

Research article**Estimating the body weight of cattle in tropical dual purpose system by using zoometric measurements**

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Abstract

The aim of this study was to determine the zoometric variables that significantly estimate the body weight of cattle from different European crosses and Zebu, using polynomial models and a geometric method, applying multiple linear regression. About 9,462 records of male and female Holstein and Brown Swiss crossed with Zebu genotypes on two management systems, the Experimental Station La Posta and Matias Romero, belonging to INIFAP were used in total. The selected variables related to live weight prediction were: height at hindquarter (haunch) (HH), height at withers (HW), thoracic perimeter (TP), abdominal circumference (AC), body length (BL) and length at withers (LW). A database was developed on a spreadsheet with the factors: genotypes (Holstein and Brown Swiss crossed with Zebu), gender (females and males) and Experimental Station (La Posta and Matias Romero). With HH, HW, TP, AC, BL and LW variables, a regression analysis was tested using the Best Subsets method with the determination coefficient (R) indicators, Mallows' Cp and Variance (S) and multiple regression with their corresponding analysis of variance (ANOVA) using the MINITAB V15 software. The length and perimeter measures were used to obtain the volume, as an estimate of body weight. According to the results of the multiple regression analysis, the zoometric measures TP, AC and BL were highly significant ($P \leq 0.0001$) to estimate the body weight of cattle of Holstein and Brown Swiss crossed with Zebu in dual-purpose systems (DPS) in the tropics. In conclusion, the zoometric measures TP, AC, BL and LW, significantly estimate the body weight of Holstein and Brown Swiss cattle crossed with Zebu.

Keywords: Cattle; zoometric measures; body weight; volume

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Introduction

Knowledge of the body weight of cattle is considered of great importance in processes of growth assessment, feed planning of the different animal

categories at different times of the year, formation of homogeneous groups, economical use of available food resources and genetic improvement. This is a very important indicator for the development and overall improvement of the dual purpose systems. With proper

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and rational use of the resources, the production can be more efficient and profitable. For reproduction, it is essential that heifers reach a certain weight to be mated or inseminated. Weight is also an important indicator for the selection of replacements, evaluation of growth and making herd groups more homogeneous. In health, weight is vital, because based on body weight pharmaceutical substances can be dosed. Economically, it is of great interest, since at the time of selling an animal, the weight decides the price; nevertheless, most of the dual purpose system (DPS) units do not have a scale due to the high cost of the instrument.

The increase of body weight is a result of changes in the size and shape of animals, which is growing in length, width, height, and therefore the development actually measured or estimated, that can efficiently represent the state of growth (Menéndez, 1984). Making use of zoometry is useful in comparison with the measures taken on a breed or genotypes, giving an idea of the variations in these over time. In addition, the use of weight prediction charts is very practical and low-cost (Mahecha et al., 2002).

A zoometric study of animals is a specific body measurement to quantify their body shape, so it can meet the production capacity of one breed or it is inclination towards certain zootechnical production. Furthermore, measurements of length determine the distance between body points in the longitudinal direction and width measures determine the distance between points in the body transverse to the longitudinal axis of the body, while the perimeter measures determine the contour of certain body regions (Torrent, 1982).

Within zoometric measures, thoracic perimeter has been the most evaluated as a predictor of cattle weight with different linear and nonlinear models, as mentioned by the most outstanding reports from Baker et al. (1995), Brookes and Harrington (1960) and Heinrichs et al. (1992), as well as the hindquarters height (Alderson, 1999). Few studies exist on the use of zoometric measures in conjunction with the thoracic and abdominal perimeters and lengths to a more reliably weight estimate of Holstein and Brown Swiss cattle crossed with Zebu in the tropics. Therefore, the aim of this study was to study the zoometric variables that could help in estimation of body weight of cattle of different European crosses using polynomial models and a geometric method, applying a multiple linear regression.

Materials and Methods

This research was conducted at the Experimental Stations (ES) La Posta and Matias Romero of the National Research Institute of Forestry, Agriculture and Livestock (INIFAP-Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias).

Herds from ES La Posta and EF Matias Romero belonged to crossed genotypes Holstein (Ho) and American Brown Swiss (ABS) with Zebu (Ze) 1/2, 5/8, 3/4 and 7/8 respectively. They were managed under intensive rotational grazing with electric fencing. The diet was consisted of forage consumed directly from the paddock. In the critical dry season, they were supplemented with a diet based on corn or sorghum silage, a mixture of minerals and water *ad libitum* was also offered.

A total of 9,462 records of male and female cattle of Ho and ABS genotypes crossed with Ze (1/2, 5/8, 3/4 and 7/8) were used in total under two management systems: cattle from ES La Posta had an average daily weight gain 300 g and those from ES Matias Romero had daily gain 400 g.

The selected variables related to body weight prediction were: height at hindquarter (haunch) (HH), height at withers (HW), thoracic perimeter (TP), abdominal circumference (AC), body length (BL) and length at withers (LW).

The measurement of the perimeters and lengths were performed with a TRUPER fiberglass measuring tape (10mx0.01cm), graduated on both sides. Body weight was obtained using an electronic scale for 1000 kg with a sensitivity of 0.1 kg, each animal was weighed at intervals of 30 days. For heights, a Nasco brand metric stick (165 cm x 0.5 cm) equipped with leveling was used.

Zoometric measures of the Ho and ABS x Ze genotypes were taken each month, from weaning stage until three years of age. The production system was mainly tropical dairy farming. A database was developed on an Excel 2003 spreadsheet with the factors: genotypes (Ho and ABS crossed with Ze), gender (females and males) and Experimental Station (La Posta and Matias Romero).

With the factors genotype, gender, experimental station and the variables HH, HW, TP, AC, BL and LW, regression analysis was tested using the Best Subsets (Chatterjee and Price, 1991) method with the determination coefficient (R) indicators, Mallows' Cp and Variance (S), and the multiple regression with the corresponding analysis of variance (ANOVA) using the MINITAB V15 software.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 \dots \beta_n X_n$$

Y = Response variable.

β_0 = Intercept.

$\beta_1 \dots \beta_n$ = Coefficients

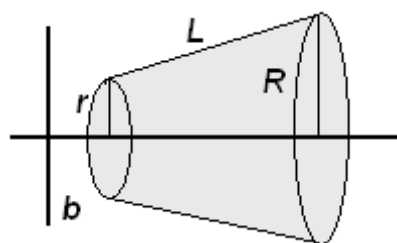
X = Variables, zoometric measures

Regression analysis was performed to three groups: the first included the genotype, gender and Experimental Station. The second group included

gender and genotype factors. The third group only included genotype. The length and perimeter measures were used to obtain volume as an estimate of body weight. The explanation is based on the relationship between the perimeter and the weight of a cylinder by the similar measures of its diameter with that of cattle. From this, we assume a trunk or truncated cone which is determined by the radius of the bases and the height (Fig. 1). In the case of cattle, we have the lengths and perimeters, with the knowledge that the animals grow and develop for a while and stop growing in height, but can develop a little more in length and width. The radius obtained from thoracic perimeter (TP) and abdominal circumference (AC) is different in all animals, that is, they can grow more TP than AC or on the contrary, without affecting the calculation of the volume of each animal.

With the following equation, the volume can be calculated through their radius (Fig. 1).

$$V = \pi h (R^2 + r^2 + (Rr))$$



V= Volume, m³

$\pi = 3.1415$

h= Length at withers, m

R²= major radius, m²

r²= minor radius, m²

R= radio mayor, m

r= radio menor, m

With the calculations mentioned previously a new database was created for the factors: Genotype (Ho and ABS), Gender (M and F), and Experimental Station (Posta and Matias), TP, AC, LW and volume. The values of the variables were converted from centimeters

to meters, with the perimeters the radius r from the smaller circle and R from the larger circle of the truncated cone were obtained.

For the linear regression analysis, the Kaleida Graph™ version 3.5 software was used. With which the prediction equation was obtained to estimate body weight for each factor such as genotype, gender and Experimental Station, from the volume. The radius' calculation was made based on the perimeter, as shown below.

$$radio = \frac{ThoracicPerimeter}{2\pi}; \quad r = \frac{P}{6.2832}$$

P= Perimeter; r= radio; $\pi = 3.1415$

Results and Discussion

Table 1 shows the results of the multiple linear regression analysis of the factors genotype, gender and Experimental Station. In Ho females and males from Matias Romero, significant variables ($P \leq 0.05$) were TP, AC and BL and highly significant ($P \leq 0.0001$) LW.

With the analysis of variance (ANOVA), significant relationship between the variables was as follows: HH and HW variables were mostly non significant, in Ho and ABS females from La Posta HW was significant, the HH variable was significant for Ho males from La Posta and highly significant for ABS females from Matias Romero.

The non-significant variables were: abdominal perimeter for ABS males, body length for Ho females from Matias Romero and ABS females from La Posta. With the VIF values close to 10 and d values close to 2, no collinearity among the significant variables was presented, but there is correlation between the variables and body weight. The R² coefficient with values from 0.89 to 0.96 indicates a good relation among the zoometric measures to estimate the body weight of crossed cattle.

The variables that had a significant effect on body weight, given R, Mallow's Cp and variance are presented

Table 1: Effect of zoometric variables on body weight estimation of female and male cattle under two dual production systems

Genotype	Gender	Station	n	HH	HW	TP	AC	BL	LW	R ²	d
Ho	F	Matias	233	(6.0)	(6.1)	** (8.2)	** (7.1)	(5.1)	** (5.8)	0.94	1.01
Ho	M	Matias	166	(8.5)	(10.8)	** (11.3)	* (13.3)	* (9.7)	** (10.6)	0.95	1.58
ABS	F	Matias	101	** (5.3)	(4.9)	* (11.1)	* (5.5)	* (6.7)	(6.8)	0.93	1.09
ABS	M	Matias	161	(6.8)	(8.1)	** (8.3)	(7.0)	** (7.1)	** (7.1)	0.93	1.24
Ho	F	Posta	200	(1.7)	* (4.6)	** (9.3)	** (6.2)	* (6.0)	* (5.7)	0.89	1.43
Ho	M	Posta	417	* (9.0)	(6.7)	** (19.1)	* (10.6)	** (10.2)	** (7.6)	0.96	1.59
ABS	F	Posta	86	(3.4)	* (3.8)	** (8.7)	* (5.2)	(5.3)	* (4.5)	0.91	1.50
ABS	M	Posta	213	(12.5)	(11.4)	** (12.5)	* (7.7)	** (12.3)	** (10.9)	0.94	1.44

Ho= Holstein, ABS=American Brown Swiss, F=Females, M=Males, HH=Hindquarters height, HW= Height at withers, TP=Thoracic perimeter, AC=Abdominal circumference, BL= Body length, LW=Length at withers; * $P \leq 0.05$, ** $P \leq 0.0001$, d =Durbin Watson, () = VIF

Table 2: Effect of zoometric variables on body weight of female and male crossed European x Zebu cattle

Genotype	Gender	Station	N	HH	HW	TP	AC	BL	LW
Ho	F	Matías	233	*	ns	*	*	*	*
Ho	M	Matías	166	*	ns	*	*	*	*
ABS	F	Matías	101	*	ns	*	*	*	*
ABS	M	Matías	161	ns	*	*	ns	*	*
Ho	F	Posta	200	*	*	*	*	*	*
Ho	M	Posta	417	*	ns	*	*	*	*
ABS	F	Posta	86	*	*	*	*	ns	*
ABS	M	Posta	213	ns	*	*	*	*	*

Ho= Holstein, ABS=American Brown Swiss, F=Females, M=Males, HH=Hindquarters height, HW= Height at withers, TP=Thoracic perimeter, AC=Abdominal circumference, BL= Body length, LW=Length at withers

Table 3: Effect of zoometric variables on body weight estimation of female and male cattle

Genotype	Gender	n	HH	HW	TP	AC	BL	LW	R ²	d
Ho	F	433	*(2.5)	(4.4)	** (10.1)	** (7.9)	** (6.6)	** (6.9)	0.93	1.29
Ho	M	583	*(8.6)	(7.3)	** (15.5)	** (10.5)	** (10.0)	** (8.3)	0.95	1.44
ABS	F	187	** (4.7)	*(5.1)	** (11.3)	** (5.9)	*(6.5)	*(6.0)	0.93	1.28
ABS	M	374	(10.4)	(10.1)	** (11.3)	*(7.9)	** (9.2)	** (9.7)	0.94	1.31

Ho= Holstein, ABS=Brown Swiss, F=Females, M=Males, HH=Hindquarters height, HW= Height at withers, TP=Thoracic perimeter, AC=Abdominal circumference, BL= Body length, LW=Length at withers; *P≤0.05, **P≤0.0001, d= Durbin Watson, ()=VIF

Table 4: Effect of zoometric variables on body weight of female and male crossed European x Zebu cattle

Genotype	Gender	n	HH	HW	TP	AC	BL	LW
Ho	F	433	*	ns	*	*	*	*
Ho	M	583	*	ns	*	*	*	*
ABS	F	187	*	*	*	*	*	*
ABS	M	374	ns	ns	*	*	*	*

Ho= Holstein, ABS=American Brown Swiss, F=Females, M=Males, HH=Hindquarters height, HW= Height at withers, TP=Thoracic perimeter, AC=Abdominal circumference, BL= Body length, LW=Length at withers

in Table 2. The HH, TP, AC, BL and LW were significant except for ABS x Ze females from La Posta and ABS x Ze males and Matias Romero. The Best Subsets regression analysis significantly selected thoracic perimeter and length at the withers from all the factors, followed by AC, BL, HH and less frequently in HW. García et al. (2009) recommended the use of body weight, TP and HW on Ho heifers, stating that the weight of animals can be estimated from TP or HW.

Table 3 shows that on the basis of genotypes (Ho x Ze) and gender, the significant variable was HH (P≤0.05) and TP, AC, BL and LW were highly significant (P≤0.0001). The ABS x Ze males, variables TP, BL and LW were highly significant and AC was significant. The ABS x Ze females, HW, BL and LW are significant and HH, TP and AC are highly significant.

According to the d value close to 2, this indicates a slight positive autocorrelation and the R² value greater than 0.90 indicates a good relation of variables to estimate body weight, referring to the VIF values there is no collinearity between the independent variables.

Heinrichs et al. (1992) found that the addition of second measures to the simple regression models do not improve much the coefficient of determination values;

having obtained added values of R² = 0.0013 for the regression models with the addition of a second additional linear as in the case of TP and HW.

Significant variables in the multiple regression analysis and their respective ANOVA shown in Table 3, matches the same response variables from the Best Subsets regression analysis to estimate the body weight from TP, AC, BL, LW shown in Table 4. For ABS males, significant variables were TP, AC, BL and LW. The variables used for each factor in each case had a different behavior, some were significant and other highly significant in Table 4, variables continue to excel as estimators of body weight are length and perimeters i.e., TP, AC, BL and LW. This confirms that body weight can be estimated by correlating zoometric measures.

Excluding Ho where HH is significant for the estimation of body weight. Table 5 clearly shows that TP, AC, BL and LW variables are highly significant for the Ho and ABS genotypes x Ze.

VIF values closed to 10 and the d value near 2 indicate that there is low multicollinearity and a slight autocorrelation, the R² coefficient value approaches 1 which indicates a high correlation of the zoometric measures to estimate the body weight of European x Ze crossed cattle in the tropics.

Table 5: Effect of zoometric variables on body weight estimation of cattle

Genotype	n	HH	HW	TP	AC	BL	LW	R ²	d
Ho	1016	*(3.9)	(5.6)	** (13.2)	** (9.2)	** (8.5)	** (7.9)	0.94	1.29
ABS	561	(7.3)	(8.0)	** (11.6)	** (7.3)	** (8.6)	** (8.6)	0.93	1.20

Ho= Holstein, ABS=American Brown Swiss, HH=Hindquarters height, HW= Height at withers, TP=Thoracic perimeter, AC=Abdominal circumference, BL= Body length, LW=Length at withers; *P≤0.05, **P≤0.0001, d= Durbin Watson, ()=VIF

Table 6: Zoometric variables that had significant effect on body weight of female and male crossed European x Zebu cattle with the factor: Genotype, analyzed by Best Subsets regression

Genotype	n	HH	HW	TP	AC	BL	LW
Ho	1016	*	*	*	*	*	*
ABS	561		*	*	*	*	*

Ho= Holstein, ABS=American Brown Swiss, HH=Hindquarters height, HW= Height at withers, TP=Thoracic perimeter, AC=Abdominal circumference, BL= Body length, LW=Length at withers

Table 7: Equations relating the volume (TP, AC and LW) and body weight of cattle from different genotypes Holstein and America Brown Swiss x Zebu in males and females, managed under a dual purpose system at Matias Romero

Genotype	Females		Males	
	Equation	R	Equation	R
Holstein	$Y = -0.020007 + 0.00085863x$	0.96	$Y = 0.007494 + 0.00073566x$	0.97
American Brown Swiss	$Y = -0.023136 + 0.00086673x$	0.95	$Y = 0.00071769 + 0.00074883x$	0.95

Y= Volume; x= Body weight

Table 8: Equations relating the volume (TP, AC and LW) and body weight of cattle from different genotypes Holstein and Brown Swiss x Zebu in males and females, managed under a dual purpose system at La Posta

Genotype	Females		Males	
	Equation	R	Equation	R
Holstein	$Y = 0.0029635 + 0.00076053x$	0.93	$Y = 0.0099425 + 0.00081147x$	0.97
Brown Swiss	$Y = -0.0077114 + 0.0007874x$	0.92	$Y = 0.0013818 + 0.00075322x$	0.97

Y= Volume; x= Body weight

It is evident in Table 6 that the HH, HW, TP, AC, BL and LW variables had a significant effect to estimate the body weight of Ho x Ze cattle. However, the only variable that had no significant effect for ABS x Ze was HH. This analysis confirms the information from Table 5, which shows that highly significant variables for both genotypes were also TP, AC, BL and LW.

Khalil and Vaccaro (2002) studied the correlation of weight with various body measurements (HW, BL and TP), TP was the best individual measure and indicator of body weight, with correlation coefficients of 0.90 to 0.93.

According to the multiple regression analysis results, the zoometric measures TP, AC and BL were highly significant to estimate the body weight of Holstein and Brown Swiss x Zebu cattle under dual purpose systems in the tropics. Based on this, we proceeded to estimate the volume of the body of cattle under study as mentioned in the methodology, based on the geometric shape of a truncated cone, in such way the volume of each cattle was calculated and correlated with body weight. Table 7 discloses the prediction equations for calculating the volume. The ABS x Ze genotypes have the same coefficient of determination (R) value; female and male Ho x Ze had the highest correlation.

Table 8 shows that for Ho and ABS x Ze females, the correlation coefficient (R) are lower compared to Ho and ABS x Ze males with the same R value, just as the

previous table, the prediction equations are highly significant for obtaining the volume as a body weight estimator.

Due to length and perimeter measures, the body of a bovine resembles a truncated cone, as it is assumed that the body of a bovine is a cylinder. The mass response (weight) to a radius increase (increased circumference) is higher as the perimeter increases. Considering that the length of the animal (height of the cylinder) increases as the thoracic perimeter increases, accordingly, as the animal grows the length and width changes. Brookes and Harrington (1960) found no significant differences between equations that differ by weight estimated by the thoracic perimeter in less than 3.5%. These authors recommended an equation that allows an error of 7.3% between the estimated weight and the actual weight (Solís et al., 1987).

Conclusions

The zoometric measures TP, AC, BL and LW clearly estimated the body weight of Holstein and American Brown Swiss cattle crossed with Zebu, through multiple linear regression and Best Subsets analysis. The volume with the TP, AC and LW variables showed a high correlation with the body weight of male and female cattle of Holstein and American Brown Swiss crossed with Zebu genotypes kept under dual purpose production

systems, therefore body weight can be estimated by calculating the volume.

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