). These authors confirm that the correlation values indicated relatively low accuracy for estimation of animal body weight in case of using single variable of either chest girth or body length as predictor variable (Fajemilehin and Salako, 2008; Puspitaningrum, 2009).

Animal chest girth dimension represented circumference of the circle in cylinder shape, and animal body length represented height of cylinder shape. Therefore, cylinder shape volume represented animal body volume that can be calculated by cylinder volume formula. The animal body represented by cylinder volume formula using component measurements of animal chest girth and body length dimensions has not been fully exploited and applied to estimate animal body weight, especially in Ongole crossbred cattle.

The objective of this research is to develop a regression equation using independent variable of body volume for estimating the live weight of Ongole crossbred cows and to contribute possibly to the existing knowledge on estimation of body weight of Ongole crossbred cows in Indonesia.

MATERIALS AND METHODS

Location of study and experimental animals

Animals used in this research were Ongole crossbred with unknown composition of Ongole breed and Local Indonesian beef cattle (breeds of Sumba, Madura) in North Sulawesi province. All animals used in this study were non-pregnant and healthy cows of age groups ranging from two to seven and half years old and they were suckling their calves at ages ranging from one week to two months old. Artificial insemination was practiced to inseminate the estrous female cows, using semen collected from Ongole Bull Sperm Bank Institution, located in Singosari, East Java Province, Indonesia. Cows household farmers were located in two villages of Tumaratas and Tonsewer, Minahasa Regency, North Sulawesi Province. This regency is categorized as agricultural areas with altitude of 600-700 m above sea level. It is characterized by cool and humid climate of 25-28°C and 70 to 80%, respectively. The number of Ongole crossbred cattle, randomly chosen in this study were 363 cows. Age was primarily determined by dentition with the indication as follows: cows showed unchanged milk teeth, indicating the age of less than one year old; cows showed two changed milk teeth, indicating the age of one and half to two and half years old; cows showed four changed milk teeth, indicating the age of two and half to three and half years old; cows showed six changed milk teeth, indicating the age of three and half to four and half years old; and cows showed eight changed milk teeth, indicating the age of above five years old. Dentition indicators were verified with household farmer information and records by the inseminators. The unhealthy and pregnant cows were excluded in this study.

Measured traits

Data of this study were recording measurements of cow body dimensions taken from July to August 2011 on each Ongole crossbred population including body length (BL), measured using a tape measure from distance between the site of pins (*tuber ischii*) to tail drop (*tuberositas humeri*), chest girth (CG), measured with a tape measure as body circumference of the chest just behind the foreleg. Animals were also weighed directly using the monitor digital electrical scale with capacity of 2000 kg. Animal body volume (BV) was estimated by cylinder volume formula.Theoretically, a circumference of the circle (C) was calculated by formula as follows: $C = 2\ \pi.r$, or $r = [(½\ C)/\ \pi]$; where, $\pi = 3.14$ and r = radius. Moreover, Size squared area (A) of a circle is given by formula $A = \pi.r^2$, or $A = \pi[(½\ C)/\pi\ ]^2$. It is also obtained that cylinder volume (V) is calculated by formula: $V= \pi r^2 h$ or $V= A.h$; where, h = height (length) of cylinder. Therefore, volume of cylinder (V) could be derived by the following formula: $V= h.\ \pi[(½\ C)/\ \pi]^2$.

In this study, the circumference of the circle (C) represented animal chest girth (CG) dimension (C=CG), the height (h) of cylinder shape was simulated as representation of animal body length (BL) dimension (h=BL), and the volume of cylinder shape (V) was simulated as representation of animal body volume (BV) or V=BV. Thus, BV can be estimated by the formula as follows: $BV = BL.\pi[(½\ CG)/\ \pi]^2$. Because BL was calculated in *cm* length and CG was calculated in squared cm (cm^2), so BV was calculated in cubic cm (cm^3) by formula as follows: $BV\ (cm^3) = BL.\pi[(½\ CG)/\ \pi]^2$. Because BV was found in unit of cm^3, this unit can also be converted into unit of dm^3. As a result, BV in unit of decimeter (dm^3) can be calculated by the formula as follows: $BV\ (dm^3) = [BL.\pi\{(½\ CG)/\ \pi\}^2]/1000$. All measurements of animal dimensions were taken in the morning before the animals were fed. Each dimension of CG and BL was recorded in centimeter (cm) while BV and animal live weight (LW) were recorded in dm^3 and in kilogram (kg), respectively.

Statistical analysis

The data collected on each animal were analysed using the Insert Function Procedure of the related statistical category (Average, Stdev, Min, Max, ttest, Correl, Intercept, Linest) in datasheet of Microsoft Office Excel (2007) within the animal age groups. The interrelationship of body weights and body measurements were

Table 1. Least square means of live weight and body measurements in Ongole crossbred cows

Age (years)	N	CG (cm)	BL (cm)	LW (kg)	BV (dm^3)
2.5 - 3.5	58	161.64 ± 9.68[a]	133.59 ± 8.81[a]	343.45 ± 56.98[a]	279.69 ± 42.27[a]
3.5 - 4.5	94	176.21 ± 6.05[b]	145.52 ± 5.31[b]	452.32 ± 30.37[b]	359.95 ± 24.94[b]
4.5 - 5.5	65	176.52 ± 7.30[b]	145.31 ± 6.27[b]	452.65 ± 45.45[b]	361.47 ± 36.67[bc]
5.5 - 6.5	56	179.18 ± 7.08[c]	144.36 ± 6.39[b]	461.32 ± 39.62[bc]	369.66 ± 34.10[bc]
6.5 - 7.5	90	179.38 ± 5.58[c]	144.86 ± 5.40[b]	467.81 ± 27.90[c]	371.50 ± 27.45[c]
2.5 - 7.5	363	175.18 ± 9.26	143.20 ± 7.59	440.21 ± 58.03	351.76 ± 45.32

Means in the same column with different superscript differ significantly (P<0.05). N = number of animals; CG = chest girth; BL = body length, LW = live weight; BV = body volume.

estimated by simple correlation and regression (Steel and Torrie, 1980). The fixed effect considered was age of animal. The model used was as follows:

$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$

Where, Y_{ij} was record of live weight and body measurement of each animal; μ was overall mean; αi was the fixed effect of i^{th} age of the animal, and ε_{ij} was random error associated with record of each animal. Age of the animals consisted of five age groups with the first age group of two and half year old to the fifth age group of seven and half year old.

To predict a live weight from body measure was used simple regression analysis. The Excel XP regression statistical program was used for the study. Simple regression model for predicting live weight from chest girth, body length and body volume in each age group of the animals was as follows:

$Y = a + bX$

Where, Y = dependent variable (animal live weight); a = intercept; and X = independent variable (body length, chest girt, or body volume).

RESULTS AND DISCUSSION

The least squares means and standard errors from the general linear model analysis of live weight (LW) and measurements of chest girth (CG) and body length (BL) in Ongole crossbred cows at the various age groups are presented in Table 1. The overall mean live weights at age groups of 2.5-3.5, 3.5-4.5, 4.5-5.5, 5.5-6.5 and 6.5-7.5 years old were 343.45, 452.32, 452.65, 461.32 and 467.81 kg, respectively. The overall mean body volume of those age groups were 279.69, 359.95, 361.47, 369.66, and 357.50 liters, respectively. The overall mean chest girth of the age groups were 161.64, 176.21, 176.52, 179.18 and 179.38 cm, respectively, while those of body length were 133.59, 145.52, 145.31, 144.36 and 144.86 cm, respectively. Age was found to significantly influence chest girth, live weight and body volume up till age groups of 5.5 to 6.5 years, but do differ significantly at age groups of 3.5 to 4.5 years old on trait of body length (Table 1).

Table 2 present the coefficients of correlation between trait pairs of animal live weight, chest girth and body length. The correlations between all pairs of measurements of chest girth, live weight and body volume were highly significant (P<0.001) except those between pair of body length and chest girth (P>0.05) for all age groups.

The summary of simple linear regression analysis and the models for predicting overall traits from live weight of animal body measurements have been demonstrated in Table 3. The analysis showed that overall cow live weight can be predicted from cow body volume (R^2=0.96), cow chest girth (R^2=0.86) and body length (R^2=0.50). The coefficients of determination (R^2) between cow live weight and body volume ranged from 0.92 to 0.98 for all animal age groups, and those between cow live weight and chest girth ranged from 0.71 to 0.86. On the other hand, those between cow live weight and body length ranged from 0.05 to 0.49.

Age strongly influenced animal live weight and body linear traits in Ongole crossbred cows, as there were changes in all traits studied for all animal age groups (Table 1). This figure was however not surprising since the size and shape of the animal was expected to increase as the animal was growing with age up to 3.5 years old. There was wide variability as the age of the animals increased most particularly in the live weight and chest girth.

The variability as the animals' aged sharply reduced among age groups of 3.5 to 4.5 years old in all traits examined as shown in the table most probably because the matured body weight of the animal was almost fully attained on this age group. This finding was in agreement with the study of Sawanon et al. (2011) who reported that at maturity, linear body measurements were essentially a constant, thereby reflecting haritable size of the skeleton. The body conditions of the animals investigated coud be said to be good and the skeletal development was normal and consistent with the animal age.

Correlations between live weight and body linear measurements of chest girth and body volume were positive and highly significant (Table 2). This implied that live weight and these linear measurements covary positively. The correlation between all pairs of linear body measurements and body live weight indicated that frame

Table 2. Coefficients of correlation between the variables in Ongole crossbred cows

Age (Years)	Variables	BL	LW	BV
2.5 -3.5	CG	0.40*	0.91**	0.92**
	BL		0.70*	0.72*
	LW			0.99**
3.5 -4.5	CG	-0.25	0.84**	0.86**
	B L		0.23	0.27
	LW			0.96**
4.5 -5.5	CG	0.29	0.90**	0.92**
	BL		0.63*	0.64*
	LW			0.98**
5.5 -6.5	CG	0.08	0.86**	0.88**
	BL		0.52*	0.54*
	LW			0.97**
6.5 -7.5	CG	0.06	0.84**	0.86**
	BL		0.53*	0.55*
	LW			0.96**
2.5 -7.5	CG	0.44*	0.93**	0.94**
	BL		0.71*	0.72*
	LW			0.98**

CG = chest girth; BL = body length, LW = live weight; BV = body volume. ** P <0.01; * P <0.05.

size of the animal was complementary and that the total size of the animal was a function body live weight and circumference measurements of animal body (chest girth) and body volume. Low correlation between body length and other traits was a confirmation of non-suitability of the parameters as a measure of the other parameter in the Ongole crossbred cattle under this study.

Based on linear regression model, live weight changes with linear body measurements of chest girth and body volume were strongly predictable with R^2 values ranging from 0.71 to 0.98 though the significance of the differences between the regression models was not tested. The R^2 values showed that 71 to 98% of every one kilogram change in live weight was caused by the variables of chest girth and body volume, respectively, while other factors not considered were responsible for between 20 and 2%. Unambiguously therefore, body volume and chest girth in the arranged order of suitability could be used to predict the live weight of the Ongole crossbred cows accurately.

Determination coefficient (R^2) values of simple regressions using independent variable of body volume were higher and more consistent (0.92-0.98) compared with those using independent variables of chest girth (0.71-0.86) and body length (0.05-0.49) among animal age groups. In animals of cattle breeds, Ozkaya and Bozkurt (2009) reported that chest girth was the best parameter of all prediction of body weight for Brown Swiss (R^2 = 0.91) and crossbred cattle (R^2 = 0.89) in comparison to Holstein cattle breed (R^2 = 0.61). In other animal of sheep, the determination coefficient (R^2) value of simple regression analysis of live body weight by chest girth was 0.88 and the (R^2) value of multiple regression analysis of live body weight by chest girth plus hip height plus height plus body length was 0.91 (Afolayan et al., 2006).

This study revealed that the more the independent variables inclusion in the model for prediction of live body weight, the higher the prediction accuracy of body weight by those variables. In this study, body volume formula involved both chest girth and body length measurements as the independent variables. Therefore, it was found that using body volume as the independent variable was consistent with multiple regressions using animal body measurement as the independent variables (Afolayan et al., 2006) and the best parameter of all for prediction of body weight in Ongole crossbred cows.

According to these results, the body weight estimation of Ongole crossbred cows using body volume formula produced higher prediction accuracies among all body measurements. The prediction accuracy of prediction of body weight from body volume formula could be defined by body measurements of both chest girth and body length. This finding indicated that animal body volume was more valuable to be considerd as the predictor of live weight than either chest girth or body length variable as

Table 3. Simple regression models for predicting live weight from chest girth, body length and body volume in Ongole crossbred cows

Age (years)	Dependent (Y)	Independent (X)	Regression equation	R^2 value
2.5 -3.5	LW	CG	-525.95024 + 5.37868 X	0.86
		BL	-264.09880 + 4.54798 X	0.49
		BV	-28.62692 + 1.33031 X	0.98
3.5 -4.5	LW	CG	-295.17355 + 4.24199 X	0.71
		BL	259.91192 +1.32219 X	0.05
		BV	31.18309 + 1.16997 X	0.92
4.5 -5.5	LW	CG	-539.70446 + 5.62165 X	0.81
		BL	-211.33261 + 4.56947 X	0.40
		BV	15.10393 + 1.21046 X	0.96
5.5 -6.5	LW	CG	-400.99196 + 4.81259 X	0.76
		BL	-2.35952 + 3.21204 X	0.27
		BV	45.33436 + 1.12532 X	0.94
6.5 -7.5	LW	CG	-288.90549 + 4.21856 X	0.71
		BL	73.25631 + 2.72378 X	0.28
		BV	103.62972 + 0.98030 X	0.92
2.5 -7.5	LW	CG	-580.36991 + 5.82584 X	0.83
		BL	-335.83476 + 5.41813 X	0.50
		BV	-3.06084 + 1.26016 X	0.96

CG = chest girth; BL = body length, LW = live weight; BV = body volume.

the single independent variable in the regression model. The valuable animal body volume in predicting live weight could be due to the inclusion of chest girth and body length variables in its formula. Consequently, as one of these measurements was decreased then the animal frame size was also decreased, affecting animal body weight. Simple regression models that can be used when measurment is to be based on animal body live volume alone found from chest girth and body length measurements are shown below:

Live weight = 1.26016 body volume - 3.06084 (R^2=0.96)

This high determination coefficient of 0.96 (Table 3) indicated that 96% of the changes of cow live weight (kg) were due to changes of body volume found from the chest girth (cm) and body length measurements following the equation model with the intercept of – 3.06084 and body volume coefficient b of 1.26016; while remaining of 4% were due to the other unknown factors.

Conclusions

Body volume (BV, dm^3) of the cows was calculated using body length (BL, cm) and chest girth (CG, cm) with the formula as follows: BV (dm^3) = $[BL.\pi\{(½\ CG)/\ \pi\}^2]/1000$**;** where, π = 3.14. The determination coefficient (R^2) values of simple regressions for dependent variable (body live weight, kg) using BV as independent variable were higher and more consistent (0.92-0.98) compared to those of CG (0.71-0.86) and BL (0.05-0.49) across the age groups. Therefore, the following simple regression model can be recommended to predict LW of Ongole crossbred cows using BV as independent variable with their age groups ranging from 2.5 to ≥7.5 years old: LW (kg) = 1.26016 BV (dm^3) - 3.06084 with determination coefficient (R^2) of 0.96. This high determination coefficient of 0.96 indicated that 96% of the changes of cow LW (kg) were due to changes of BV found from the CG (cm) and BL (cm) measurements following the above equation model with the *intercept* of -3.06084 and the BV coefficient *(b)* of 1.26016; while the remaining 4% were due to other unknown factors.

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