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Relationship between body weight and scrotal circumference in growing Pelibuey sheep raised under tropical conditions

[Relação entre o peso corporal e a circunferência escrotal em ovinos Pelibuey *em crescimento criados em condições tropicais]*

M.A. *Ramírez-Bautista*[1], A.A. *Cruz-Tamayo*[2], M.Á. *Gastélum-Delgado*[3],
J.A. *Aguilar-Quiñónez*[3], T.L. *Tyasi*[4], A.L.C. *Gurgel*[5],
R.A. *García-Herrera*[6], A. J. *Chay-Canul*[6*]

[1]Tecnológico Nacional de México/Instituto Tecnológico de Chiná, Chiná, Campeche, México
[2]Facultad de Ciencias Agropecuarias, Universidad Autónoma de Campeche, Escárcega, Campeche, México
[3]Facultad de Agronomía, Universidad Autónoma de Sinaloa, Culiacán, Sinaloa, México.
[4]Department of Agricultural Economics and Animal Production, University of Limpopo, South Africa
[5]Universidade Estadual de Maringá, Maringá, Paraná, Brasil
[6]División Académica de Ciencias Agropecuarias, Universidad Juárez Autónoma de Tabasco, Tabasco, México

ABSTRACT

The body weight (BW) of an animal is a vital economic trait that might help in decision-making in the handling of animals. The objective of the present study was to develop equations for the prediction of BW in Pelibuey sheep using scrotal circumference (SC). The BW (23.40 ± 6.96 kg) and SC (20.25 ± 6.19 cm) have been recorded in 405 male Pelibuey at the Southeastern Center for Ovine Integration, Mexico. Linear, logarithmic, quadratic, exponential, cubic, and power regression models were used for data analysis. Pearson correlation (R), Coefficient of determination (R^2), Adjusted coefficient of determination (Adj.R^2) Root mean square error (RMSE), Akaike information criterion (AIC), and Bayesian information criterion (BIC) were used to select the best model. Power regression model showed the highest R (0.93), R^2 (0.86), Adj.R^2 (0.86) and lowest RMSE (0.02), AIC (-989.44) and BIC (-981.44). The current study suggests that SC might be used as the only predictor for BW of growing Pelibuey sheep raised under tropical conditions.

Keywords: body weight estimation, Pelibuey lambs, mathematical models, regression models

RESUMO

O peso corporal (PC) do animal é uma característica econômica importante, que pode auxiliar na tomada de decisões no manejo dos animais. O objetivo do presente estudo foi desenvolver equações para a predição do PC em ovinos Pelibuey *por meio da circunferência escrotal (CE). O PC (23,40±6,96kg) e a CE (20,25±6,19cm) foram registrados em 405 ovinos machos da raça* Pelibuey *no Centro de Integração Ovina da Região Sudeste do México. Os modelos lineares, logarítmicos, quadráticos, exponenciais, cúbicos e de regressão de potência foram utilizados para a análise dos dados. A correlação de Pearson (R), o coeficiente de determinação (R^2), o coeficiente de determinação ajustado (Adj.R^2), o erro do quadrado médio (EQM), o critério de informação de Akaike (AIC) e o critério de informação bayesiano (BIC) foram usados para selecionar o melhor modelo. O modelo de regressão de potência apresentou maiores R (0,93), R^2 (0,86), Adj.R^2 (0,86) e menores EQM (0,02), AIC (-989,44) e BIC (-981,44). O estudo atual sugere que a CE pode ser usada como um único preditor para o PC de ovinos Pelibuey em crescimento criadas em condições tropicais.*

Palavras-chave: cordeiros Pelibuey, *estimativa de peso corporal, modelos matemáticos, modelos de regressão*

*Corresponding author: alfonso.chay@ujat.mx
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INTRODUCTION

The determination of body weight (BW) is one of the most accurate measurements to know the degree of growth of sheep. It is an important economic trait that can help in decision-making in the feeding and handling of animals (Gurgel *et al.,* 2023). Small producers rarely have access to scales for weighing their animals and monitoring their growth (Chay-Canul *et al.,* 2019; Canul-Solís *et al.,* 2020; Gurgel *et al.,* 2021a).

Recently, some low-cost and easy practical methods have been developed and evaluated in sheep, which could allow small producers to monitor the growth of the animals. These alternative methods are based on the use of biometric measurements, such as heart girt, hip width, and body volume, which have been reported to have high correlations with the BW of Pelibuey sheep (Chay-Canul *et al.,* 2019; Canul-Solís *et al.,* 2020; Salazar-Cuytun *et al.,* 2022).

On the other hand, the development of testes in sheep can be indicative of their sexual performance and has been associated with several reproductive characteristics of the ram's sisters and future daughters, such as age at puberty, fertility, prolificacy, and duration of the breeding season (Jiménez-Severiano *et al.,* 2010). Testicular development is determined by different factors, mainly age, breed, and nutrition (Ramírez-Bautista *et al.,* 2020). Specifically, the scrotal circumference (SC) can be considered a criterion for the selection of animals in breeding programs (Notter, 2012), given its moderate heritability (0.29–0.40) (Duguma *et al.,* 2002). In addition, it has been reported that there is a positive correlation between BW and SC, therefore, these parameters should be considered in the evaluation of the development of the reproductive capacity of lambs (Koyuncu *et al.,* 2005; Camela *et al.,* 2018). Thus, a simple and reliable technique that can measure reproductive capacity is important in the evaluation of the male (Bongso *et al.,* 1982).

Because it has been previously reported that testicular traits may differ between sheep of wool and hair breeds (Jiménez-Severiano *et al.,* 2010), it is important to evaluate the relationship between BW and SC in each of them. In Pelibuey sheep, this relationship has been little evaluated. Therefore, the objective of this study was to evaluate the relationship between BW and SC in growing Pelibuey sheep managed under humid tropical conditions.

MATERIALS AND METHODS

Animals included in the present study were managed in compliance with the guidelines and regulations for ethical animal experimentation of the División Académica de Ciencias Agropecuarias of the Universidad Juárez Autónoma de Tabasco). The experiment was carried out at the Southeastern Center for Ovine Integration (Centro de Integración Ovina del Sureste [CIOS]; 17° 78" N, 92° 96" W; 10 masl) at 25 + 3 km of the Villahermosa-Teapa road in the town of Alvarado Santa Irene 2nd Section in the state of Tabasco, Mexico. Four hundred and five male fattening Pelibuey sheep between three to eight months of age.

The sheep were finished in a raised-slatted floor cage system. The diet comprised 80% concentrate and 20% forage, with about 15% crude protein (Technical…, 1993). The dietary ingredients were cereal grains (maize or sorghum), soybean meal, tropical grass hay, vitamins and minerals.

The BW and SC have been recorded in 405 clinically healthy male Pelibuey sheep from 2 to 8 months of age. The average BW of 23.40±6.96 kg and SC of 20.25± 6.19 kg were used. In each animal, the BW was determined using a digital scale (model EQB, Torrey, Mexico) and the SC was determined using a flexible fiberglass tape (Truper®, S.A. de C.V., San Lorenzo, Mexico).

A descriptive statistical analysis was performed using the PROC MEANS procedure in SAS (SAS Inst. Inc., Cary, NC, 2010). In the same software, correlation coefficients among variables were also estimated using the PROC CORR procedure (SAS Ver. 9.3, 2010) and regressions were carried out using the PROC REG procedure (SAS Ver. 9.3, 2010). Table 1 showed the regression models used to estimate the relationship between measured traits.

Table 1. Regression models to describe the relationship between body weight and testicular measurements in growing Pelibuey sheep.

Models	Mathematical equations
Linear	$y = \beta_0 + \beta_1 * x$
Logirithmic	$y = \beta_0 + \beta_1 * \ln(x)$
Quadratic	$y = \beta_0 + \beta_1 * x + \beta_2 * x^2$
Exponential	$y = \beta_0 + \beta_1 (\beta_{2x,1} + \beta_{p+1} x_{i,}1) + e_{i6}$
Cubic	$y= \beta_0 + \beta_1 * x + \beta_2 * x^2 + \beta 3 * x^3$
Power	$y = \beta_0 * x^{\beta 1}$

β_0 - $\beta 3$: model parameters; y: body weight; x: scrotal circunference

An analysis of residuals was included to identify atypical data; these data were detected by plotting the student residuals against the values predicted by the equations. Atypical data were eliminated if the corresponding values of the student residuals were outside the range of −2.5 to 2.5. The precision of the models was evaluated by the determination coefficients (R^2); root mean squared error (RMSE); Akaike information criterion (AIC); bayesian information criterion (BIC).

RESULTS AND DISCUSSION

The mean body weight and scrotal circumference of growing Pelibuey sheep are shown in Table 2. The overall body weight (BW) and scrotal circumference (SC) were 23.49±6.96kg and 20.25±6.19cm, respectively. The coefficients of variance were 29.62% and 30.55% for BW and SC, respectively. These findings are similar to the study of Mukasa-Mugerwa and Ezaz (1992) on Menz ram lambs at puberty, averaging BW = 19.3±0.4kg and SC=21.5±0.3cm. However, these results are lower than those of Yakubu *et al.* (2013) in indigenous rams Yankasa of Nigeria, which had a BW of 35.10 kg and SC of 26.34 cm. The discrepancies in values might be due to breed differences, as it has been reported there exist breed differences in the size of the testicular parameters (Gemeda and Workalemahu, 2017). Also, a previous study has shown that SC in ram lambs varies according to both age and body weight (Söderquist and Hultén, 2006).

Table 2. Descriptive analyses of the data measured in growing Pelibuey sheep

Variable	Description	N	Mean ± SD	Maximum	Minimum	CV (%)
BW (kg)	Body weight	405	23.49±6.96	8.00	32.00	30.55
SC (cm)	Scrotal circumference	405	20.25±6.19	8.94	46.85	29.62

N: number of observations; SD = Standard deviation; CV = Coefficient of variation

In the present study, the results indicated that BW had a highly significant positive correlation (P<0.01) with SC (r=0.89). The observed highly significant correlation between BW and SC in this study suggested that selection for SC would lead to males with a high potential for sperm production. This observation supports other studies (Bongso *et al.*, 1982; Salhab *et al.*, 2001; Akpa *et al.*, 2012; Yakubu and Musa-Azara, 2013; Gemeda and Workalemahu, 2017) who reported that body weight was a significant positive correlation with an average scrotal circumference in ram lambs and goats of different breeds. The strong positive correlation between SC and BW is an indication that improvement in both traits is possible through selection procedures, considering their high genetic correlations. Also, this suggests that genes that contributed to BW had an influence on the reproductive ability of animals (Yakubu *et al.*, 2013).

Table 3 shows the parameter values of the models in the study. All the models were significant, however, the β2 parameter of the quadratic model showed non-significant. In the goodness of fit criteria, the power model presented the values of R (0.93) R^2 (0.86), and Adj. R^2 (0.86). Therefore, according to the power model, SC explains more than 85% of the variation in lambs' BW, a value higher than the other models (Table 4). Considering RMSE, the power and exponential models were the ones that best estimated the exact value of BW, with an RMSE value of 0.02kg. The values of BIC and AIC indicate that the power model more precisely and accurately describes the relationship between BW and SC.

Table 3. Estimators of the models relating scrotal circumference to body weight in growing Pelibuey sheep

Models	Parameters			
	β0 ± SE	β1 ± SE	β2 ± SE	β3 ± SE
Linear	3.07 ± 0.52*	1.01 ± 0.03*	-	-
Logirithmic	-29.78 ± 1.38*	18.04 ± 0.46*	-	-
Quadratic	3.52 ± 1.67*	0.96 ± 0.18*	0.01 ± 0.00^{NS}	-
Exponential	8.70 ± 0.19*	0.05 ± 0.00*	-	-
Cubic	-16.12 ± 4.75*	4.38 ± 0.80*	-0.18 ± 0.04*	0.00 ± 0.00*
Power	1.80 ± 0.09*	0.86 ± 0.02*	-	-

β0 - β3 = model parameters, SE = Standard error, * = significant (P<0.05), NS = non-significant (P>0.05).

There are numerous statistical techniques used to assess the precision and accuracy of mathematical models (Tedeschi, 2006; Bautista-Diaz *et al.,* 2020; Gurgel *et al.,* 2021b). However, no technique used in isolation can adequately evaluate models' performance (Tedeschi, 2006). Thus, in the present study, a set of statistical methods were associated with evaluating the predictive performance of the equations. The coefficient of determination (R^2) shows the percentage of BW variation explained by SC (Gurgel *et al.,* 2023). Therefore, R^2 evaluates the proximity of the data to the fitted regression line. In this sense, the closer to 1.0 the more precise the model. It should be noted that the interpretation of the value of R^2 is often wrong since these criteria measure the precision and not the accuracy of the equation (Gurgel *et al.,* 2023). The values of BIC, AIC, and RMSE admit the existence of a model, among a group of evaluated models, which minimizes errors (Bozdongan, 1987; Tedeschi, 2006). Thus, smaller values denote more accurate estimates.

Table 4. Goodness of fit criteria for the models

Criteria	Linear	Logirithmic	Quadratic	Exponential	Cubic	Power
R	0.90	0.89	0.90	0.91	0.90	0.93
R^2	0.81	0.79	0.81	0.83	0.82	0.86
Adj. R^2	0.81	0.79	0.81	0.83	0.81	0.86
RMSE	9.39	10.10	9.41	0.02	8.99	0.02
AIC	1478.42	1471.04	1480.44	-999.03	1486.91	-989.44
BIC	1492.433	1479.04	1486.41	-991.03	1502.90	-981.44

R = Correlation coeffient, R^2 = Coefficient of determination, Adj. R^2 = Adjusted coefficient of determination, RMSE = Root mean square error, AIC = Akaike's information criterion; BIC = Beyesian information criterion.

The interpretation of this set of criteria that assess the goodness of fit of the models allowed us to identify that the power model provides more precise and accurate estimates of the body weight of sheep using SC as the only predictor. In addition, the most parsimonious model is sought, that is, the one that involves the fewest possible parameters (Canul-Solis *et al*., 2020; Gurgel *et al*., 2021a). In this aspect, the power model has advantages over other functions that have a similar fit, as this equation has only two parameters. However, it should be taken into account that this equation was developed from data from lambs kept in a confinement system receiving a total mixed ration. Therefore, its application is limited to animals raised under these conditions (Tedeschi, 2006). If we want to use the power model in other types of animals, races, or production systems, it would be necessary to carry out its reparametrization and evaluation according to specific conditions.

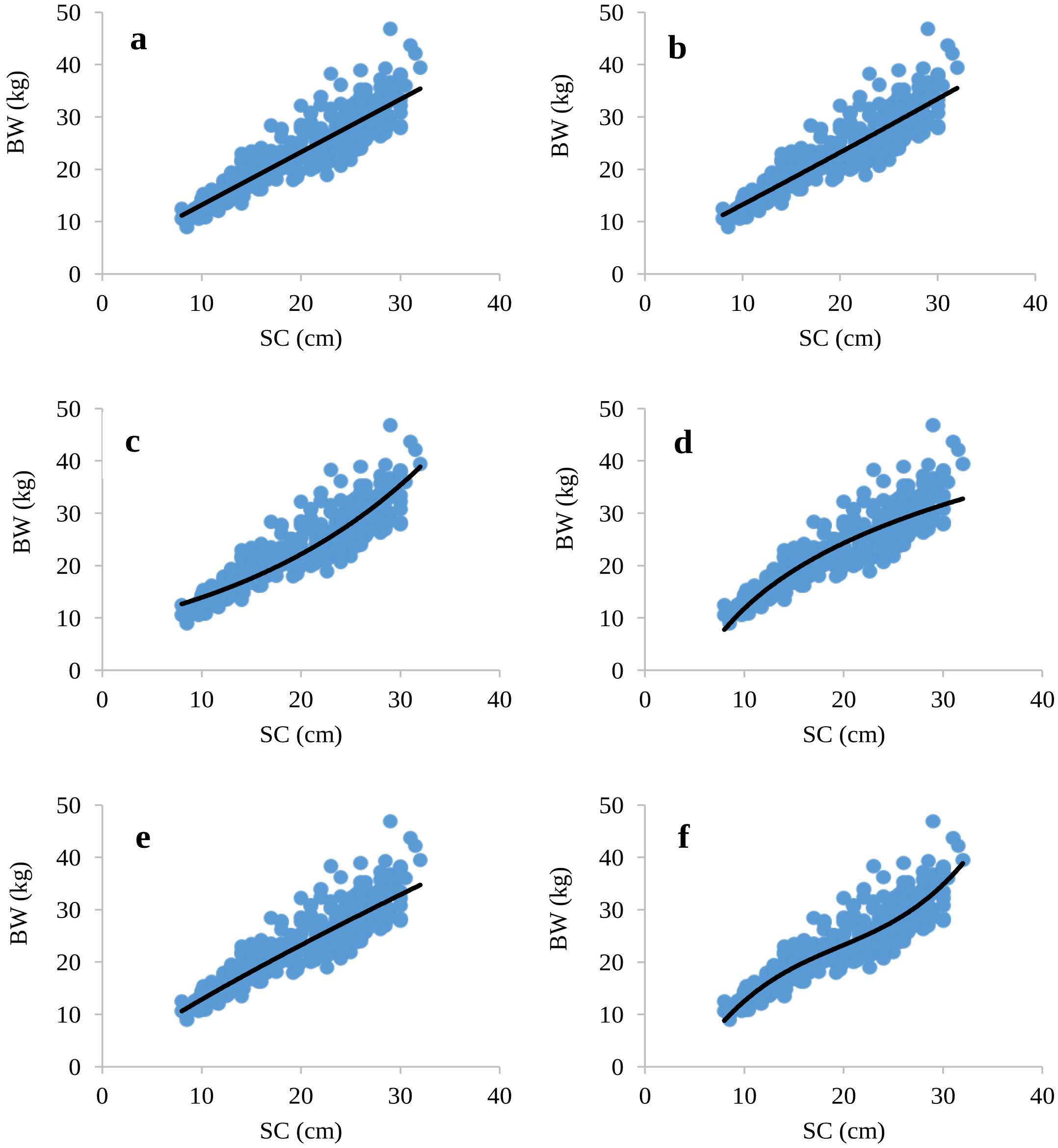

Figure 1. Relationship between body weight (BW) and scrotal circumference (SC) in growing Pelibuey sheep explained by: a) linear regression model, b) quadratic regression model, c) exponential regression model, d) logarithmic regression model, e) power regression model, and f) cubic regression model.

CONCLUSION

In the present study, the power regression model has correctly predicted the BW using the SC in growing Pelibuey sheep. The SC might be used as the only predictor for BW of growing Pelibuey sheep raised under tropical conditions.

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