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Comparative evaluation between F1 (Duroc × Hampshire) and Moura in the growing and finishing phases

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ABSTRACT: The objective of this study was to evaluate the performance, allometric measurements, organ weight and intestinal morphometry of F1 (Duroc × Hampshire) and Moura pigs. For this purpose, 12 animals aged approximately 70 days were used, distributed in a randomized block design. The animals were housed individually in stalls with a compact floor, equipped with dummy-type drinking fountains and masonry feeders. The animals were slaughtered at 180 days of age. Crossbred animals had higher feed consumption in phase growth II and throughout finishing, higher weight gain in all phases, better feed conversion in the first three phases and higher carcass yield ($p < 0.05$). There was an effect ($p < 0.05$) for the allometric measurements. F1 pigs had a lower relative spleen weight, higher intestinal villus height, a better villus height/crypt depth ratio and a larger absorptive area in the duodenum than Moura pigs. It can be concluded that the F1 pigs had better intestinal parameters and a greater area of contact with the food, which probably had a positive effect on the zootechnical indices. And allometric measurements such as chest circumference can be used to estimate the live weight of animals in the growing and finishing phases.

Key words: crossbred pigs; genetic group; intestinal parameters; native race; productive efficiency

Avaliação comparativa entre suínos F1 (Duroc × Hampshire) e Moura nas fases de crescimento e terminação

RESUMO: Objetivou-se com este estudo avaliar o desempenho, medidas alométricas, peso de órgãos e a morfometria intestinal de suínos F1 (Duroc × Hampshire) e Moura. Para isso, foram utilizados 12 animais com aproximadamente 70 dias de idade, distribuídos em delineamento em blocos casualizados. Os animais foram alojados individualmente em baias com piso compacto, equipadas de bebedouros do tipo chupeta e comedouros de alvenaria. Aos 180 dias de idade os animais foram abatidos. Animais cruzados apresentaram maior consumo de ração nas fases de crescimento II e toda a terminação, maior ganho de peso em todas as fases, melhor conversão alimentar nas três primeiras fases e maior rendimento de carcaça ($p < 0,05$). Houve efeito ($p < 0,05$) para as medidas alométricas. Suínos F1 apresentaram menor peso relativo de baço, maior altura de vilosidades intestinais, melhor relação altura da vilosidade/profundidade de cripta e maior área absortiva no duodeno em relação aos da raça Moura. Conclui-se que os suínos F1 apresentaram melhores parâmetros intestinais e maior área de contato com o alimento, o que provavelmente refletiu positivamente nos índices zootécnicos. E as medidas alométricas como perímetro torácico podem ser utilizadas para estimar o peso vivo dos animais nas fases de crescimento e terminação.

Palavras-chave: suínos mestiços; grupo genético; parâmetros intestinais; raça nativa; eficiência produtiva

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Introduction

Brazilian pig farming plays a leading role on the world stage due to the constant advances made in the areas of nutrition, health, ambience and genetic improvement. For some years now, the national herd has been made up mainly of foreign or exotic breeds, imported from the beginning of the 20th century, including the products of crossbreeding between them and the so-called commercial lines. However, another genetic group makes up the national herd, consisting of national or native breeds (Araújo et al., 2020), essentially present in less intensive and/or subsistence production systems.

Among the best-known foreign breeds raised in Brazil are the Large White, Landrace, Duroc, Pietrain and Hampshire. Among the main national breeds are the Piau, Moura, Canastra, Caruncho, Nilo, Tatu, Pereira and Piratinga.

Foreign-bred pigs have high productive and reproductive potential, especially as a result of intense genetic improvement over the years. One example is Duroc pigs. These animals have coats ranging from dark brown to red-orange, which ensure greater resistance to UVB and UVA rays, which are more intense in hot climates, when compared to light-coated breeds such as Landrace and Large White (Ogawa et al., 2019). In addition, Duroc pigs stand out for their good precocity, especially with regard to productive performance characteristics (Zhang et al., 2019), which confers rapid growth.

Hampshire pigs have a black coat with a white stripe around the shoulder. They are medium-sized animals that have good carcass quality, with less fat deposition to the detriment of lean meat, good rusticity, and are preferably used in crossbreeding with other breeds (Ferreira, 2012).

Crossbreeding is defined as the mating of males and females of different breeds or strains to produce F1 pigs for slaughter (Figueiredo et al., 2023). The aim of crossbreeding is to take advantage of the effects of heterosis, i.e. the superiority of crossbred offspring in relation to the average of purebred parents, especially for low heritability traits such as survival and reproduction (Ferreira, 2012).

In turn, the main characteristics of national breeds are their rusticity, resistance to disease, lower health and nutritional management requirements and high adaptability. The Moura breed, for example, still stands out for the marbling fat in its meat, which guarantees good quality and palatability (Araújo et al., 2020), but they are late animals when compared to foreign breeds. In addition, national breeds are considered to be of the lard type because they have a small loin depth and a high fat cover (Demattê Filho et al., 2019).

In this context, the physiological particularities of these two genetic groups can explain their respective aptitudes and how the balance of the gastrointestinal tract and the maintenance of the integrity of the intestinal epithelium help in the process of nutrient utilization, directly reflecting on productive performance characteristics, lean meat deposition and those related to carcass yield, meat quality and reduced feed costs.

The aim of this study was to evaluate the performance, allometric measurements, weight of digestive and non-digestive organs, carcass characteristics and intestinal morphometry of F1 pigs (Duroc × Hampshire) compared to animals of the Moura breed.

Materials and Methods

The experimental trial was carried out in the Pig Farming Laboratory of the Animal Science Department of the Center for Human, Social and Agrarian Sciences of the Universidade Federal da Paraíba, Campus III, municipality of Bananeiras, Paraíba state, Brazil. Experimental protocol no. 3999060320 was approved by the Ethics Committee for the Use of Animals at the Universidade Federal da Paraíba.

Twelve animals were used, six surgically castrated males and six females, from the CCHSA Pig Farming Laboratory, six F1 (Duroc × Hampshire) and six of the Moura breed, with an average initial weight of 20 ± 2.6 kg and approximately 70 days of age. These were distributed in a randomized block design and divided into two treatments: Treatment 1 - F1 animals (Duroc × Hampshire) and Treatment 2 - animals of the Moura breed. The animals were housed individually in stalls with compact masonry floors, equipped with dummy-type drinking fountains and masonry feeders.

The experimental diets (Table 1) were formulated according to the recommendations of Rostagno et al. (2017) in order to meet the minimum nutritional needs of the pigs in the following phases: growth I (70 - 91 days of age); growth II (92 - 112 days of age); finishing I (113 - 140 days old); and, finishing II (141 - 180 days old). Throughout the experimental period, the animals were given water ad libitum and fed twice a day.

To assess performance, the animals were weighed at the start of the experiment and at the end of each production phase, the feed consumption of each animal was measured. To this end, the feed offered and the leftovers were weighed weekly. Weight gain and feed conversion were calculated. The performance results were evaluated over the following periods:

- Period I - from 74 to 93 days of age;
- Period II - from 74 to 116 days of age;
- Period III - From 74 to 151 days of age;
- Period IV - from 74 to 179 days of age.

At the end of each evaluation period, allometric measurements were taken using a tape measure, measuring areas of the skull, body and limbs of the animals at 14 points based on the descriptors proposed by Barba (2005). The points measured are described in Table 2, and the measurement diagram is shown in Figure 1.

At the end of the experimental period (180 days of age) the animals were fasted on solids for 12 hours and slaughtered at the Center for Human, Social and Agrarian Sciences Abattoir belonging to the Meat Products Research

Table 1. Centesimal composition of the experimental diets used[1] and calculated values of nutrients supplied.

Ingredients	Experimental diets			
	Growth I	Growth II	Finishing I	Finishing II
Corn bran	78.09	81.80	86.07	88.67
Soy bran	17.57	13.68	10.08	7.35
Bicalcium phosphate	1.25	1.04	0.91	0.85
Soy oil	0.85	0.85	0.50	0.50
Limestone	0.70	0.64	0.61	0.60
L-Lysine HCl	0.49	0.48	0.49	0.48
Salt	0.37	0.34	0.32	0.30
Vitamin Premix[2]	0.20	0.20	0.20	0.20
L-Threonine	0.17	0.16	0.15	0.14
DL-Methionine	0.11	0.08	0.08	0.06
Mineral Premix[3]	0.10	0.10	0.10	0.10
L-Tryptophan	0.05	0.06	0.06	0.06
Inert[4]	0.00	0.51	0.39	0.62
Total	100.00	100.00	100.00	100.00
Calculated values (%)				
Metabolizable energy (Mcal/kg)	3.25	3.25	3.25	3.25
Crude protein	15.41	13.93	12.66	11.62
Calcium	0.66	0.57	0.52	0.49
Available phosphorus	0.32	0.28	0.25	0.24
Digestible tryptophan	0.19	0.17	0.16	0.14
Digestible lysine	0.96	0.87	0.80	0.73
Digestible methionine	0.33	0.29	0.27	0.24
Digestible methionine + cystine	0.57	0.51	0.48	0.44
Digestible threonine	0.62	0.56	0.52	0.47

[1] Nutritional values obtained from the ingredients were recommended by Rostagno et al. (2017). [2] Vitamin Premix: vitamin A - 4,000 IU; vitamin D3 - 220 IU; vitamin E - 22 mg; vitamin K - 0.5 mg; vitamin B2 - 3.75 mg; vitamin B12 - 20 mg; calcium pantothenate - 12 mg; niacin - 20 mg; choline - 400 mg. [3] Mineral Premix: iodine - 140 µg; selenium - 300 µg; manganese - 10 mg; zinc - 100 mg; copper - 10 mg; iron - 99 mg. [4] Washed sand.

Table 2. Description of the allometric measurements taken on the experimental animals.

Allometric measurements	Measuring zone
BL - Body length	Distance between occipital base and coccygeal vertebra
CW - Croup width	Distance between the external iliac tuberosities
CH - Croup height	Measured between the ground and the highest point of the lumbosacral transition
LL - Leg length	Measured from the tip of the iliac tuberosity to the conversion tip
WH - Withers height	Measured from the highest point of the withers to the ground
PL - Palette length	Measured from the point of the withers to the elbow
HL - Head length	Measured from the snout to the external occipital protuberance
HW - Head width	Measurement between the zygomatic and temporal apophyses
EL - Ear length	Distance between the center point of the base of the ear and the vertex
EW - Ear width	Distance between the widest and shortest base edges
SP - Shin perimeter	Measure around the middle third of the metacarpal bone
AP - Abdominal perimeter	Measured in the region of the iliac tuberosity
TP - Thoracic perimeter	Measured in the region of the slope of the withers
NP - Neck perimeter	Measured in the cervical region of the neck

and Development Laboratory. The animals were stunned by electronarcosis with a voltmeter adjustable between 350 and 750 volts, and then bled vertically via the jugular vein for 3 minutes. All the slaughter procedures were carried out in accordance with the principles of humane slaughter, as described by the Ministério da Agricultura Pecuária e Abastecimento (MAPA) and the regulations of the Conselho Nacional de Controle e Experimentação Animal (CONCEA).

Immediately after slaughter, the animals were eviscerated to measure the weights of the spleen, lungs, kidneys, heart, liver, pancreas, stomach, small, and large intestines (full and empty), the length of the small and large intestines and the collection of small intestine segments. With this data, the relative weights of the organs in relation to the live weight of the animals were calculated.

The carcasses were then sawn in half and weighed immediately afterwards to obtain the hot carcass weight, and after 24 hours in a refrigeration chamber (5 °C) the carcasses were weighed to obtain the cold carcass weight. The calculation of carcass yield was based on the animal live weight before slaughter and the weight of the eviscerated hot carcass.

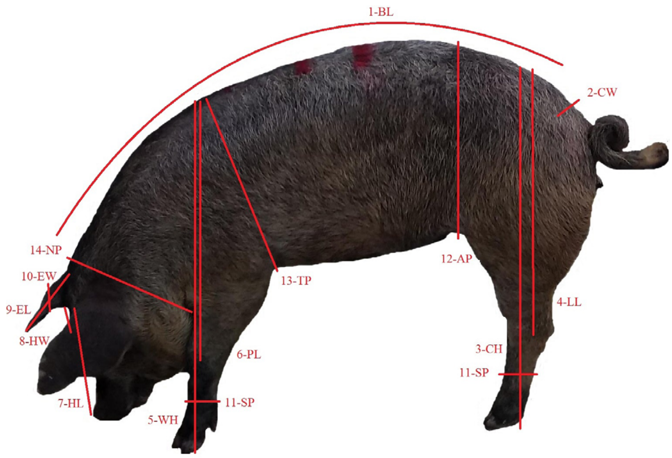

Figure 1. Diagram illustrating the allometric measurements taken on the animals during the experimental period. 1 - BL: Body length; 2 - CW: Croup width; 3 - CH: Croup height; 4 - LL: Leg length; 5 - WH: Withers height; 6 - PL: Palette length; 7 - HL: Head length; 8 - HW: Head width; 9 - EL: Ear length; 10 - EW: Ear width; 11 - SP: Shin perimeter; 12 - AP: Abdominal perimeter; 13 - TP: Thoracic perimeter; 14 - NP: Neck perimeter.

For intestinal morphometry, samples of approximately 1 cm were taken from the duodenum and jejunum. The intestinal segments were fixed in Metacarn solution (containing 60% methanol, 30% chloroform and 10% acetic acid) for twelve hours and kept refrigerated, after which they were soaked in a 70% alcohol solution. The samples were taken to the Histology Laboratory of the Agricultural Sciences Center/Universidade Federal da Paraíba, Campus II, in the municipality of Areia, Paraíba state, Brazil. They were then dehydrated in increasing series of alcohols and passed through a battery of xylol and, at the end of this stage, embedded in paraffin. The paraffin blocks were then microtomized to make the histological slides.

The slides were stained using Periodic-acid reactive Schiff (P.A.S.) + hematoxylin to measure the variables of villus height (VH), crypt depth (CD), and villus width (VW). Once the data was available, the villus height/crypt depth ratio (VH/CD) and the absorptive area (AA) were calculated by multiplying the villus height by its width. To measure the intestinal variables, 4 photomicrographs were taken (with a 20× objective) per animal, with 3 measurements in each one, totaling 12 measurements per animal and 72 measurements per treatment. Photomicrographs of the histological slides were taken using an Olympus BX53 light microscope and a Zeiss Axion camera, coupled with the Cellsens Dimension digital image capture program. The measurements were taken using ImageJ, a specific program for image processing.

The observed data was subjected to analysis of variance using the GLM (General Linear Models) procedure and the means were compared using Student T-test. Pearson correlation analysis was carried out between allometric measurements and the animals live weight. All data was analyzed using SAS Universtity (2018) statistical software, and the data was considered significant at 5%.

Results and Discussion

The performance data is described in Table 3.

The Moura breed animals had lower ($p < 0.05$) daily feed consumption values for phases growth II, finishing I, and finishing II when compared to the F1 animals. However, this was not reflected in production efficiency, since the F1 animals from the Hampshire × Duroc crossbreed showed higher ($p < 0.05$) daily weight gains in all the phases studied and better ($p < 0.05$) feed conversion values in the first three phases.

The carcass yield and final weight of the F1 animals were higher ($p < 0.05$) than those of the Moura breed, maintaining the same behavior seen for the performance data, since they are correlated.

The Moura breed showed worse production indices than the F1 animals (Hampshire × Duroc), as shown in Table 3, and this can be explained by the lower selection pressure that occurred in the Moura breed, and because it is a lard-type genetic material that performs well in reproductive aspects, but it is observed that in production data, they are inferior to meat-type animals, with low daily weight gain, poor feed conversion and low carcass quality (Figueiredo et al., 2023). Furthermore, animals crossed between two breeds increase the degree of heterosis like the breeds crossed in the experiment, and one breed complements the other in terms of better growth rate, feed conversion and lean meat yield, increasing production gains without increasing production costs (Barbosa & Crocomo, 2022).

The new breeds have better production rates and a final product that meets the demands of today consumer market, while the native breeds no longer reflect the genetic reality of today pig farming. However, native breeds have tenacity,

Table 3. Performance and carcass yield of crossbred pigs (Duroc × Hampshire) compared to Moura breed pigs.

Variables	Genetic group		P-value[1]	SEM[2]
	Duroc × Hampshire	Moura		
Growth I				
DFC, kg	1.64	1.58	0.56	0.196
DWG, kg	0.90a	0.69b	0.001	0.072
FD	1.82b	2.3a	0.022	0.304
Growth II				
DFC, kg	1.99a	1.74b	0.01	0.132
DWG, kg	0.9a	0.66b	<0.001	0.046
FD	2.23b	2.67a	0.002	0.172
Finishing I				
DFC, kg	2.29a	2.02b	0.009	0.135
DWG, kg	0.89a	0.68b	<0.001	0.048
FD	2.58b	2.98a	0.001	0.133
Finishing II				
DFC, kg	2.38a	2.13b	0.016	0.148
DWG, kg	0.84a	0.69b	0.001	0.052
FD	2.85	3.07	0.099	0.204
CY	81.91a	77.46b	0.033	3.073
FW, Kg	109.11a	95.13b	<0.001	0.039

DFC: Daily feed consumption; DWG: Daily weight gain; FD: Feed conversion; CY: Carcass yield; FW: Final weight; [1] Averages on the same line followed by different letters differ ($p < 0.05$) by Student's T-test. [2] Standard error of the mean.

disease resistance, low feed requirements, high adaptability, and offer differentiated products on the market (Juliatto, 2016).

Although the gender variable was not analyzed, it is worth noting that castrated males are more precocious than females, depositing adipose tissue earlier. Whole male pigs are the last to deposit adipose tissue and have a higher proportion of muscle tissue, so it is clear that the sex of pigs is a determining factor in performance and quantitative carcass characteristics (Moreira, 2022).

Females have a higher hot carcass yield than immunocastrated males, which in turn have a higher yield than castrated males. Immunocastrated females and males have a higher percentage of lean meat than castrated males (Moraes et al., 2010).

However, comparing castrated males and females during phases finishing I and II, it was observed that males had higher feed consumption than females, as well as higher daily weight gain ($p < 0.01$) (Moreira, 2022).

The values related to the animals allometric measurements taken throughout the experimental period can be seen in Tables 4 and 5.

It can be seen that in phase growth I there was an effect ($p < 0.05$) of the genetic groups for the variables of ear length (EL), ear width (EW), body length (BL), palette length (PL), croup height (CH), and leg length (PLL), in which the animals of the Moura breed obtained higher values. As for the croup width (CW) and thoracic perimeter (TP) variables, the F1 animals had higher values.

For phase growth II, the variables of ear length (EL), ear width (EW), and thoracic perimeter (TP) were influenced ($p < 0.05$) by the genetic groups, with EL and EW being greater for Moura breed pigs and TP being greater for F1 animals.

In the phase finishing I, there was an effect ($p < 0.05$) of the genetic groups on ear length (EL) and ear width (EW), in which the animals of the Moura breed obtained higher values. The F1 pigs had higher values for the variables

Table 4. Allometric measurements (cm) of crossbred pigs (Duroc × Hampshire) compared to Moura breed pigs in phases growth I and II.

Variables	Genetic group		P-value[1]	SEM[2]
	Duroc × Hampshire	Moura		
	Growth I			
HL	20.92	20.92	1	0.933
EL	13.17b	15.67a	<0.001	0.77
EW	10.67b	12.92a	<0.001	0.411
HW	10.5	10.58	0.823	0.625
BL	85.17b	90.67a	0.001	1.808
WH	45.67	46.33	0.36	1.198
PL	22.83b	25.25a	0.003	1.064
CH	51.25b	54.17a	0.002	1.21
LL	34.08b	37.17a	0.016	1.811
CW	19.92a	18.33b	0.002	0.654
SP	14.42	13.92	0.105	0.481
TP	77.25a	72b	0.006	2.564
AP	74.42	72.17	0.189	2.739
NP	58	56.75	0.28	1.881
	Growth II			
HL	22.33	21.33	0.105	0.962
EL	14.67b	16.83a	0.001	0.822
EW	13.17b	14.75a	0.001	0.595
HW	13	12.5	0.293	0.776
BL	97.83	99.67	0.507	4.596
WH	54	50.17	0.056	3.032
PL	30.17	27.33	0.066	2.343
CH	56.5	59.67	0.124	3.233
LL	37.33	38.33	0.684	4.114
CW	25.5	24.33	0.591	3.622
SP	18.75	16.92	0.066	1.518
TP	93.67b	85.33b	0.003	3.485
AP	89	88.67	0.905	4.714
NP	71.17	67.83	0.053	2.589

HL: Head length; EL: Ear length; EW: Ear width; HW: Head width; BL: Body length; WH: Withers height; PL: Palette length; CH: Croup height; LL: Leg length; CW: Croup width; SP: Shin perimeter; TP: Thoracic perimeter; AP: Abdominal perimeter; NP: Neck perimeter. [1] Averages on the same line followed by different letters differ ($p < 0.05$) by Student T-test. [2] Standard error of the mean.

Table 5. Allometric measurements (cm) of crossbred pigs (Duroc × Hampshire) compared to Moura breed pigs in phases finishing I and II.

Variables	Genetic group		P-value[1]	SEM[2]
	Duroc × Hampshire	Moura		
	Finishing I			
HL	24	23.33	0.549	1.856
EL	16.83b	17.92a	0.048	0.818
EW	15.83b	17a	0.005	0.553
HW	15.33	14.5	0.13	0.866
BL	116.33	115.83	0.803	3.368
WH	61.5	60.83	0.644	2.411
PL	34.33a	30.5b	0.019	2.327
CH	68.83a	66.33b	0.035	1.745
LL	46.5	43.83	0.152	2.95
CW	30.67a	25.5b	<0.001	1.566
SP	21.83	21.17	0.531	1.774
TP	107.5a	98.42b	0.001	3.3
AP	105.17	101.5	0.121	3.708
NP	79.83	77.42	0.179	2.874
	Finishing II			
HL	23.83	25	0.188	1.417
EL	16.92b	19a	0.003	0.883
EW	15.33b	16.83a	0.032	1.023
HW	14.92	15.67	0.281	1.131
BL	118.17	120.42	0.238	3.083
WH	66	64.17	0.274	2.723
PL	35.5a	31.33b	0.004	1.908
CH	72.67	72	0.708	2.981
LL	47	48.83	0.214	2.375
CW	31.33a	27.83b	0.001	1.251
SP	18.75	16.92	0.066	1.518
TP	93.67b	85.33b	0.003	3.485
AP	89	88.67	0.905	4.714
NP	71.17	67.83	0.053	2.589

HL: Head length; EL: Ear length; EW: Ear width; HW: Head width; BL: Body length; WH: Withers height; PL: Palette length; CH: Croup height; LL: Leg length; CW: Croup width; SP: Shin perimeter; TP: Thoracic perimeter; AP: Abdominal perimeter; NP: Neck perimeter. [1] Averages on the same line followed by different letters differ ($p < 0.05$) by Student T-test. [2] Standard error of the mean.

palette length (PL), croup height (CH), croup width (CW), and thoracic perimeter (TP).

As expected and similarly, there was an effect ($p < 0.05$) of the genetic groups in phase finishing II (final evaluation phase), with Moura animals maintaining ear length (EL) and ear width (EW). On the other hand, palette length (PL), croup width (CW), and thoracic perimeter (TP) remained higher in F1 animals.

With the results obtained from the allometric measurements, Pearson correlation was made with the animal live weight. Among the correlations made, the one that showed the greatest margin of accuracy was the correlation of thoracic perimeter (TP) with the animal live weight (LW), as can be seen in Table 6.

In Figure 2 we can see that there is a high positive correlation between the chest girth and the live weight of the animals, which means that we can use this measurement to estimate the live weight of the animals using only a tape measure.

The difference observed in the ears may have been affected by the Asian ear type of the Hampshire breed and inherited these characteristics to the crossbred pigs used in the experiment. Differences in ear length and width may not be important for animal production, but they are directly linked to racial characterization (Juliatto, 2016).

Table 6. Correlation of measurements (cm) with the live weight of the animal (kg).

Correlation matrix				
Variables	BL	TP	AP	NP
TP	0.886	__		
	<0.0001			
AP	0.92	0.947	__	
	0.905	0.953	0.957	__
NP	0.905	0.953	0.957	__
	<0.0001	<0.0001	<0.0001	
LW	0.91	0.966	0.931	0.943
	<0.0001	<0.0001	<0.0001	<0.0001

Cell content: Pearson correlation; P-value. BL: Body length; TP: Thoracic perimeter; AP: Abdominal perimeter; NP: Neck perimeter; LW: Live weight of the animal.

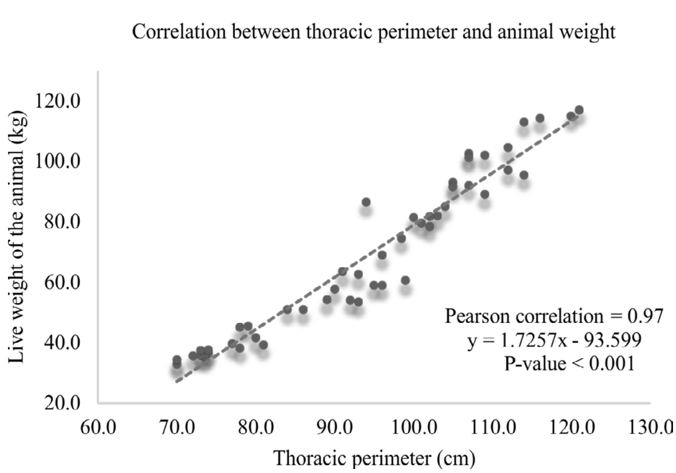

Figure 2. Correlation between thoracic perimeter and live weight of the animal.

The animals in the experiment were close in their other allometric measurements, since the Moura breed does not differ from some of the characteristics of the exotic breeds, but they do have their qualitative phenotypic characteristics for the breed to fit into. Allometric measurements are used to try to mitigate the loss of genetic resources in the pig species, and the conservation and recording of genetic characteristics has been carried out by some centers in Brazil (Juliatto, 2016).

The result of the correlation between the thoracic perimeter found in this work shows a strong correlation, and shows that it is possible to use this variable in mathematical methods that establish the live weight of animals based on allometric measurements, since it has a high degree of reliability. In his work with native breed pigs, Cruz (2019) also found a higher correlation between this analyzed variable and the live weight of animals. This correlation can be a viable alternative for obtaining animal weights on farms that do not have mechanical or digital scales, due to the high price and mobility of this equipment, as well as the fact that it does not interfere with animal handling, avoiding stress and bruising.

According to the results, there was no influence ($p > 0.05$) of the genetic groups on the relative weight of the digestive organs: liver, pancreas, full and empty stomach, full and empty small and large intestines, nor on the length of the latter (Table 7).

There was an effect ($p < 0.05$) of the genetic groups on the relative weight of the spleen. However, there was no influence ($p > 0.05$) on the other non-digestive organs analyzed: lungs, heart, and kidneys (Table 8).

The spleen has important functions in the body, including the formation of blood cells, iron recycling, blood filtration and storage, phagocytosis and acting in the immune response (Santos et al., 2015). The greater relative weight of the spleen could probably be a reflection of the immune system of the Moura animals, in order to fight off any possible infection caused by pathogenic microorganisms or antigens that are often associated with the ingredients in the diet, as well as the fact that they are known to be more hardy

Table 7. Relative weight of digestive organs and intestinal length of F1 pigs (Duroc × Hampshire) compared to Moura breed pigs.

Variables	Genetic group		P-value[1]	SEM[2]
	Duroc × Hampshire	Moura		
Liver	1.57	1.56	0.947	0.17
Pancreas	0.16	0.18	0.379	0.05
Full stomach	1.05	1.08	0.871	0.29
Empty stomach	0.61	0.67	0.193	0.08
Full small intestine	2.52	2.79	0.283	0.42
Empty small intestine	1.71	1.92	0.227	0.15
Full large intestine	3.98	3.76	0.599	0.69
Empty large intestine	2.11	2.46	0.086	0.31
Small intestine length (m)	16.77	15.58	0.233	1.62
Large intestine length (m)	5.35	4.85	0.271	0.74

[1] Averages on the same line followed by different letters differ ($p < 0.05$) by Student T-test. [2] Standard error of the mean.

Table 8. Relative weight of non-digestive organs in F1 pigs (Duroc × Hampshire) compared to Moura breed pigs.

Variables	Genetic group		P-value[1]	SEM[2]
	Duroc × Hampshire	Moura		
Lungs	0.61	0.64	0.726	0.14
Heart	0.41	0.42	0.744	0.04
Kidneys	0.34	0.34	0.939	0.04
Spleen	0.18b	0.28a	0.017	0.03

[1] Averages on the same line followed by different letters differ ($p < 0.05$) by Student T-test. [2] Standard error of the mean.

animals, and therefore may have a more robust and resistant immune system, although this hypothesis needs further in-depth studies to be confirmed.

The results for the organs evaluated are in line with those found in the literature (Nascimento et al., 2020) for pigs of a similar age and weight to those used in this experiment. However, variations between the values of the organs analyzed and those in the literature may be due to factors such as: diet composition, age of the animals, slaughter weight and the genetic group used.

There was probably no influence of the genetic groups on the weight of almost all the organs evaluated due to the fact that the variation in organ weights, especially digestive organs, is directly related to the composition of the diets, especially the energy and protein content, indicating that, if provided in equal quantities, the weights tend to be similar (Oliveira et al., 2021).

In this respect, the consumption of low-protein diets supplemented with synthetic amino acids affected the weight of the gastrointestinal tract, but not that of the liver, kidneys, pancreas, and heart of growing pigs (Oliveira et al., 2021).

With regard to energy sources, we can mention fibers, while some sources and/or types of fibers, when they are not completely digested by the enzymes present in the gastrointestinal tract, can affect the physical characteristics of the contents of the intestine, with possible changes in the morphology of the organs that participate in the digestion process (Gomes et al., 2006).

In a study using non-genetically improved crossbred pigs, the authors only observed an increase in the gastrointestinal tract and empty stomach of the animals that consumed the fibrous diet, with no significant changes in the other organs evaluated (Gomes et al., 2006). However, when replacing up to 24% of corn with babassu meal, other authors found no difference ($p > 0.05$) in the relative weight of the organs evaluated (Gomes et al., 2020).

Figure 3 shows the villi and intestinal crypts in the duodenum and jejunum of the respective genetic groups evaluated.

There was an influence ($p < 0.05$) of the genetic groups on the intestinal morphometry variables in the duodenum. It was observed that F1 animals (Duroc × Hampshire) showed greater villus height, greater absorptive area and a better villus height/crypt depth ratio when compared to Moura pigs. There was no effect ($p > 0.05$) for the villus width

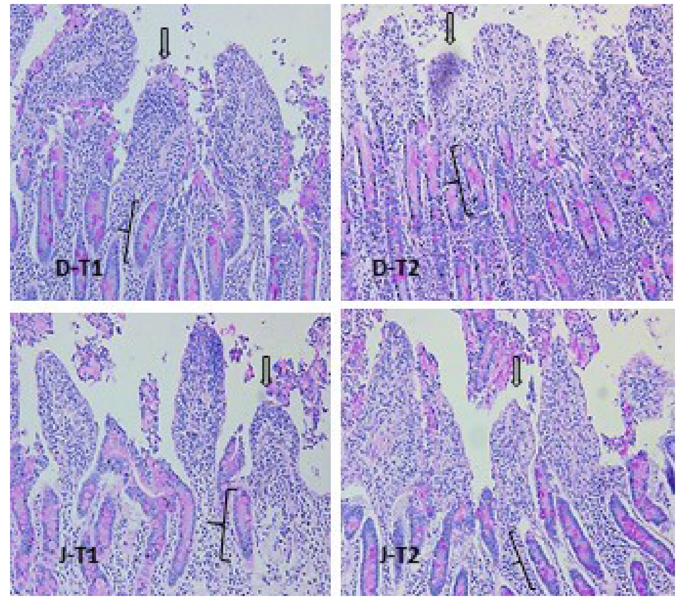

Figure 3. Photomicrographs of cross-sections of the wall of the small intestine, duodenum, and jejunum. You can see the intestinal villi (arrow) and the crypts of Lieberkühn (keys). DT1 - Duodenum of F1 pigs (Duroc × Hampshire); DT2 - Duodenum of Moura pigs; JT1 - Jejunum of F1 pigs (Duroc × Hampshire); JT2 - Jejunum of Moura pigs. 200× magnification. Periodic-acid reactive Schiff (P.A.S.) staining.

and crypt depth variables. The different genetic groups did not influence ($p > 0.05$) the morphometric variables in the jejunum (Table 9).

The size of the intestinal villi is directly proportional to the processes of digestion and absorption of nutrients, so the larger the villi, the greater the capacity for these processes, since the brush borders are where the intestinal digestive enzymes are produced (Nunes, 2017), so larger villi means a larger contact surface area for the absorption of nutrients and, consequently, more energy for productive and reproductive processes.

In turn, the decrease in the height of the intestinal villi may be due to an increase in the rate of desquamation of the epithelium, resulting from the proliferation of pathogenic

Table 9. Morphometric parameters of F1 pigs (Duroc × Hampshire) compared to Moura breed pigs.

Variables	Genetic group		P-value[1]	SEM[2]
	Duroc × Hampshire	Moura		
		Duodenum		
Villus height	243.19a	218.84b	0.007	53.36
Villus width	112.7	109.12	0.395	28.98
Crypt depth	120.31	127.96	0.529	49.44
Vilo/crypt ratio	2.17a	1.72b	0.002	1.02
Absorptive area	27144.76a	23863.30b	0.017	8916.03
		Jejunum		
Villus height	225.39	226.32	0.891	58.44
Villus width	104.31	106.47	0.59	29.88
Crypt depth	128.99	131.97	0.605	45.04
Vilo/crypt ratio	1.81	1.72	0.233	0.89
Absorptive area	23418.61	24434.13	0.597	11372.75

[1] Averages on the same line followed by different letters differ ($p < 0.05$) by Student T-test. [2] Standard error of the mean.

microorganisms; or it may also be related to changes in the depth of the crypts as a compensatory mechanism to ensure the turnover of cells, especially in the apical region (Oetting et al., 2006). In addition, the composition of the diet can play a fundamental role in modifying intestinal transit and enzymatic activity, which can reflect on the morphology of the intestinal epithelium.

The use of fruit waste (e.g. pineapple and mango) as a source of fiber in the diets of finishing pigs promoted a decrease in villus height when compared to animals that did not consume such waste (Oliveira, 2015). In this context, the recovery of the epithelium depends on changes in management, nutrition and, if necessary, therapeutic interventions.

Although villus height and crypt depth are parameters for analyzing the intestinal mucosa, the ratio between these two variables is a more accurate parameter for verifying the integrity and health of the intestinal mucosa. Thus, the higher the villus height/crypt depth ratio, the better the integrity and health of the intestinal epithelium (Almeida et al., 2021) and, consequently, there will be a greater area for absorbing nutrients and lower energy losses for cell renewal.

The differences observed in the parameters related to intestinal integrity, in which the F1 animals (Duroc × Hampshire) were superior to the Moura breed, may probably be related to the intense genetic improvement over the years, reflecting the balance of the gastrointestinal tract and the maintenance of the integrity and health of the intestinal epithelium.

Conclusions

F1 pigs (Duroc × Hampshire) showed better integrity and health of the intestinal epithelium and greater contact area with the food, which probably reflected positively on the performance indices evaluated. Allometric measurements such as body length, thoracic perimeter, abdominal perimeter and neck perimeter have a positive correlation with the live weight of Moura pigs and can be used to estimate the live weight of animals during the growth and finishing phases.

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Compliance with Ethical Standards

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Literature Cited

Almeida, J.M.S.; Pascoal, L.A.F.; de Almeida, J.L.S.; Guerra, R.R.; Da Silva, J.H.V.; Silva, D.R.P.; Silva Neto, M.R.; Martins, T.D.D. Effects of dietary L-glutamine and glutamic acid combination, and whey powder on the performance and nutrient digestion in weaned piglets fed grain-based diets. Animal Bioscience, v. 34, n. 12, p.1963-1973, 2021. https://doi.org/10.5713/ab.20.0613.

Araújo, G.G.A.; Valentim, J.K.; Marques, O.F.C.; Lopes, I.M.G.; Souza, J.P.; Maciel; F. R.; Silva, B.A.N. Potencialidades e valorização da raça de suíno nativo Piau no contexto dos assentamentos de reforma agrária. RealizAção, v. 7, n. 13, p.145-154, 2020. https://doi.org/10.30612/realizacao.v7i13.11517.

Barba, C. J. Caracterización morfológica y productiva. In: Curso internacional de especializacion sobre la conservacion y utilizacion de las razas de animales domésticos locales em sistemas de explotacion tradicionales, 5., 2005, Córdoba. Córdoba: CYTED, 2005. DVD.

Barbosa, N.P.M.O.; Crocomo, L.F. Influência da genética e dos métodos de conservação sobre a qualidade do sêmen suíno. Ciência Animal, v. 32, n. 1, p. 115–130, 2022. https://revistas.uece.br/index.php/cienciaanimal/article/view/9453. 29 Mar. 2023.

Cruz, M.S. Estimativa de peso vivo por meio de medidas corporais de suínos de raças nativas. Recife: Universidade Federal Rural de Pernambuco, 2019. 39 p. Master's Dissertation. https://repository.ufrpe.br/handle/123456789/984. 19 Apr. 2023.

Demattê Filho, L.C.; Pereira, D.C.O.; Pereira, G. V. Produção e mercado de suínos com atributos de qualidade difereciada - Criação de cadeias de valor. Brazilian Journal of Animal and Environmental Research, v. 2, n. 5, p. 1624–1641, 2019. https://ojs.brazilianjournals.com.br/ojs/index.php/BJAER/article/view/3351. 22 Apr. 2023.

Ferreira, R. A. Suinocultura: manual prático de criação. 1.ed. Viçosa: Aprenda Fácil, 2012. 443p.

Figueiredo, E.A.P.; Costa, O.A.D.; Coldebela, A.; Bertol, T.M. Desempenho reprodutivo de porcas de genótipos para sistemas convencionais e alternativos de produção. Brazilian Journal of Animal and Environmental Research, v. 6, n. 2, p.985–1000, 2023. https://doi.org/10.34188/bjaerv6n2-005.

Gomes, J.D.F.; Fukushima, R. S.; Grossklaus, S.M.P.C. Efeitos do incremento da fibra em detergente neutro na dieta de suínos sobre a morfologia dos órgãos digestivos e não digestivos. Brazilian Journal of Veterinary Research and Animal Science, v. 43, n. 2, p. 202-209, 2006. https://doi.org/10.11606/issn.1678-4456.bjvras.2006.26500.

Gomes, P.E.B.; Lopes, J.B.; Moreira, E.M. S.C.; Merval, R.R.; Ribeiro, M.N.; Albuquerque, D.M. de N.; Segundo, B.L. de M.; Moreira Filho, M.A.; Lemos, J.G.S. de. Farelo de babaçu em dietas para suínos mestiços. Brazilian Journal of Animal and Environmental Research, v. 3, n. 3, p.1515–1524. 2020. https://doi.org/10.34188/bjaerv3n3-068.

Juliatto, R.P.M.M. Caracterização fenotípica de suínos remanescentes da raça Moura. Curitiba: Universidade Federal do Paraná, 2016. 69p. Master's Dissertation. http://hdl.handle.net/1884/43372. 21 Apr. 2023.

Moraes, E.; Kiefer, C.; Silva, I. S. Ractopamina em dietas para suínos machos imunocastrados, castrados e fêmeas. Ciência Rural, v. 40, n. 2, p. 409-414, 2010. https://doi.org/10.1590/S0103-84782010000200023.

Moreira, V.S. Efeito da suplementação de extrato vegetal com minerais e da ractopamina sobre o desempenho e qualidade da carne de suínos. Pirassununga: Universidade de São Paulo, 2022. 56 p. Master's Dissertation. https://doi.org/10.11606/D.74.2022.tde-27022023-151834.

Nascimento, C.L.M.M.; Dutra Junior, W.M.; Rabello, C.B.V.; Ludke, M.C.M.M.; Nascimento, G.R.; Palhares, L.O. Desempenho e características de carcaças de fêmeas suínas alimentadas com farelo de algodão. Arquivos de Ciências Veterinárias e Zoologia da UNIPAR, Umuarama, v. 23, n. 1cont., e2302, 2020. https://doi.org/10.25110/arqvet.v23i1cont.2020.7194.

Nunes, A.N. Valor nutritivo, energia líquida de dietas e morfometria intestinal de suínos alimentados com níveis crescentes de casca de soja. Belo Horizonte: Escola de Veterinária da Universidade Federal de Minas Gerais, 2017. 181p. Doctoral Thesis. http://hdl.handle.net/1843/BUOS-ARBFZA. 20 Apr. 2023.

Oetting, L.L.; Utiyama, C.E.; Giani, P.A.; Ruiz, U.S.; Miyada, V.S. Efeitos de extratos vegetais e antimicrobianos sobre a digestibilidade aparente, morfometria e histologia intestinal de leitões recém-desmamados. Revista Brasileira de Zootecnia, v.35, n.4, p.1389-1397, 2006. https://doi.org/10.1590/S1516-35982006000500019.

Ogawa, S.; Konta, A.; Kimata, M.; Ishii, K.; Uemoto, Y.; Satoh, M. Estimation of genetic parameters for farrowing traits in purebred Landrace and Large White pigs. Animal Science Journal, v. 90, n. 1, p. 23–28. 2019. https://doi.org/10.1111/asj.13120.

Oliveira, A.C. Resíduo do abacaxi e da manga na restrição alimentar qualitativa em dietas de suinos em terminação. Areia: Universidade Federal da Paraíba, 2015. 104p. Doctoral Thesis. https://repositorio.ufpb.br/jspui/handle/123456789/26152. 19 Apr. 2023.

Oliveira, E.R.A.; Martins, T.D.; Thomaz, M.C.; Pascoal, L.A.F.; Silva, J.H.V.; Silva, T.R.G.; Brito, M.S.; Almeida, J.M.S.; Almeida, J.LS. Use of biofermented plants adapted to the semi-arid region in piglets diets. Revista Brasileira de Saúde e Produção Animal. v.22, e2122072021, 2021 https://doi.org/10.1590/S1519-99402122072021.

Rostagno, H.S.; Albino, L.F.T.; Hannas, M.I.; Donzele, J.L; Sakomura, N.K.; Perazzo, F.G.; Saraiva, A.; Teixeira, M.L.; Rodrigues, P.B.; Oliveira, R.F.; Barreto, S.L.T; Brito, C.O. Tabelas Brasileiras para Aves e Suínos: composição dos alimentos e exigências nutricionais. 4.ed. Viçosa: UFV, 2017. 448p.

Santos, A.L.Q.; Vieira, L.G.; Hirano, L.Q.L.; Kaminishi, Á.P.S.; Mendonça, J.S.; Rodrigues, T.S.; Siqueira, S.E. Estudo da vascularização arterial do baço em javalis (*Sus scrofa scrofa*, linnaeus - 1758). Pubvet, v. 7, n. 10, e1540, 2015. https://doi.org/10.22256/pubvet.v7n10.1540.

Statistical Analysis System Institute - SAS. SAS users guide: statistics. Cary: SAS, 2018. 956p.

Zhang, Z.; Chen, Z.; Ye, S.; He, Y.; Huang, S.; Yuan, X.; Chen, Z.; Zhang, H.; Li, J. Genome-wide association study for reproductive traits in a Duroc pig population. Animals, v. 9, n.10, e732, 2019. https://doi.org/10.3390/ani9100732.