Morphological growth curves for locally adapted swine in Brazil

Dall Cortivo, P.R.[1@]; Bretas, A.A.[1]; Silva, I.M.[1]; Braccini, J.[1] and McManus, C.[2]

[1]Department of Animal Science. Federal University of Rio Grande do Sul. Porto Alegre. RS. Brazil.
[2]Faculty of Agronomy and Veterinary Medicine. University of Brasília. Brasília. DF. Brazil.

SUMMARY

Growth curves were determined for four breeds of Brazilian locally adapted swine (Moura, Piau, Nilo and Monteiro) using nonlinear models. Data was collected on 13 morphological measurements of 220 animals of both sexes from 30 days of age to adult stages. Curves were fitted using nonlinear regression equations (Gompertz, Weibull, Logistic, Brody, Von Bertalanffy and Richards). The best curve was selected by the highest R^2 and lowest root mean squared error. The Weibull function was the most suitable for all breeds and genders. In general, females reached their adult size earlier, but males were larger. On the one hand, the Moura breed is the most similar to industrial breeds one, possibly because it is reared in fattening systems. On the other hand, the Monteiro breed was a later-developing one. Brazilian pig breeds have different growth patterns, associated with the genetic origin of the breed and its adaptations to environment.

ADDITIONAL KEYWORDS

Animal breeding.
Genetic resource.
Nonlinear analysis.
Phenotypic characterization.
Weibull distribution.

Curvas de crescimento morfológico para suínos localmente adaptados no Brasil

RESUMO

No presente estudo objetivou-se determinar curvas de crescimento para quatro raças de suínos naturalizados do Brasil (Moura, Piau, Nilo e Monteiro) através de ajustes não lineares. Foram coletados dados de 13 medidas morfológicas de 220 exemplares de ambos os sexos entre os 30 dias de vida até a idade adulta. As curvas foram ajustadas usando regressão não linear, pelas equações de Gompertz, Weibull, Logística, Brody e Richards. A melhor função foi selecionada pelo maior R^2 e menor erro quadrático médio, sendo a função de Weibull a mais apropriada para todas as raças e sexos. No geral, as fêmeas de todas as raças atingiram as medidas adultas com mais precocidade, porém os machos cresceram mais do que as fêmeas. O crescimento da raça Moura é o que mais se assemelha ao crescimento das raças industriais, isso pode estar relacionado ao fato de grande parte dos exemplares serem criados em sistemas de engorda. Por outro lado, a raça Monteiro foi a que apresentou um crescimento mais tardio. Conclui-se que as raças de suínos naturalizados brasileiros possuem crescimento diferenciado, que está relacionado com a origem genética da raça e adaptação ao ambiente.

PALAVRAS CHAVE ADICIONAIS

Melhoramento animal.
Recursos genéticos.
Análise não linear.
Caracterização Fenotípica.
Distribuição de Weibull.

INFORMACIÓN

Cronología del artículo.
Recibido/Received: 10.2.2015
Aceptado/Accepted: 18.10.2015
On-line: 10.12.2015
Correspondencia a los autores/Contact e-mail:
00173267@ufrgs.br

INTRODUCTION

Basic information on the differential growth of chemical body components in pigs assists in as interpretation of analyzed (Kielanowski, 1976) and in prediction of growth performance with models which simulate nutrient utilization and tissue accretion (Whittemore, 1983; Black *et al.*, 1986; Moughan *et al.*, 1987).

Genetic models for studying feed efficiency or related traits need to be improved. Although many studies have aimed to modeling longitudinal data (Verbeke and Molenberghs, 1997), genetic studies on pigs often focus on summarized phenotypes or use a simple repeatability model (Arthur *et al.*, 2001), which supposes, too narrowly, a uniform correlation between measurements that can bias parameter estimations. Other studies applied random regression models (Schnyder *et al.*, 2001; Lorenzo Bermejo *et al.*, 2003b; Manzanilla *et al.*, 2014).

Among the various applications of animal growth curves, there are the population growth characteristics, as some parameters of nonlinear models used have biological interpretation and can identify a population in the heaviest animals at younger ages, and these information can be obtained through the K parameters of growth curves, which express the rate of decline in the growth rate relative and the animal's weight limit or assindotic weight (Sandland and McGilchrist, 1979;

Table I. Characteristics description in locally adapted Brazilian pigs (McManus *et al.*, 2010b) Descrição de características em suínos brasileiros localmente adaptados (McManus *et al.*, 2010b).

Trait	Description
Body length (BL)	Distance from the external occipital protuberance to the base of the tail on the dorsal line; distance between tip of scapula and ischium, measured as the distance between the point of shoulder and the pin bone.
Dorso-sternal distance (DD)	From the point of the shoulder to the sternum; distance between dorso and sternum.
Eye distance (ED)	Inter orbital distance.
Ear length (EL)	From central point of the base to the vertix; from the base of the notch to the most distant point of the margin of the pinna (external ear).
Head length (HL)	From the external occipital protuberance occipital to tip of nasal bone.
Heart girth (HG)	Total distance around the animal (circumference) measured directly behind the front leg; total distance around the animal (circumference) measured directly behind the front leg.
Interisquiatic distance (DI)	Distance between external point of both isquial bones.
Interorbital distance (ID)	Between both frontal sigmoid apophysis; distance between left and right endocanthion.
Length of hip (LH)	From the external iliac tuberosity to the point of the pin bone; from the external angle of the ileum to the isquiatic tuberosity.
Longitudinal distance (LD)	From point of the shoulder to the point of the pin bone.
Shoulder height (SH)	Distance from the surface of a platform to the top of the shoulder.
Shoulder length (SL)	From the superior border of the scapula to the carpus.
Snout length (SL)	Tip of the nasal bone to coronal suture; From the frontal-nasal suture to the point of the snout.
Tail length (TL)	From insertion of the tail to the tail tip.

Drap-est in genetic evaluations (Mansour *et al.*, 1991). In this way knowledge of the growth curve of livestock species is of great importance in animal production as it allows you to indirectly evaluate genetic and environmental factors that influence growth, and it is also possible to identify animals with faster growth (Sarmento *et al.*, 2006).

Freitas and Costa (1983) and Rodrigues *et al.* (1992) studied the different functions (Bertalanffy, Logistic, Gompertz and Richards) to estimate growth curves of pigs from birth to slaughter, they concluded that these models had good fit of the data with high R^2 values. Dutra Jr. *et al.* (2001) mentioned that muscle, fat and bone tissue of pigs are also estimated with good accuracy by growth curves.

Using this technique, the large number of data taken over time is reduced to a few parameters (Freitas, 2005), and interpretation of these provides an explanation of what is happening to the animal biologically (Kshirsagar and Smith, 1995). Some of these parameters have direct interpretation and can be compared between different production systems. Brown *et al.* (1972) and Fitzhugh (1976) state that by observing the growth curve is possible to select animals that reach slaughter age faster. The best model to describe growth curves needs to be calculated for different species. Nonlinear models for these curves have been developed, such as those of Brody, Richards, Weibull, Gompertz and Logistic (Freitas, 2005). Kusec *et al.* (2007) pointed out the Logistic model as the most appropriate to describe the growth curves for pigs from different crosses.

These parameters can be used to predict growth rates and maturity in different breeds (McManus *et al.*, 2003) and tracking growth enables informed decisions about nutritional programs. Accurate assessments growth progress can be made so that irregular growth rates may be linked to developmental diseases and nutrition (McManus *et al.*, 2010a).

Brazilian locally adapted pigs originated from those brought to Brazil from the Iberian Peninsula at the time of the discovery, and include Piau, Nilo, Monteiro and Moura (Cavalcanti, 2000). These breeds are threatened with extinction, being raised on small farms mainly for the production of meat and lard. According to Mariante and Cavalcanti (2000), these breeds have undergone natural selection and have acquired adaptive traits in specific locations over time.

Egito *et al.* (2002) observed that the in-depth study of the breeds can facilitate the development and rational control of breeding programs in the future. Studies on genetic and phenotypic characterization and conservation of genetic resources are important, taking into consideration their rapid genetic erosion (Scherf, 2000), and the need for genetic variability for future uncertainties (Notter, 1999). Moreover, there are few studies on locally adapted pigs, especially young animals (McManus *et al.*, 2010b). The objective of this study was to determine nonlinear growth curves for four breeds of naturalized pigs from Brazil: Moura, Piau, Nilo and Monteiro.

MATERIAL AND METHODS

Morphometric measures were collected on 220 locally adapted pigs from the Moura (63 females and 41 males), Piau (23 females and 14 males), Monteiro (38 females and 25 males) and Nilo (7 females and 9 males) breeds **(table I)**. All animals were kept in semi-extensive rearing systems in various regions of the country (Nilo in Brasília, Federal District; Monteiro in Poconé, Mato Grosso do Sul and Brasilia; Moura in Concordia, Santa Catarina and Brasilia DF; Piau in Itaberaba, Bahia and Brasilia DF). Growth curves per breed were calculated using TableCurve 2D program (Systat Software, Inc., San José, California, USA), from 30 days of age to adulthood for all measures per breed and sex except for the Nilo where a single curve was adjusted for both sexes due to lack of data. The morphometric

Table II. Mean squared error for the Weibull function in swine locally adapted in Brazil (Erro quadrático médio para a função de Weibull em suínos localmente adaptados no Brasil).

	BL	DD	EL	HL	HG	DI	ID	LH	LD	SH	SL	SnL	TL
Monteiro fêmea	8.001	4.219	10.14	2.739	0.807	11.13	11.13	4.943	1.560	4.676	1.640	6.203	2.731
Monteiro macho	5.872	6.424	8.564	3.284	0.652	10.15	10.15	2.189	1.776	5.403	2.105	6.147	4.411
Moura fêmea	5.421	4.587	6.667	3.638	0.773	11.53	11.41	2.210	1.067	3.368	1.494	4.909	—
Moura macho	4.602	4.010	5.322	3.270	0.903	6.387	5.657	2.181	1.156	4.027	1.676	3.817	—
Nilo	3.952	—	—	—	0.471	5.343	10.61	0.829	0.408	1.668	—	0.408	1.258
Piau fêmea	9.165	3.758	5.570	3.381	1.823	15.11	18.12	2.770	32.13	4.789	1.335	7.487	3.793
Piau macho	5.759	3.230	3.077	2.017	0.621	9.609	8.036	1.967	0.933	3.320	1.260	5.538	2.470

BL= Body length; DD= Dorso-sternal distance; EL= Ear length; HL= Head length; HG= Heart girth; DI= Interisquiatic distance; ID= Interorbital distance; LH= Length of hip; LD= Longitudinal distance; SH= Shoulder height; SL= Shoulder length; SnL= Snout length; TL= Tail length.

measures were taken using a measuring tape, callipers and hipometer standing symmetrically on a flat solid surface as described in McManus *et al.* (2010b): The morphometric curves were analyzed according to age through the following functions:

Brody $Y= A^*(1-B^*exp(-kt))$

Von Bertalanffy $Y= A^*(1+B^*exp(Kt))^3$

Logistic $Y= A/(1+B^*exp(-kt))$

Gompertz $Y= A^*(exp (B^*exp(kt))$

Richards $Y= A^*(1-B ^*exp(-kt))^m$

Weibull $Y= A-(B^*exp(-kt)^*exp(d))$

Where:

A= asymptotic mature weight represents the estimated mature weight;

B= is an integration constant related to the initial weight of the animal, indicating the proportion of the asymptotic growth to be gained after birth, established by the initial values of the measure and t (time);

k= corresponds to the index of maturity, determines the efficiency of animal growth, an indicator of the speed with which the animal is approaching adulthood;

m= called inflection parameter and refers to the point in which the animal passes from one stage of growth to another, indicating the point at which it starts to grow with lower efficiency;

t= time (age);

d= integration parameter.

Procedures described by Perreira e Arruda (1987) and SAS® (Statistical Analysis System, Cary, North Carolina) were used for convergence of non-linear data. The values of sum of squares of the residual (SQr), coefficient of determination (R^2) and divergence from regression for each function were calculated. The R^2 was calculated as $R^2= 1-((SQr)/(SQt))$, where SQt is the total sum of squares (Kvålseth, 1985). The best curve was selected by the highest R^2 and lowest root mean square error.

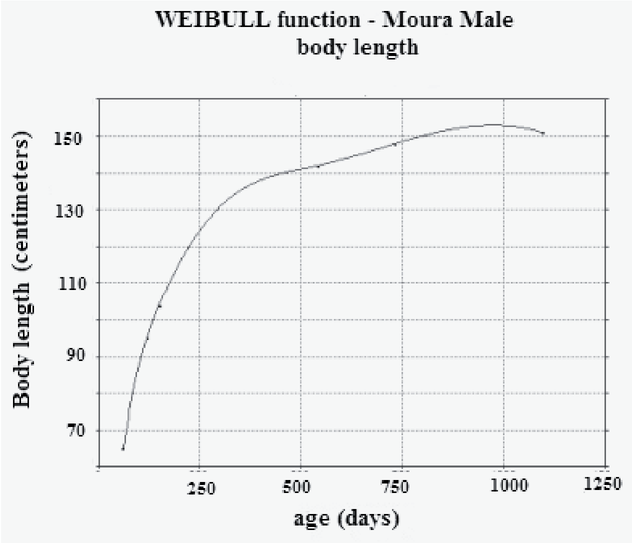

Figure 1. Moura breed body length Weibull growth curve (Curva de crescimento Weibull da raça Moura macho para o comprimento do corpo).

RESULTS AND DISCUSSION

The function that best expressed the morphological growth of the breeds studied was the Weibull function **(figure 1)**. There was significant difference ($p<0.05$) in the equation parameters between males and females, which demonstrates significant sexual dimorphism. The Weibull model showed the lowest mean square error, with an average of 4.824 **(table II)** and higher R^2 value, over 60 % **(table III)**. Brody and Von Bertalanffy tended not to converge for any of the measures in any breed; Gompertz did not converge for length of muzzle, tail length, heart girth and body length, R^2 with the other measures less than 50 % and mean square error averaging 9.233. The Richards curve most resembled the Weibull, with R^2 above 40 % and mean square error of 6.467, but did not converge for any measure in Piau and Nilo breeds.

Freitas and Costa (1993) and Rodrigues *et al.* (1992) affirm that the Gompertz, Richards, Von Bertalanffy and Logistic functions are good fit to describe the growth of pigs. In this study, the Weibull function was the best. The former studies did not use this curve. This can be explained by the fact that there was a lot of discrepancy in the measurements between the different breeds and the aim of this work was not to seek the

Table III. R^2 values for the Weibull function in swine locally adapted in Brazil (Valores de R² para a função de Weibull em suínos localmente adaptados no Brasil).

R^2	BL	DD	EL	HL	HG	DI	ID	LH	LD	SH	SL	SnL	TL
Monteiro fêmea	0.76	0.828	0.715	0.577	0.694	0.816	0.75	0.646	0.756	0.681	0.826	0.488	0.83
Monteiro macho	0.913	0.771	0.858	0.74	0.925	0.89	0.89	0.938	0.825	0.771	0.788	0.608	0.634
Moura fêmea	0.916	0.933	0.931	0.548	0.87	0.909	0.891	0.919	0.92	0.902	0.855	0.714	—
Moura macho	0.941	0.93	0.947	0.716	0.852	0.968	0.967	0.926	0.91	0.858	0.875	0.782	—
Nilo	0.961	—	—	—	0.975	0.979	0.948	0.992	0.99	0.96	—	0.994	0.915
Piau fêmea	0.833	0.963	0.963	0.891	0.386	0.855	0.805	0.898	0.06	0.875	0.911	0.466	0.773
Piau macho	0.925	0.708	0.98	0.934	0.921	0.931	0.946	0.958	0.961	0.923	0.946	0.537	0.939

BL= Body length; DD= Dorso-sternal distance; EL= Ear length; HL= Head length; HG= Heart girth; DI= Interisquiatic distance; ID= Interorbital distance; LH= Length of hip; LD= Longitudinal distance; SH= Shoulder height; SL= Shoulder length; SnL= Snout length; TL= Tail length.

Table IV. Asymptotic values (A) for body measures in locally adapted swine in Brazil (Valores assintóticos (A) para as medidas corporais de suínos localmente adaptadas no Brasil).

	BL	DD	EL	HL	HG	DI	ID	LH	LD	SH	SL	SnL	TL
Monteiro fêmea	62.86	210.21	230.2	8.038	5.662	99.48	88.69	33.95	13.08	28.16	16.58	25.47	25.95
Monteiro macho	70.57	44.48	76.71	18.71	11.91	109.5	109.5	37.62	14.50	32.83	18.18	29.14	33.74
Moura fêmea	77.43	68.27	104.5	22.04	11.75	149.6	134.04	35.39	15.18	42.29	19.97	37.66	—
Moura macho	85.29	69.93	111.2	29.06	12.72	162.2	139.3	37.82	18.26	43.49	23.06	41.40	—
Nilo	54.50	—	—	—	10.00	90.57	99.50	29.07	9.516	24.50	—	14.00	14.00
Piau fêmea	78.14	64.82	102.3	31.42	10.72	137.2	125.6	36.60	24.28	43.50	17.65	32.39	28.93
Piau macho	88.30	34.58	117.1	1031.3	29.69	175.8	288.0	55.81	20.49	51.62	403.3	51.14	38.87

BL= Body length; DD= Dorso-sternal distance; EL= Ear length; HL= Head length; HG= Heart girth; DI= Interisquiatic distance; ID= Interorbital distance; LH= Length of hip; LD= Longitudinal distance; SH= Shoulder height; SL= Shoulder length; SnL= Snout length; TL= Tail length.

best function for each breed, but the function that, in general, best described the morphological growth of all breeds studied. The Brody function, according to Dutra Junior *et al.* (2001), had the worst fit for pigs, as seen in this study. Many of the variations between breeds and sexes are related to the history of the animal and the breeding system.

Among the breeds used in this study, Moura had characteristics linked to muscle growth (Thoracic Perimeter, body length and longitudinal diameter) that were later developing than the size of the head in relation to females of Monteiro and Piau breeds. It´s rump size was earlier developing than other breeds with later body growth, compared to the size of the head, thus forming a broad back and loin, but it is less precocious than other breeds.

The Moura is closest to the commercial breeds. This also has resemblance to the Monteiro growth and can be designed to dual purpose and low demand in management.

The Nilo had characteristics of the shoulder, rump and interisquia distance earlier than muzzle size, compared to the Piau and Moura females. This can be attributed to the fact that the former is a lard type, requiring a structural base for the deposition of fat, and so is developed for this purpose.

The Monteiro retain many wild features. Females have body growth proportional to the height of the croup. Males have body growth and longitudinal diameter earlier than the height of the croup, demonstrating a tapered and rustic profile, as well as growth precocity.

The determination coefficients for the regressions were generally high **(table III)**. In general, allometry coefficients between different sexes within breeds are of the same order but differ between breeds, showing that the breeds develop differently.

The values of A **(table IV)** are the estimates of the measures when the animal reaches maturity. In general, the values obtained are in agreement with those published by McManus *et al.* (2010b) in a study on the phenotypic characterization of locally adapted swine in Brazil, Uruguay and Colombia. In that study, it was concluded that Moura was the nearest to commercial breeds and Monteiro is the furthest. This is in accordance with the present study because as the Moura reached adult measures more quickly, similar to commercial breeds.

The values of the parameter B **(table V)** - the integration constant that relates the initial weights of the animals with a ratio of asymptotic growth to be gained after birth - were all greater than one (1) and the distribution occurred in a concave parabolic down shape. There was a large discrepancy between the values of parameter *b* for each trait measured in different breeds. This demonstrates the discrepancy between the rate of growth of the different parts of the animal body; some parts are larger at birth and grow somewhat as the time passes and others are smaller at birth and show great potential for growth. Other studies on allometric

Table V. Values f the integration constant (B) in locally adapted swine in Brazil (Valores da constante de integração (B) de suínos localmente adaptados no Brasil).

	BL	DD	EL	HL	HG	DI	ID	LH	LD	SH	SL	SnL	TL
Monteiro fêmea	48.81	193.95	199.3	9.962	4.409	77.13	63.05	22.09	9.085	22.56	12.31	22.07	20.09
Monteiro macho	55.81	37.66	458.0	15.86	6.302	79.98	79.98	23.08	10.93	28.59	11.51	22.25	21.96
Moura fêmea	76.21	68.80	105.8	17.87	6.569	140.7	132.1	27.92	12.09	77.24	15.69	26.47	—
Moura macho	83.51	68.20	110.3	20.89	8.342	148.3	138.8	35.49	14.81	61.95	20.90	29.08	—
Nilo	41.08	—	—	—	6.123	63.71	76.56	17.58	7.082	17.45	—	9.374	10.84
Piau fêmea	385.9	225.5	369.5	67.41	11.53	289.0	7269.7	1679.9	44.60	2246.0	37.75	1586.8	574.7
Piau macho	64.10	18.47	87.53	1023.1	23.38	139.4	252.8	41.05	16.34	40.44	396.0	36.71	30.26

BL= Body length; DD= Dorso-sternal distance; EL= Ear length; HL= Head length; HG= Heart girth; DI= Interisquiatic distance; ID= Interorbital distance; LH= Length of hip; LD= Longitudinal distance; SH= Shoulder height; SL= Shoulder length; SnL= Snout length; TL= Tail length.

Table VI. Values of maturity index (k) in locally adapted swine in Brazil (Valores de índice de maturidade (K) de suínos localmente adaptados no Brasil).

	BL	DD	EL	HL	HG	DI	ID	LH	LD	SH	SL	SnL	TL
Monteiro fêmea	0.004	0.0008	0.001	0.008	0.002	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.004
Monteiro macho	0.003	0.004	0.009	0.003	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.001
Moura fêmea	0.006	0.005	0.006	0.006	0.004	0.005	0.005	0.005	0.004	0.009	0.006	0.004	—
Moura macho	0.005	0.005	0.006	0.004	0.004	0.005	0.005	0.005	0.003	0.008	0.006	0.003	—
Nilo	0.004	—	—	—	0.005	0.003	0.004	0.003	0.003	0.003	—	0.003	0.008
Piau fêmea	0.008	0.005	0.005	0.004	0.004	0.004	0.008	0.008	0.003	0.008	0.004	0.008	0.007
Piau macho	0.001	0.002	0.001	0.0001	0.0005	0.001	0.0007	0.001	0.001	0.001	0.0002	0.0008	0.001

BL= Body length; DD= Dorso-sternal distance; EL= Ear length; HL= Head length; HG= Heart girth; DI= Interisquiatic distance; ID= Interorbital distance; LH= Length of hip; LD= Longitudinal distance; SH= Shoulder height; SL= Shoulder length; SnL= Snout length; TL= Tail length.

growth in locally adapted pigs were not found in the literature.

The K values **(table VI)** were generally higher for females, indicating that they reach adult measures earlier. This is in agreement with studies in other species, which also show that in adult female measures are reached sooner. Santos *et al.* (1999) studied the height growth curve for the Pantanal horse, obtaining a higher K value for females. In the comparison between breeds, Piau females had higher values for chest girth, head size, size of the muzzle, interisquitric distance and size of the tail. There was much discrepancy between the values obtained for males and females, and between breeds.

In general, body measurements usually develop later than the muzzle, and earlier in relation to the size of the head and hip height. The muzzle size is an early developing feature, while the body length is later developing. The animal is born with a big nose, compared to the proportion of body and head. These characteristics may be related to a lower body area when young to avoid heat loss. In contrast, the muzzle is of great importance in contact with the mother and feeding. Unlike other domestic animals, the pig uses its snout to look for food (Bright, 2012) and dig.

The development of body measurements is later on of muzzle size, and earlier in relation to the size of the head and hip height. When comparing breeds of pigs, the Moura breed females obtained characteristics linked to muscle growth (thoracic perimeter, body length and longitudinal diameter) later that the size of the head. Already Nile breed females showed the characteristics: size of the palette, size of the rump and distance interisquiática and earlier than the muzzle size The Moura breed showed little difference in K values between males and females. Overall, Moura reached adult measures earlier. This may be related to the fact that most of the breed are raised on farms in Rio Grande do Sul, Santa Catarina and Paraná States in fattening systems. The lowest K was found in the Monteiro, for both males and females, which reflects a greater time required to reach maturity.

According Albarella *et al.* (2009), geography is an important factor of phenotypic variation in boar ancestor of pigs. The same is true for domestic pigs. In this work, Brazilian naturalized pig breeds showed great variation in measurements between races and in general have: long ears with a mean of 16 cm; long snout with a mean of 12 cm; tail averaging 30 cm in length; average size of 35 cm back of the palette and such on average 30 cm. Adedeji (2012), in his work on characterization of Nigerian naturalized pigs, showed that in that country this animals have short ears 7 to 14 cm, long snout and straight averaging 14 cm, predominantly straight tail with a mean length of 15.05 cm for males and 19.37 cm for females, body length of 83.75 cm for males and 92.78 for females, and body circumference of 65.50 cm for males and 76.08 for females. Matiuti *et al.* (2010) conducted a study of phenotypic characterization of hybrids - pigs crossed with wild boar - in the Commune Bârzava (Romania). These animals have a long snout, a long, slightly concave and larger head than wild boar and the elbow height of about 88.7 cm. The animals ranged from 150 to 170 cm from head to tail. This demonstrates the there is wide divergence of evolution which resulted in the modern pig, and that there was an adaptation process to local environments, each with different eating patterns as well as edaphic and climatic conditions which result in different body measures as seen in the present study.

The measurements of length and width of the body as well as the parameters of non-linear growth curves may be useful indicators for the classification of breeds in terms of domestication. According to Albarella and Payne (2005) there was a decrease in some of the morphological measures in some domesticated mammals compared with their wild relatives, including the pig. However, Evin *et al.* (2013) argue that the shape and size of the teeth are the most reliable indicators to make these classifications, but this parameter is not taken into account in this study.

CONCLUSION

The Weibull function was best expressed the morphological growth of locally adapted pigs in Brazil. Differences were seen between sexes and breed and these should be taken into account when formulating management practices for the different breeds. These results can be used in conservation programs to define nutritional strategies and accompany development of breeding programs over time. With the advent of climate change these curves can also be used to monitor the development of locally adapted pigs countrywide and identify regions of greater impact.

ACKNOWLEDGMENT

To INCT Pecuária (MCT/FAPEMIG/CNPq), CNPq, and Propesq UFRGS for scholarship and funding.

Statement of interest. No conflicting interests were identified.

BIBLIOGRAPHY

Adedeji, T. 2012. Qualitative and quantitative characterization of body morphometric of indigenous pigs in the humid environment of Nigeria Continental . *J Anim Vet Res,* 4: 11-16.

Albarella, U. and Payne, S. 2005. Neolithic pigs from Durrington Walls, Wiltshire, England: a biometrical database. *J Archaeol Sci,* 32: 589-590.

Albarella, U.; Dobney, K. and Rowley-Conwy, P. 2009. Size and shape of the Eurasian wild boar *(Sus scrofa)*, with a view to the reconstruction of its Holocene history. *Environ Archaeol,* 14: 103-136.

Arthur, P.F.; Archer, J.A.; Johnston, D.J.; Herd, R.M.; Richardson, E.C. and Parnell, P.F. 2001. Genetic and phenotypic variance and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle. *J Anim Sci,* 79: 2805-2811.

Black, J.L.; Campbell, R.G., Williams, I.H.; James, K.J. and Davies, G.T. 1986. Simulation of energy and amino acid utilisation in the pig. *Res Develop Agricul,* 3: 121-145.

Bright, J.A. 2012. The importance of craniofacial sutures in biomechanical finite element models of the domestic pig. *PLoS ONE,* 7: 31769.

Brown, J.E.; Fitzhugh, H.A. and Cartwright, T.C. 1976. A comparison of nonlinear models for describing weight-age relationship in cattle. *J Anim Sci,* 42: 810-818.

Cavalcanti, S.S. 2000. Suinocultura dinâmica. Fep-Mvz Ed. Contagem. MG. Brasil. 494 pp.

Davidian, M. and Giltinan, D.M. 1996. Nonlinear models for repeated measurement data. 2 ed. Chapman Hall. London. 359 pp.

Draper, N.R. and Smith, H. 1980. Applied regression analysis. 2 ed. Wiley. New York. 709 pp.

Dutra Júnior, W.M.; Ferreira, S.; Donzele, J.L.; Euclydes, R.F.; Albino, L.F.T.; Cardoso, L.L. e Fernandes, S.P. 2001. Predição de curvas de crescimento de tecidos de fêmeas suínas por intermédio da função alométrica estendida. *Rev Sociedad Bras Zootecn,* 30: 1007-1014.

Egito, A.A.; Mariante, A.S. e Albuquerque, M.S.M. 2002. Programa brasileiro de conservação de recursos genéticos animais. *Arch Zootec,* 51: 39-52.

Evin, A.; Cucchi, T.; Cardini, A.; Vidarsdottir, U.; Larson, G. and Dobney, K. 2013. The long and winding road: identifying pig domestication through molar size and shape. *J Archaeol Sci,* 40: 735-743.

Fitzhugh, J. and Taylor, S. 1976. Genetic analysis of growth curves and strategies for altering their shape . *J Anim Sci*, 42: 1036-1051.

Freitas, A.R. e Costa, C.N. 1983. Ajustamento de modelos não lineares a dados de crescimento de suínos. *Pesq Agropec Bras,* 18: 1147-1154.

Freitas, A.R. 2005. Curvas de crescimento na produção animal. *Rev Bras Zootecn,* 34: 786-795.

Kielanowski, J. 1976. The chemical composition of the liveweight gain and the Performance of growing pigs. *Livest Prod Sci,* 3: 257-269.

Kshirsagar, A. and Smith, W.B. 1995. Growth curves. Marcel Dekker. New York. 359 pp.

Kusec, G.; Baulainb, U. ; Kallweitb, E. and Glodek, P. 2007. Influence of MHS genotype and feeding regime on allometric and temporal growth of pigs assessed by magnetic resonance imaging. *Livest Sci,* 110: 89-100.

Kvålseth, T.O. 1985. Cautionary note about R^2. *Am Statist,* 39: 279-285.

Lorenzo Bermejo, J.; Roehe, R.; Schulze, V.; Rave, G.; Looft, H. and Kalm, E. 2003. Random regression to model genetically the longitudinal data of daily feed intake in growing pigs. *Livest Prod Sci,* 82:189-199.

Mansour, H.; Jensen, E.L. and Johnson, L.P. 1991. Analysis of covariance structure of repeated measurements in Holstein conformation traits. *J Dairy Sci,* 74: 2757-2766.

Manzanilla, C.I.; Veerkamp, R.F.; Calus, M.P.; Zom, R.; van Knegsel, A.; Pryce, J.E. and De Haas, Y. 2014. Genetic parameters across lactation for feed intake, fat- and protein corrected milk, and live weight in first-parity Holstein cattle. *J. Dairy Sci,* 97: 5851-5862.

Mariante A.S. and Egito, A.A. 2002. Animal genetic resources in Brazil: result of five centuries of natural selection. *Theriogenology,* 57: 223-235.

Mariante, A.S. e Cavalacante, N. 2000. Animais do descobrimento: Raças domésticas da história do Brasil. Embrapa Recursos Genéticos e Biotecnologia. Brasilia. DF. 228 pp.

Matiuti, M.; Bogdan, A.; Crainiceanu, E. and Matiuti, C. 2010. Research regarding the hybrids resulted from the domestic pig and the wild boar. *Anim Sci Biotechnol,* 43: 89-91.

McManus, C.; Evangelista, C.; Fernandes, L.A.C.; Miranda, R.M.; Moreno-Bernal, F.E. e Santos, N.R. 2003. Curvas de crescimento de ovinos Bergamácia criados no Distrito Federal. *Rev Bras Zootecn,* 32: 1207-1212.

McManus, C.; Louvandini, H. and Campos, V.L. 2010a. Non-linear growth curves for weight and height in four genetic groups of horses. *Ciênc Anim Bras,* 11: 84-93.

McManus, C.; Paiva, S.R.; Silva, A.V.R.; Murata, L.S.; Louvandini, H.; Cubillos, G.P.B.; Castro, G.; Martínez, R.A.; Dellacasa, M.S.L. and Pérez, J.E. 2010b. Phenotypic characterization of naturalized swine breeds in Brazil, Uruguay and Colombia. *Braz Arch Biol Technol,* 53: 583-591.

Moughan, P.J.; Smith, W.C. and Pearson, G. 1987. Description and validation of a model simulating growth in the pig (20-90 kg liveweight). *NZ J Agric Res,* 30: 481-489.

Notter, D.R. 1998. The importance of genetic diversity in livestock populations of the future. *Anim Sci,* 77: 61-69.

Rodrigues, P.B.; Muniz, J.A. e Pereira, F.A.1992. Estudo comparativo de curvas de crescimento em suínos. *Ciênc Prática,* 16: 151-157.

Sandland, R.L. and McGilchrist, C.A. 1979. Stochastic growth curve analysis. *Biometrics,* 35: 255-271.

Santos, S.A.; Souza, G.S.; Oliveira, M.R. and Sereno, J.R.B. 1999. Using nonlinear models to describe height growth curves in Pantaneiro horses. *Pesq Agropec Bras,* 34: 1133-1138.

Sarmento, J.L.R.; Regazzi, A.J.; Souza, W.H.; Torres, R.A.; Breda, F.C. e Menezes, G.R.O. 2006. Estudo da curva de crescimento de ovinos Santa Inês. *Rev Bras Zootecn,* 35: 435-442.

Schnyder, U.; Hofer, A.; Labroue, F. and Kunzi, N. 2001. Genetic parameters of a random regression model for daily feed intake of performance tested French Landrace and Large White growing pigs. *Genet Sel Evol,* 33: 635.658.

Verbeke, G. and Molenberghs, G. 1997. Linear mixed models for longitudinal data. Springer Series in Statistics. Springer-Verlag. New-York.

Whittemore, C.T. 1983. Development of recommended energy and protein allowances for growing pigs. *Agri Systems,* 11: 159-186.