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Morphometric measurements associated with mathematical prediction of body weight as a management tool in goat herds

de Oliveira Costa, E.[1]; dos Santos, S.A.[1]; Guimarães de Carvalho Rodrigo, T.C.[1]; da Costa Pinto Filho, R.[1]; Libânio Tosto, M.S.[1]; Pinto de Carvalho, G.G.[1]; Silva Mariz, L.D.[2@]; de Jesus Pereira, T.C.[1]

[1]School of Veterinary Medicine and Animal Science, Federal University of Bahia, Salvador, Bahia, Brazil
[2]Department of Animal Science, Federal University of Ceará, Fortaleza, Brazil

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SUMMARY

Data control is critical to success the production systems. However, goat farming in semi-arid and tropical regions mostly produce artisanal dairy derivatives or handcraft meat products as sausages and salami. Despite the importance, body weight (BW) is frequently unmeasured by small and medium producers due to lack of weighing scales, pen structures and inadequate rural installations. The main objective of this study was to establish equations to estimate BW in Saanen and Anglo Nubian. Data were collected from 125 animals comprising of 65 goats Saanen and 60 goats Anglo-Nubian of different age groups. Measurements were made for withers height, rump height; body length, chest depth, thoracic girth (TG), rump length, rump width (RW), abdominal circumference and BW. For all relationships evaluated between BW (kg) and morphometric measurements (cm), gender effect was significant (P < 0.01), but the breed was not (P > 0.01). The RW presented the highest correlations (R2 = 0.92) with BW of females, while the measurements of TG presented the highest correlations (R2 = 0.92) with BW of males. The following equations were adjusted: BW females = 0.1188 × RW2 + 0.5732 × RW - 5.5888; and BW males = 0.0127 × TG2 – 0.6611 × TG + 11.261. In addition, to estimate BW considering the age in days (t): BW = 36.5674 × exp (-2.2404 exp (-0.0046t)) for males and BW = 27.2616 × exp (-2.4151 exp (-0.00775t)) for females.

Palavras chave adicionais

Anglo Nubiana.
Largura da Garupa.
PerímetroTorácico.
Saanen.

Medidas morfométricas associadas à predição matemática do peso corporal como ferramenta de manejo em rebanhos de caprinos

RESUMO

O controle de dados é fundamental para o sucesso dos sistemas de produção. No entanto, a criação de cabras nas regiões semiárida e tropical produz principalmente derivados artesanais, lácteos ou produtos de carne como embutidos e salame. Apesar da importância, o peso corporal (PC) geralmente não é medido por pequenos e médios produtores devido à falta de balanças, estruturas de baias e instalações rurais inadequadas. O principal objetivo deste estudo foi de estabelecer equações para estimar o PC de caprinos Saanen e Anglo Nubian. Foram coletados 125 dados de animais constituídos por 65 cabras Saanen e 60 cabras anglo-nubianas de diferentes faixas etárias. As medidas foram feitas para a altura da cernelha, altura da garupa; comprimento corporal, profundidade do peito, perímetro torácico (PT), comprimento da garupa, largura da garupa (LG), circunferência abdominal e PC. Para todas as relações avaliadas entre PC (kg) e medidas morfométricas (cm), o efeito do sexo foi significativo (P <0,01), mas o efeito da raça não foi significativo (P> 0,01). A LG apresentou as maiores correlações (R2 = 0,92) com o PC para as fêmeas, enquanto as medidas do PT apresentaram as maiores correlações (R2 = 0,92) com o PC dos machos. As seguintes equações foram ajustadas: PC fêmeas = 0,1188 × LG2 + 0,5732 × LG - 5,5888; e PC machos = 0,0127 × PT2 - 0,6611 × PT + 11,261. Além disso, para estimar o PC considerando a idade em dias (t): PC = 36.5674 × exp (-2.2404 exp (-0.0046t)) para machos e PC = 27.2616 × exp (-2.4151 exp (-0.00775t)) para as fêmeas.

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laysmariz@yahoo.com.br

INTRODUCTION

Goats contribute strongly to economic activity in semi-arid and tropical regions, where is predominant the extensive grazing systems. The data control is critical to success the production systems, however, goat farming in these regions is characterized by handcraft traditional practices with a minimum technology. These farms mostly produce artisanal dairy derivatives or meat products as sausages and salami. The known about body weight and growing rate are important tools to provide information about performance and productivity, as well as to development selection programs (Hashimoto et al. 2012, pp. 439, Iqbal et al., 2013). Despite the importance, body weight is frequently unmeasured by small and medium producers due to lack of weighing scale, pen structures and inadequate rural installations. Then, it is necessary to develop practical techniques to accurately estimate body weight at each farm.

Several studies have reported that morphometric measurements can be easily taken; and their correlation with body weight is usually a method to predict this corporal weight (Alade et al. 2008, p. 52, Mahieu et al. 2011, pp. 1). Iqbal et al. (2013, pp. 459) reported that live body weight estimation in female goats above one-year-old can be best estimated with the combination of three body measurements like body length, height at withers and thoracic perimeter. In addition, Alade et al. (2008, p.54) showed that thoracic perimeter efficiency is greater among male goats at the post weaning stages. Abd-Allah et al. (2019, p.3) reported that body weight of the male was accurately predicted by the thoracic perimeter and neck circumference, while body length and paunch girth were used in female goats.

It is important emphasized that the correlations between body weight and morphometric measurements could be differ due to several factors such as breed, gender and age (Kumar et al. 2017, pp. 126, Jimmy et al. 2010, pp. 98). Then, that is still necessary improve the categorization of data according these factors and development more studies comparing different breeds. Therefore, in this study we assess morphometric traits of Saanen and Anglo Nubian at different ages and gender, focusing on relationship between body weight and morphometric measurements to establish an equation to estimate the body weight.

MATERIAL AND METHODS

Ethical Considerations

All the animal care and handling procedures were approved by the Ethics Committee on Animal Use of the School of Veterinary Medicine and Animal Science at the Federal University of Bahia, with protocol number 27/2014.

Location, Animals And Measurements Collection

The experiment was conducted at the Experimental Farm of the School of the same institution, located in the Entre Rios municipality, and other private farm, located in the Santo Antônio de Jesus municipality, both in Bahia State, Brazil. Data on the different parameters were collected during April 2016 to April 2017.

In total, 125 animals comprising of 65 Saanen goats (53 females and 12 males) and 60 Anglo-Nubian goats (53 females and seven males) were used. Data were ranged between early birth ages and adulthood. The differences in ages were justified to obtain a database with wide range in size and body weight. The animals were housed in collective pens (total of 5 to 11 animals/pen), completely covered with a slatted floor, and equipped with individual feeders and water drinkers.

Animals were confined in order to control and standardize environmental conditions. The diets consisted of corn silage, sorghum or transvala hay (Digitaria decumbens Stent.) as the forage source. The concentrate was a mixture of ground corn, soybean meal, wheat meal, mineralized salt and urea/ammonium sulphate. The proportions of nutrients in the diets was adjusted according to animal categories, considering differences for weight gain and lactation phase. The diet was offered to animals twice daily (0800 and 1500h pm) in similar proportions. Intake was adjusted to maintain the orts near to 15% of the offered amount.

The morphometric measurements were performed using a measure tape rule, with the animals standing on a flat surface with head held up. All the measurements were made in centimeters and the following data were collected: Withers Height (WH): distance from the surface of a platform to the withers; Rump height (RH): rump height, corresponding to the distance from the top of the sacrum to the soil surface; Body length (BL): distance from the head of humerus to the distal end of the pubic bone; Chest Depth (CD): distance between the top behind the scapular and the flow of the sternum (taken to be the depth of brisket) immediately behind forelegs; Thoracic girth (TG): perimeter taking the sternum and withers as base, passing the tape after the palette; Rump length (RL): distance from the hip (tuber coxa) to the pin (tuber ischi); Rump width (RW): maximum width between the trochanters of the femurs; Abdominal circumference (AC): measured as body circumference in front of the sacrum. Animals were weighed individually by using a pallet balance of 100 (for animals until 12 months) or 300 kg (to animals from one year of age) capacity. The body weight was taken in the morning before the feeding period.

The measurements were performed at different times considering age variations. Body weight and body measurements were collected at 15-day intervals for animals up to one-year-old. These intervals were used for growing goats to obtain greater amplitude in the collected data. In addition, the measurements were determined one time to animals after one-year-old.

Statistical Analyses

The selection process to identify significant morphometric variables that influence body weight was performed. First, a study of the correlation between variables was performed using PROC CORR of SAS (version 9.3, SAS Inst. Inc., Cary, NC). Significant variables were added to the model using PROC REG of SAS, by implementing the STEPWISE tool (version 9.3, SAS Inst. Inc., Cary, NC), which will select significant variables in descending order. Then, the candidate variables to compose models were evaluated according to the generic statistical model exposed below, to determine the main effects:

$$Y\_ij= \beta_0+ S_i+\beta_1\times X_{ij}+b_i\times X_{ij}+\varepsilon_{ij}$$

where Yij = dependent variable measured in the experimental unit, in this case the body weight ; β_0 = general intercept considered random effect; S_i = random effect of i^{th} farm; β_1 = general regression coefficient of the response variable as a function of X (fixed effect); Xij = predictor variable; b_i = random effect of the farm on the regression of the response variable as a function of X; ε_{ij} = residual error, assuming ε_{ij}; b_i and S_i as independent random variables. From this model, other random variables were considered: breed (Saanen and Anglo-Nubian), gender (uncastrated male, female) and physiological phase (growth, lactation and maintenance).

The relationship between body weight and age was also used to evaluate the growth curve of goats. Four nonlinear sigmoid models were fitted to describe these mathematical relationships. The difference between the models was given by the definition of the curve's inflection point (Fitzhugh Jr., 1976):

Brody: $BW = \alpha\ (1\text{-}be^{(-kt)})$

Gompertz: $BW = ae^{((-be(-kt)))}$

Logistic: $BW = \alpha\ (1+be^{(-kt)})^{m}$

Von Bertalanffy: $BW = \alpha\ (1\text{-}be^{(-kt)})^{3}$

Where: BW = body weight (kg); a = adult weight; k = maturity rate; b = mathematical constant, without biological definition; t = age (days); m = exclusive constant of logistic model.

Criterions to evaluate the best model that fitted body weight in function of age were the lowest asymptotic standard deviation (ASD), the lowest mean square of error (MSE) and the lowest absolute mean deviation (AMD) among the obtained equations. The AMD was calculated according to Sarmento et al. (2006). Models were fitted by PROC NLIN of SAS (version 9.3, SAS Inst. Inc., Cary, NC). The critical level for type I error was 0.05.

RESULTS

There was a high and positive correlation ($P < 0.01$) between BW and all morphometric measurements evaluated (**Table I**). It is important to note that the values of abdominal circumference and body weight ranged from 28 to 117 cm and 2.0 to 74.4 kg, respectively. This was expected because the data set were composed by different ages and phenotypes.

The maximum likelihood averages for relationships between body weight and morphometric measures for gender (females and males) and breed (Saanen and Anglo-Nubian) were presented in **Table II**. There was no interaction ($P > 0.05$) between gender and breeds to none of the variables evaluated. Considering all relationships evaluated between morphometric measurements and body weight, the gender effect was significant ($P < 0.01$), but the genetic group was not ($P > 0.01$). Then, because those differences were found between males and females, gender was analyzed separately for the relationship evaluated. In addition, breed was not considered in the mentioned analyzes.

In the present study, the highest correlation ($P < 0.01$) was demonstrated between body weight and rump width ($R^2 = 0.92$) for the female and of thoracic girth ($R^2 = 0.92$) for male goats (**Table III**). Then, for females were recorded lowest coefficient correlation of body weight with body length, rump length, withers height, rump height, thoracic girth, and the accumulated R^2 obtained was of 0.9456 ($P = 0.03$). In males, were recorded lowest coefficient correlation of body weight with body length and rump width and the accumulated R^2 obtained was of 0.9375 ($P = 0.02$). There were no significant R^2 values ($P > 0.05$) to abdominal perimeter and the depth of the chest, for gender and breeds classes. Thus, the body weight predict equations were obtained based on significant morphometric measurements.

According R^2 the best prediction to estimate body weight were based on rump width for the females and thoracic girth (TG) for the males. It is emphasized that R^2 between rump width (RW) represented 98 % of the total estimated variability for this relationship for the females, and of thoracic perimeter represented 99 % of the total for the males. Thus, the following equations were adjusted to estimate BW in goats for females and males, respectively (**Figures 1 and 2**):

$BW_{females} = 0.1188 \times RW^2 + 0.5732 \times RW - 5.5888$; $R^2=0.9431$;

Table I. Descriptive statistics of the morphometric measurements (cm) and body weight (Kg) in Saanen and Anglo-Nubian goats (Estatística descritiva das medidas morfométricas (cm) e peso corporal (Kg) em cabras Saanen e Anglo-Nubiana).

Item	n	Mean	SD	Median	Minimun	Maximun	r	P-value
WH	489	50.9	9.6	50.0	30.0	81.0	0.97	<0.01
RH	489	52.3	10.2	51.0	30.0	85.0	0.98	<0.01
BL	489	46.5	10.9	44.0	25.0	81.0	0.96	<0.01
CD	489	23.3	5.5	23.0	12.0	40.0	0.96	<0.01
TP	489	53.4	14.7	51.0	27.0	96.0	0.98	<0.01
RL	489	11.4	2.9	11.0	6.0	24.0	0.96	<0.01
RW	489	10.5	3.3	10.0	5.0	24.0	0.96	<0.01
AC	485	61.7	18.9	61.0	28.0	117.0	0.96	<0.01
BW	489	14.8	12.3	10.1	2.0	74.4	1.00	<0.01

SD: standard desviation, WH: withers height; RH: rump height ,cm; BL:body length,cm; CD: chest depth,cm; TP:thoracic perimeter,cm, RL: rump length,cm; RW:rump width,cm; AC: abdominal circumference,cm; BW body weight,Kg; r : linear correlation of Pearson

Table II. Maximum likelihood means, effect of sexual class and genetic group on average relationship between body measurements (kg) and morphometric measurements (cm) in Saanen and Anglo-Nubian goats (Média verossimilhança, efeito da classe sexual e grupo genético na relação média entre as medidas corporais (kg) e as medidas morfométricas (cm) em cabras Saanen e Anglo-Nubiana).

	Sexual class		Genetic group		SEM	P-value		
Item	Male	Female	Anglo-Nubian	Saanen		SC	GG	SC x GG
WH	1.81	1.53	1.65	1.68	0.04	<0.01	0.54	0.18
RH	1.82	1.55	1.67	1.71	0.03	<0.01	0.55	0.18
BL	1.67	1.43	1.53	1.57	0.03	<0.01	0.41	0.26
CD	0.98	0.72	0.83	0.88	0.03	<0.01	0.25	0.17
TP	1.79	1.53	1.63	1.68	0.03	<0.01	0.26	0.13
RL	0.25	0.02	0.10	0.16	0.03	<0.01	0.23	0.15
RW	-0.09	0.12	0.001	0.03	0.03	<0.01	0.44	0.21
AC	1.65	1.86	1.75	1.76	0.02	<0.01	0.70	0.07

Adjustment obtained through the Gamma probability density function; SEM standard error of the mean, SC: sexual class; GG:genetic group; SC x GG: interaction between sexual class and genetic group; WH: withers height; RH: rump height ,cm; BL:body length,cm; CD: chest depth,cm; TP:thoracic perimeter,cm, RL: rump length,cm; RW:rump width,cm; AC: abdominal circumference,cm

Table III. Analysis of morphometric measurements for estimate the body weight (Kg) in Saanen and Anglo-Nubian goats using the Stepwise tool (Análise de medidas morfométricas para estimar o peso corporal (Kg) em cabras Saanen e Anglo-Nubiana usando a ferramenta Stepwise).

Number of Steps	Variable	Partial R^2	Accumulated R^2	*P-value*
Females				
1	RW	0.9268	0.9268	< 0.01
2	BL	0.0065	0.9333	< 0.01
3	RL	0.0084	0.9418	< 0.01
4	WH	0.0017	0.9434	< 0.01
5	RH	0.0012	0.9446	0.02
6	TP	0.0010	0.9456	0.03
Males				
1	TP	0.9287	0.9287	<0.01
2	BL	0.0068	0.9355	<0.01
3	RW	0.0020	0.9375	0.02

RW:rump width,cm; BL:body length,cm; RL: rump length,cm; WH: withers height; RH: rump height,cm; TP: thoracic perimeter,cm, Adjusted Prediction Equations: Females: Body Weight= -23.25356 (0.69) + 3.62189 (0.06) x RW (P < 0.01 n = 305), Males: Body weight = -19.52004 (0.62) + 0.61358 (0.01) x TP (P < 0.01 n = 184)

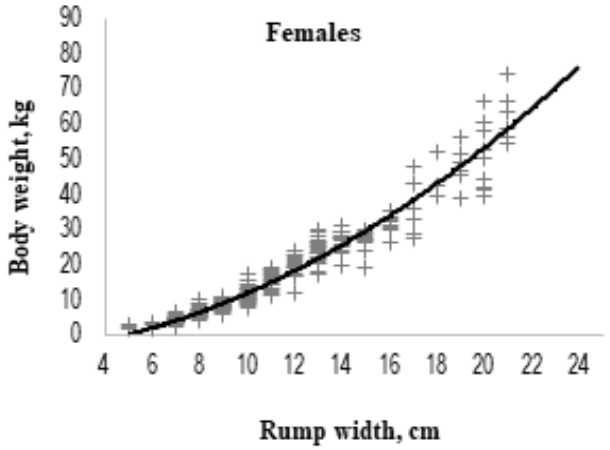

Figure 1. Dispersion of database and body weight (dependent variable) in relation to rump width (independent variable) in goats, given by the equation: Y = 0.1188 x2 + 0.5732 x – 5.5888 (R2 = 0.9431). The dispersion database was represented by the symbol "+" (Dispersão do banco de dados e peso corporal (variável dependente) em relação à largura da garupa (variável independente) em cabras, dada pela equação: Y = 0,1188 x2 + 0,5732 x - 5,5888 (R2 = 0,9431). O banco de dados de dispersão foi representado pelo símbolo "+").

BW_{males}= 0.0127 × TG²- 0.6611 × TG+11.261; R^2=0.9748;

Growth curves were evaluated from four mathematical models (**Table IV).** All of them have presented convergence, and parameters were fitted (P < 0.05). The Gompertz model presented the best fitting, because it performed with the lowest values for MSE (7547.4), ASD (4.12) and AMD (0.0051). These criterions were used to evaluate goodness of fitting. Then, Gompertz model was sliced to obtain individual equations for males and females. This slice was applied once body weight performed differently between sexual classes in the first analysis for body measurements. Thus, growth curves for the females and males were obtained as a function of its ages. There were significant adjustments (P < 0.01) in both models for the Gompertz growth curve, resulting in sigmoid shape of body weight as a function of age, in days (**Figure 3**).

Finally, the following equations were suggested to estimate body weight (BW) in function of age (t), for males and females goats, respectively:

DISCUSSION

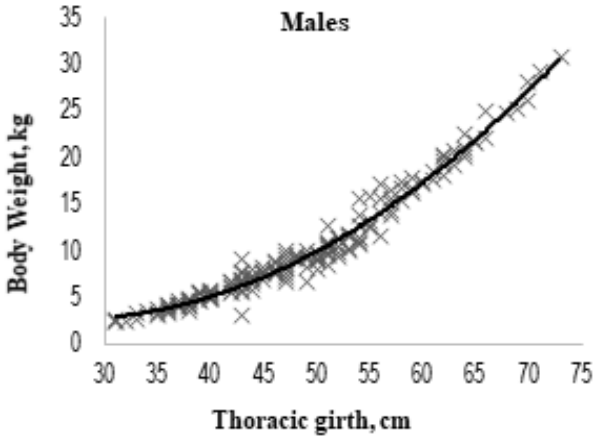

Figure 2. Dispersion of database and body weight (dependent variable) in relation to thoracic girth (independent variable) in goats, given by the equation: Y = 0.0127 x2 – 0.6611 x + 11.261 (R2 = 0.9748). The dispersion database was represented by the symbol "x" (Dispersão do banco de dados e peso corporal (variável dependente) em relação à circunferência torácica (variável independente) em cabras, dada pela equação: Y = 0,0127 x2 - 0,6611 x + 11,261 (R2 = 0,9748). O banco de dados de dispersão foi representado pelo símbolo "x").

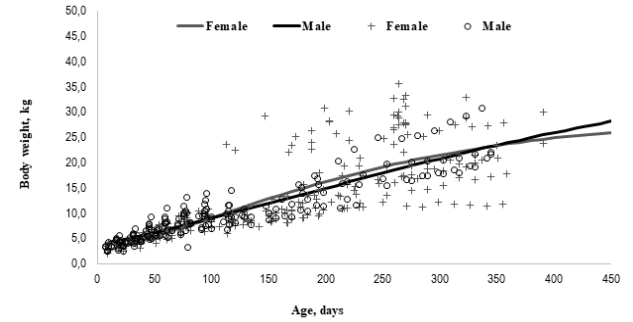

Figure 3. Dispersion data and changings in body weight in function of age for male and female goats (Dados de dispersão e alterações no peso corporal em função da idade para machos e fêmeas).

The known about body measurements of the goats are useful to select animals more adequate for different productive systems. Our findings for morphometrics traits were lower than previous studies with similar breed. Pesmen and Yardimci (2008, pp. 35) reported that the estimates obtained for withers height, body length, chest depth and body weight for the females adult Saanen in lactation were 66.94, 109.75, 32.54 cm and 55.37 kg, and non-lactating were 62,07, 101,55, 30,27 cm and 41,03 kg. While Mello & Schmidt (2008, pp.531) using Anglo-Nubian goats reported the values of thoracic perimeter 89.9 and 84.6; withers height: 80.3 and 75.8; rump height 80.1 and 76.1; body length 83.9 and 77.4; rump length: 22.6 and 21.0 and rump width: 10.9 and 12.2, for males and females, respectively. However, it is also important to consider differences between ages. According Bolacali & Kucuk (2012, pp. 24) the values of wither height, body length, chest depth for Saanen goats were 34.7, 33.3 and 13.3, cm at birth and 56.7, 58.3 and 25.1 cm at age of 180 days, respectively. Considering that in the present study 66 % of animals were under 12 months of age, we can infer that the variability observed in the literature findings can be justified by age differences. In addition, it is reported that different factors such as gender, breed, nutrition, environment, and handling have influence on body measurements (Alade et al. 2008, pp. 54, Bolacali & Kucuk (2012, pp. 23)

In relation to breed factor, Clemente (2009, pp.39) demonstrated differences in morphometric characteristics between the genotypic groups, with the highest measurements obtained for Alpine breed compared to the Saanen breed. In addition, these authors reported that thoracic girth and body length were the morphometric variables that best fit the body weight estimate, generating the following regression equations: BW = -34.117 + 0.438BL + 0.44TG (r^2 = 0.9283) and BW = -35.675 + 0.493BL + 0.427 TG (r^2 = 0.9199) for Alpine and Saanen breed, respectively. However in the current study no differences were observed between Saanen and Anglo Nubian.

Table IV. Descriptive statistics of age and body weight measurements used to fit equations for growth curve, and evaluation of four sigmoid models fitted with these data for female and male goats (Estatística descritivas de medidas de idade e peso corporal utilizadas para ajustar as equações da curva de crescimento, e avaliação de quatro modelos sigmóides ajustados com estes dados para fêmeas e machos caprinos).

Item	n	Mean	SD	Median	Minimum	Maximum
Female age	255	161.6	102.5	156.0	9.0	391.0
Female BW	255	13.0	8.2	10.1	2.0	35.6
Male age	184	117.8	95.8	82.0	7.0	345.0
Male BW	184	10.1	6.0	8.7	2.4	30.7
			Model evaluation			
Model	a		b		k	
Brody	$61.6432_{\pm 27.678}$		$0.9633_{\pm 0.0119}$		$0.00128_{\pm 0.0007}$	
Gompertz	$29.1785_{\pm 2.6267}$		$2.2517_{\pm 0.0899}$		$0.00655_{\pm 0.0001}$	
Logistic	$0.00121_{\pm 0.8836}$		$2.0300_{\pm 332.4}$		$-0.0008_{\pm 0.1036}$	
Von Bertalanffy	$32.5009_{\pm 3.9567}$		$0.5554_{\pm 0.0156}$		$0.00479_{\pm 0.0001}$	
	MSE		ASD		AMD	
Brody	7634.4		4.13		0.0127	
Gompertz	7547.4		4.12		0.0051	
Logistic	9012.0		4.50		0.1812	
Von Bertalanffy	7572.5		4.15		0.0261	

BW: body weight, kg; SD: standard-deviation; MSE: Mean square error; ASD: asymptotic standard-deviation; AMD: absolute mean deviation; "a", "b" and "k" are adjusted parameters
Parameter "m" of Logistic model was: $7.6612_{\pm 1415.0}$

Different morphometric measurements have been used in different studies to estimate body weight in different species and sexual class (Chitra et al. 2012, pp. 410 ; Mahieu et al. 2012, pp. 13). In general the studies using sheep and goats have demonstrated high correlation between thoracic girth and body weight (Pesmen & Yardimci, 2008 pp. 31), which was demonstrate in our study by the high value to r^2 obtained for goats males. These results are in agreement with Sebolai et al. (2011, pp. 901) that working with indigenous Tswana goats demonstrated that all models, thoracic girth contributed most in explaining variation in body weight as demonstrated by high values of partial R^2 which ranged from 0.48 for female mature to 0.80 for mature male goats. In addition, Chitra et al. (2012, pp. 410), using Malabari females, reported that prediction of body weight based on thoracic girth alone (BW=-13.4480 + 0.5663 TG, R^2 = 0.709) or combined with body length (BL) and withers height (WH) (BW= -14.8598 + 0.1234BL + 0.4773WH, R^2 = 0.719) presented higher coefficient of determination and lower residual mean square.

The knowledge about morphometric traits could be useful to characterize animals by types and functions, and to select markers for future improvement of its production (Kouri et al. 2019, pp. 7; Praharani et al. 2019, pp. 31). It is important emphasis that our findings demonstrated no genetic groups effects (Saanen and Anglo Nubian) on relationship between BW and morphometric measurements, but we observed differences between females and males. Mello and Schmidt (2008) in a study to characterize Anglo-Nubian goat breed reported that these presented a tendency to increase the rump height over the years, which was attributed to selection pressure for this desirable characteristic in dairy females. It is important to emphasize the differences in physiological development between females and males, being reported that female's have more tendency to develop rump region, while males are more relative to anterior region of the body (Couto, 2013). In the present study, considering the high correlation coefficients obtained between body weight and rump width for the female and with thoracic girth for male goats, we can suggest that these measurements can predict good estimates of body weight for each sexual class of Saanen or Anglo Nubian goats.

We noted that goats' males presented higher growth rate compared to females at all ages. The differences between sexual classes seems to be in agreement with reported by Perez et al. (2016, pp. 3) when studying adults mixed-breed goats. They showed the male goats consistently had higher morphometric measurements and body weights in relation to female goats. Similarly, Momani et al. (2012, pp. 119), evaluating the growth performance of the Sahelian, ½ crossbreds of Anglo-Nubian and ¾ AN, showed that males was heavier in relation to females at birth (2.81 ± 0.68 and 2.52 ± 0.53, respectively), also with 100 days (11.70 ± 2.77 and 11.03 ± 2.68 and, respectively).

Studies have shown that factors such as age and physiological stage must be considered when estimating body weight. Pesmen & Yardimci (2008, pp. 34) working with Saanen groups showed two regression equations to estimate BW of goats, being one for goats with 2-2.5 years at first lactation period (BW= -100.084 + 1.698*TG; R^2 = 0.89), and other one to the group that included the goats ready to be inseminated for the first time (BW = - 53.061 + 1.120*TG; R^2 = 0.71). Our study suggests two practical equations to estimate body weight of Saanen and Anglo Nubian in function of ages.

The studies of growth curve are useful to predict changes in animal development over time, and to predict mature body weight. Pires et al. (2017, pp. 1047) studying Repartida goats reported that the logistic model showed the best fit for describing their growth curve. They also reported that the growth rate of these animals at maturity is very slow in comparison to others meat breeds, resulting in lower body weight in adulthood. Waheed et al. (2011, pp. 292) working with Beetal goats, reported that Brody and Gompertz models explained growth of Beetal kids very well, however sex did not influence any of the parameters in both models. Waiz et al. (2019, pp. 3) reported that the Brody model provided the best fit of growth curve in both males and female of Sirohi goat. It is important to consider that several factors as such sexual class, genetic potential and the influence of environment and nutrition could be affect post-natal growth and development of the animals (Rout et al 2019, pp. 29).

The present study demonstrated significant differences in growth rates between males and females and that the Gompertz model provided the best fit of growth curve in both genders of Saanen and Anglo Nubian. Additionally, our results demonstrated that males presented a tendency to continue growth rate even after 400 days, however the females presented deceleration in the growth after this time, which can justify that females mature earlier. This result agrees with the study of Jalil et al. (2018, pp.97) using goats at different ages from birth to 36 months. They reported that animals reached mature (>24 months age) body weight for male and female goats as 29.9±1.76 and 23.6±0.81 kg, respectively. These differences obtained by the present study in growth curves could be useful to adopt strategies that can improve production systems.

CONCLUSIONS

The rump width in females and of thoracic girth in males presented significant correlation coefficients with body weight. Based on our results, the equation to estimate BW in Saanen or Anglo Nubian goats were: BW females = $0.1188 \times RW^2 + 0.5732 \times RW - 5.5888$; and BW males = $0.0127 \times TG^2 - 0.6611 \times TG + 11.261$. The estimates of body weight considering the age in days (t) were: $BW = 36.5674 \times \exp(-2.2404 \exp(-0.0046t))$ for males and $BW = 27.2616 \times \exp(-2.4151 \exp(-0.00775t))$ for females.

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