Shaeffer's formula as an estimator of body weight in slick and wild type-haired Puerto Rican Holstein calves and heifers[1]

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ABSTRACT

Recording body weight (BW) regularly is a useful tool for cattle management. However, weighing scales (WS) are not always available on farms, hence the need for BW estimating formulas, which are frequently breed- and/or age-specific. Thus, the current study evaluated the reliability of Shaeffer's formula (SF), BW=[body length x (thoracic perimeter)^2]/300), in nine slick (SLICK) and nine wild type-haired (WT) Holstein calves/heifers. The SF results were compared with those obtained using a WS by the REG and GLIMMIX Procedures (SAS). During weeks 1 to 8, there was a strong association between both weighing methods used on SLICK (R^2=0.88; *P*<0.0001) and WT (R^2=0.85; *P*<0.0001) calves. On average, during this period the SF overestimated BW by 6.39 kg, when compared with the WS (*P*<0.0001). From 3 to 33 months of age, a strong association was also observed between both weighing methods in the SLICK (R^2=0.97; *P*<0.0001) and WT (R^2=0.97; *P*<0.0001) heifers. Sampling and weighing method interacted (*P*<0.0001) due to the divergence of the SF and WS curves between 8 and 33 months of age, ranging from 23.20 (*P*=0.0435) to 80.41 kg (*P*<0.0001) greater BW by the SF. Shaeffer's formula turned out to be a feasible and reliable method for BW estimation in the SLICK and WT calves/heifers evaluated in this study, that can be further improved by subtracting the average of overestimated values.

Keywords: body weight, Shaeffer's formula, slick-haired cattle, wild type-haired cattle

RESUMEN

Evaluación de la fórmula de Shaeffer como un estimador de peso corporal en becerras y novillas Holstein puertorriqueñas de pelo corto o de pelaje normal

La recolección frecuente de pesos corporales (PC) es una herramienta útil para el manejo del ganado. Sin embargo, no todas las fincas tienen acceso a balanzas para pesar el ganado (BA), lo que crea la necesidad de

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usar fórmulas para estimar el peso corporal, las cuales frecuentemente son específicas en cuanto a raza y/o edad. El presente estudio evaluó la confiabilidad de la fórmula de Shaeffer (FS; PC=[largo corporal x (perímetro torácico)^2]/300) en becerras/novillas de pelaje corto (n=9; PELONAS) y de pelaje normal (n=9; REGULARES). Los resultados de la FS se compararon con aquellos obtenidos con una BA mediante los procedimientos REG y GLIMMIX (SAS). Durante las semanas 1 a 8, ambos métodos de pesaje resultaron estar asociados entre sí en las becerras PELONAS (R^2=0.88; *P*<0.001) y REGULARES (R^2=0.85; *P*<0.0001). En promedio, durante este periodo la FS sobreestimó los PC por 6.39 kg, en comparación con la BA (*P*<0.0001). Entre los 3 y 33 meses de edad, también se observó una asociación entre ambos métodos de pesaje en las novillas PELONAS (R^2=0.97; *P*<0.0001) y en las REGULARES (R^2=0.97; *P*<0.0001). El muestreo y el método de pesaje interactuaron (*P*<0.0001) debido a la separación de las curvas de PC obtenidas con la FS y con la BA entre los 8 y 33 meses de edad, siendo mayores los resultados de la FS entre 23.20 (*P*=0.0435) y 80.41kg (*P*<0.0001). La FS resultó ser un método viable y confiable para la estimación del PC en las becerras/novillas PELONAS y REGULARES evaluadas en la presente investigación, el cual puede ser mejorado si se restan los promedios sobreestimados arriba mencionados.

Palabras clave: peso corporal, fórmula de Shaeffer, ganado de pelaje corto, ganado de pelaje regular

INTRODUCTION

Recording body weight is a useful tool for proper management in most cattle production scenarios. Regular recording of this variable in cattle may provide useful information related to their reproductive capacity (Handcock et al., 2020; Kasimanickam et al., 2021), nutritional status (Diskin y Kenny, 2016), performance (Seebeck and Campion, 1964), growth (de Behr et al., 2001), and health (Huxley, 2013). It is also convenient to have an accurate body weight value when determining medication dosages in cattle (Machila et al., 2008) or milk allowance in calves (Khan et al., 2011). While commercial cattle weighing scales or platforms are available and provide body weight values with acceptable reliability and accuracy, the small-scale producer does not always have a weighing scale available on the farm, mainly due to the cost of this instrument. Several methods that do not require expensive or complex instruments have been developed for body weight estimation in cattle. One such estimator is Shaeffer's formula, established by Sastry et al. (1982) and reviewed by multiple others, including Jawale et al. (2009), Bhat et al. (2012), and Sharma and Shukla (2017). This formula uses body length and thoracic perimeter of the animal, which can be measured with an inexpensive flexible measuring tape, for estimating body weight. Although Shaeffer's formula has been previously validated in multiple species and breeds, to the authors knowledge, its accuracy has not yet been determined in Puerto Rican dairy cat-

tle. Thus, the current study aimed to compare body weight values determined with Shaeffer's formula with the respective weighing scale values of slick and wild type-haired Puerto Rican Holstein calves and heifers.

MATERIALS AND METHODS

Animals

A total of 18 Holstein female calves (nine slick and nine wild type-haired) from the University of Puerto Rico's Agricultural Experiment Station herd in Lajas were enlisted in the study at birth. Because slick cattle are in the minority (approximately 33% of the total herd is slick-haired), calf recruitment was always initiated with a slick calf. Between 5 September and 5 December 2019, each slick-haired female calf born in the herd was paired with the closest wild type-haired calf (born during the same week), until nine pairs were completed. Calves received 4 L of colostrum (divided in two doses) and their navels were twice disinfected with a 7% iodine solution during their first day of life (both at birth and around eight hours later). Each calf was individually housed and fed 6 L/d of pasteurized whole milk during the first six weeks of life. Calf starter and water were also provided ad libitum beginning on day 3. On week 7, milk was reduced daily by 20% until weaning. Calves remained in individual pens until the 8th week of life. Beginning their 9th week, calves were moved into a group pen with ad libitum access to water and tropical grasses hay. Calf starter was provided up to a maximum rate of 2 kg/calf/d. At an average body weight of 227 kg, heifers were moved to a grazing paddock with access to *Digitaria eriantha* grass, water, and dairy cow concentrate feed (at an approximate rate of 2 kg/heifer/d). The grazing paddock had access to natural shade along its fences. Heifers were synchronized and bred using sexed semen following the Ovsynch protocol and artificial insemination at a fixed time. Artificial insemination bulls used were balanced between hair coat type groups. For the study, inseminations continued until 78% of the heifers were pregnant (6/9 slick and 8/9 wild type-haired heifers). All 18 heifers were kept in the study until they were 33 months old (the calving age of the last pregnant heifer).

Sampling

Sampling was divided into two periods: (1) the first eight weeks of life (when calves were individually housed, including milk feeding), and (2) from 3 to 33 months of age (when heifers were group housed, until the last pregnant heifer calved). During the first period, samples were

recorded once a week. During the second period, samplings were carried out monthly. Samplings were always performed on Tuesday (for the weekly samplings) and on the third Tuesday of each month (from 3 to 33 months of age). At each sampling, body weight was recorded for each calf / heifer by means of a commercial weighing scale for cattle. These body weights were used as gold standard values for the evaluation of estimated weights by Shaeffer's formula. Additionally, body length [the distance between the pin bone (tuber ischii) and the point of the shoulder (lateral tuberosity of the humerus)] and the thoracic perimeter (the body circumference immediately behind the elbow) were also recorded for each animal at all weighing events. Shaeffer's formula was used to estimate the animal's body weight (in pounds; 1 pound=0.45 kg) using the respective body length and thoracic perimeter values as follows:

$$\text{Body weight} = [\text{body length} \times (\text{thoracic perimeter})^2] / 300,$$

where body length and thoracic perimeter were recorded in inches (1 inch=2.54 cm). The results obtained were then converted into kilograms of body weight. All measurements were taken by the same technicians with heifers standing square over a level surface.

Statistical Analysis

Data were divided into the two sampling periods for statistical analysis: from 1 to 8 weeks of life and from 3 to 33 months of age. The REG Procedure of SAS was used to evaluate the relationship between the actual body weights (those obtained with the weighing scale) and the respective weights calculated with Shaeffer's formula throughout the samplings in each period evaluated. The GLIMMIX Procedure of SAS was used to compare the samplings, hair coat types, and weighing methods. There, body weight was included as the dependent variable of the model, while fixed effects included sampling (1 to 8 weeks of life and 3 to 33 months of age), hair coat type (slick vs. wild type-haired), and weighing method (weighing scale vs. Shaeffer's formula). The respective triple and double interactions were evaluated. The calf / heifer identification number was included as the random effect of the model. Significant differences were detected at a P-Value ≤ 0.05.

RESULTS AND DISCUSSION

The linear regression analyses between body weight values obtained from Shaeffer's formula and those recorded by the weighing scale in slick and wild type-haired cattle are shown in Figures 1 to 4. Figures 1 and 2 show the first eight samplings (recorded weekly

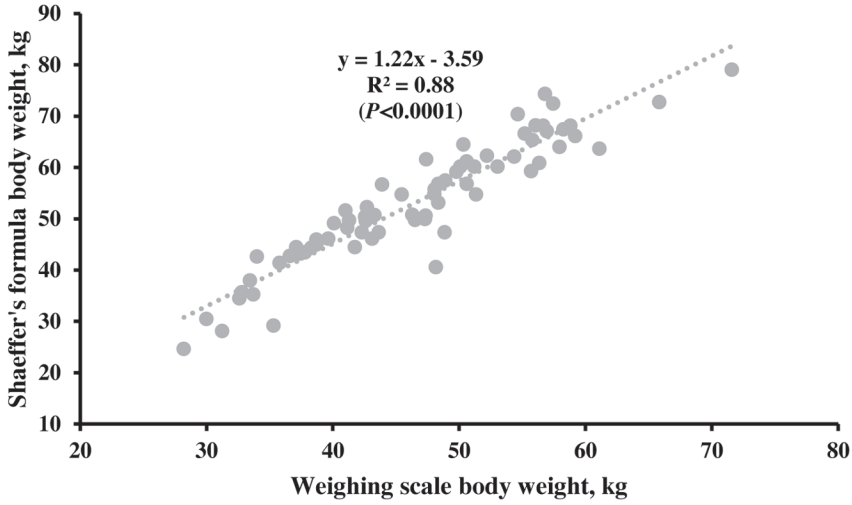

FIGURE 1. Linear regression analysis of body weights obtained by Shaeffer's formula and the respective values recorded by a weighing scale in slick-haired Holstein calves (n=9) during the first eight weeks of life. Body weight data were recorded on a weekly basis.

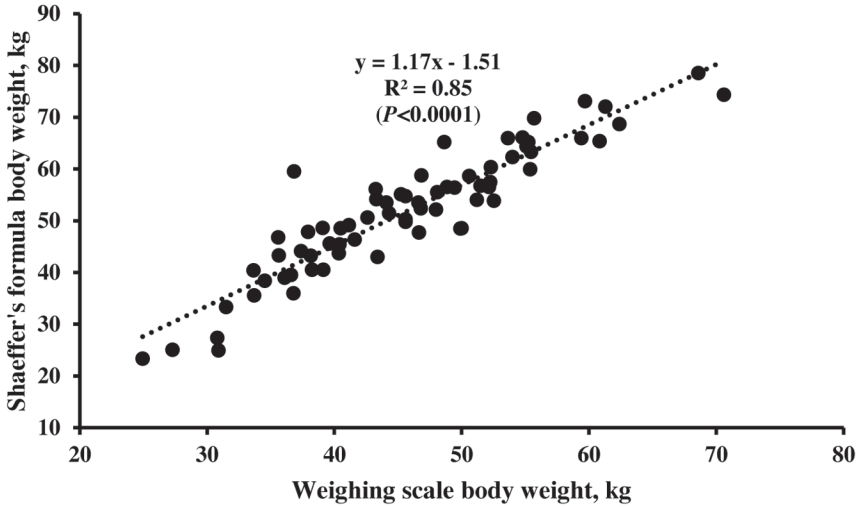

FIGURE 2. Linear regression analysis of body weights obtained by Shaeffer's formula and the respective values recorded by a weighing scale in wild type-haired Holstein calves (n=9) during the first eight weeks of life. Body weight data were recorded on a weekly basis.

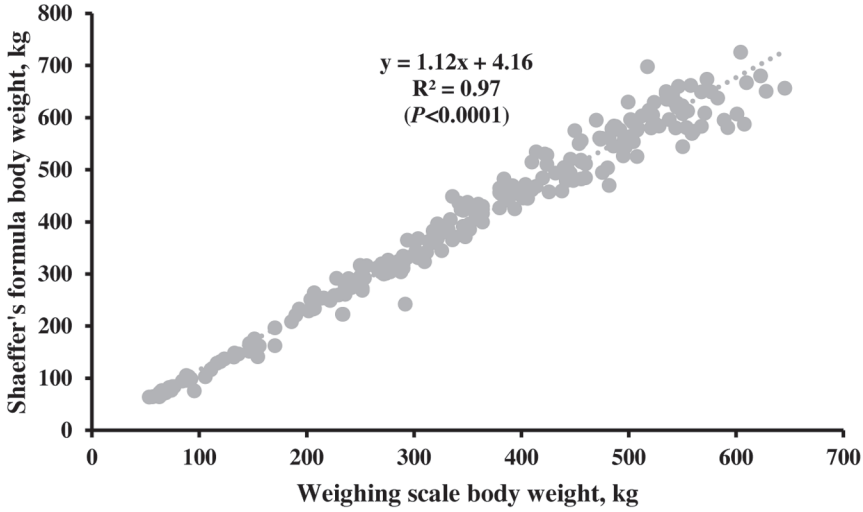

FIGURE 3. Linear regression analysis of body weights obtained by Shaeffer's formula and the respective values recorded by a weighing scale in slick-haired Holstein heifers (n=9) between 3 and 33 months of age. Body weight data were recorded on a monthly basis.

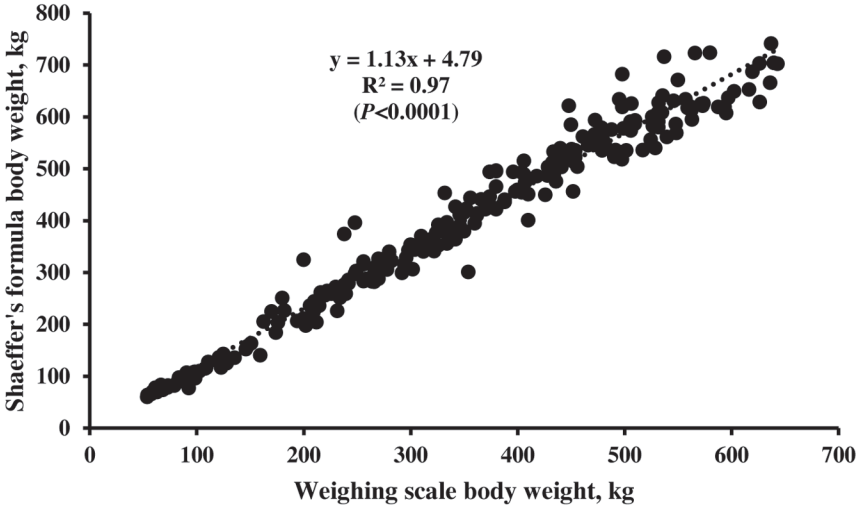

FIGURE 4. Linear regression analysis of body weights obtained by Shaeffer's formula and the respective values recorded by a weighing scale in wild type-haired Holstein heifers (n=9) between 3 and 33 months of age. Body weight data were recorded on a monthly basis.

from birth) and Figures 3 and 4 present the monthly values (recorded from 3 to 33 months of age). A considerable amount of variability in the body weights estimated by Shaeffer's formula was explained by those recorded with the weighing scale in all evaluated groups and periods. During the first eight samplings, coefficients of determination of 0.88 (P<0.001) and 0.85 (P<0.0001) were observed in the slick and wild type-haired calves, respectively. During the samplings corresponding to the 3 to 33 months of age, coefficients of determination of 0.97 (P<0.0001) were observed for both the slick and wild type-haired heifers. In a regression, the coefficient of determination (R^2) represents the variation in the dependent variable that is described by the independent variable (Freund and Littell, 1981) or "how well the regression model fits the data" (Kaps and Lamberson, 2017). Deleon-Saura and Masinading-Andante (2018) stated that coefficients of determination greater or equal to 0.70 indicate a very strong relationship between the variables evaluated. Similarly, Apryani-Nurunnisha et al. (2020) noted that a coefficient of determination between 0.82 and 1.0 denotes a very high or strong influence of one variable over the other. Therefore, in all the cases evaluated, Shaeffer's formula estimated body weight values highly associated with those recorded by the weighing scale. In the literature, several researchers have successfully used Shaeffer's formula for body weight estimation in different livestock breeds or species, including: Sahiwal female calves (Bhatt et al., 2022), Holstein cattle (Los et al., 2023), Brown Swiss and Jersey crossbred cattle (Wangchuk et al., 2018), Pelibuey sheep (Montoya-Santiyanes et al., 2022), *Bos indicus* mature cattle (Riaz et al., 2018), buffalos (Tiwari et al., 2015; Sharma and Shukla, 2017; Riaz et al., 2018), and *Bos indicus* calves (Riaz et al., 2018). In fact, Pater (2007) published a University of Arizona Extension bulletin recommending the use of Shaeffer's formula for the estimation of body weight in beef cattle, small ruminants, pigs, and horses. Moreover, in the Riaz et al. (2018) study, coefficients of determination of 0.68 (P<0.001), 0.94 (P<0.001), and 0.97 (P<0.001) were observed when regressing Shaeffer's formula estimated body weights with the actual body weights of *Bos indicus* mature cattle, buffalos, and *Bos indicus* calves, respectively. Both Wangchuk et al. (2018) and Riaz et al. (2018) concluded that Shaeffer's formula is a reliable estimator of body weight in cattle.

Weekly body weights, recorded by a commercial scale or calculated from Shaeffer's formula, of slick and wild type-haired Puerto Rican Holstein calves are presented in Figure 5. Significant triple or double interactions between sampling, hair coat type, and weighing method did not affect body weight values. Nor was a hair coat type simple effect observed on body weight (P=0.8483). However, sampling

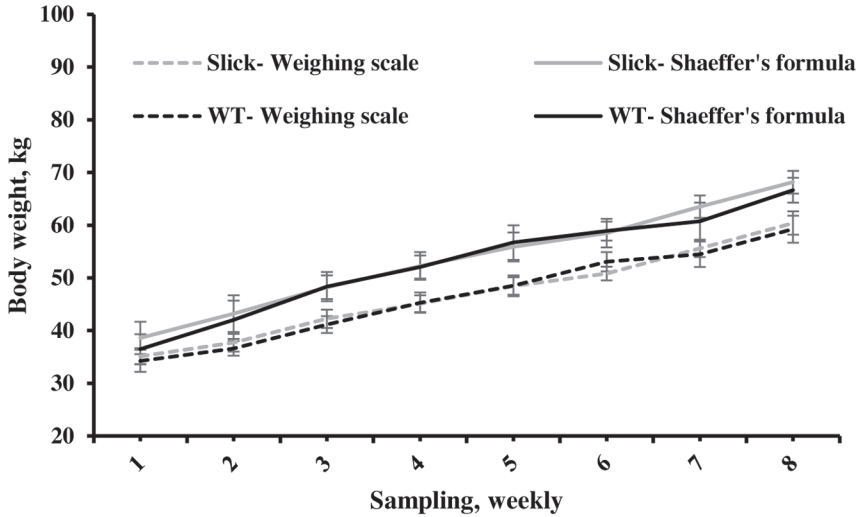

FIGURE 5. Weekly body weights (±SEM) of slick (n=9) and wild type-haired Holstein calves (n=9) during the first eight weeks of life as determined by using a cattle weighing scale and Shaeffer's formula. Sampling x hair coat type x weighing instrument (P=0.9790); hair coat type x weighing method (P=0.5886); sampling x hair coat type (P=0.5219); sampling x weighing method (P=0.0679); sampling (P<0.0001); hair coat type (P=0.8483); weighing method (P<0.0001).

(P<0.0001) and weighing method (P<0.0001) affected the body weight values obtained. Average increases in body weight of 3.56 and 4.07 kg/week were observed between samplings 1 to 8 for the values obtained by the commercial scale and Shaeffer's formula, respectively. On average, Shaeffer's formula resulted in body weight values 6.39 kg greater than the weighing scale. When evaluating small-sized animals, Riaz et al. (2018) also reported the overestimation of body weight values with Shaeffer's formula in *Bos indicus* mature cattle, buffalos, and *Bos indicus* calves. In the current study, during the first eight weeks of life, subtracting 6.39 kg from the results of Shaeffer's formula represented a feasible way to estimate body weight in the evaluated group of slick and wild type-haired calves.

Figure 6 presents the monthly body weights of slick and wild type-haired Puerto Rican Holstein heifers as recorded by a weighing scale or determined from Shaeffer's formula. Here, no significant triple interaction (P=0.9993) between sampling, hair coat type, and weighing method was observed for body weight. Neither was a hair coat type x weighing method interaction (P=0.5588) or a hair coat type simple effect (P=0.3511) observed. However, the sampling x hair coat type (P<0.0001) and the sampling x weighing method (P<0.0001) interac-

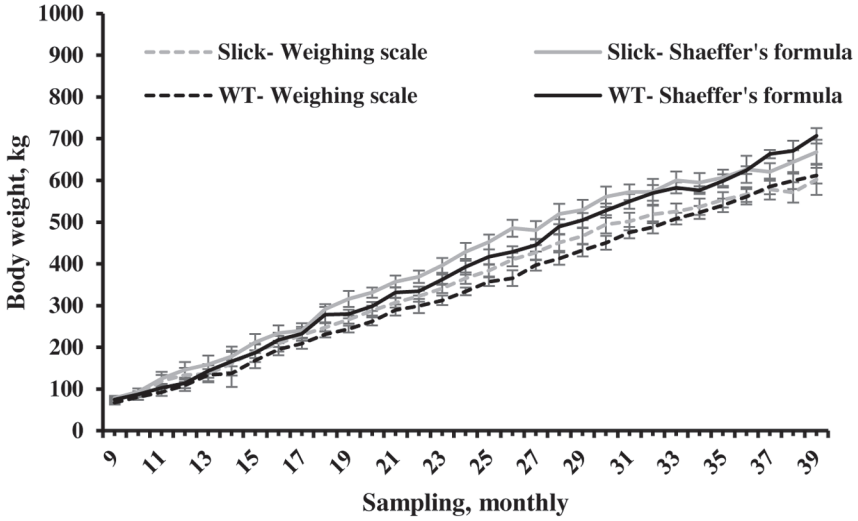

FIGURE 6. Monthly body weights (±SEM) of slick (n=9) and wild type-haired Holstein heifers (n=9) between 3 and 33 months of age as determined by using a cattle-weighing scale and Shaeffer's formula. Sampling 9 was performed when calves were three months old. Sampling x hair coat type x weighing method (P=0.9993); hair coat type x weighing method (P=0.5588); sampling x hair coat type (P<0.0001); sampling x weighing method (P<0.0001); sampling (P<0.0001); hair coat type (P=0.3511); weighing method (P<0.0001).

tions, as well as the sampling (P<0.0001) and the weighing method (P<0.0001) simple effects affected body weight. Such significant sampling x weighing method interaction is due to the overall divergence of the body weight curves of Shaeffer's formula and the weighing scale as sampling numbers progress. No differences between sampling methods were observed in samplings 9 to 13 (3 to 7 months of age). However, an increasing difference between sampling methods was observed in samplings 14 to 39 (8 to 33 months of age). Such differences ranged, on average, from 23.20 kg at sampling 14 (P=0.0435) to 80.41 kg at sampling 39 (P<0.0001), the body weight values obtained with Shaeffer's formula being greater. Table 1 presents the specific average difference in body weight between both weighing methods from samplings 14 to 39. Thus, between 3 to 7 months of age, Shaeffer's formula represents a feasible and reliable approach for estimating body weight in slick and wild type-haired heifers, with no required mathematical corrections. From 8 to 33 months of age, subtracting the respective difference (Table 1) from the body weight values obtained from Shaeffer's formula may allow for greater accuracy and reliability in the body weight values obtained. Sampling x hair coat type interacted because in sampling 26 (20 months of

TABLE 1.—*Average overestimation of body weight values calculated using Shaeffer's formula in comparison with the weighing scale platform in slick and wild type-haired heifers during samplings 14 to 39 (8 to 33 months of age).* The values provided are the average differences between the estimated body weights calculated with Shaeffer's formula and the respective values obtained from the weighing scale.

Sampling	(Shaeffer's – Scale) difference in body weight, kg	Sampling	(Shaeffer's –Scale) difference in body weight, kg
14	23.20	27	50.75
15	20.19	28	72.66
16	23.88	29	67.38
17	17.07	30	71.54
18	45.75	31	72.43
19	42.90	32	68.25
20	39.57	33	74.38
21	45.89	34	55.39
22	40.98	35	55.62
23	52.60	36	62.03
24	61.08	37	59.75
25	63.83	38	72.29
26	69.02	39	80.41

age) the slick-haired group showed 44.88 (P=0.0538) and 56.70 kg (P=0.0166) greater average body weight (on the weighing scale and with Shaeffer's formula, respectively) than their wild type-haired counterparts. It is worth mentioning that such a difference only occurred in one sampling out of a total of 39, which may suggest the possibility of some uncontrolled external factor affecting the results at this point. Therefore, inferences should be made taking into consideration the remaining segments of the curves. In such a case, the aforementioned interaction loses its significance and leads to the conclusion that Shaeffer's formula had similar reliability in both hair coat types. No other differences associated with this interaction were observed.

CONCLUSIONS

Based on the number of cattle evaluated, our study shows that when a weighing scale platform is not available, using Shaeffer's formula represents a feasible and reliable way to estimate body weight in slick and wild type-haired Puerto Rican calves and heifers. Because the only instrument required for this calculation is a flexible measuring tape, this option is also inexpensive compared to a commercial weighing scale platform. By subtracting the aforementioned overestimated

values, when necessary, Shaeffer's formula's accuracy can be further improved. Future studies should explore evaluating this formula for the estimation of body weight in a larger population of calves and heifers to further establish the utility of this tool. Also, research should be conducted for the evaluation of this formula in older cattle, including lactating and dry cows.

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