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Short communication: Development and evaluation of predictive models of body weight for crossbred Holstein-Zebu dairy heifers

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ABSTRACT

Equations to predict body weight (BW) of crossbred Holstein-Zebu dairy heifers were developed and compared with current models (Heinrichs et al. for Holsteins, United States; Reis et al. for crossbred Holstein-Zebu, Brazil). The data set was constructed from 150 measurements of BW (320 ± 107 kg) and biometric measurements such as heart girth (HG, 161 ± 19.5 cm), withers height (WH, 126 ± 11.0 cm), and hip height (HH, 132 ± 11.3 cm) of heifers from 5 commercial dairy producers in the southern Amazon region in Brazil. The data were evaluated using mixed nonlinear models with herd as a random effect. Three nonlinear equations were fitted: BW (kg) = 0.00058·HG (cm)$^{2.6135}$; BW (kg) = 0.000618·HG (cm)$^{2.7362}$; and BW (kg) = 0.000196·HH $^{2.8793}$. An independent database was constructed to evaluate the models from 38 treatment means of 4 feeding trials: BW 258 ± 54.3 kg, HG 142.5 ± 11.8 cm, WH 113.2 ± 6.0 cm, and HH 118.7 ± 9.1 cm (mean ± SD). The evaluations were based on the relationship between observed and predicted values of BW by linear regression, root mean square prediction error (RMSPE), and concordance correlation coefficient analysis. Only the proposed model using HG accurately predicted observed BW, with bias (observed − predicted) of 4.83 kg and RMSPE of 5.41% of observed BW (87.7% of random error). The models using WH and HH failed to accurately predict observed BW, with a bias of −3.06 and 72.02 kg, and RMSPE of 9.40% of observed BW (75.2% of random error and 23.1% of systematic error) and 30.81% of observed BW (81.2% of mean bias). Additionally, the models of Heinrichs and Reis used for comparison did not predict BW accurately, with a bias of 19.32 and 29.37 kg and RMSPE of 9.08% of observed BW (68.4% of mean bias and 31.4% of random error) and 12.58% of observed BW (81.9% of mean bias). The largest concordance correlation coefficient of the proposed HG-nonlinear model (0.930), compared with the models of Heinrichs and Reis of 0.845 and 0.708, confirmed the greater accuracy and precision of the new equation to predict BW in crossbred Holstein-Zebu dairy heifers.
Key words: body growth, meta-analysis, modeling

Short Communication

Body weight measurements are essential in growing systems for dairy heifers to determine nutritional requirements and feeding, breeding, health, and reproductive management. However, the adoption of BW measurement by farmers remains a challenge. Surveys performed in several dairy regions in Brazil have demonstrated that fewer than 10% of dairy farmers weigh their heifers, due to the low availability of scales on farms (Diagnóstico da Pecuária Leiteira do Estado do Minas Gerais, 2005; Diagnóstico da Cadeia Produtiva do Leite do Estado de Mato Grosso, 2011). Thus, a feasible alternative would be to provide an indirect, fast, and low-cost method able to estimate BW of heifers on commercial herds.

Biometrics measurements such as heart girth (**HG**), withers height (**WH**), hip height (**HH**), and body length represent an alternative to estimate BW (Davis et al., 1961). Some predictive equations have been developed for Holsteins in the United States (Heinrichs et al., 1992) and for crossbred Holstein-Zebu in Brazil (Reis et al., 2008) that are able to assess the BW through biometric measurements. However, these models were empirically developed, which means their accuracy and precision are population dependent. Furthermore, the models proposed by Heinrichs et al. (1992) and Reis et al. (2008) have not been evaluated using an independent data set, which could make their full acceptance and recommendation questionable.

Thus, the objectives were (1) to develop equations to predict BW of dairy crossbred Holstein-Zebu heifers through the use of biometrics measurements, and (2) to evaluate the adequacy of the proposed predictive models compared with the models of Heinrichs et al. (1992) and Reis et al. (2008) using an independent database.

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Table 1. Descriptive statistics of the data sets used to develop and evaluate model predictions of BW in dairy heifers

Body measurement	Mean	Minimum	Maximum	Median	SD
Development (n = 150)[1]					
BW, kg	319.6	86.0	605.0	333.0	107.2
Heart girth, cm	161.2	110.0	200.0	166.0	19.5
Withers height, cm	126.2	90.0	149.0	128.0	11.0
Hip height, cm	131.7	96.0	150.0	134.0	11.3
Evaluation (n = 38)[2]					
BW, kg	257.8	146.9	347.4	257.9	54.3
Heart girth, cm	142.5	118.0	159.6	143.7	11.8
Withers height, cm	113.2	100.8	123.2	113.4	6.0
Hip height, cm	118.7	116.6	129.6	113.2	9.1

[1]One hundred fifty heifers in 5 herds.

[2]Miranda et al. (1999); Guimarães (2009); Vidaurre, (2009); Santos et al. (2010).

Table 2. Solution for fixed effects of nonlinear equations for predicting BW in crossbred and Holstein dairy heifers from body measurements[1]

Model	Biometric measurement	Equation	*P*-value	AIC	BIC	S_{xy}
[1]	Heart girth (HG)	$BW = 0.00058 \cdot HG^{2.6135}$	<0.001	1,398.6	1,397.0	0.96
[2]	Withers height (WH)	$BW = 0.000618 \cdot WH^{2.7362}$	<0.001	1,561.7	1,560.1	0.90
[3]	Hip height (HH)	$BW = 0.000196 \cdot HH^{2.8793}$	<0.001	1,505.5	1,503.9	0.89

[1]AIC = Akaike information criterion; BIC = Bayesian information criterion; S_{xy} = correlation coefficient between predicted and observed values.

The data set of BW and biometrics measurements was obtained from 150 crossbred Holstein-Zebu dairy heifers from 5 commercial dairy herds in the south Amazon region in Brazil (Table 1). The main biometric measurements taken were HG, WH, and HH, as described by Heinrichs and Lammers (1998).

Three nonlinear equations (allometric) were fitted in an attempt to predict BW from HG, WH, and HH. Sta-

Table 3. Analysis of regression between observed (Y) and predicted (X) values of BW for various models used for Holstein and crossbred Holstein-Zebu dairy heifers

	Model[2]					
Item[1]	Model [1] (HG)	Model [2] (WH)	Model [3] (HH)	H1	H2	Reis
Y, kg of BW	257.84	257.84	257.84	257.84	257.84	257.84
X, kg of BW	253.00	260.93	185.82	238.52	263.47	228.47
Intercept (β_0)	1.34	−89.40	−147.06	22.84	42.81	27.81
P-value (H_0: $\beta_0 = 0$)	0.908	0.002	<0.001	0.039	0.027	0.017
Slope (β_1)	1.014	1.330	2.180	0.985	0.816	1.007
P-value (H_0: $\beta_1 = 1$)	0.763	0.002	<0.001	0.738	0.012	0.884
R^2	0.936	0.833	0.809	0.935	0.799	0.928
Mean bias (Y – X)	4.84	−3.06	72.02	19.32	−5.60	29
MSEP, kg × kg	194.30	588.40	6.319.7	545.24	668.84	776.44
Root MSEP, % of BW observed	5.41	9.41	30.83	9.05	10.03	12.59
Partition of MSEP, %						
Squared bias	12.05	1.63	82.08	68.41	4.74	81.97
Systematic error	0.24	23.15	9.92	0.17	3.64	0.468
Random error	87.71	75.22	8.00	31.43	91.63	17.56
CCC (0 to 1)	0.930	0.850	0.241	0.845	0.878	0.708
ρ (0 to 1)	0.935	0.913	0.899	0.904	0.886	0.826
C_b (0 to 1)	0.994	0.931	0.268	0.935	0.991	0.857

[1]Models [1], [2], and [3] = models in the current study using heart girth (HG), withers height (WH), and hip height (HH); H1 = model proposed by Heinrichs et al. (1992) using heart girth; H2 = model proposed by Heinrichs et al. (1992) using withers height; Reis = model proposed by Reis et al. (2008) using heart girth.

[1]MSEP = mean squared error of prediction; CCC = concordance correlation coefficient; ρ = correlation coefficient estimate; and C_b = bias correction factor.