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Technical note

Development and evaluation of equations to predict body weight of Pelibuey ewes using heart girth

Alfonso J. Chay-Canul [a]

Ricardo A. García-Herrera [a*]

Rosario Salazar-Cuytún [b]

Nadia F. Ojeda-Robertos [a]

Aldenamar Cruz-Hernández [a]

Mozart A. Fonseca [c]

Jorge R. Canul-Solís [d]

[a] Universidad Juárez Autónoma de Tabasco, División Académica de Ciencias Agropecuarias. Carretera Villahermosa-Teapa, km 25, R/A. La Huasteca 2ª Sección, 86280 Villahermosa, Tabasco, México. Tel. DACA: (993) 358-1585, 142-9151, Fax DACA: (993) 142-9150.

[b] Universidad Autónoma de Yucatán. Facultad de Medicina Veterinaria y Zootecnia, Mérida, Yucatán, México.

[c] University of Nevada, Department of Agriculture Nutrition & Veterinary Sciences. Reno, Nevada. USA.

[d] Tecnológico Nacional de México, Instituto Tecnológico de Tizimín. Yucatán, México.

* Corresponding author: ricardogarciaherrera@hotmail.com

Abstract

The main objective was to develop equations to predict body weight (BW) using heart girth (HG) in Pelibuey ewes. A second objective was to evaluate this model for precision using an independent dataset. For model develop a data set composed by 366, 2-3-yr-old, non-pregnant and non-lactating ewes; with a mean BW of 45.7 ± 9.16 kg and HG of 87.55 ± 7.93 cm was used. A linear equation was fitted: BW= -47.97 (±2.01) + 1.07 (±0.02)×HG (r^2 = 0.86, Root mean square error (RMSE)= 3.46, y n= 366). A second data set composed by 67 animals, with similar characteristics (BW of 38.25 ± 8.62 kg and HG of 80.37 ± 7.03 cm) was used to evaluate the developed equations. For the evaluation, the relationship between observed and predicted values of BW by linear regression, the mean squared error of prediction (MSEP) and root MSEP (RMSEP), and concordance correlation coefficient analysis were used. The proposed equation was highly precise (R^2 =0.913) and accurate (Cb=0.996) with a reproducibility index of 0.95. The MEF has indicated a higher efficiency of prediction with higher proportion of the total variance of the observed values been explained by the predicted data (0.91). The partition of the MSEP has indicated a very small mean bias (0.082). The systematic bias has shown that only 1.93 % of the error of prediction was associated with the slope and most of the error was explained by the random component indicating small biases with the predictions. The proposed equation accurately and precisely estimated the BW of non-pregnant and non-lactating Pelibuey ewe using HG and therefore is recommended to be used.

Key words: Biometric measurements, Pelibuey sheep, Body weight, Prediction.

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Body weight (BW) is one of the most accurate measurements to determine livestock growth[1]. The further understanding of body growth allows for novel diet optimization approaches with consequences on the improvement of prediction of sales prices[2], as well as management strategies that can improve therapeutic treatments for livestock diseases[2,3].

Despite of BW being an important economic trait that can assist feeding and management decision supports; small producers can rarely afford expensive scales necessary to perform such measurement[3,4,5]. Although, several techniques to measure or estimate the BW of livestock have been reported, the use if weighing scales, are still the most accurate method, but less preferred by small producers because it’s cumbersomeness, time-consuming efforts, associated cost for implementation, and stress to animals[1,2].

Recently, it has been reported that the sheep lose a significant amount of BW over a short-term delay prior to weighing as a result of handling operations leading to losses around to 1.8 to 2.9 kg or 3.5 to 5.6 % BW[1]. Therefore, it is important to develop alternative practical methods that are of low cost and ease allowing smallholders to monitor the body growth of production animals[4,6].

Among alternative method, the use of biometric measurements (BM) such as the heart girth (HG), body length (BL) and withers height (WH) are valuable and rather simple tools used for the estimation of the BW of production animals[5]. The HG is highly correlated with the BW of small ruminants (sheep and goats) of different breeds and therefore is used more frequently[6-9].

In this regard, Yilmaz *et al*[8] estimated the BW based on HG in Karya sheep and found medium precision (r^2 of 0.63). Others[10] also noted that the HG was related (= 0.79) with the BW of Pelibuey ewe lambs at slaughter. Similarly, Bautista-Diaz *et al*[11] reported that the HG can be used to predict the BW in Pelibuey ewes (r^2= 0.72). Despite of agreements on the correlations of both variables, there are no studies under field conditions designed to evaluate the relationship between BW and HG in Pelibuey sheep. Moreover, the predictive equations reported for small ruminants have rarely been evaluated for Pelibuey sheep. The main objective of current study was to develop equations to predict body weight (BW) using heart girth (HG) in non-pregnant and non-lactating Pelibuey ewes. A second objective was to evaluate this model for precision using an independent dataset.

All procedures involving animals were conducted within the guidelines of official techniques of animal care and health in México (NOM-051-ZOO-1995).

The experiment was carried out in the commercial farm “El Rodeo”, located at 17° 84” N, 92° 81” W; 10 masl and 14 km from the road Villahermosa-Jalapa, Tabasco, Mexico. A data set composed by 366, of 2 to 3-yr-old, non-pregnant and non-lactating, clinically healthy Pelibuey ewes; with a mean BW of 45.7 ± 9.16 kg was used. A second data set composed by 67 animals, with similar characteristics and mean BW of 38.25 ± 8.62 kg was used to evaluate the developed equations.

According to the management of the farm, the ewes were grouped in confinement open-sided facilities provided with a roof and concrete floor. The diet consisted of 66 % forage and 34 % concentrate, with an estimated of metabolizable energy of 12 MJ /kg DM and 10% CP[12]. The dietary ingredients were composed of cereal grains (corn or sorghum), soybean meal, tropical grasses hay, vitamins, and minerals. Each ewe had the BW (digital scale; Model EQB, Torrey, Mexico) and heart girth (HG), taken. The HG was measured as the smallest circumference just posterior to the anterior legs, in the vertical plane using a flexible tape fiberglass (Truper®, Truper S.A. de C.V., San Lorenzo, Mexico) as described Bautista-Diaz *et al*[11].

Statistical analyses were performed using SAS[13]. Descriptive statistics were obtained with PROC MEANS. The PROC REG was used to develop the predictive equation to estimate BW using HG measurements. Outliers were tested by plotting the studentized residual against the statistical model-predicted values. Data points were removed if the studentized residual was outside the range of −2.5 to 2.5. The goodness-of-fit of the regression was assessed by the root of the mean square error (RMSE) and the r^2.

As recommended by Tedeschi[14], additional statistics were used to assess the adequacy of the models, including standard deviation (SD), the mean squared error of prediction (MSEP) and root MSEP (RMSEP), to account for the distance between the prediction and its true value. The mean bias (MB), was used as representation of the average inaccuracy of the model[15]. The modelling efficiency factor (MEF), which represents the proportion of the variation explained by the line Y = X, was used as an indicator of goodness of fit[16,17]. The coefficient of model determination (CD) was used to assess the variance of the predicted data. The bias correction factor (Cb), a component of the concordance correlation coefficient (CCC)[18], was used as an indicator of the deviation from the identity line, whereas CCC as the reproducibility index simultaneously accounting for accuracy and precision. It was assumed high accuracy and precision when coefficients were >0.80 and low accuracy and precision when coefficients were <0.50. Finally, all calculations were obtained using the Model Evaluation System (http://nutritionmodels.tamu.edu/mes.htm; last accessed mayo 17, 2018;[14].

The average, maximum, and minimum values for BW and HG are presented in Table 1. It was observed that the BW of ewes, ranged from 75.00 to 25.55 kg whereas HG ranged from 70 to 114 cm. The correlation coefficient (r) between BW and HG was 0.93, and the regression equation fitted was: BW= -47.97 (±2.00*) + 1.07 (±0.022) × HG (r^2= 0.86, RMSE= 3.46, y n= 366).

Table 1: Descriptive analyses of the BW (kg) and HG (cm) recorded in non-lactating and non-pregnant Pelibuey ewes

Variables	**N**	**Mean ± SD**	**Maximum**	**Minimum**
Development				
BW, kg	366	45.72± 9.16	75.00	25.55
HG, cm	366	87.55± 7.93	114.00	70.00
Evaluation				
BW, kg	67	33.14 ± 8.58	62.00	21.44
HG, cm	67	80.37± 7.03	100.00	65.00

BW= body weight; HG= heart girth; SD= standard deviation.

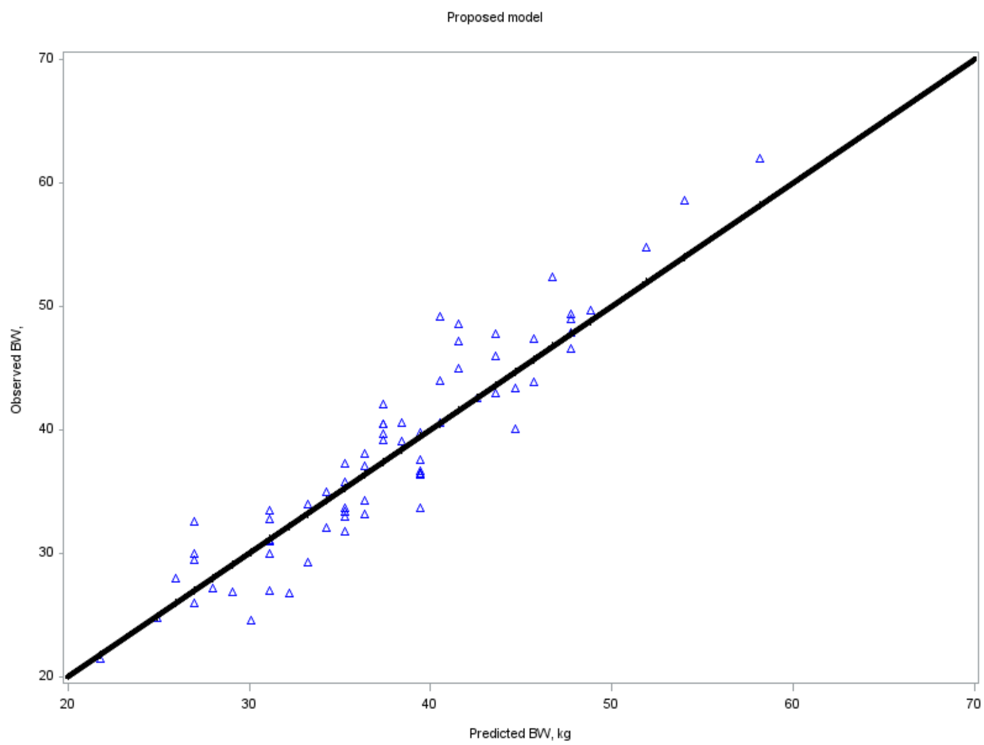
The simultaneous test failed to reject the null hypothesis of an intercept equal to zero and slope equal to one (*P*>0.05). The proposed equation was highly precise (R^2= 0.913) and accurate (Cb= 0.996) with a reproducibility index of 0.95 (Table 2). The MEF have indicated a higher efficiency of prediction with higher proportion of the total variance of the observed values been explained by the predicted data (0.91) (Figure 1).

Table 2: Mean and descriptive statistics of the accuracy and precision of the relationship among observed and predicted values for body weight using the heart girth in Pelibuey ewes

Variable[1]	**Obs**	**[Eq. 1]**
Mean	33.1	36.6
SD	8.58	7.52
Maximum	62	59.0
Minimum	21.4	21.6
r^2	---	0.913
CCC	---	0.95
Cb	---	0.996
MEF		0.91
CD		1.19
Regression analysis		
Intercept (β_0)		
Estimate	---	-1.60
SE	---	1.53
P-value (β_0 = 0)	---	0.30
Slope (β_1)		
Estimate	---	1.04
SE	---	0.04
P-value (β_1 = 1)	---	0.263
MSEP source, % MSEP		
Mean bias	---	0.082
Systematic bias	---	1.93
Random error	---	98.0
Root MSEP		
Estimate	---	8.12
% of the mean	---	7.61

Obs= observed evaluation data set; CCC is the concordance correlation coefficient; Cb is the bias correction factor; MEF is the modeling efficiency; CD is the coefficient of model determination; MSEP is the mean square error of the prediction.

Figure 1: Relationships between observed and predicted BW using the HG in non-pregnant and non-lactating Pelibuey ewes



The CD indicated medium to low variability in the predicted data (1.19) whereas the partition of the MSEP have indicated a very small mean bias (0.082) showing a very small inaccuracy with most of the errors concentrated away from the mean. The systematic bias has shown that only 1.93 % of the error of prediction was associated with the slope and most of the error was explained by the random component indicating small biases with the predictions.

The current study presents an evaluation of the practicality of use the HG to predict BW of Pelibuey ewes. Although, some articles have been published on this topic in other species and in other sheep breeds; in Pelibuey ewes, there are no reports that evaluate this relationship under field conditions. Moreover, it has been reported that this type of models should be developed for each breed under the conditions of handling and system of production[19]. On the other hand, the use of empirical equations developed for the prediction of BW and productive performance, among others, is limited by the lack of evaluation of its predictive capacity with independent data that were used for its development, which makes it difficult to ascertain its accuracy and precision[14].

Among the more common BM used to predict the BW; the HG it has been used in heifers[6], goats and sheep[9,20]. It is in agreement with other authors, indicating that this BM is highly correlated with the BW for different animal species[8]. In the same way, Yilmaz *et al*[8] estimated the BW using the HG in of Karya sheep breed and noticed that the r^2 was 0.63. In addition, it was also reported[10] that the HG was related (r= 0.79) with BW of Pelibuey lambs.

Under experimental conditions, Bautista-Diaz *et al*[11] found that the HG was the best predictor of BW in Pelibuey, compared to other BM (r^2 = 0.72). This coincides with the results obtained in other study using sheep[21]. In other work[21] they found that the HG was highly correlated with BW (r= 0.99 and 0.98, for males and females respectively) in Sudan Nilotic sheep; nonetheless this authors, obtained a non-linear regression ($y= ax^b$), the equations had an r^2 values of 0.98 and 0.96 for male and female lambs, respectively.

The small variance surrounding the slope of the proposed equation indicates that BW can be explained by the variance of HG. The HG itself contributes to the body area where most of organs are housed. It seems that the thoracic circumference of Pelibuey ewe play a bigger role on the determination of BW than body length. The practical implications are that the volume and weight of organs housed in the abdominal cavity may represent better determinants on body mass which determines the bulk of nutrient requirements of maintenance[22].

In addition, Kunene *et al*[3] reported that the relationship between HG and BW had significant r-values that ranged from 0.33 to 0.86 in of Zulu (Nguni) sheep in different age groups. Also, informed that the HG was a more accurate predictor of BW in young Zulu sheep (<15 mo), therefore concluded that BW in Zulu sheep can be reasonably estimated using the HG. Furthermore, Souza *et al*[23] concluded that the equations generated using the heart girth and body length can be used to estimate the body weight of male and female meat-type sheep of different breeds and ages. This it agrees with several authors who have reported the importance of HG in BW estimation in sheep of different breeds[7,9,20].

On the other hand, in the literature, exist different approaches and techniques to evaluate models, according to Mayer and Butler[17], the main evaluation techniques are based on subjective assessment, comparative graphs, measures of deviation (based on the differences between observed and predicted values) and statistical tests. In the present study, were used the tests and analysis of Model Evaluation Systems described by Tedeschi[14].

The parameters for precision and accuracy showed that the equation proposal presented an average accuracy (R^2= 0.913 %) and high accuracy (Cb =0.996) and reproducibility (CCC= 0.95) to predict the BW in non-pregnant and non-lactating Pelibuey ewes. The result of the model efficiency (MEF= 0.91) indicates a relatively high value of concordance between the observed values with their predicted that, in a perfect fit, it might be one. The MEF has been reported as the best measure of concordance between the observed and predicted values; however, with respect to CD, on a perfect fit would be worth one, if its value close to one indicates an improvement in the predictions of the model (CD>1 is an indicator of sub prediction and CD<1 Of on prediction). The CD found in the present study was 1.19, which indicates an underestimation of the BW with a variation of about 2 %[14]. The RCCMEP accounted for 9.27 % of the BW observed. Based on the results of the statistical evaluations, the proposed model predicts the in non-pregnant and non-lactating Pelibuey ewes with good precision and accuracy. For Tedeschi[14], the assessment of the adequacy of a model is only possible through a combination of statistical analysis according to the purpose for which the model was conceptualized and developed. It further concluded that the identification and acceptance of inaccuracies of a model is the first step in the evolution model to a more accurate and more confidence.

The results of present study may contribute to estimation the BW of Pelibuey ewes and this information may to contribute to updating with the data for BW estimation of some parameters required by nutritional models in order to predict the performance of hair sheep breeds[24,25].

Conflicts of interest

The authors state that there are no conflicts of interest.

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