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ANIMAL PRODUCTION

Morada Nova lambs' meat production potential description through morphometric evaluation

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ABSTRACT: Morada Nova breed has a low effective herd, and its white variety is in risk of extinction. The selection of individuals based on breed standard without correlation with productive aptitude is predominant today. We believe that the best way to rescue this valuable genetic resource is to describe its productive potential for commercial use. Thus, this study described the meat production potential of Morada Nova lambs through morphological and zoometric data, performance and carcass characteristics. Twenty-four non-castrated male lambs from two genetic groups were used: Morada Nova red ($M_{NR)}$) and crossbreed Morada Nova (red x Morada Nova white-M_{NF1}) distributed in a completely randomized design. Univariate and multivariate analysis were used. The yields of commercial cuts and the physicochemical characteristics and qualitative measurements of the carcass were similar between the genetic groups. Seven of the 28 characteristics of the carcass were greater in M_{NF1} lambs. The chest height, rump height and anamorphosis index showed to be important variables in the choice of M_N lambs with meat production potential. Based on factor and hierarchical cluster analysis, the Morada Nova beef morphometric index (M_{NBMI}) was created. Both of groups have high thoracic development, ability to produce meat, weight gain, feeding efficiency and breathing capacity, infusing greater rusticity and adaptability; however, the application and validation of the developed index showed superiority for meat production in the crossed lambs. Thus, the M_{NF1} lambs are a sustainable option for sheep production in drylands.
Key words: animal genetic resources, carcass, sheep production, semi-arid, zoometric analysis.

Descrição do potencial de produção de carne de cordeiros Morada Nova por meio da avaliação morfométrica

RESUMO: A raça Morada Nova possui um baixo rebanho efetivo, e sua variedade branca está em risco de extinção. A seleção de indivíduos com base no padrão racial sem correlação com a aptidão produtiva é predominante até hoje. Acreditamos que a melhor forma de resgatar esse valioso recurso genético é descrever seu potencial produtivo para uso comercial. Assim, este estudo teve como objetivo descrever o potencial de produção de carne de cordeiros Morada Nova por meio de dados morfológicos e zoométricos, desempenho e características de carcaça. Foram utilizados 24 cordeiros machos não castrados de dois grupos genéticos: Morada Nova Vermelho (M_{NV}) e mestiços Morada Nova (vermelho x Morada Nova branco-M_{NF1}) distribuídos em delineamento inteiramente casualizado. Análises univariadas e multivariadas foram utilizadas. Os rendimentos dos cortes comerciais e as características físico-químicas e medidas qualitativas da carcaça foram semelhantes entre os grupos genéticos. Sete, das 28 características da carcaça, foram maiores nos cordeiros M_{NF1}. A altura do peito, altura da garupa e índice de anamorfose mostraram-se variáveis importantes na escolha de cordeiros M_N com potencial de produção de carne. Com base na análise fatorial e hierárquica de agrupamento, foi elaborado o índice morfométrico da carne da raça Morada Nova (IMC_{MN}). Ambos os grupos apresentam alto desenvolvimento torácico, capacidade de produção de carne, ganho de peso, eficiência alimentar e capacidade respiratória, infundindo maior rusticidade e adaptabilidade, porém, a aplicação e validação do índice desenvolvido mostrou superioridade para produção de carne nos cordeiros cruzados. Assim, os cordeiros M_{NF1} são uma opção sustentável para a produção ovina em terras áridas.
Palavras-chave: análise zoométrica, carcaça, ovinocultura, recursos genéticos animais, semiárido.

INTRODUCTION

The Brazilian semi-arid region has traditionally raised sheep with a total of 68.5% of the national effective herd [Brazilian Institute of Geography and Statistics (IBGE, 2017)], with the potential for semi-intensive exploitation in sheep meat farming mainly using native breeds and their crosses to increase meat production (LOBO, 2019). Among these breeds, Morada Nova (M_N) is one of the main genetic resources of hair sheep in the Brazilian semi-arid region, being recognized for its resistance to gastrointestinal endoparasites (TOSCANO et al., 2019), adaptability to the thermal environment (COSTA, et al., 2018), potential as a maternal breed in terminal crossbreeding (LANDIM, et al., 2021), fertility without seasonal influence (MOURA et al., 2019), and carcasses with fatty acid profiles with potential benefit to human health (LAGE et al., 2020). Certainly, on a scientific basis, the Brazilian Agricultural Research Corporation (Embrapa Goats & Sheep) recommended carrying out a reproductive

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and productive survey of the breed in order to encourage its sustainable inclusion in Brazilian sheep production systems (LOBO, 2019).

The Brazilian Association of Sheep Breeders (*Associação Brasileira de Criadores de Ovinos - ARCO*) recognizes the genetic record of two genetic groups of the M_N breed: red (M_{NR}) and white hair, and uses as genealogical control criteria, morphological characteristics and breed standard in the registration of animals. These traits are also promoted at events such as exhibitions, auctions and the animal trade of the breed. Empirically, Brazilian sheep breeders have judged the white variety as "poorly adapted" whereas the red variety is considered "too small for meat production". These kinds of claims are contradicted by the studies cited on the breed. Despite the genetic differentiation existing among the varieties of the M_N breed, (FERREIRA, et al., 2014), there is population fragility due to extinction risk, low effective number of the herd and increased inbreeding rate caused by the indiscriminate introduction of exotic breeds (NUNES et al., 2020).

The body biometrics is a simple tool applied in commercial herds and/or in nuclei to preserve genetic resources in order to assist in zootechnical characteristic studies. With the association of these measures from different body regions, it is possible to generate zoometrical indices which identify the aptitude and productive potential of the animals, defining the breeding standard and ability for commercial exploitation (GUIMARÃES, 2018), in addition to relating these indicators to the performance and carcass characteristics. At the same time, this description is an essential step in the recovery of a genetic resource [Commission on Genetic Resources for Food and Agriculture Assessments (FAO, 2012)].

Brazilian sheep farmers have empirically implemented crossbreeding of Morada Nova varieties, but the adequate characterization of those is weak or inexistent. This lack of scientific information precludes further conclusions about this native breed and their crosses. Considering the risk status of the breed, the lack of knowledge about the productive potential of meat in the breed and its varieties, the empirical management given in the selection and commercialization of animals and the basic knowledge of breeders about the morphological evaluation of animals; this study described the meat production potential of M_{NR} and crossed M_{NR} and white (M_{NF1}) lambs using morphological and zoometric data, performance and carcass characteristics.

MATERIALS AND METHODS

Experiment site

The study was conducted at the Research Center for Nutrition of Small Ruminants at the Experimental Farm of the State University Vale do Acaraú (*UVA*), located in Sobral, Ceará, Brazil (3° 36" S, 40° 18" W and 56 m asl). The region's climate is Bsh (B - Dry, S - Semi-arid, low h-latitude) according to the Köppen Climate Classification (ALVARES et al., 2013).

Animals, experimental design and diet

A total of 24 non-castrated male lambs from two genetic groups were used (12 lambs per group): Morada Nova red (M_{NR}) and F_1 Morada Nova red x Morada Nova white ($M_{NF1;}$ ½ M_{NR} ½ M_{NW}) with an average initial body weight of 16.9 ± 3.43 kg and an average age of four months distributed in a completely randomized design. The use of pure M_{NW} lambs in this study was not possible due to the small population of this genetic group considered to be in extinction (NUNES et al., 2020). The lambs were fed with a standard isoproteic and isoenergetic diet during the experimental period according to the nutritional requirements recommended by the National Research Council (NRC, 2007) for lambs of late maturity in the finishing phase with a predicted weight gain of 200 g day^{-1}. Water and mineral salt were supplied *ad libitum*.

Measurements and morphometric indices in vivo

Morphometry was measured in the last week prior to slaughtering the animals with a tape measure and a biometric rod adapted according to (ARAÚJO, et al., 2014; BIANCHINI et al., 2006; REZENDE et al., 2014). The lambs were kept in the correct upright position on a horizontal concrete floor without slope during the measurements. The withers height (W_H), rump height (R_H), chest height (C_H), thoracic depth (T_D), chest width (C_W), body length (B_L), and chest girth (C_G) were measured. The morphometric measurements were combined to elaborate conformation indices, aptitudes and productive and genetic potential according to (CONTRERAS et al., 2011; RAMOS, I. O. et al., 2019; SILVA-JARQUIN et al., 2019). The indices with their respective equations were: 1) Body index (B_I): body length divided by thoracic perimeter (longiline animals have B_I > 0.90; medium-length or medigline 0.86 ≤ B_I ≤ 0.88; and short-length or brevigline animals B_I < 0.85); 2) Relative body index (R_{BI}): ratio of body length to withers height; 3) Thoracic perimeter relation index (T_{PRI}): chest circumference divided by withers height; 4) Anamorphosis index (A_I): thoracic perimeter squared divided by withers height, multiplied by 100; 5) Body capacity index "1" (B_{CI} "1"): corresponding to the quotient between weight and body length; 6) Body capacity index "2" (B_{CI} "2"): corresponding to the quotient between weight and thoracic perimeter; 7) Withers-rump relation index ($W\text{-}R_{RI}$): withers height divided by rump height; in which: values equal to 1 describe an animal with thoracic and pelvic limbs of the same height (balance); 8) Body side index (B_{SI}): withers height divided by body length, multiplied by 100. This index provides an understanding of the general shape of the animal's body, meaning if it is long and leggy or short, also indicating production capacity; and a last index was proposed, 9) Thoracic body index (T_{BI}): (body length / withers height) ÷ (withers height / chest depth) x 100.

Slaughter and carcass characteristics

The lambs were slaughtered at 210 (± 8 days) of age. The animals were fasted on a solid diet for 16 hours and then weighed prior to slaughter. The slaughter procedure was carried out following the rules of the Industrial and Sanitary Inspection of Products of Animal Origin, that including animal welfare protocols (*RIISPOA - Regulamento da Inspeção Industrial e Sanitária de Produtos de Origem Animal*), (BRASIL, 2017). Then, the non-carcass components were eviscerated and weighed. After obtaining the carcasses, the pH 0 hour after slaughter was measured using a portable digital pH meter (Testo 205, *São Paulo*, Brazil) provided with a glass electrode, calibrated with pH 7.0 and pH buffer solution 4.0. The carcasses were identified and weighed to determine the hot carcass weight (H_{CW}). The empty body weight (E_{BW}) was determined according to SILVA SOBRINHO et al., (2005). Then, the carcasses were packed in plastic bags and sent to a cold chamber (4°C for 24 hours). After this period, the cold carcass was weighed and the pH 24 hours after slaughter was determined. The cooling weight loss [C_{WL}, %) = (H_{CW} - C_{CW}) × 100/H_{CW}], in which: H_{CW} = hot carcass weight (kg) and C_{CW} = cold carcass weight (kg). The cuts and carcass composition were longitudinally sectioned using a cold saw (G Paniz SF248, *Rio Grande do Sul*, Brazil), and the left half carcasses were divided into six commercial cuts: leg, shoulder, rib, breast, neck, and loin. These cuts were individually weighed to determine their respective yields (%). In addition, subcutaneous fat thickness (S_{FT}) was measured using a 200 mm digital caliper (ZAAS-01.0013, *São Paulo*, Brazil). Finally, the loin eye area of the *Longissimus lumborum* (L_L) muscle exposed on the 12th thoracic rib was calculated using the geometric method (CEZAR & SOUSA, 2018).

Qualitative analysis of the carcass

Conformation, finishing and evaluation of perirenal fat were determined by visually evaluating the carcass according to the methodology described by CEZAR & SOUSA (2018). For conformation, a score of 1 was given for poor conformation to 5 as very good according to the musculature and adipose tissue deposition in relation to the skeleton. Meanwhile, finishing was classified into five categories (score 1 = very thin and 5 = very fat) according to the subcutaneous fat amount and distribution in the chilled carcass. A score of 1 to 3 was assigned for perirenal fat assessment according to the amount of fat in the abdominal cavity around the kidneys (1 = left kidney without fat cover; 2 = fully coated left kidney and the right partially; and 3 = both are covered by a thick layer of fat).

Morphometric measurements and carcass indexes

The morphometric measurements were obtained from the carcass and were carried out as recommended by CEZAR & SOUSA (2018). The morphometric measurements were: carcass external length (C_{EL}), carcass chest girth (C_{CG}), leg length (L_L), leg girth (L_G), arm length (A_L), arm girth (A_G), carcass internal length (C_{IL}), carcass internal width (C_{IW}). The carcass indexes and their equations were*:* 1) Arm compactness index (A_{CI}): the quotient between the shoulder weight and the arm length; 2) Leg compactness index (L_{CI}): relationship between the shank weight and the leg length; 3) Carcass compactness index (C_{CI}): the relationship between the cold carcass weight and the internal carcass length; and 4) Carcass economic index (C_{EI}): [(Hot carcass yield * 0.25 + Loin eye area * 0.15 + Leg yield * 0.1 + Loin yield × 0.1 + Subcutaneous fat thickness × 0.1 + Carcass compactness index × 0.09 + Conformation × 0.05 + finish × 0.05) / (Cooling weight loss × 0.05 + age × 0.06)] × 100. This last index was proposed based on commercial values for the Brazilian sheep meat market.

Data analysis

All analyzes were processed and analyzed using the SPSS® software statistical package (IBM CORP., 2013). All continuous variables met the assumptions of the analysis of variance (ANOVA) on univariate normality by the Shapiro-Wilk test ($P > 0.05$) and homoscedasticity of the variances by the Levene test.

The data were submitted to ANOVA followed by Tukey's means test (P < 0.05) for all continuous variables. The effect of genetic groups at two levels (M_{NR} and M_{NF1}) was considered in the linear model of ANOVA. The Kruskal-Wallis non-parametric analysis (P < 0.05) was used for qualitative carcass variables which did not present a normal distribution using the median as a measure of central tendency.

In multivariate analyses, a maximum of 24 characteristics were evaluated simultaneously. Nine groups of traits were used in the Canonical Discriminant Analysis (C_{DA}) to classify the genetic groups under study: *I.* body morphology, *II*. zoometric indices; *III.* carcass and muscle; *IV.* carcass morphometry; *V*. carcass indices; *VI.* carcass performance; *VII.* commercial cuts; *VIII.* cut yield; and *IX*. mix of variables (all variables simultaneously). The homogeneity of multivariate covariance matrices was assessed using Box's M statistical test (P > 0.05). The discriminant function significance was determined using the Wilks' Lambda statistic (P < 0.05). The main discriminating characteristics between genetic groups was identified by the highest value of the standardized coefficient of the canonical discriminating function (r > 0.50). A factor analysis (F_A) was performed to identify the most relevant characteristics in meat production for the evaluated genetic groups. In addition to reducing the number of variables in factors. The analysis was initially performed for each group of characteristics in a similar way to that described in the C_{DA}. After identifying the main variables within each group of characteristics, an F_A was performed to extract the factors. The number of extracted factors followed the Kaiser criterion (eigenvalues > 1; (KASIER, 1960) with orthogonal rotation. The factors were renamed according to the importance of the factor weights of the variables within each factor (> ± 0.50). The model adequacy was assessed using Kaiser-Meyer-Olkin statistical test (KMO = 0.59) and the significance by Bartlett's sphericity test (P < 0.05).

The definition of the potential for each genetic group according to the renamed factors was performed through the hierarchical cluster analysis (HCA). Ward's method and Euclidean distance were used to measure similarity. Next, individual eigenvalues of the M_{NR} and M_{NF1} lambs were used in the regression method to generate the matrix. From these, the average factor score by genetic group was generated and for each renamed factor. As a complementary analysis, the result of the grouping was plotted using a heatmap generated using the HeatMapper software program (BABICKI et al., 2016).

The Morada Nova beef morphometric index (M_{NBMI}) was created to facilitate identifying lamb selection to provide greater potential for meat production. The morphometric characteristics and zoometric indices which integrated. The index was selected according to the commonality of each characteristic in the F_A. The M_{NBMI} was built from the factor weights of the variables using morphometric measurements, zoometric indices and productive characteristics resulted in the following equation:

$M_{NBMI} = (A_I \times 0.771 + C_H \times 0.759 + R_H \times 0.878 + T_{PRI} \times 0.876 + B_I \times 0.550 + C_W \times 0.905)/100$

In which: A_I is the anamorphosis index; C_H is chest height; R_H is rump height; T_{PRI} is the thoracic perimeter relation index; B_I is body index; and C_W is chest width. An ANOVA between genetic groups was performed followed by a means comparison by the Tukey test (P < 0.001) to validate and apply the M_{NBMI}.

RESULTS

Differences between M_{NR} and M_{NF1} (P < 0.05) were observed in 12 of the 29 variables for the body morphometric characterization and zoometric indices (Table 1). The zoometric indices (B_I, T_{PRI}, A_I, B_{SI}, T_{BI}) classify both genetic groups as longitudinal, compact biotype, prone to meat production ability and respiratory capacity. Differences were observed (P < 0.05) for the anamorphosis index (A_I) and thoracic body index (T_{BI}). Carcass chest girth, arm length, carcass inner width, and carcass compactness index were heavier (P < 0.05) in the crossbred lambs.

Of the 28 variables studied, including productive and physicochemical characteristics of the carcass, commercial cuts and cut yields (Table 2), only 7 differed between the genetic groups, observing a higher value for M_{NF1} lambs (P < 0.05). Regarding these variables, the fasting body weight, hot carcass and right half of the carcass weight, rib eye area and rib, loin and brisket weights stood out. Cut yields and carcass physicochemical characteristics were similar (P > 0.05) between genetic groups. Qualitative characteristics (conformation, finishing and evaluation of perirenal fat) did not show an effect on genetic groups (P < 0.05).

The C_{DA} showed that it is possible to differentiate M_{NR} from M_NF_1 lambs from the groups of the 9 clusters (Table 3). The zoometric indices were the group of variables which had the highest percentage of correctly classified cases (C_{CC}) in their group of origin,

Table 1 - Mean and standard deviation of measurements and morphometric indices *in vivo* and in the carcass of the Morada Nova red breed (M_{NR}) lambs and F1 crossbred with Morada Nova white breed (M_{NF1}).

---Traits---	---Genetic groups---	
	M_{NR}	M_{NF1}
Slaughter weight	26.3 ± 4.0 [b]	30.7 ± 3.9 [a]
---Morphometry in vivo (cm)---		
Withers height (W_H)	58.2 ± 4.7	61.3 ± 3.0
Rump height (R_H)	58.4 ± 4.2 [b]	62.8 ± 3.4 [a]
Chest height (C_H)	28.5 ± 1.6 [b]	31.1 ± 1.7 [a]
Thoracic depth (T_D)	29.7 ± 3.9	30.2 ± 1.6
Chest width (C_W)	16.1 ± 1.2 [b]	17.5 ± 1.0 [a]
Body length (B_L)	64.4 ± 2.8 [b]	67.3 ± 2.9 [a]
Chest girth (C_G)	67.7 ± 4.2 [b]	72.5 ± 2.9 [a]
---Zoometric index---		
Body index (B_I)	94.7 ± 5.0	93.2 ± 2.0
Relative body index (R_{BI})	110.5 ± 6.0	110.2 ± 2.9
Thoracic perimeter relation index (T_{PRI})	116.6 ± 5.1	118.1 ± 3.7
Anamorphosis index (A_I)	79.2 ± 5.9 [b]	85.9 ± 4.7 [a]
Body capacity index "1" (B_{CI} "1")	0.41 ±0.05	0.45 ± 0.04
Body capacity index "2" (B_{CI} "2")	0.38 ± 0.04	0.42 ± 0.03
Withers-rump relation index ($W\text{-}R_{RI}$)	0.99 ± 0.02	0.97 ± 0.03
Body side index (B_{SI})	90.7 ± 5.1	90.78 ± 2.4
Thoracic body index (T_{BI})	56.1 ± 2.2 [a]	52.4± 2.1 [b]
---Morphometric (cm) and Carcass index---		
Carcass external length (C_{EL})	53.0 ± 2.9	53.1 ± 3.6
Carcass chest girth (C_{CG})	62.5 ± 4.1 [b]	67.0 ± 2.9 [a]
Leg length (L_L)	27.6 ± 2.4	30.3 ± 3.7
Leg girth (L_G)	33.0 ± 2.2	34.0 ± 3.6
Arm length (A_L)	23.4 ± 2.1 [b]	26.0 ± 2.7 [a]
Arm girth (A_G)	18.5 ± 1.7	17.3 ± 3.2
Carcass internal length (C_{IL})	42.5 ± 3.9	42.1 ± 6.5
Carcass internal width (C_{IW})	17.4 ± 2.4 [b]	19.3 ± 1.3 [a]
Arm compactness index (A_{CI})	0.043 ± 0.0	0.044 ± 0.0
Leg compactness index (L_{CI})	0.071 ± 0.01	0.076 ± 0.01
Carcass compactness index (C_{CI})	0.30 ± 0.05 [b]	0.36 ± 0.07 [a]
Carcass economic index (C_{EI})	18.8 ± 0.51	19.3 ± 0.59

[ab] Different letters in the same columns indicate significant differences by the Tukey test ($P < 0.05$).

followed by morphometry. The mix of variables in the simultaneous assessment of all variables belonging to the discriminating groups pointed out that T_{BI}, leg yield, C_G and rib weight are the main predictor variables to differentiate purebred lambs from crossbred. The yield of the cuts in isolation did not show any power to differentiate ($P = 0.092$) the genetic groups.

The eigenvalues and commonality of the variables distributed in the factors are shown in table 4. High commonality values (> 0.90) were obtained in the ranked variables of C_{WL}, T_{PRI}, A_I and C_{EI}, while the other variables had values > 0.70. The first four factors explained 85.90% of the total variation in the data, in which the first factor retained 38.5% of the total variance, and constituted the variables with the highest factor load, being renamed morpho-economic. There was a positive association between C_{CI}, L_{EA}, R_H, C_H, T_D, C_W, A_I and C_{EI}, but negative

Table 2 - Mean and standard deviation of productive and physicochemical characteristics of the carcass, commercial cuts and yields of cuts in the Morada Nova red breed lambs (M_{NR}) and F1 crossbred with Morada Nova white breed (M_{NF1}).

Variables	Genetic groups	
	M_{NR}	M_{NF1}
Age at slaughter (days)	111.8 ± 4.2	113.4 ± 6.0
Fasting body weight (kg)	26.3 ± 4.3 [b]	31.0 ± 4.3 [a]
Productive and physicochemical of carcass traits		
Hot carcass weight (H_{CW}; kg)	13.0 ± 2.2 [b]	15.6 ± 2.3 [a]
Cold carcass weight (C_{CW}; kg)	12.9 ± 2.2	15.2 ± 2.6
Right half of the carcass weight (R_{HCW}; kg)	6.1 ± 0.9 [b]	7.2 ± 1.1 [a]
Hot carcass yield ($H_{CY;\ \%}$)	49.6 ± 1.6	50.5 ± 1.7
Loin eye area (L_{EA}; cm^2)	9.86 ± 1.3[b]	11.54 ± 1.7[a]
Subcutaneous fat thickness (S_{FT}; mm)	1.33 ± 0.19	1.24 ± 0.34
Cooling weight loss (C_{WL}; %)	7.9 ± 1.3	6.7 ± 1.2
pH:		
0 hour after slaughter	6.7 ± 0.18	6.9 ± 0.25
24 hours after slaughter	6.0 ± 0.13	6.1 ± 0.25
Carcass temperature		
Initial (I_T;°C)	31.1 ± 3.2	29.2 ± 1.0
Final (F_T;°C)	6.9 ± 0.6	6.3 ± 0.9
Commercial cuts: Weight (kg)		
Leg	1.94 ± 0.35	2.20 ± 0.34
Shoulder	1.01 ± 0.16	1.16 ± 0.25
Rib	0.59 ± 0.07 [b]	0.72 ± 0.11 [a]
Loin	0.59 ± 0.09 [b]	0.71 ± 0.10 [a]
Brisket	1.49 ± 0.32 [b]	1.83 ± 0.27 [a]
Neck	0.46 ± 0.12	0.55 ± 0.13
Yields (%)		
Leg	31.8 ± 0.97	30.6 ± 1.79
Shoulder	16.73 ± 2.32	16.09 ± 1.87
Rib	9.82 ± 1.15	10.08 ± 0.55
Loin	9.71 ± 0.89	9.95 ± 0.89
Brisket	24.38 ± 2.89	25.48 ± 1.10
Neck	7.52 ± 1.10	7.72 ± 1.05
Qualitative carcass measurements*		
Finish	2.50 – 0.63	2.50 – 1.00
Conformation	2.50 – 0.75	3.25 – 0.63
Perirenal fat (P_F)	2.50 – 0.63	2.50 – 0.63

[ab] Different letters on the same columns indicate significant differences by Tukey's test (P < 0.05).

*Qualitative carcass measurements with different letters on the same columns indicate significant differences by Kruskal-Wallis test (P < 0.05).

with C_{WL}. Higher coefficients in the morpho-productive factor were obtained by C_Y, C_{WL} and T_{PRI}, with 18.8% of the explained variance. The factor associated with the commercial characterization was composed of two variables with greater load (Leg yield and B_I). Finally, the equilibrium factor was given by the list of variables which met the analysis assumptions (> 0.5), and that it was not possible to allocate these variables in the first three factors due to their compared low factor load.

The heat map (Figure 1) demonstrated the dynamics of the genetic groups based on

Table 3 - Canonical discriminant analysis for carcass characteristics, morphometry and zoometric indices in Morada Nova red breed lambs (M_{NR}) and F1 crossbred with Morada Nova white breed (M_{NF1}).

Group of discriminating variables	C_{CC} [1] (%)	Classification by genetic group[2] (%)		Variance Explained (%)	Lambda de Wilks[3] (P-value)	Main Traits[4]
		MN_{RED}	M_NF_1	F_{C1}	F_{C1}	FC_1
Body morphometry	91.3	90.9	91.7	100	0.008	C_H. C_G. C_W. R_H
Zoometric index	95.7	90.9	100.0	100	0.023	B_I. T_{PRI}. A_I. T_{BI}
Evaluation of carcass and muscle	65.2	81.8	50.0	100	0.049	L_{EA}. P_F
Carcass morphometric	73.9	63.6	83.3	100	0.013	C_{GC}
Carcass index	56.5	63.6	50.0	100	0.045	C_{CI}
Performance and carcass	60.9	54.5	66.7	100	0.021	H_{CW}
Commercial cuts (kg)	65.2	72.7	58.3	100	0.022	Rib; Loin
Cut yield (%)	69.6	81.8	58.3	100	0.092	Leg Y.
Mix of variables	87.0	90.9	83.3	100	0.027	T_{BI}. Leg Y. C_G. Rib

[1]Total percentage of cases correctly classified: CCC = cases correctly classified.

[2]Percentage of cases correctly classified by genetic group.

[3]Statistic test: Canonical functions (FC1) with P < 0.05 of Wilks' Lambda were considered significant.

[4]Main traits of the groups: C_H = chest height; C_G = chest girth; C_W = chest width; R_H = rump height; B_I = body index; T_{PRI} = Thoracic perimeter relation index; A_I = anamorphosis index; T_{BI} = thoracic body index; L_{EA} = loin eye area; P_F = perirenal fat; C_{GC} = carcass chest girth; C_{CI} = carcass compactness index; H_{CW} = hot carcass weight; Leg Y. = leg yield.

the four factors extracted, thus revealing the productive potential of each group, in which the M_NF_1 lambs showed aptitude in the morpho-commercial and morpho-economic aspects (positive value of Z -scores) and M_{NR} showed a high association for the balance factor. The application and validation of the M_{NBMI} is shown in figure 2, in which crossbred lambs presented greater (P < 0.001) potential for meat production.

DISCUSSION

The morpho-functional and productive description of the M_N breed is non-existent, since the morphological evaluation is limited to considerations about breed standard and is only used in promotional events, fairs and exhibitions organized by breeders' associations. This study assesses the productive potential of the M_N breed through morphometric, zoometric, productive data and carcass characteristics using a systematic approach with successive multivariate techniques for different objectives.

Our main findings were: (*i*) zoometric analyzes show the capacity for morpho-productive classification of lambs from the two genetic groups of the M_N breed; (*ii*) the zoometric indices and body morphometry are the main factors responsible for differentiation between the genetic groups evaluated in the study; and (*iii*) the M_{NBMI} has potential in the area of selection criteria for conservation programs and genetic improvement Morada Nova sheep breed.

The morphological indices used in this study were able to characterize the phenotypic and production potential of M_N lambs using the T_{PRI}, A_I, B_{CI} "1" and B_{CI} "2" variables, enabling the classification of breeding groups in high thoracic development, ability to produce meat, weight gain, feeding efficiency and breathing capacity, infusing greater breed rusticity and adaptability for both genetic groups (CONTRERAS et al., 2011; RAMOS, I. O. et al., 2019; SILVA-JARQUIN et al., 2019). These characteristics are in agreement with other studies which evaluated adaptability and productive potential of the M_N breed, especially the red variety which has greater potential for meat production (LEITE et al., 2020; MELO et al., 2018; REZENDE et al., 2014), in addition to breaking

Table 4 - Factor analysis for carcass productive characteristics, morphometry and zoometric indices in Morada Nova lambs.

-------------Variables-------------	----------------------Factors[1]	----------------------	----------------------	----------------------	Commonality
	Morpho - Economic (1)	Morpho - Productive (2)	Morpho commercial (3)	Equilibrium (4)	
Carcass compactness index (C_{CI})	0.809	-0.252	-0.093	-0.022	0.727
Loin eye area (L_{EA})	0.789	-0.235	-0.108	0.408	0.819
Hot carcass yield (H_{CY})	0.318	0.659	0.572	0.042	0.865
Cooling weight loss (C_{WL})	-0.914	0.155	-0.280	0.037	0.940
Leg yield (Leg Y)	-0.131	0.205	0.589	-0.627	0.800
Rump height (R_H)	0.878	-0.287	0.025	-0.149	0.877
Chest height (C_H)	0.759	-0.149	0.233	0.354	0.778
Chest girth (C_G)	0.649	-0.433	-0.143	-0.458	0.839
Chest width (C_W)	0.905	0.030	-0.141	-0.096	0.849
Body index (B_I)	-0.480	-0.424	0.550	0.383	0.860
Thoracic perimeter relation index (T_{PRI})	-0.001	0.876	-0.386	0.090	0.925
Anamorphosis index (A_I)	0.771	0.494	-0.339	-0.018	0.954
Carcass economic index (C_{EI})	0.677	0.452	0.512	0.114	0.938
Partial variance. %	38.50	18.80	17.50	11.00	-
Total variance	38.50	57.30	74.80	85.90	-

[1]Factor loads in bold indicate greater participation of the variable in the respective factor.

paradigms about the low adaptability of white M_N to the semi-arid environment.

The scarcity of data associated with morphometry and productive indicators in sheep raised in the Northeast region of Brazil makes it impossible to compare results with other breeds. Other studies carried out in a semi-arid region of Africa with Uda sheep classify this breed as short bodied, large proportionality which correlate with good health, breviline, poor thoracic development which is an indication of poor traction (DAUDA, 2018).

The superiority observed in some morphometric and productive characteristics in crossbred lambs are justified by the fact that this crossbreed brought together intrinsic characteristics of the white group, meaning that we still observe the result of the heterosis process and complementarity of characteristics between genetic groups, even within the same breed. This is mainly because the M_{NW} breed is larger when compared to the M_{NR} (NUNES et al., 2020). Therefore, it is inferred that the crossing between the genetic groups of the M_N breed is another alternative to increase the carcass weight resulting in greater cuts, especially noble ones (rib, loin and breast), but with similar cut yields indicating proportionality between carcass and non-carcass components within the two genetic groups. This result may be a peculiar characteristic of using the M_N breed in crossbreeding's, since LANDIM et al. (2017) observed similarities between the cut yields in pure M_N lambs when compared to crossbred *Rabo Largo* × M_N and *Santa Inês* × M_N lambs.

The developed thoracic body index (T_{BI}) was fundamental for the survey of the phenotypic diversity among the genetic groups. We believe that the combination of morphometric measures associated with the profile and productive aptitude of the animals, such as B_L, W_H and T_D, used in the index equation was able to efficiently discriminate the genetic groups. Studies indicate the great importance of the T_D measurement due to the close relationship with digestive capacity and rusticity (SANTOS, L. T. A. Dos, 2019).

The direct relationship between S_T and C_{WL} (Table 2) is associated with the carcass quality during the final post-slaughter process, since the cover fat has the main objective to act as a thermal insulator in cooling the carcass, thus providing less loss of weight during the maturation process (LANDIM, et al., 2011; NASCIMENTO, et al., 2018). However, S_T was not sufficient to maintain thermal insulation for the evaluated genetic groups, exceeding the value considered adequate ($C_{WL} < 7$ %; OLIVEIRA et al., 2017).

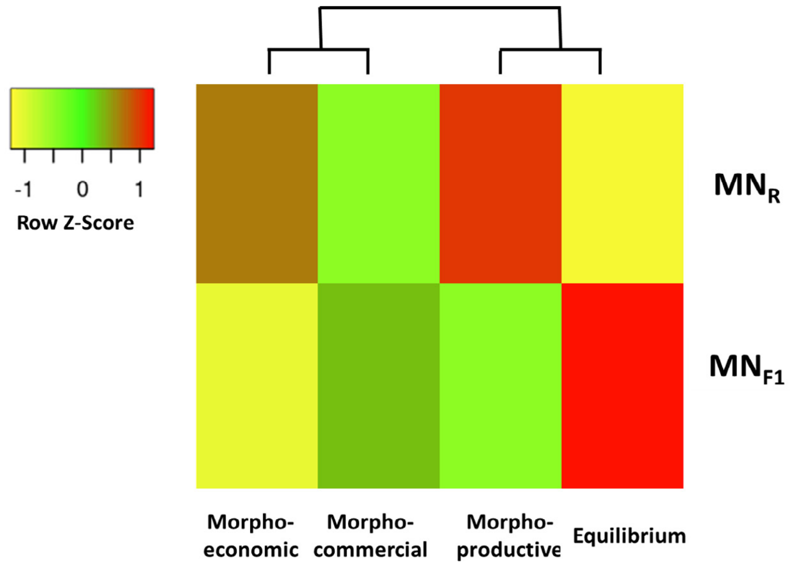

Figure 1 - Heatmap of the main components for productive carcass characteristics, morphometry and zoomometric indexes in Morada Nova breed red lambs (MNR) and crossbred with the white (MNF1). Positive Z-score values show a positive association between the genetic groups (lines) and factors.

The discrimination in only one canonical discriminating function (Table 3) for the nine selected groups is explained because the genetic groups (white and red) belong to the same breed, which reduced the discriminatory variance shared between the groups. Cut yields do not have the capacity to discriminate genetic groups, which is justified by the similarity between yields (Table 2). The shank yield showed discriminatory power between the genetic groups when all variables were simultaneously analyzed. However, this characteristic acted in a complementary way to the others (T_{BI}, C_G and rib weight) to classify 87.0% of the lambs in their group of origin. It is emphasized that adopting the mix of variables is important to identify the main predictor variables for inclusion in genetic breeding programs for M_N breed, especially due to the lack of research.

The higher classification rates observed when the zoometric indices and body morphometry were partially analyzed are justified by the higher values in the characteristics related to the thoracic part and the height of the crossbred lambs (Tables 1 and 2), which infer in the efficiency response from the productive point of view, i.e. the ability to gain weight and intake dry matter, which justifies the higher performance of these animals. In contrast, the lowest rates were observed in carcass performance and indexes, as the effect of crossbreeding between genetic groups did not influence most carcass variables (MELO et al., 2018; RAMOS, I. O. et al., 2019).

In this study, the potential for meat production was assessed by factor analysis, in which the characteristics linearly associated with each other were distributed through their respective loads, making it possible to compose factors with biological and economic interpretation. The first factor grouped a larger number of variables including those which indirectly affect the final carcass characteristics; and therefore, acted in the economic scope of meat production. This factor also pointed out that C_{WL} is the single factor which most compromises the economic index, since losses due to cooling interfere with the carcass weight and quality, and consequently reduce its price. For LANDIM et al. (2017, 2021), an alternative to increase C_{WL} is the use of the *Rabo Largo* breed in terminal crossbreeding.

The C_{EI} inferred greater explanatory power due to the four factors extracted, in addition to having a high correlation with the A_I, which is considered an important indicator of meat production (SABBIONI et al., 2016). Therefore, if there is selection in the M_N breed for this morphological index, there will indirectly be a positive influence on the economic aspect. We highlight the associations between morphometric measures and important traits in meat production (e.g., chest height and rib eye area, C_{CI}

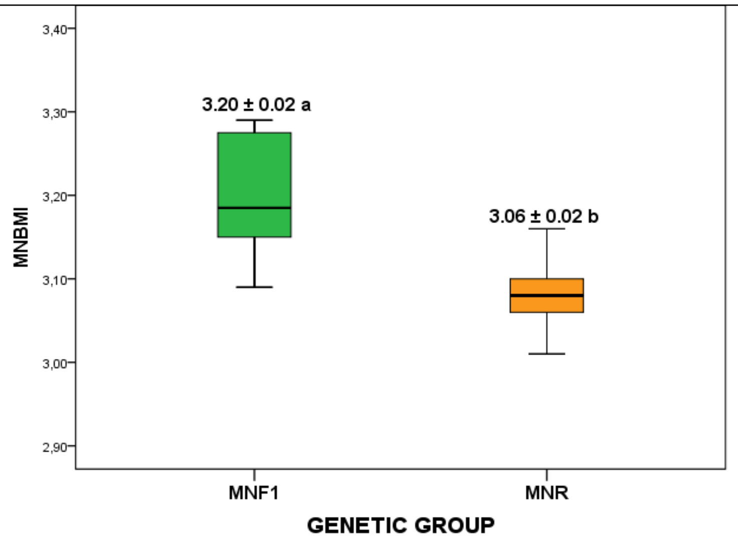

Figure 2 - Boxplot of the Morada Nova beef morphometric index (MNBMI). Morada Nova breed red (MNR) and crossbred with the white (MNF1). Means followed by different letters are statistically different by the Tukey test (P < 0.001).

and R_H and A_I with C_{EI}), verified by the proximity of the trait eigenvalues and their high commonality values, table 4. Considering the variables of greatest importance and association within the first factor, it is observed that it is possible to carry out sheep selection through measurements and zoometric indices, indirectly resulting in the carcass traits, which in principle would only be analyzed after slaughter.

The second factor extracted in the factor analysis, is associated with characteristics which exert great influence on the productive potential of the M_N breed. It is possible to predetermine the digestive capacity and weight gain of a given animal using T_{PRI} (NUNES et al., 2020), while C_Y can be used in sheep farming in response to the relative percentage of meat to be marketed, as lambs generally have high yields and small variations between biotypes (OLIVEIRA, et al., 2018).

The factor associated with commercial characterization, which in turn is directly related to the animal's production capacity, and consequently greater body and carcass weight, has a direct influence with Leg Yield, as this variable has the greatest quantitative representation of a sheep carcass (OLIVEIRA, F. G. et al., 2018; TADEU et al., 2013). The chest height indicates the stature of the animal, and it is recommended to raise small sheep for the *Caatinga* biome since the availability of food during the dry period of the year is mostly located in herbaceous extract (NUNES et al., 2020). In addition, animals with a compact profile and small to medium body structure should be chosen if the breeder intends to raise animals for meat production with a high capacity for weight gain (RAMOS, I. O. et al., 2019).

The grouping plotted on the heat map clarified the specificities for meat production of the genetic groups. M_{NF1} lambs presented superiority in the productive, commercial and economic aspects, while the M_{NR} lambs were balanced. Moreover, ISSAKOWICZ et al. (2018) report that the lower meat production potential for the M_{NR} breed when compared to other native sheep breeds is related to the small size of this breed group; however, morpho-productive characterizations are useful approaches to circumvent this limitation, as they identify the main characteristics related to the productive potential and use them as a selection criterion. The cluster formed by the morpho-economic and morpho-commercial factors is justified by their direct relationship between factors, while the balance was related to the morpho-productive factor, especially with emphasis on the crossbred lambs due to their greater production when compared to the purebred lambs.

The M_{NBMI} suggests that sheep obtained by crossbreeding the white and red genetic groups of the M_N breed have a greater potential for meat production when compared with M_{NR} lambs, demonstrating the importance of the white genetic group participating in terminal crossbreeding. Finally, this research identified predictive morphological parameters for meat production with the creation of an aggregate index obtained from the variables with greater participation in the multivariate analysis. This index presents itself as an early and practical selection criterion for meat production in M_N lambs, and can be used in breeding programs for sheep and by farmers, since biometrics is a simple and easy tool to perform. It is also expected to contribute to the recovery process of the M_N white breed variety, as its use has been shown to be favorable in sheep meat production.

CONCLUSION

M_{NR} and M_{NF1} lambs present high thoracic development, compact biotype and aptitude for meat production. Traits such as T_{BI}, Leg yield., C_G and rib weight were generally the most important for differentiating the genetic groups of the M_N breed. The chest height, rump height and anamorphosis index showed to be important variables in the choice of M_N lambs with meat production potential. The M_{NF1} lambs were shown to have greater potential for meat production than M_{NR}, being recommended as a sustainable strategy in semi-arid regions. Additionally, this crossing would facilitate the conservation of the white variety of the M_N breed, in imminent risk of extinction. It is recommended that M_{NBMI} be used as a tool for morpho-productive selection criteria in M_N breeding programs; however, further studies are needed in larger populations of this breed and in other small native breeds.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

[Aline Vieira Landim], [Wilder Hernando Ortiz Vega] and Hélio Henrique Araújo Costa conceived and designed experiments. [Genilson César Alves] and [Hélio Henrique Araújo Costa]; performed the laboratory analyses. [Wilder Hernando Ortiz Vega] performed statistical analyzes of experimental data. [Genilson César Alves], [Wilder Hernando Ortiz Vega] and [Robson Mateus Freitas Silveira] prepared the draft of the manuscript. [Aline Vieira Landim], supervised and coordinated the animal experiments. All authors critically reviewed the manuscript and approved the final version.

BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

All clinical procedures and examines were approved by the Ethical Committee Use Animals from State University of Acaraú Valley (Protocol nº 002.10.020.UVA.504.02.).

REFERENCES

ALVARES, C. A. et al. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrif**. v.22, n.6, p.711–728, 2012. Available from: <http://www.lerf.eco.br/img/publicacoes/Alvares_etal_2014.pdf>. Accessed: Aug. 8, 2021. doi: 10.1127/0941-2948/2013/0507.

ARAÚJO, A. A. De O. et al. Pelvimetry pig strains Agroceres and DanBred. **Revista Brasileira de Ciência Veterinária**. v.21, n.4, p.262–267, 2014. Available from: <https://www.cabdirect.org/cabdirect/abstract/20153076225>. Accessed: Apr. 4, 2021. doi: 10.4322/rbcv.2015.307.

BABICKI, S. et al. Heatmapper: web-enabled heat mapping for all. **Nucleic acids research**. v. 44, n.W1, p.W147–W153, 2016. Available from: <https://academic.oup.com/nar/article/44/W1/W147/2499381>. Accessed: Sept. 18, 2021. doi: 10.1093%2Fnar%2Fgkw419.

BIANCHINI, E. et al. Características corporais associadas com a adaptação ao calor em bovinos naturalizados brasileiros. **Pesquisa Agropecuária Brasileira**. v.41, n.9, p.1443–1448, 2016. Available from: <http://dx.doi.org/10.1590/S0100-204X2006000900014>. Accessed: Jun. 18, 2021. doi: 10.1590/S0100-204X2006000900014.

BRASIL. **Regulamento da Inspeção Industrial e Sanitária de Produtos de Origem Animal (RIISPOA)**. Diário Oficial da União. Ministério da Agricultura, Pecuária e Abastecimento.

CEZAR, M.F.; SOUSA, W.H. **Manual de classificação e tipificação de carcaças caprinas e ovinas**. João Pessoa, Brazil: UFCG; EMEPA, 2018.

CONTRERAS, G. et al. Caracterización morfológica e índices zoométricos de vacas Criollo Limonero de Venezuela. **Revista de la Facultad de Agronomía de La Universidad del Zulia**. v.28, No.1, 2011, p.91-103, 2011. Available from: <https://produccioncientificaluz.org/index.php/agronomia/article/view/26867>. Accessed: Sept. 29, 2021. issn-e: 2477-9407.

COSTA, W. P. et al. Coat characteristics and physiological responses of locally adapted ewes in semiarid region of Brazil. **Semina:**

Ciencias Agrarias. v. 39, n. 3, p. 1281–1293, 2018. Available from: <https://doi.org/10.5433/1679-0359.2018v39n3p1281>. Accessed: Jun. 24, 2021. doi: 10.5433/1679-0359.2018v39n3p1281.

DAUDA, A. Morphological indices and stepwise regression for assessment of function and type of Uda sheep . **J Res Rep Genet**. v.2, n.3, p. 13–16, 2018. Available from: <http://www.alliedacademies.org/research-reports-on-genetics>. Accessed: Aug. 10, 2021. issn: 2591-7986.

FAO COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE ASSESSMENTS. **Phenotypic characterization of animal genetic resources**. Rome: FAO copyright, 2012. V. No 11.

FERREIRA, J. S. B. et al. Genetic diversity and population structure of different varieties of Morada Nova hair sheep from Brazil. **Genetics and Molecular Research**. v.13, n.2, p.2480–2490, 2014. Available from: <https://doi.org/10.4238/2014.april.3.20>. Accessed: Aug. 9, 2021. doi: 10.4238/2014.april.3.20.

GUIMARÃES, J. De O. **Utilização da morfometria geométrica na caracterização racial e produtiva de ovinos Morada Nova, Santa Inês, Somalis e Dorper.** 2018. 83f. Mestrado em zootecnia. Programa de Pós-Graduação em Zootecnia da Universidade Estadual do Sudoeste da Bahia.

IBM CORP. SPSS Inc. **IBM SPSS** Statistics for Windows.

ISSAKOWICZ, J. et al. Crossbreeding locally adapted hair sheep to improve productivity and meat quality. **Scientia Agricola**. v.75, n.4, p.288–295, 1 jul. 2018. Available from: <http://dx.doi.org/10.1590/1678-992X-2016-0505>. Accessed: Jun. 20, 2021. doi: 10.1590/1678-992X-2016-0505.

KASIER, H. F. The application of electronic computers to factor analysis. **Educational and Psychological Measurement**. v.XX, n.1, p.141–151, 1960. Available from: <https://psycnet.apa.org/doi/10.1177/001316446002000116>. Accessed: Aug. 8, 2021. doi: 10.1177/001316446002000116.

LAGE, R. R. P. et al. Effect of breed on meat quality and global acceptance of native lambs and their crosses. **South African Journal of Animal Science**. v.50, n.1, p.150–160, 2020. Available from: <http://dx.doi.org/10.4314/sajas.v50i1.16>. Jun. 20, 2021. doi: 10.4314/sajas.v50i1.16.

LANDIM, A. V. et al. Physical, chemical and sensorial parameters for lambs of different groups, slaughtered at different weights. **Tropical Animal Health and Production.** v.43, n.6, p.1089–1096, 24 ago. 2011. Available from: <http://link.springer.com/10.1007/s11250-011-9806-4>. Aug. 9, 2021. doi: 10.1007/s11250-011-9806-4.

LANDIM, A. V. et al. Sheep meat production in the Brazilian semi-arid region: crossing between indigenous breeds. **Small Ruminant Research**. v.53(5):510, oct. 9, 2021. Available from: <https://doi.org/10.1007/s11250-021-02947-1>. Accessed: Sept. 10, 2021. doi: 10.1007/s11250-021-02947-1.

LANDIM, A.V. et al. Desempenho produtivo e características de carcaça de cordeiros Rabo Largo puro e cruzados com Santa Inês. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**. v.69, n.5, p.1267–1274, out. 2017. Available from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S010209352017000501267&lng=pt&tlng=pt>. Accessed: Aug. 8, 2021. doi: 10.1590/1678-4162-9210.

LEITE, J. H. G. M. et al. Coat color and morphological hair traits influence on the mechanisms related to the heat tolerance in hair sheep. **International Journal of Biometeorology**. 2020. v.64, n.12, p.2185–2194, 2020. Available from: <http://hdl.handle.net/11449/199389>. Apr. 15, 2021. doi: 10.1007/s00484-020-02014-8.

LOBO, R. N. B. Opportunities for investment into small ruminant breeding programmes in Brazil. **Journal of Animal Breeding and Genetics**. v.136, n.5, p.313–318, 2019. Available from: <https://doi.org/10.1111/jbg.12396>. Accessed: Sept. 29, 2021. doi: 10.1111/jbg.12396.

MELO, B. A. De et al. Body morphometric measurements in murrah crossbred buffaloes (Bubalus bubalis). **Journal of Applied Animal Research**. v.46, n.1, p.1307–1312, 2018. Available from: <https://doi.org/10.1080/09712119.2018.1502669>. Accessed: Sept. 25, 2021. doi:10.1080/09712119.2018.1502669.

MOURA, B. A. B. et al. Differences in the thermal sensitivity and seminal quality of distinct ovine genotypes raised in tropical conditions. **Theriogenology**. v.123, p.123–131, 2019. Available from: <https://doi.org/10.1016/j.theriogenology.2018.09.037>. Accessed: Jul. 20, 2021. doi: 10.1016/j.theriogenology.2018.09.037.

NASCIMENTO, U. F. S. et al. Performance and carcass characteristics of lambs ½ Dorper + ½ Santa Inês , slaughtered with different thicknesses of subcutaneous fat. **Revista Brasileira de Saúde e Produção Animal**. v.19, n.1, p.125–135, 2018. Available from: <http://dx.doi.org/10.1590/s1519-99402018000100012>. Accessed: Jul. 22, 2021. doi: 10.1590/s1519-99402018000100012.

NRC. Nutrient requirements of small ruminants. In: WASHINGTON: NATIONAL ACADEMIES PRESS (Org.). **NATIONAL RESEARCH COUNCIL** – NRC. Washington DC: [s.n.], 2007, p.347.

NUNES, S. F. et al. Morphometric characterization and zoometric indices of white Morada Nova breed: The first step for conservation. **Small Ruminant Research**. v.192, n. May, p.106178, 2020. Available from: <https://doi.org/10.1016/j.smallrumres.2020.106178>. Accessed: Jun. 08, 2021. doi: 10.1016/j.smallrumres.2020.106178.

OLIVEIRA, F. G. et al. Carcass characteristics of Santa Ines sheep with different biotypes and slaughtering weights. **Revista Brasileira de Saúde e Produção Animal**. v.19, n.3, p.347–359, 2018. Available from: <https://doi.org/10.1590/S15199402018000300011>. Accessed: May, 15, 2021. doi: 10.1590/S1519-99402018000300011.

OLIVEIRA, J. P. F. De et al. Características de carcaça de ovinos Santa Inês alimentados com mazoferm substituindo o farelo de soja. **Revista Ciencia Agronomica**. v.48, n.4, p.708–715, 2017. Available from: <https://doi.org/10.5935/1806-6690.20170082>. Accessed: Jul. 12, 2021. doi: 10.5935/1806-6690.20170082.

RAMOS, I. O. et al. Body conformation of Santa Inês, Texel and Suffolk ewes raised in the Brazilian Pantanal. **Small Ruminant Research**. 172, n. January, p.42–47, 2019. Available from: <http://dx.doi.org/10.1016/j.smallrumres.2019.01.011>. Accessed: Sept. 29, 2021. doi: 10.1016/j.smallrumres.2019.01.011.

REZENDE, M. P. G. De et al. Caracterização zoométrica de novilhas remanescentes da raça Pantaneira. **Ciencia Rural**. v.44, n.4, p.706–709, 2014. Available from: <https://doi.org/10.1590/S0103-84782014000400022>. Accessed: Sept. 29, 2021. doi: 10.1590/S0103-84782014000400022.

SABBIONI, A. et al. Allometric coefficients for body measures and morphometric indexes in a meat-type sheep breed. **Small Ruminant Research**. v.144, p.248–254, 2016. Available from: <http://dx.doi.org/10.1016/j.smallrumres.2016.10.005>. Accessed: Sept. 29, 2021. doi: 10.1016/j.smallrumres.2016.10.005.

SANTOS, L. T. A. Dos. **Caracterização morfométrica de ovinos da raça Bergamácia Brasileira**. 2019. 78f. Mestrado em zootecnia. Programa de Pós-Graduação em Zootecnia do Centro de Ciências Agrárias, da Universidade Federal de Alagoas.

SILVA SOBRINHO, A. G. et al. Muscularity and leg composition in lambs of different genotypes and ages at slaughter. **Pesquisa Agropecuaria Brasileira**. v.40, p.1129–1134, 2005. Available from: <http://hdl.handle.net/11449/194647>. Accessed: Feb. 15, 2020.

SILVA-JARQUIN, J. C. et al. Morphostructural characterization of the black creole goat raised in central Mexico, a currently threatened zoogenetic resource. **Animals**. v.9, n.7, 2019. Available from: <https://doi.org/10.3390%2Fani9070459>. Accessed: Apr. 25, 2021. doi: 10.3390%2Fani9070459.

TADEU, M. et al. Performance and carcass quality in three genetic groups of sheep in Brazil. **Revista Brasileira de Zootecnia**. v.42, n.10, p.734–742, 2013. Available from: <www.sbz.org.br>. Accessed: Apr. 17, 2021. doi: 10.1590/S1516-35982013001000007.

TOSCANO, B. J. H. et al. Morada Nova sheep breed : Resistant or resilient to Haemonchus contortus infection? **Veterinary Parasitology: X**. v.276S, Oct. 09, 2019 p. Available from: <https://www.sciencedirect.com/science/article/pii/S2590138919300153>. Accessed: Aug. 15, 2021. doi: 10.1016/j.vpoa.2019.