Reliability and concordance of Schaeffer and Agarwal formulae for predicting crossbred dairy cattle weight

Fiabilidad y concordancia de las fórmulas de Schaeffer y Agarwal para predecir el peso de ganado lechero cruzado

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ABSTRACT. The study was aimed to evaluate the reliability and concordance of the Schaeffer and Agarwal formulae for predicting body weight in Gyr (Holstein×Cebu) crossbred cows and heifers. Body weight (BW), heart girth (HG) and body length (BL) were recorded in 156 cows and 98 heifers. There was a strong positive correlation ($p < 0.0001$) between BW observed and BW predicted using the Schaeffer and Agarwal formulae ($r \geq 0.96 \leq 0.97$). Although reliability and agreement were low, as indicated by the CCC values, they were higher for the Agarwal formula. The results suggest that BW predictions using the Agarwal formula are preferable to those using the Schaeffer formula. The results suggest that Agarwal's formula may be useful for estimating BW in crossbred cattle kept under humid tropical conditions in southeastern Mexico.
Keywords: Liveweight, biometric measures, heifers, tropics.

RESUMEN. El objetivo del estudio fue evaluar la fiabilidad y concordancia de las fórmulas de Schaeffer y Agarwal para predecir el peso corporal en vacas y novillas cruzadas Gyr (Holstein×Cebú). Se registró el peso vivo (PV), perímetro torácico (PT) y longitud corporal (LC) en 156 vacas y 98 vaquillas. Se obtuvo una fuerte correlación positiva ($p < 0.0001$) entre el PV observado y el PV estimado mediante las fórmulas de Schaeffer y Agarwal ($r \geq 0.96 \leq 0.97$). Aunque la fiabilidad y la concordancia fueron bajas, como indican los valores de CCC, estas fueron mayores con la fórmula de Agarwal. Los resultados indican que las predicciones del PV con la fórmula de Agarwal son preferibles a las obtenidas con la fórmula de Schaeffer. Los resultados sugieren que la fórmula de Agarwal puede ser útil para estimar el PV en ganado cruzado mantenidos bajo condiciones de trópico húmedo en el sureste de México.
Palabras clave: Peso vivo, medidas biométricas, terneras o vaquillas en zona tropical.

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INTRODUCTION

Although body weight (BW) is an important economic and decision-support trait for livestock management and feeding, it is rarely measured by smallholder farmers due to the lack of weighing scales because of their high acquisition costs (Wood *et al*. 2015, Lukuyu *et al*. 2016, Tebug *et al*. 2016). Although there are several techniques to measure or estimate the BW of animals, it has been reported that although weighing is the most accurate method, it is less preferred by producers because it is complex, time consuming, expensive to implement and stressful for the animals (Wangchuk *et al*. 2018). Therefore, it is important to develop other practical animal weight monitoring methods that are inexpensive and user-friendly for smallholders (Dingwell *et al*. 2006, Oliveira *et al*. 2013, Herrera-Lopez *et al*. 2018).

Therefore, alternative methods have been developed to determine BW in dairy and beef cattle (Dingwell *et al*. 2006, Bretschneider *et al*. 2014), including the use of body biometric measurements (MBs) such as heart girth (HG), hip width (HW), body length (BL), height at withers (HW) and height at rump (RH), among others. These MBs can be used to estimate BW in dairy and beef heifers and cows (Heinrichs *et al*. 1992, Dingwell *et al*. 2006, Reis *et al*. 2008, Lesosky *et al*. 2012, Bretschneider *et al*. 2014; Lukuyu *et al*. 2016). However, some studies have evaluated the relationship between BW and some MBs (Reis *et al*. 2008, Oliveira *et al*. 2013, Mota *et al*. 2013, Franco *et al*. 2017) in animals from tropical dairy breeds such as Gyr and their crosses with Holstein (Holstein × Zebu). On the other hand, in recent years, due to the social media revolution, the Schaeffer formula has been widely promoted as an alternative for determining body weight in livestock (Colorado-Garcia *et al*. 2024). Some BMS, such as HG and BL, are included in this formula. However, there are not many studies that have evaluated the reliability and concordance of this formulae for predicting bovine BW in different management scenarios. At present, there are no studies that have evaluated the Schaeffer formula in animals raised in the humid tropical conditions of Mexico. Therefore, the objective of this study was to evaluate the reliability and concordance of the Schaeffer and Agarwal formulae for predicting body weight in Holstein × Zebu crossbred cows and heifers kept under humid tropical conditions in southeastern Mexico.

MATERIALS AND METHODS

Body weight (BW) data and BMs were recorded from 156 cows and 98 Gyr crossbred heifers (Holstein × Zebu). The cows ranged in age from 3 to 6 years and the heifers from 6 to 22 months. They were grazed on star grass (*Cynodon nlemfuensis*) and humidicola grass (*Brachiaria humidicola*) pastures without supplementation. Data were collected at "Rancho la Esperanza", located at 17°36′27″N, 93°11′35″W; 120 masl and 10 km from the Juárez-Reforma road, in the municipality of Juárez, Chiapas, southern Mexico.

Biometric measurements (BMs) were expressed in cm and were performed in accordance with the description of Oliveira *et al*. (2013) and Bretschneider *et al*. (2014). Recorded BMs included: 1) heart girth (HG) and 2) body length (BL). A flexible fibreglass tape measure (Truper®) was used. Animals were weighed on a fixed platform balance with 2 000 kg capacity and 1 kg accuracy.

Schaeffer's formula for calculating BW was BW = (BL × HG²)/300, where BW is body weight in pounds, BL is body length in inches, and HG is heart girth in inches. The final weight was converted to kilograms according to Wangchuk *et a*l. (2018). While Agarwal's formula to calculate BW was BW = (HG x BL)/Y, where BW was body weight in kg, BL was body length in cm, and HG was heart girth in cm, and Y was 9.0 for HG <65 cm, Y was 8.5 for HG between 65 cm and 80 cm, and Y was 8.0 for HG >80 cm, according to Wangchuk *et al*. (2018).

Statistical Analyses

To determine how well the Agarwal and Schaeffer formulae predicted the true (observed) weights of the experimental animals, the relationship between the variables was first explored through a scatterplot, which included the correlation value (Pearson) between predicted and observed values for both formulae, as well as the concordance correlation coefficient (CCC), which quantifies the agreement and reliability between predicted and observed values (Lin 1989, Lin 2000). Secondly, two simple linear regression models were fitted for each estimate (formula), with the corresponding estimate as the independent variable and the observed weight as the dependent variable. In both cases, the data were previously log-transformed (base 10) to meet the assumptions of the linear model used (Fox and Weisberg 2018). The coefficient of determination (R^2) was used as a measure of effect size, and the root mean square error (RSME) was used to measure the distance between predicted and observed values. The R programming environment (R Core Team 2024) was used for graph generation and data analysis.

RESULTS AND DISCUSSION

The range of BW was from 366.00 to 704.00 kg for cows and from 182.00 to 550.00 for heifers. The range of HG and BL was from 144.00 to 209.00 cm and from 95.00 to 128.00 cm, respectively for cows. While for heifers the range of HG and BL was from 133.00 to 198.00 cm and from 109.00 to 115.00 cm, respectively (Table 1).

Table 1. Minimum and maximum values of body weight (kg), heart girth (cm) and body length (cm) in crossbred Gyr cows and heifers (Holstein × Zebu) kept under humid tropical conditions.

Variable	Description	Mean	SD	Minimum	Maximum
Cows (n = 156)					
BW	Body weight (kg)	520.01	63.54	366.00	704.00
HG	Heart girth (cm)	190.96	9.17	144.00	209.00
BL	Body length (cm)	109.50	6.38	95.00	128.00
Heifers (n = 98)					
BW	Body weight (kg)	318.70	99.95	182.00	550.00
HG	Heart girth (cm)	161.77	17.64	133.00	198.00
BL	Body length (cm)	92.70	13.11	108.00	115.00

According to the exploratory analysis, there is a strong correlation between predicted and observed values in both data sets (Figure 1). However, agreement and reliability are low, as indicated by the CCC values. The results obtained using both models show a very good level of goodness of fit according to R^2 (Figure 2). The results obtained using Agarwal's formula are preferable to those obtained using Schaeffer's formula, as indicated by the lower value of RSME.

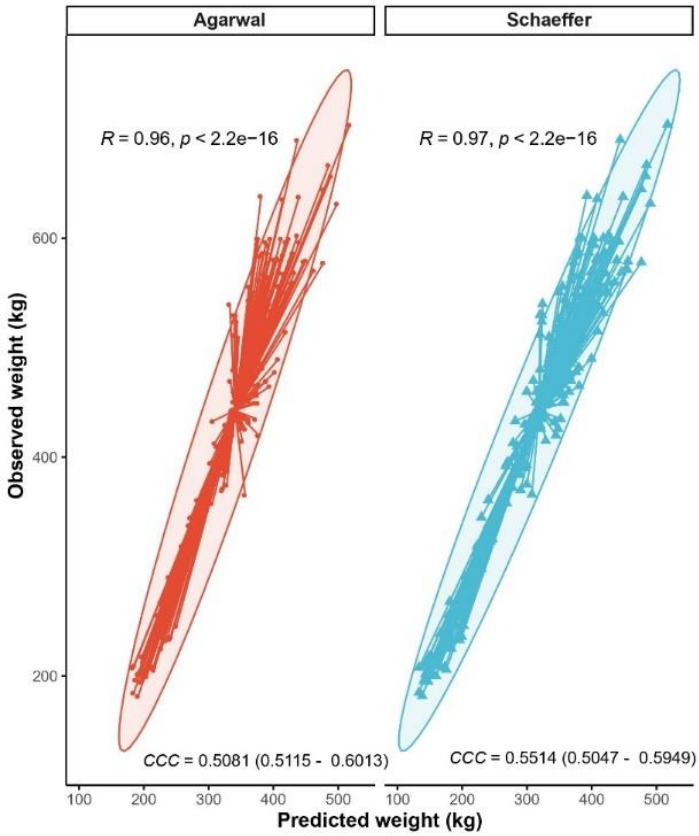

Figure 1. Scatterplot of predicted and observed weights for the two formulas considered in this paper. Pearson correlation coefficients (R) and concordance correlation coefficients (CCC) are included.

Several MBs, including thoracic girth, hip width, body length, withers height, and rump height, have been used to predict BW in Holstein x Zebu crosses (Reis *et al*. 2008, Oliveira *et al*. 2013, Mota *et al*. 2013). Reis *et al*. (2008) reported that breed, age, body size, condition and physiological status may influence BW estimation accuracy using MB. Franco *et al*. (2017) reported r = 0.88 and r^2 of 0.83 between BW and HW in Holstein crossbred cows. These authors concluded that HW had a high correlation with BW but a low R^2 with high variability compared to other variables like BL, WH and RH. In crossbred dairy heifers (Holstein × Zebu), Mota *et al*. (2013) found high correlation coefficients ($p < 0.01$) between BW and HGT (r = 0.93), WH (r = 0.77) and RH (r = 0.73). Bretschneider *et al*. (2014) observed that BW could be estimated with good accuracy using HW in Holstein replacement cows.

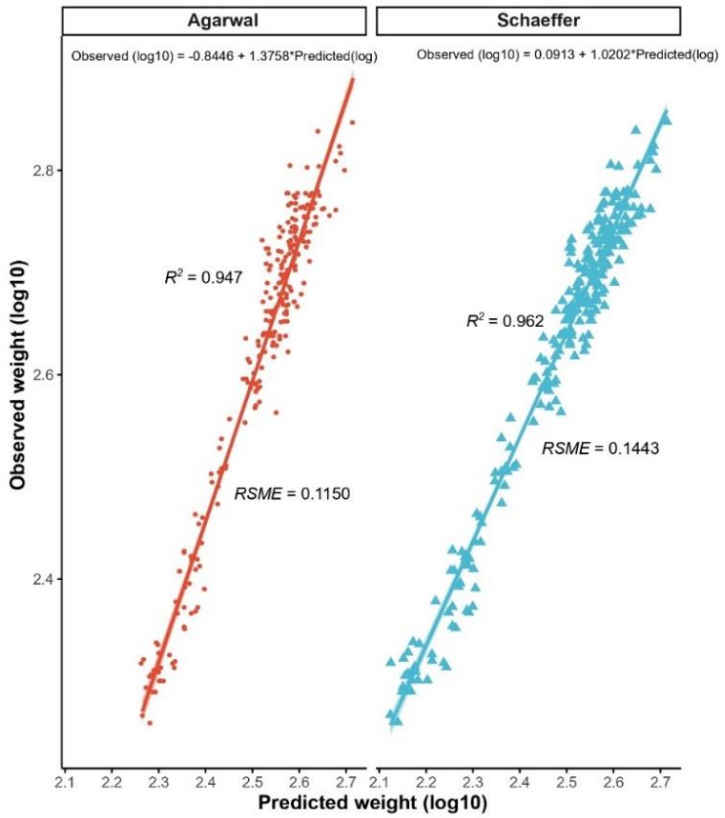

Figure 2. Comparison of fitted simple linear regression models for Agarwal's and Schaeffer's formula estimates in relation to the observed weight of the experimental animals. Statistics related to the fit of the models (R^2, RSME) and the 95% confidence interval for the lines are included.

On the other hand, Shaeffer's formula is one of the most widely used techniques for predicting live weight, especially in large animals such as cattle in India (Wangchuk *et al*. 2018). While Agarwal's formula is the modified Shaeffer's formula (Wangchuk *et al*. 2018). These two formulae's use the HG and DBL to estimate the BW. These formulae's have been used in different livestock species and conditions. Wangchuk *et al*. (2018) also concluded that Schaeffer's formula is the most reliable of all techniques for estimating live weight of cattle, followed by weigh tape, while Agarwal's formula tape is less reliable and its use in the field must be limited. Similarly, Navarro *et al*. (2023) did not find significant differences ($p < 0.0001$) between actual and Schaeffer formula estimates of BW in Zebu 322.36 vs. 313.67; Bradford 250.28 vs. 243.50; Brangus 259.09 vs. 248.30 and their crosses 333.11 vs. 324.87 kg. Furthermore, a strong positive correlation ($p < 0.0001$) was found between the observed BW and the BW estimated by the Schaeffer y Agarwal formulae ($r \geq 0.94 \leq 0.99$). However, regardless of the biotype, the Agarwal formula overestimated the true BW by 14, 23, 19 and 14% for Zebu, Bradford, Brangus and cross-bred cattle respectively. Their study concludes that the Schaeffer formula is more accurate for the estimation of BW in animals of the main biotypes used, compared with the Agarwal formula, which overestimates BW and is therefore not recommended. The results contrast with those observed in the current study, where the results indicated that BW predictions obtained using Schaeffer's formula were less reliable and feasible than those obtained

using Agarwal's formula. Although there were no significant differences ($p < 0.0001$) and a strong positive correlation was found between observed BW and estimated BW ($r \geq 0.96 \leq 0.97$; $p < 0.0001$), the reliability and concordance were low, as indicated by the CCC values of BW predictions using the Schaeffer and Agarwal formulae. However, the results suggest that BW predictions using the Agarwal formula are preferable to those using the Schaeffer formula.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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