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Relation between swine weight and morphometric measurements

Relação entre o peso e medidas morfométricas de suínos

Relación entre el peso de los cerdos y las medidas morfométricas

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Abstract

Objective was to define a mathematical model that better explain the relationship of the animals weight depending not only on the animals age but also on the animals morphometric measurements. 40 piglets, half Duroc-Large White blood, were used, 20 males and 20 females, from 3 to 35 days of age (lactation phase) initially weighing 1.518 ± 0.121 kg and from 36 to 66 days of age (calving phase) with a body weight of 7.010 ± 0.704 kg. The animals were weighed weekly on a digital balance. The relationship of animal weight, age and morphometric measurements of male and female piglets were performed using regression models: existing, linear and power. The models were evaluated according to nine criterialinear model was the most adequate to explain the weight of male pigs, while for female pigs was the power. The age of the pig, the shank and palette length, as well as the circumference of the shank jointly explain the weight of the male piglets. The weight of females is explained jointly by age, body length, thorax and hip circumference.

Keywords: Power model; Morphometry; Weight estimation; Linear model.

Resumo

Objetivou-se definir um modelo matemático que melhor explique a relação do peso do animal em função não só apenas da idade do animal como também das medidas morfométricas do animal. Utilizou-se 40 leitões meio sangue Duroc-Large White, sendo 20 machos e 20 fêmeas, dos três aos 35 dias de idade (fase de aleitamento) pesando inicialmente 1,518 ± 0,121 kg e dos 36 aos 66 dias de idade (fase de cria) com peso corporal de 7,010 ± 0,704 kg. Os animais foram pesados semanalmente em balança digital de gancho. A relação do peso do animal, da idade e das medidas morfométricas dos leitões machos e fêmeas foram realizadas através dos modelos de regressão: existente, linear e potência. Os modelos foram avaliados segundo nove critérios. O modelo linear foi o mais adequado para explicar o peso dos suínos macho, enquanto que para os suínos fêmeas foi o potência. A idade do animal, o comprimento de pernil e da paleta, assim como a circunferência do pernil explicam conjuntamente o peso dos suínos machos, já o peso das fêmeas é explicado conjuntamente pela idade, comprimento corporal, circunferência de tórax e de quadril.

Palavras-chave: Modelo potência; Morfometria; Estimação ponderal; Modelo linear.

Resumen

El objetivo fue definir un modelo matemático que explique mejor la relación del peso del animal en función no solo de la edad del animal sino también de las medidas morfométricas del animal. Se utilizaron cuarenta lechones, la mitad sangre Duroc-Large White, 20 machos y 20 hembras, de 3 a 35 días de edad (fase de lactancia) con un peso inicial de 1,518 ± 0,121 kg y de 36 a 66 días de edad (fase de parto) con un peso corporal de 7.010 ± 0.704 kg. Los animales se pesaron semanalmente en una báscula de gancho digital. La relación de peso animal, edad y medidas morfométricas de lechones machos y hembras se realizó mediante modelos de regresión: existente, lineal y de potencia. Los modelos se evaluaron según nueve criterios. El modelo lineal fue el más adecuado para explicar el peso de los machos, mientras que para las hembras fue la potencia. La edad del animal, la longitud de la pierna y el hombro, así como la circunferencia de la pierna en conjunto explican el peso de los cerdos machos, mientras que el peso de las hembras se explica en conjunto por la edad, la longitud corporal, la circunferencia del pecho y la cadera.

Palabras clave: Modelo de potencia; Morfometría; Estimación de peso; Modelo lineal.

1. Introduction

Pig farming worldwide is undergoing intense genetic improvement, producing pigs with high growth potential, feed efficiency and good carcass composition (Lima et al., 2018). Studying growth using a function that describes the entire lifetime of the animal, relating weight and age, has been researched by several authors (Nascimento et al., 2017; Luo et al., 2015).

Studies on growth curves in pig farming relating weight-age have been extensively studied by Luo et al. (2015) and Silva et al. (2013) using logistic model, Nascimento *et al.* (2017) using the cubic polynomial model and Schinckel et al. (2004) using the quadratic exponential model.

The aforementioned researches, however, did not reach a consensus on which model best explains the pigs weight behavior. Although the use of conventional balance is considered the best way to determine an animal body weight, weight estimation from linear body measurements is gaining space among researchers.

Thus, the objective was to define a mathematical model that better explains the relationship of the animal weight depending not only of age but also of the morphometric measurements.

2. Methodology

Research had the character of a quantitative study, characterized as experimental research, carried out through techniques of execution and analysis of tests, numerical evaluation and data processing using statistical techniques (Pereira et al., 2018). Research was carried out at the Swine Experiment Bioterium of the Federal Rural University of Pernambuco (Serra Talhada County Campus), in the semiarid region of Pernambuco State, northeastern Brazil (07° 57’ 01” S, 38° 17’ 53” E, at an elevation of 429 meters) (Silva et al., 2019).

Animal procedures were approved by the Animal Use Ethics Committee (License n° 071/2018 of July 18, 2018) and were carried out according to the Animal Experimentation Guide of the Federal Rural University of Pernambuco.

40 piglets half-blood Duroc-Large White were used, 20 males and 20 females, from three to 35 days of age (lactation phase) initially weighing 1.518 ± 0.121 kg and from 36 to 66

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days of age (brooding phase) with a body weight of 7.010 ± 0.704 kg. The animals were weighed and randomly distributed, by draw, in masonry stalls, keeping one animal per stall.

The animals were housed in an experimental shed with East-West orientation, in stalls measuring 6 m^2 each, with ceramic tile cover and equipped with a masonry feeder and pacifier type water drinker. Feed and water (flow 1,0 $L.min^{-1}$) were given to the piglets at will during the experimental period. The diet provided for the evaluation period was formulated based on corn, soybean meal, vitamin-mineral premix and common salt (Rostagno et al., 2017) (Table 1).

Table 1. Composition of the experimental feed provided to the piglets during the experimental period.

Ingredients	Inclusion levels (%)
Corn	62.600
Soybean meal, 45%	30.210
Corn gluten, 60%	3.800
Dicalcium phosphate	1.650
Calcitic limestone	0.750
Common salt	0.400
L-Lisine	0.250
L- Threonine	0.040
Choline chloride 60%	0.100
Premix vitamin / mineral[1]	0.200
TOTAL	100.000
	Percent composition calculated
Crude protein	21.700
Metabolizable energy (Kcal/kg)	3.150

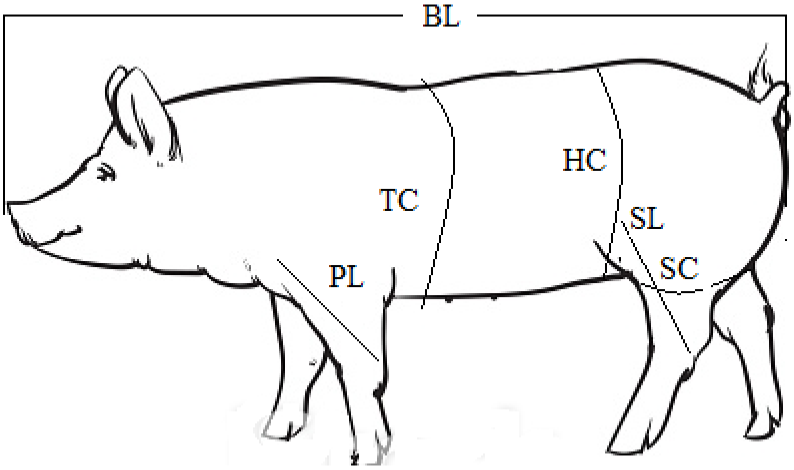
Calcium	0.820
Phosphor	0.420
Sodium	0.200
Fat	2.170
Digestible lysine	1.120
Digestible methionine	0.329
Digestible methionine + cystine	0.638
Digestible threonine	0.728

[1]Premix vitamin/mineral/ kg of product: Folic Acid 106.00 mg; Pantothenic 2,490 mg; Antifungal 5,000 mg; Antioxidant 200 mg; Biotin 21 mg; Coccidiostatic 15,000 mg; Choline 118,750 mg; Vitamin K3 525.20 mg; Niacin 7,840 mg; Pyridoxine 210 mg; Riboflavin 1,660 mg, Thiamine 360 mg; Vitamin A 2,090,000 IU; Vitamin B12 123,750 mcg; Vitamin D3 525,000 IU; Vitamin E 4,175 mg. Cu 2,000 mg; I 190 mg; Mn 18,750 mg; Se 75 mg; Zn 12,500 mg. Source: The authors.

The animals were weighed weekly on a digital hook balance with 10g precision. For accuracy during measurement, the animals were restrained using a bag made of fabric that safely supported the entire body of the piglet, attenuating the animals movement during weighing.

Biometric measurements were performed every seven days in order to obtain the following morphometric measurements: body length (BL); thorax circumference (TC); palette length (PL); shank length (SL); shank circumference (SC) and hip circumference (HC) (Figure 1). The measurements were performed using millimeter tape.

Figure 1. Piglets of morphometric measurements.



Source: The authors.

The relationship of animal weight, age (ID) and morphometric measurements of male and female piglets were performed using the following regression models: existing (Khanji et al., 2018), linear and power described by:

Existing model

$$W = 69{,}3 * TC_i^2 * BL_i + \varepsilon_i$$

Linear model

$$W = \beta_0 + \beta_1 ID_i + \beta_2 BL_i + \beta_3 SL_i + \beta_4 PL_i + \beta_5 TC_i + \beta_6 SC_i + \beta_7 HC_i + \varepsilon_i$$

Power model

$$W = \beta_0 ID_i^{\beta_1} BL_i^{\beta_2} SL_i^{\beta_3} PL_i^{\beta_4} TC_i^{\beta_5} SC_i^{\beta_6} HC_i^{\beta_7} \varepsilon_i$$

where, W_i is weight of the i-th piglet, ID_i is age of the i-th piglet, BL_i is the body length of the i-th piglet, SL_i is the shank length of the i-th piglet, PL_i is the palette length of the i-th piglet, TC_i is the chest circumference of the i-th piglet, SC_i is the shank circumference of the i-th piglet and HC_i is the hip circumference of the i-th piglet, ε_i is the i-th error associated with the weight of the piglets, in which present normal distribution of mean 0 and constant variance σ^2. β_0, β_1, β_2, β_3, β_4, β_5, β_6 e β_7 are the parameters associated to model.

The models were evaluated using the model evaluation criteria described in Table 2. All analyzes were performed using the R-Project version 2.13.1 software.

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Table 2. Criterion for the evaluation of pig weight estimates.

Criteria evaluation	
Absolute error (AE)	$\sum_{i=1}^{n} \lvert Y_i - \hat{Y}_i \rvert$
Mean absolute deviation (MAD)	$\frac{\sum_{i=1}^{n} \lvert Y_i - \hat{Y}_i \rvert}{n}$
Mean squared error (MSE)	$\frac{\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2}{n}$
Mean absolute percentage error (MAPE)	$\frac{\sum_{i=1}^{n} \frac{\lvert Y_i - \hat{Y}_i \rvert}{Y_i} * 100}{n}$
Sum of squares of errors (SSE)	$\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2$
Model determination coefficient (R^2)	$1 - \frac{\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n} (Y_i - \bar{Y})^2}$
Willmott index (d)	$1 - \frac{\sum_{i=1}^{n} (\hat{Y}_i - Y_i)^2}{\sum_{i=1}^{n} (\lvert \hat{Y}_i - \bar{Y} \rvert + \lvert Y_i - \bar{Y} \rvert)^2}$

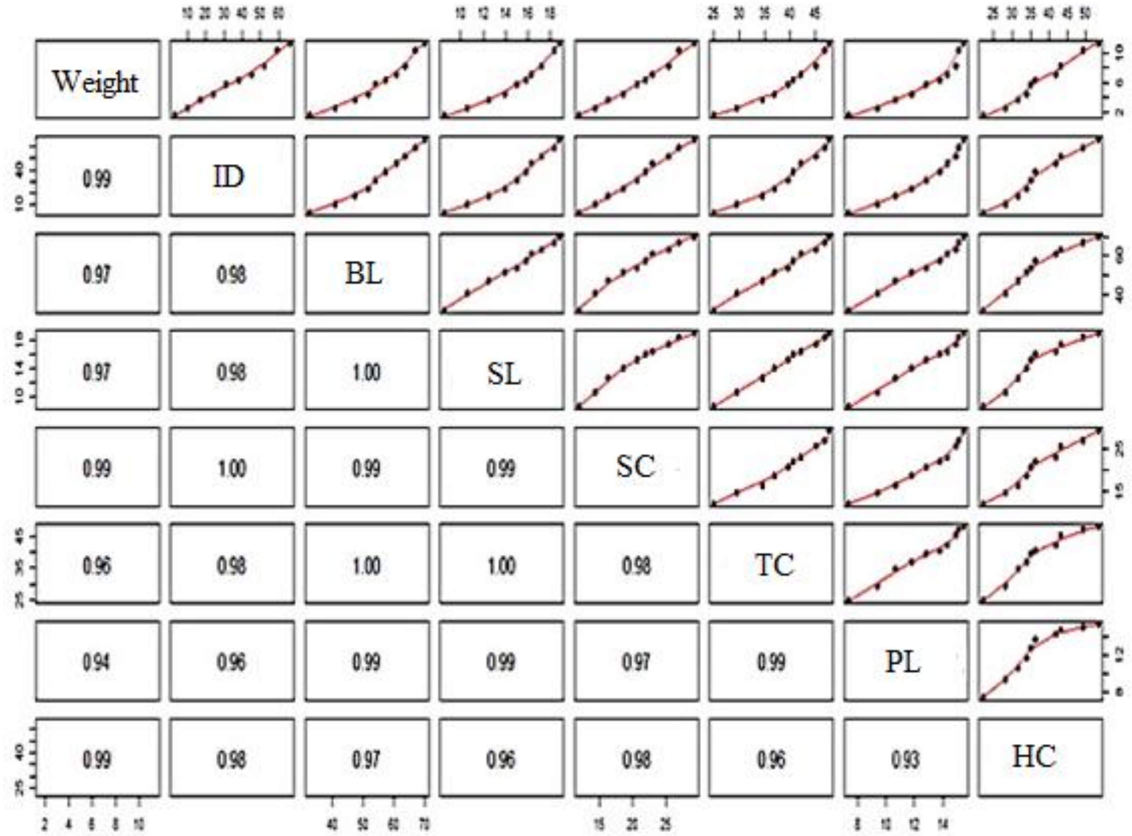
Source: The authors.

where, Y_i is the value of the i-th weight observed, $\hat{Y}_i$ is the i-th value of the estimated weight, $\bar{Y}$ is the mean of the observed weights and n is the total of observations.

3. Results and Discussion

In Figure 2, can be observed that in the evaluation of male pigs, the correlations between all the variables studied are positively correlated (correlation greater than 0.94).

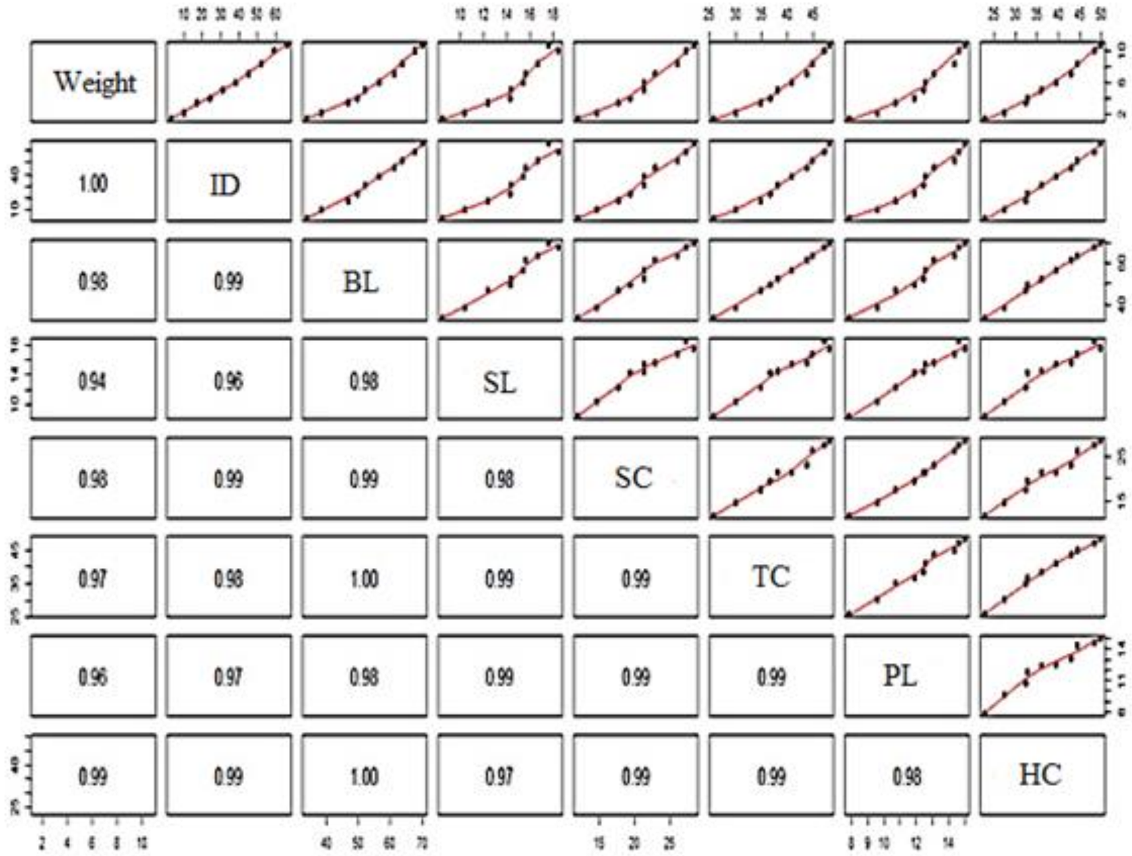
Figure 2. Correlation of morphometric variables for male piglets.



Source: The authors.

In Figure 3, can be observed that in the evaluation of swine females the correlation between all biometric variables showed high positive correlations (correlation greater than 0.94). The same correlations observed in males were also observed in swine females. The variables that most correlate with the animal weight are: age of the animal, shank circumference (SC) and hip (HC), all with a correlation coefficient of 0.98.

Figure 3. Correlation of morphometric variables for female swine.



Source: The authors.

In the evaluation of male pigs, it is noted that in the linear and power models the variables: age of the animal, body length (BL), shank circumference (SC) and palette length (PL) were defined as significant to explain the weight of the animal (Table 3).

Table 3. Estimation of the weight of male and female pigs according to the different regression models.

Models	Equation
	Males
Linear	W = 0.102ID + 0.7SL + 0.235SC - 1.0PL
Power	$W = ID^{0.58}\ SC^{2.06}\ PL^{-1.45}\ BL^{-0.7}$
Existing	$W = 69.3*TC^{2}*BL$
	Females
Linear	W = 0.069ID + 0.544SC - 1.101PL + 0.145HC
Power	$W = ID^{0.48}\ TC^{-6.87}\ HC^{2.19}\ BL^{4.35}$
Existing	$W = 69.3*TC^{2}*BL$

Source: The authors.

In the evaluation of the females, verified that in the linear model the variables: age, palette length (PL), shank circumference (SC) and hip (HC) were defined as significant to explain the weight. However, in the power model, the variables: age, body length (BL), thorax circumference (TC) and hip (HC) were the that most explained the animal weight.

The high correlations with live weight indicate that the variables used in the models were sufficient to predict body weight without using a balance, even in very young animals. High correlation coefficients between body weight and thorax circumference make estimating body weight based on chest circumference an efficient tool.

Khanji et al. (2018) estimating the weight of marrãs using an existing model, concluded that the errors are greater than the regression models used in the prediction and explain that more accurate estimates can be obtained when the regression model considers other variables as the physiological state, thoracic perimeter and body length, body score and fat thickness.

According to Vincek et al. (2012), differentiation in the development of different types of tissues (muscle, fat and bone) can be applied with good accuracy to study growth curves in pigs. Walugembe et al. (2014) state that body development can be measured using biometric measurements, being able to predict body weight relatively accurately and correlate them to some carcass characteristics.

Although initially proposed for finishing animals, the research was also carried out on young pigs to predict body weight without using a balance. Assessing linear measurements of piglets at different weaning ages Birteeb et al. (2015) claim that, among linear body measurements, breast circumference is the best predictor of body weight, regardless of the piglets age.

Differences between pig sexes when using measuring tape to evaluate morphometric measurements in farm animals were found by Li et al. (2013), Formenton et al. (2019) and Rahman et al. (2019). The speed of development of a given region of the body advances until reaching the maximum and begins to decrease as the animal phase adulthood. The animals accumulated weight in relation to its age follows a sigmoid curve, composed of a pre-puberty phase of self-acceleration and another post-puberty of deceleration. (Berg & Butterfield, 1976). If there are no food and environmental restrictions, the animal will develop until phase adult weight, following a sigmoidal curve, described by the allometric equation $Y = aX^b$, where Y is weight and X the animal age (Sakomura & Rostagno, 2016).

For males verified that, among the seven criteria evaluated, the linear model proved to be more efficient in six. Evaluating the females, verified that the power model presented the best adequacy criteria. The existing model showed the worst model adequacy criteria for both sexes of pigs (Table 4).

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Table 4. Criteria of evaluating the models for estimating the weight of male and female pigs.

Adequacy criteria	Models		
	Existing	Linear	Power
	Males		
AE	2.469	1.178	1.469
MAD	0.247	0.118	0.147
MSE	0.097	0.019	0.035
MAPE	4.949	3.207	2.448
SSE	0.970	0.196	0.353
R^2	0.989	0.998	0.996
d	0.997	0.999	0.999
	Females		
AE	4.512	1.325	0.934
MAD	0.451	0.132	0.093
MSE	0.269	0.025	0.017
MAPE	8.549	3.449	1.226
SSE	2.692	0.252	0.172
R^2	0.970	0.997	0.998
d	0.993	0.999	0.999

AE - absolute error; MAD - Mean absolute deviation; MSE - Mean square error; MAPE - Mean absolute percentage error; SSE - Sum of squares of errors; R^2 - Model determination coefficient; d - Willmott index. Source: The authors.

4. Conclusions

The age of the pig, the shank and palette length, as well as the circumference of the shank jointly explain the weight of the male piglets. The weight of females is explained jointly by age, body length, thorax and hip circumference. Biometric variables explain the weight of pigs with high precision power.

To improve the results found, new studies can be used with more morphometric characteristics and their associations with weight of animal.

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