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Communication

[*Comunicação*]

Use of biometrics in the prediction of body weight in crossbred lambs

[*Uso da biometria na predição do peso corporal de cordeiros mestiços*]

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In the semi-arid region of Northeastern Brazil the majority of sheep farms are family-owned, with an average size of 13 ha, producers having low formal education and herds consisting of around 25 head (Hermuche *et al*., 2013). In this scenario, with limited use of technologies and low investment in infrastructure, it is common for animals not to be weighed periodically, which makes their weight control and their sale on a live-weight basis difficult (Conrado *et al*., 2015). Body measurements can be a viable alternative to estimate body weight due to the correlation between these traits and the live weight of an animal (Grandis *et al*., 2018; Souza *et al*., 2019). Thus, mathematical models emerge as an important tool to predict the live weight of sheep based on their body measurements (Souza *et al*., 2019).

Therefore, the present study examines the hypothesis that biometric measurements can be used to predict live weight in crossbred lambs. The objective was to propose a mathematical model to predict lamb body weight based on biometric measurements.

The experiment was conducted in accordance with the norms set forth by the Ethics Committee on Animals Use - CEUA/UFRN (approval no. 055/2016).

Data from 51 lambs (26 males and 25 females) were used. All lambs had a genetic constitution of at least 50% Santa Inês breed and originated from a breeding station of the dam herd of the Forage Crops Research Group of the Federal University of Rio Grande do Norte (5°53'34" S 35°21'50" W). Shortly after lambing, dams and offspring were placed in a maternity paddock where they spent seven days together. Subsequently, the lambs were separated from their mothers and managed in the controlled-feeding system. Lambs were kept on *Panicum maximum* cv. Massai pastures during the day (from 07h00 to 16h00) and moved to a shed with collective stalls at night. Concentrate feed (composition: 66.0% ground maize, 29.5% soybean meal, 3.0% mineral salt and 1.5% soybean oil) was provided *ad libitum* to the lambs, aiming at around 10% orts.

Lamb weight was monitored throughout the post-weaning phase (from the 7th to the 91st day of age) by weighing the animals weekly on a scale suitable for sheep. After weighing, the following measurements were taken using a tape measure and a horse measuring stick: withers height (WH) - from the highest point at the withers to the ground; rump height (RH) - from the coxal tuberosity to the ground; body length (BL) - from the acromion to the extremity of the ischium; chest width (CW) - distance between the acromia; rump width (RW) - distance between the ischial tuberosities; heart girth (HG) - measured around the thoracic cavity; and abdominal circumference (AC) - measured around the abdominal cavity. The biometric measurements were used as input variables for the model to estimate lamb weight.

Model fitting and selection of variables were carried out using the REG procedure and a correlation analysis between the variables was

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performed by applying the PROC CORR procedure of the SAS statistical package (SAS University Edition, Sas Institute Inc. Cary, CA, USA). Outliers were tested by evaluating the studentized residuals in relation to the values predicted by the model. Residues that were outside the range of -2.5 to 2.5 were discarded. The following model adequacy evaluation criteria were adopted: determination coefficient (R^2); F-test, for the identity of the parameters ($\beta0=0$ and $\beta1=1$) of the regression of predicted on observed data; cophenetic correlation coefficient (CCC); root mean square error of prediction (RMSEP); and decomposition of the mean square error of prediction (MSEP) into mean error, systematic bias and random error (Tedeschi, 2006), using Model Evaluation System software version 3.2.2. nce the model was proposed, the sexes were compared using a 'Dummy' variable, as suggested by Regazzi (2003). The significance level was set at 5% in all statistical analyses.

Positive and significant correlations ($P<0.05$) were observed between all biometric variables and body weight (Table 1). However, body weight showed a high correlation with CC, followed by AC and RH. Only these three biometric measurements (CC, AC and RH) were used to estimate body weight, since no other measurement reached the level of significance to enter the model. The quadratic value of these variables was tested and revealed that, when squared, RH and AC provided better model fits. The intercept was not significant ($P>0.05$) and was thus excluded from the equation.

In this way, the following equation was generated to estimate lamb body weight:
Weight (kg)=0.4455 * CC - 0.5794 * AC + 0.0053 * AC^2 + 0.0019 * RH^2,
where CC=chest circumference (cm); AC=abdominal circumference (cm); and RH=rump height (cm).

Table 1. Linear correlations between weight and biometric variables of crossbred lambs

	Weight	BL	WH	RH	CW	RW	CC	AC
Weight	1.000	-	-	-	-	-	-	-
BL	0.606*	1.000	-	-	-	-	-	-
WH	0.665*	0.617*	1.000	-	-	-	-	-
RH	0.740*	0.576*	0.848*	1.000	-	-	-	-
CW	0.535*	0.374*	0.652*	0.589*	1.000	-	-	-
RW	0.314*	0.316*	0.506*	0.405*	0.715*	1.000	-	-
CC	0.836*	0.541*	0.571*	0.633*	0.559*	0.341*	1.000	-
AC	0.818*	0.568*	0.668*	0.682*	0.515*	0.418*	0.729*	1.000

Body length (BL), withers height (WH), rump height (RH), chest width (CW), rump width (RW), chest circumference (CC) and abdominal circumference (AC), * significant at 5%.

Chest and abdominal circumferences are measurements highly related to the digestive and respiratory capacity of the animal (Conrado *et al*., 2015) and, as such, are important performance indicators. Studies with ruminants of different species, breeds and sexes and wide variations in weight and age also showed that chest circumference was the best measurement to estimate live weight (Reis *et al*., 2008; Mahieu *et al*., 2011; Grandis *et al*., 2018). The negative coefficient for abdominal circumference indicates that live weight reaches a plateau. This fact is possibly associated with the inflection of the growth curve of the animal, which is reached after sexual maturity (Kopuzlu *et al*., 2014).

The estimates of average live weight and of the standard deviation of the estimated weight were equal ($P=0.99$) to the actual data (Table 2 and Figure 1). In the analysis of model adequacy, the null hypothesis was accepted ($P=0.99$), that is, the biometric measurements provided predictions similar (β 0=and $\beta1=1$) to the observed weights (Table 2 and Figure 1). The decomposition of the mean square error of prediction showed that 100% of the equation error has a random origin. Coupled with the adjusted R^2 value of 0.82 and the CCC of 0.94, these findings indicate that the model has good predictive capacity as well as high accuracy and precision (Tedeschi, 2006; Zanetti *et al*., 2019). Lastly, RMSEP revealed that the model has a good ability to predict the exact animal weight value, with a RMSEP of 1.25 kg. This RMSEP value points to an average error of only 6.9% in body weight predictions.

Table 2. Evaluation of model adequacy for the prediction of live weight in crossbred lambs based on biometric measurements

Item	Observed	Estimated[1]
Mean (kg)	18.05	18.05
Standard deviation	3.69	3.46
Minimum (kg)	10.30	10.17
Maximum (kg)	26.90	27.62
P-value	-	0.99
R^2	-	0.88
CCC	-	0.93
RMSEP	-	1.25
Mean error	-	0.00 (0.00%)
Systematic error	-	0.00 (0.00%)
Random error	-	1.56 (100.00%)

[1]Weight (kg)=0.4455 * CC - 0.5794 * AC + 0.0053 * AC^2 + 0.0019 * RH^2; R^2=adjusted coefficient of determination; CCC=cophenetic correlation coefficient; RMSEP=root mean square error of prediction.

Because no effect of sex was observed (P>0.05), the equation can be used to predict the weight of males and females. In spite of the effect of testosterone in males (Reddy *et al*., 2015), which causes them to have a greater ability to convert the consumed feed into body tissue (Pires *et al*., 2011), this effect is more pronounced after the animals reach sexual maturity, at ages above than those evaluated here.

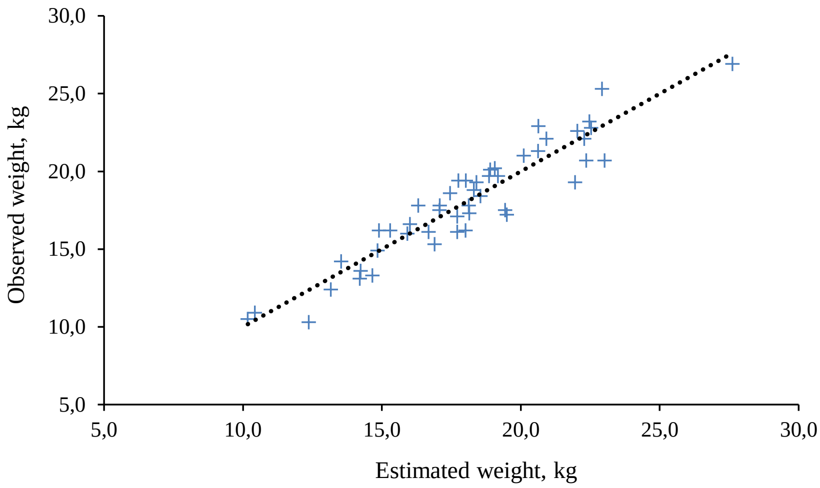

Figure 1. Relationship between observed and predicted weight through biometric measurements in crossbred lambs.

In conclusion, chest circumference, abdominal circumference and rump height showed a high correlation with body weight and can thus be used as predictors of body weight in crossbred sheep. Therefore, the proposed equation (Weight (kg)=0.4455 * CC - 0.5794 * AC + 0.0053 * AC^2 + 0.0019 * RH^2) can be used to estimate live weight in crossbred lambs regardless of sex.

Keywords: abdominal circumference, modeling, heart girth, rump height, sheep

RESUMO

O objetivo deste trabalho foi propor um modelo matemático para predição do peso corporal de cordeiros com base nas medidas biométricas. Foram utilizados dados de 51 cordeiros, com composição genética de pelo menos 50% da raça Santa Inês. O peso corporal (PC) dos animais foi acompanhado durante 91 dias por meio de pesagens semanais. Após as pesagens, foram tomadas as medidas: altura anterior (AA); altura posterior (AP); comprimento corporal (CC); largura de peito (LP); largura de garupa (LG); perímetro torácico (PT) e perímetro de barril (PB). Essas medidas foram utilizadas como variáveis de entrada do modelo. Foi observado correlações positivas e significativas (P<0,05) entre todas as variáveis biométricas com o PC. No entanto, o PC apresentou uma alta correlação com o PT (0,836), seguido do PB (0,818) e AP (0,740). Dessa forma, essas três medidas foram significativas para estimativa do PC. Portanto, o modelo para predizer o PC dos cordeiros foi: Peso (kg)=0,4455 PT - 0,5794 * PB + 0,0019 * AP^2 + 0.0053* PB^2. O perímetro torácico, perímetro de barril e altura de posterior podem ser utilizados como variáveis preditoras do peso corporal em ovinos mestiços, independente do sexo.*

Palavras–chave: altura de posterior, modelagem, ovinos, perímetro de barril, perímetro torácico

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