An Acad Bras Cienc (2020) 92(Suppl. 1): e20190340 DOI 10.1590/0001-3765202020190340
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

AGRARIAN SCIENCES

The effects of genetic group and sex on residual feed intake, performance, morphometric, testicular, and carcass traits' in lambs

ANA CAROLINA B. FREITAS, RICARDO L.D. COSTA, CELIA R. QUIRINO, AYLTON BARTHOLAZZI JUNIOR, WILDER H.O. VEGA, RENATO T. BELTRAME & FÁBIO P. CAMPOS

Abstract: The aim of this study was to analyze the effects of genetic group and sex on residual feed intake, performance, testicular size, carcass and morphometric traits in Santa Ines purebred and Dorper ´ Santa Ines crossbred lambs. A total of 32 lambs, with initial body weight of 18±3.7 kg were used. Analysis of variance, considering the interaction between sex and genetic group of all the traits were performed. Crossbred females (-0.018±0.06) and purebred males (-0.018±0.05) were more efficient ($p<0.001$) in residual feed intake than crossbred males (0.018±0.04) or purebred females (0.018±0.04). The most efficient animal in residual feed intake consumed 37.9% less feed (1.179 kg/day) than the least efficient animal (1.899 kg/day). Crossbred, when compared to purebred, showed higher values for body weight, average daily gain, testicle size, carcass traits; had greater muscle accumulation, were more compact and with more aptitude to beef. Purebred were taller, but with lower body length and thoracic perimeter than crossbred. Males had greater muscle accumulation, were more compact and with more aptitude to meat. Crossing of native (Santa Ines) with exotic breed (Dorper) is an alternative to align efficiency in feed use, testicular size, compactness, aptitude for meat and ability for muscle accumulation.

Key words: Crossbred, Dorper, feed efficiency, purebred, Santa Ines, sheep.

INTRODUCTION

At the heart of livestock-based feed production is the ability of animals to receive complex plant constituents and convert them into protein form that are palatable and readily digested by the human gastrointestinal tract. The role of producers is to design, maintain, and monitor systems that maximize the efficiency of this process of nutrient intake, uptake, and conversion so that economic input costs and output returns are optimized.

To initiate a breeding program for genetic improvement of sheep productivity, information is needed about breeding objectives of sheep breeds (Tabbaa et al. 2019). Several native breeds, such as the Santa Ines, with specific adapted characteristics are found in Brazil, however, the productive performances of these breeds are usually low when compared to exotic breeds, as the Dorper. Thus, the crossing of native with exotic breeds is an alternative to align productivity and hardiness (Figueiredo et al. 2019). Dorper is a sheep breed suitable for many countries throughout the world due to its hardiness, adaptability, fast-growth for meat production and early weaning (Norhayati et al. 2018). Since the highest cost of an animal production is related to feed (Arthur & Herd 2008), the selection of sheep for characteristics related to feed efficiency has shown to be a good option to reduce feeding costs, increase productivity (Cockrum et al. 2013) and reduce environmental impact (Paula et al. 2013). Residual feed intake (RFI) is the difference between the expected intake of the animal and what it actually consumes, based on its metabolic weight and average daily gain. This parameter has been widely used in animal production because no alterations are observed in the adult size or growth of animals selected for it (Sobrinho et al. 2011). For RFI to be an appropriate measure of feed efficiency in the sheep industry, it must not be unfavorably correlated with growth, reproduction and carcass traits, so it is necessary to fully investigate the potential impacts associated with these traits (Cockrum et al. 2013).

During the course of growth, the animal's different body parts change in proportion. So, body dimensions or linear measurements have been used in conformation appraisal for many livestock species as a supplement to body weights when measuring the productivity (Zhang et al. 2018). The evaluations of growth, carcass characteristics, feed efficiency, and body morphometrics make possible to find early maturing and more efficient animals, reducing production time and increasing profitability (Figueiredo et al. 2019). Moreover, the body linear measures are easily obtained and provide assistance to evaluate qualities and weaknesses of the animals (Souza et al. 2015).

The objective of this study was to investigate the effects of genetic group and sex on RFI, performance, testicular measurements (right testicular diameter and length; scrotal circumference), carcass traits and morphometric indices in Santa Ines purebred (Pu) and Dorper ´ Santa Ines crossbred (Cr) lambs, in Brazil.

MATERIALS AND METHODS

Animal care

This study was approved by the Ethics Committee on Animal Use of the Instituto de Zootecnia (CEUA-IZ), approval number 224-16.

Animals, diet and feeding

The experiment was conducted at Instituto de Zootecnia, Nova Odessa, São Paulo state, Brazil (latitude - 47" 19' W and longitude - 22" 47' S). Thirty-two lambs (*Ovis aries*) with 90±10 days of age (soon after weaning) and average initial body weight (BW) of 18±3.7 kg were used. Sixteen lambs were of the Santa Ines breed (8 non-castrated males and 8 females) and 16 were crossbred 7/8 Dorper ´ Santa Ines (8 non-castrated males and 8 females).

Lambs were housed in two indoor pens (males x females) bedded with sugarcane bagasse and were fed with chopped hay (Cynodon cv. Tifton 85), commercial concentrate, water and mineral salt, ad libitum (Table I). Each pen contained four automated feed stations (INTERGADO®, Contagem, MG, Brazil), two only providing hay and the other two only concentrate (to measure the exact consumption of each kind of feed). The mineral salt was provided separately. The automated feeder recorded daily the consumption of concentrate (DCC) and hay (DCH), in kg.

The lambs were moved into the indoor animal houses 15 days before the start of measurements by the equipment, in order to allow them to adapt to the facility conditions. After the adjustment period, the equipment carried out the measurements of feed consume during 65 days.

Samples of feed offered and their residues left, were analyzed for proximate and cell wall constituents as per AOAC (2005) and Van Soest et al. (1991) method. Dry matter, ether extract,

Table I. **Chemical composition of the hay and concentrate in % of dry matter.**

Chemical composition (%)	Commercial concentrate	Hay
Dry matter	88.9	93.0
Crude protein	19.8	13.4
Ether extract	1.9	1.4
ASH[a]	13.5	6.9
Acid detergent fiber	15.2	36.6
Neutral detergent fiber	37.6	74.3
Hemicellulose	22.4	37.7
Cellulose	.	31.3
Lignin	.	4.2
Total digestible nutrients (TDN)	67.8	62.6

[a] Composition of product: calcium 120 g/kg, phosphorus 87 g/kg, sodium 147 g/kg; sulfur 18 g/kg, copper 590 mg/kg; cobalt 40 mg/kg, chromium 20 mg/kg, iron 1800 mg/kg, iodine 80 mg/kg, manganese 1300 mg/kg, selenium 15 mg/kg, zinc 3800 mg/kg; molybdenum 300 mg/kg; and fluorine (max.) 870 mg/kg.

mineral matter and crude protein were analyzed according to AOAC (2005); neutral detergent fiber, acid detergent fiber, hemicellulose, cellulose and lignin according to Van Soest et al. (1991); total digestible nutrients according to Kearl (1982) (Table I).

Measurements

Performance and feed efficiency traits calculated, calculated using automated feed stations and body measurements informations, were: dry matter intake (DMI) = (concentrate consumption x dry matter content of concentrate) + (hay consumption x dry matter content of hay); total dry matter intake (concentrate+hay)/body weight (DMI/BW); dry matter intake of concentrate/body weight (DMIC/BW); average body weight (ABW) = mean of body weight during the feeding period (Gomes et al. 2012); average daily gain (ADG) = (final body weight – initial body weight)/days on feed (Yeaman et al. 2013); mid-trial metabolic body weight (MMBW) = $[(\text{initial body weight} + \text{final body weight})/2]^{0.75}$ (Koch et al. 1963); feed efficiency (FE) = ADG/DMI; feed conversion ratio (FCR) = DMI/ADG (Arthur & Her 2008) and residual feed intake (RFI) = DMI observed – DMI expected (Koch et al. 1963).

The body weight, body and testicular morphometric measurements were obtained every 14 days, since day 7 of adaptation period, totalizing 6 measurements. The testicular measurements were: scrotal circumference (SC), in cm; right testicle length (RTL), in mm; and right testicle diameter (RTD), in mm (Toe et al. 2000). The linear body measurements (in cm) were: withers height (WH); rump height (RH); body length (BL); and thoracic perimeter (TP) (Costa et al. 2014). Morphometric indices were calculated by the ratio between morphometric measures and/or body weight: body capacity 1 (BCin1) = body weight/body length; body capacity 2 (BCin2) = body weight/thoracic perimeter; body index (Bin) = body length/thoracic perimeter x 100; body side index (BSin) = withers height/body length x 100; compactness index (Cin) = body weight/withers height x 100; body proportionality index (BPin) = compactness index/body index x 100 (Costa et al. 2014); proportionality index (Pin) = body length/withers height x 100 (Bravo & Sepúlveda 2010) and anamorphosis index (Ain) = thoracic perimeter^2/withers height x 100 (Rezende et al. 2014).

On the last day of the experiment, ultrasound pictures were obtained between the 12th and 13th intercostal space (next to last rib) using a Chison D600VET (Chison Medical Imaging Co., China) coupled to a linear transducer operating at 7.5 MHz. The ImageJ® software was used to measure, in mm, the height of *Longissimus dorsi* muscle (Hldm); length of *Longissimus dorsi* muscle (Lldm); ribeye area (RAldm) and subcutaneous fat thickness (SFT) (Menezes et al. 2013).

Statistical analysis

Residual feed intake was calculated using the MIXED procedure in SAS® (SAS Inst. Inc., Cary, NC), as the difference between actual and expected dry matter intake. The base model used to calculate estimated dry matter intake was determined by Koch et al. (1963), but a large increase in R2 values (which increases the precision of the prediction) and decrease in BIC (Bayesian information criterion) was observed (Montanholi et al. 2009). By the incorporation of sex, genetic group, feed efficiency (FE) and daily dry matter intake of concentrate as a function of percentage of body weight (DMIC%BW) in the base model (Table II).

Analysis of variance of feed efficiency (including RFI), carcass, body and testicular morphometric measurements was performed using PROC GLM. Means of all the traits measured were tested using SNK multi comparison test and the model used was:

$$Yijk = \mu + Si + GGj + (S*GG)ij + eijk$$

Where: Yijk = dependent variable; μ = general mean, associated with the dependent variable; Si = effect of sex i; GGj= effect of genetic group j; (S*GG) = effect of the interaction of sex and genetic group ij; eijk = random residual associated with each observation $e \sim N(0, I\sigma^2_e)$.

The effect of sex, genetic group and the interation between these two traits was significant and we opened the model and performed the analyzes separately.

In this study we compared the means and standard deviations (Table III) between the genetic groups and sex (male purebred, female purebred, male crossbred and female crossbred). The double interactions assessed were: female crossbred x male crossbred; female crossbred x female purebred; male purebred x female purebred; male purebred x male crossbred (Figures 1 and 2). Results were considered statistically significant when P≤0.05.

RESULTS

The original model to define RFI (RFI_{kock}) had the lowest R^2 (0.6486) and the second highest BIC (-10.9). The inclusion of sex, genetic group, FE and DMIC%BWincreased R^2 (0.9667) and decreased BIC (-63.1), so this model was used to define RFI in this study. The DMI of concentrate in relation to BW was 3.9±1.4% and the DMI of hay in relation to BW was 0.37±0.29%.

Crossbred females (-0.018±0.062, P<0.001) and purebred males (-0.018±0.05, P<0.001) showed negative RFI (more efficient). Crossbred males (0.018±0.04, P<0.001) and purebred females (0.018±0.04, P<0.001) showed positive RFI (less efficient). In view of this, we show the results focusing in crossbred females and purebred males and their relationship with the other genetic group or sex (Figures 1 and 2).

Table II. **Predictive equation models used to estimate feed intake for the calculation of residual feed intake and respective fit as indicated by coefficient of determination (R^2) and Bayesian information criterion (BIC).**

Model	Equation	R^2	BIC
Model 1*	y(EDMI)=βO + β1(ADG) + β2(MMWT) + Ɛ	0.6486	-10.9
Model 2	y(EDMI)=βO + β1(ADG) + β2(MMWT) + β3(SEX) + β4(GG) + Ɛ	0.6626	-5.9
Model 3	y(EDMI)=βO + β1(ADG) + β2(MMWT) + β3(SEX) + β4(GG) + β5(DMIC%BW) + Ɛ	0.9331	-44.4
Model 4	y(EDMI)=βO + β1(ADG) + β2(MMWT) + β3(SEX) + β4(GG) + β6(FE) + Ɛ	0.8733	-33.9
Model 5	y(EDMI)=βO + β1(ADG) + β2(MMWT) + β3(SEX) + β4(GG) + β5(DMIC%BW) + β6(FE) + Ɛ	0.9667	-63.1

***Model described by (Koch et al. 1963).**
EDMI = expected dry matter intake. ADG = average daily gain. MMBW = mid-trial metabolic body weight - $[(BW_{initial} + BW_{final})/2]^{0.75}$. GG = genetic group. FE = feed efficiency. DMIC%BW = dry matter intake of concentrate as a function of percentage of body weight. Ɛ = residuals (represents the RFI). DMI = dry matter intake. R^2 = coefficient of determination (bigger is better). BIC = Bayesian information criterion (smaller is better). y = expected dry matter intake. β0 = regression intercept. β1, β2, β3, β4, β5, β6 are the coefficients of the multiple linear regression of DMI on ADG, MMWT, sex (male or female), genetic group (Santa Ines or Dorper x Santa Ines), DMIC%BW and FE, respectively.

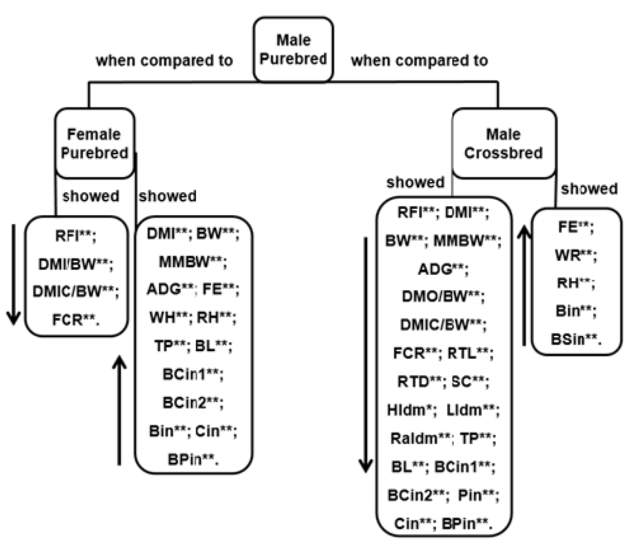

Figure 1. **Comparison between means of female crossbred x male crossbred, female crossbred x female purebred. **P < 0.001; *P < 0.05.**
ADG = average daily gain; Ain = anamorphosis indice; BCin1 = body capacity indice 1; BCin2 = body capacity indice 2; Bin = body indice; BL = body length; BPin = body proportionality indice; BSin = body side indice; BW = body weight; Cin = compactness indice; DMI = dry matter intake; DMI/BW = dry matter intake/body weight; DMIC/BW = dry matter intake of concentrate/ body weight; FCR = feed conversion ratio; FE = feed efficiency; Hldm = height in Longissimus dorsi muscle; Lldm = length in Longissimus dorsi muscle; MMBW = metabolic body weight; Pin = proportionality indice; RAldm = ribeye area in longissimus dorsi muscle; RH = rump height; RTD = right testicular diameter; RTL = right testicle length; SC = scrotal circumference; SFT = subcutaneous fat thickness; TP = thoracic perimeter; WH = wither height.

Table III. Mean and standard deviation of genetic group and sex for efficiency traits, testicular parameters, carcass ultrasound, body morphometric and indices measurements.

Trait	Purebred male Mean±SD	Purebred female Mean±SD	Crossbred male Mean±SD	Crossbred female Mean±SD
Residual feed intake (kg)	-0.018±0.051	0.018±0.043	0.018±0.045	-0.018±0.062
Dry matter intake (kg/day)	1.3±0.33	1.2±0.41	1.7±0.52	1.2±0.47
Body weight (kg)	29.6±2.36	24.0±3.20	33.5±2.34	28.5±3.85
Metabolic body weight (kg)	12.7±0.87	10.8±1.11	13.9±0.78	12.3±1.34
Average daily gain (kg/day)	0.27±0.044	0.22±0.023	0.29±0.048	0.19±0.047
Feed efficiency (kg/kg/day)	0.26±0.18	0.23±0.096	0.21±0.074	0.19±0.065
Feed conversion ratio (kg/kg)	4.1±1.19	4.8±1.54	5.1±1.37	5.6±1.66
Dry matter intake/body weight (%bw/day)	4.3±1.01	4.7±1.42	5.0±1.01	4.2±1.25
Dry matter intake of concentrate/body weight (%bw/day)	3.8±1.33	4.1±1.54	4.2±1.48	3.6±1.45
Larger testicle length (mm)	60.8±19.83	.	71.2±20.82	.
Larger testicular diameter (mm)	40.4±12.39	.	50.0±13.61	.
Scrotal circumference (cm)	21.4±4.61	.	23.9±3.95	.
Height in *Longissimus dorsi* muscle (cm)	2.4±0.24	2.4±0.27	2.9±0.36	2.5±0.57
Length in *Longissimus dorsi* muscle (cm)	4.6±0.54	4.6±0.55	5.5±0.23	5.3±0.50
Ribeye area (cm)	8.5±0.95	8.8±1.31	12.2±2.09	11.2±2.72
Subcutaneous fat thickness (mm)	1.6±0.88	1.7±0.52	1.3±0.34	1.6±0.26
Wither height (cm)	62.1±4.17	58.5±3.24	58.6±2.85	57.4±3.67
Rump height (cm)	63.2±3.78	60.3±3.65	59.8±3.41	58.2±2.90
Thoracic perimeter (cm)	72.6±5.61	70.1±6.97	78.8±4.43	78.0±7.48
Body length (cm)	66.9±5.74	62.7±6.23	69.3±6.65	65.9±5.54
Body capacity indice 1	0.40±0.055	0.36±0.062	0.44±0.062	0.40±0.063
Body capacity indice 2	0.37±0.056	0.32±0.057	0.38±0.069	0.34±0.045
Body indice	92.1±4.32	89.7±6.49	87.8±5.94	84.8±4.96
Proportionality indice	107.8±6.59	107.2±7.96	118.1±8.86	114.9± 6.70
Body side indice	93.1±5.76	93.8±7.55	85.1±6.41	87.3±4.96
Anamorphosis indice	85.2±10.20	84.5±14.34	106.3±9.82	106.5±16.23
Compactness indice	43.5±6.47	39.0±7.62	52±8.04	47.1±7.44
Body proportionality indice	47.2±7.11	43.8±9.60	59.2±8.12	55.8±9.90

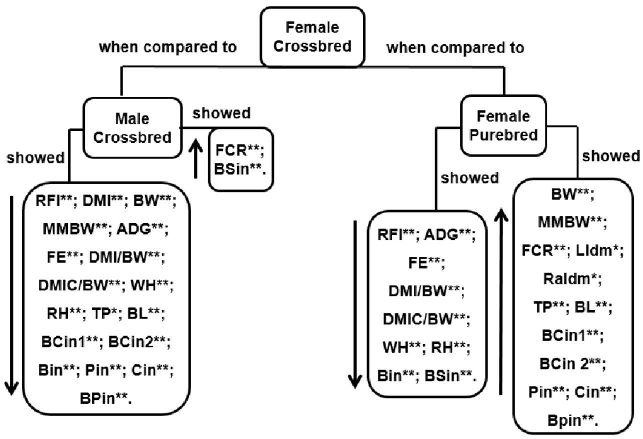

Figure 2. Comparison between means of male purebred x female purebred, male purebred x male crossbred. **P < 0.001; *P < 0.05.
ADG = average daily gain; Ain = anamorphosis indice; BCin1 = body capacity indice 1; BCin2 = body capacity indice 2; Bin = body indice; BL = body length; BPin = body proportionality indice; BSin = body side indice; BW = body weight; Cin = compactness indice; DMI = dry matter intake; DMI/BW = dry matter intake/body weight; DMIC/BW = dry matter intake of concentrate/ body weight; FCR = feed conversion ratio; FE = feed efficiency; Hldm = height in Longissimus dorsi muscle; Lldm = length in Longissimus dorsi muscle; MMBW = metabolic body weight; Pin = proportionality indice; RAldm = ribeye area in longissimus dorsi muscle; RH = rump height; RTD = right testicular diameter; RTL = right testicle length; SC = scrotal circumference; SFT = subcutaneous fat thickness; TP = thoracic perimeter; WH = wither height.

DISCUSSION

The animal is considered more efficient in feed use when actual intake is lower than the expected intake value upon adjustment for body size and body weight gain (negative RFI) (Montanholi et al. 2017). The most efficient animal in RFI had a DMI average of 1.179 kg/day, while the least efficient animal consumed an average of 1.899 kg/day. This means that the most efficient animal consumed an average of 0.720 kg/day less feed than the least efficient (37.9% difference). When considering animals finished in confinement for about 90 days before slaughter consuming large amounts of concentrate, the most efficient animal could consume 64.8 kg/90days less food than the least efficient. As feed is a major cost of sheep production, and improved conversion of feed into product is one approach to increase the profitability of an enterprise (Cammacki et al. 2005), this decrease in feed expenses is quite significant.

Crossbred males showed greater testicle size than purebreds (right testicular diameter and length; scrotal circumference). Scrotal circumference and testicle diameter are good indicators of rams' breeding ability (Benôit et al. 2017) and have a direct relationship with sperm production (Elmaz et al. 2008). The differences in SC in lambs could be due to the effect of genotype or breed (Benôit et al. 2017) and nutrition (Lisboa-Neto et al. 2017). In our study, crossbred animals were heavier than purebreds and increase of BW can lead to increased SC (Assis et al. 2008). Body capacity 1 and 2 allows estimating or classifying animals as to the potential for body development and indicates the ability of muscle accumulation in the carcass (Araújo Filho et al. 2007). The body side indice indicates that animals with lower values are closer to rectangular, a predominant shape in animals with aptitude for meat (Casanova & Pere-Miquel 2007). Since the proportionality index uses the same variables as body side indice, but in reverse order, animals with higher values show more aptitude for meat. Animals with high values of compactness indice are more compact (Costa et al. 2014). The body proportionality indice refers to the animal's conformation, i.e., the extent to which the animals are compact or longilineal (Costa et al. 2014). The longilineal animals (known as "waders") have long limbs and bodies while the compact ones have short limbs and bodies, which is the predominant and desirable conformation for animals with aptitude for meat (Costa et al. 2014).

Crossbred, when compared to purebred, showed higher values for body weight, average daily gain, carcass traits (length, ribeye area and height of *Longissimus dorsi* muscle), had greater muscle accumulation (body capacity 1 and 2), were more compact (compactness and proportionality indices) and with more aptitude to beef (body side and proportionality indices). The Dorper breed is considered precocious, with high body weight gain, high carcass quality, good conformation and fat distribution (Lisboa-Neto et al. 2017). The differences observed between the genetic groups in this study may be related to the absorbent crossing of the Santa Ines breed with the Dorper. Crossbred can present, when compared to Santa Ines purebred, greater quantities of muscle tissue (mainly in rump, which is the location of one of the main sheep carcass cuts), better distribution of muscularity (emphasized by ribeye area) and adiposity, so meat has better sensorial quality (Cartaxo et al. 2017).

Purebred were taller, but with lower body length and thoracic perimeter than crossbred. Santa Ines animals have proportionally higher limbs to facilitate the search of feed, since they come from a semi-arid region with feed shortages (Cartaxo et al. 2017). The crossbred animals were 7/8 Dorper ´ 1/8 Santa Ines, and Dorper is a specialized breed for meat production and inherit shorter limbs due to the more compacted body conformation, resulting from genetic improvement seeking higher body depth in detriment to the corporal extremities, since the greater carcass proportion comes from depth (Cartaxo et al. 2017).

Subcutaneous fat thickness values were similar between crossbred and purebred. This similarity between genetic groups can be a result of receiving the same high quality nutrition and age (Garcia et al. 2010). The animals may not have reached physiological maturation of the carcass (after maturation, the adipose tissue starts to be deposited in a larger proportion than other tissues), so they were not at the optimal point for slaughter (Andrade et al. 2017).

Males, when compared to females, were higher in the body morphometric measurements, had greater muscle accumulation (body capacity 1 and 2), were more compact (compactness and proportionality indices) and with more aptitude to beef (proportionality indice). The sex-related differences might be partly a function of the between-sex differential hormonal effects on growth (Jimmy et al. 2010).

Genetic group (Santa Ines purebred and Dorper ´ Santa Ines crossbred) and sex (male or female) are important factors to be considered when making comparisons between residual feed intake, performance, testicular measurements, carcass traits, body measurements and morphometric indices. Crossing of native (Santa Ines) with exotic breed (Dorper) is an alternative to align efficiency in feed use, testicular size, compactness, aptitude for meat and ability for muscle accumulation, or in other words, productivity and hardiness. Males sheep were more efficient animals to meat production, since they had the best growth performance, were more compact, showed greater aptitude for meat and ability to accumulate muscle than the females, so they can reduce production time and increase profitability.

Acknowlegments

We thank the researchers Wilder Vega, André Geraldo, Júlia Jardim, Yuri Montanholi, Mauro Bueno and Alexandra Elbakyan for the technical instructions. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brazil (CAPES) - Finance Code 001) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

REFERENCES

ANDRADE ACS, MACEDO FAF, ANTOS GRA, QUEIROZ LO, MORA NHAP & MACEDO TG. 2017. Regional composition of carcass and tissue composition of cuts from lambs slaughtered with different subcutaneous fat thicknesses. Semin Cienc Agrar 38: 2019-2028.

AOAC. 2005. Official methods of analysis of the Association Analytical Chemists. 18th ed., Gaithersburg: Maryland, 1015 p.

ARAÚJO FILHO JT, COSTA RG, FRAGA AB, SOUSA WH, GONZAGA NETO S, BATISTA ASM & CUNHA MGG. 2007. Efeito de dieta e genótipo sobre medidas morfométricas e não constituintes da carcaça de cordeiros deslanados terminados em confinamento. Rev Bras Saude Prod Anim 8: 394-404.

ARTHUR JPF & HERD RM. 2008. Residual feed intake in beef cattle. Rev Bras Zootec 37: 269-279.

ASSIS RM, PÉREZ JRO, BARRETO FILHO JB, DE PAULA OJ, ALMEIDA TRV, MACEDO JUNIOR GL & FRANÇA PM. 2008. Evolução do peso testicular de cordeiros da raça Santa Inês alimentados com diferentes níveis de energia. Arq Bras Med Vet Zootec 60: 1219-1226.

BENOÎT KG, ULBAD TP, CYRILLE BK, SERGE ZM & CHRISTIAN H. 2017. Testicular and body morphometric traits of mature rams of djallonke and ouda breeds reared in north Benin. Int J Vet Sci 6: 108-113.

BRAVO S & SEPÚLVEDA N. 2010. Índices Zoométricos en Ovejas Criollas Araucanas. Int J Morphol 28: 489-495.

CAMMACK KM, LEYMASTER KA, JENKINS TG & NIELSEN MK. 2005. Estimates of genetic parameters for feed intake, feeding behavior, and daily gain in composite ram lambs. J Anim Sci 83: 777-785.

CARTAXO FQ, SOUSA WH, CEZAR MF, CUNHA MGG, MENEZES LM, RAMOS JPF, GOMES JT & VIANA JA. 2017. Desempenho e características de carcaça de cordeiros Santa Inês e suas cruzas com Dorper terminados em confinamento. Rev Bras Saude e Prod Anim 18: 388-401.

CASANOVA P & PERE-MIQUEL LSD. 2007. Análisis biométrico y funcional de la raza ovina aranesa. Rev Electron Vet 8: 1-8.

COCKRUM RR, STOBART RH, LAKE SL & CAMMACK KM. 2013. Phenotypic variation in residual feed intake and performance traits in rams. Small Rumin Res 113: 313-322.

COSTA RLD, QUIRINO CR, AFONSO VAC, PACHECO A, BELTRAME RT, MADELLA-OLIVEIRA AF, COSTA AM & SILVA RMC. 2014. Morphometric indices in Santa Ines sheep. Int J Morphol 32: 1370-1376.

ELMAZ O, DIKMEN S, CIRIT U & DEMIR H. 2008. Prediction of postpubertal reproductive potential according to prepubertal body weight, testicular size, and testosterone concentration using multiple regression analysis in Kivircik ram lambs. Turkish J Vet Anim Sci 32: 335-343.

FIGUEIREDO GC, REZENDE MPG, FIGUEIREDO MP, BOZZI R, SOUZA JUNIOR AA, CARNEIRO PLS & MALHADO CHM. 2019. Morphofunctional characteristics of Dorper sheep crossed with Brazilian native breeds. Small Rumin Res 170: 143-148.

GARCIA IFF, COSTA TIR, ALMEIDA AK, PEREIRA IG, ALVARENGA FAP & LIMA NLL. 2010 Performance and carcass characteristics of Santa Inês pure lambs and crosses with Dorper e Texel at different management systems. Rev Bras Zootec 39: 1313-1321.

GOMES RC, SANTANA MHA, FERRAZ JBS, LEME PR & SILVA SL. 2012. Ingestão de Alimentos e Eficiência Alimentar de Bovinos e Ovinos de Corte. Ribeirão Preto: FUNPEC Editora, 77 p.

JIMMY S, DAVID M, DONALD KR & DENNIS M. 2010. Variability in body morphometric measurements and their application in predicting live body weight of mubende and small east African goat breeds in Uganda. Middle-East J Sci Res 5: 98-105.

KEARL LC. 1982. Nutrient requirements of ruminant in development contries. Logan: Utah State University, 381 p.

KOCH RM, SWIGER LA, CHAMBERS D & GREGORY KE. 1963. Efficiency of feed use in beef cattle. J Anim Sci 22: 486-494.

LISBOA-NETO AFS, MARIANO-FILHO PG, CARVALHO JR, ARAÚJO MS, SANTOS AC, MACHADO FCF, SILVA-FILHO ML & MACHADO-JÚNIOR AAN. 2017. Effect of racial crossing on the scrotum-testicular biometry in sheep submitted to scrotal insulation. Pesqui Vet Bras 37: 291-294.

MENEZES AM, LOUVANDINI H, ESTEVES GIF, DALCIN L, CANOZZI MEA, BARCELLOS JOJ & MCMANUS C. 2013. Performance and carcass traits of Santa Ines lambs finished with different sources of forage. Rev Bras Zootec 42: 428-437.

MONTANHOLI YR, HAAS LS, SWANSON KC, COOMBER BL, YAMASHIRO S & MILLER SP. 2017. Liver morphometrics and metabolic blood profile across divergent phenotypes for feed efficiency in the bovine. Acta Vet Scand 59: 1-11.

MONTANHOLI YR, SWANSON KC, SCHENKEL FS, MCBRIDE BW, CALDWELL TR & MILLER SP. 2009. On the determination of residual feed intake and associations of infrared thermography with effi ciency and ultrasound traits in beef bulls. Livest Sci 125: 22-30.

NORHAYATI Z, ZAHARI MW, NOORAISYAH S, SHANMUGAVELU S & RAHMAN AA. 2018. Carcass characteristics of male dorper sheep weaned at different ages. J Vet Malaysia 30: 20-22.

PAULA EFE, SANTANA MHA, MONTEIRO ALG, KULIK CH, KOWALSKI LH & CRUZ TA. 2013. Consumo alimentar residual em ovinos. Acta Tecnol 8: 12-21.

REZENDE MPG, LUZ DF, RAMIRES GG & OLIVEIRA MVM. 2014. Índices zootécnicos de novilhas da raça pantaneira. Vet Zootec 21: 550-555.

SOBRINHO TL, BRANCO RH, FIGUEIREDO S, BONILHA M, CASTILHOS M, FIGUEIREDO LA, RAZOOK AG, EUGÊNIA M & MERCADANTE Z. 2011. Residual feed intake and relationships with performance of Nellore cattle selected for post weaning weight. R Bras Zootec 40: 929-937.

SOUZA JC, REZENDE MPG, RAMIRES GG, GONÇALVES VT, SOUZA CF, OLIVEIRA NM & RIBEIRO RV. 2015. Phenotypic traits of equines raised in the Pantanal of Mato Grosso do Sul. Semina Ciênc Agrár 36: 3341-3352.

TABBAA MT, BARAKEH FS & BAKER MM. 2019. Factors influencing farmers decision on breeding objectives and selection criteria for sheep breeds in Abu Dhabi Emirate, UAE. Bulg J Agric Sci 25: 141-152.

TOE F, REGE JEO, MUKASA-MUGERWA E, TEMBELY S, ANINDO D, BAKER RL & LAHLOU-KASSI A. 2000. Reproductive characteristics of Ethiopian highland sheep I. Genetic parameters of testicular measurements in ram lambs and relationship with age at puberty in ewe lambs. Small Rumin Res 36: 227-240.

VAN SOEST PJ, ROBERTSON JB & LEWIS BA. 1991. Methods of dietary fiber, neutral detergent fiber and non starch polysaccharides in relation to animal nutrition. J Dairy Sci 74: 3583-3597.

YEAMAN JC, WALDRON DF & WILLINGHAM TD. 2013. Growth and feed conversion efficiency of Dorper and Rambouillet lambs. J Anim Sci 91: 4628-4632.

ZHANG ALN, WU BP, JIANG CXH, XUAN DCZ, MA EYH & ZHANG FYA. 2018. Development and validation of a visual image analysis for monitoring the body size of sheep. J Appl Anim Res 46: 1004-1015.

How to cite

FREITAS ACB, COSTA RLD, QUIRINO CR, BARTHOLAZZI JUNIOR A, VEGA WHO, BELTRAME RT & CAMPOS FP. 2020. The effects of genetic group and sex on residual feed intake, performance, morphometric, testicular, and carcass traits' in lambs. An Acad Bras Cienc 92: e20190340. DOI 10.1590/0001-3765202020190340.

Manuscript received on March 21, 2019;
accepted for publication on August 9, 2019

ANA CAROLINA B. FREITAS[1]
https://orcid.org/0000-0002-0412-6298

RICARDO L.D. COSTA[2]
https://orcid.org/0000-0001-8888-6915

CELIA R. QUIRINO[1]
https://orcid.org/0000-0001-6039-1259

AYLTON BARTHOLAZZI JUNIOR[1]
https://orcid.org/0000-0002-9373-9781

WILDER H.O. VEGA[1]
https://orcid.org/0000-0001-9742-4501

RENATO T. BELTRAME[3]
https://orcid.org/0000-0001-6622-7126

FÁBIO P. CAMPOS[2]
https://orcid.org/0000-0001-9220-450X

[1] Universidade Estadual do Norte Fluminense Darcy Ribeiro, Laboratório de Reprodução e Melhoramento Genético Animal, Av. Alberto Lamego, 2000, 28013-602 Campos dos Goytacazes, RJ, Brazil

[2] Centro de Pesquisa em Zootecnia Diversificada, Instituto de Zootecnia, Rua Heitor Penteado, 56, 13380-011 Nova Odessa, SP, Brazil

[3] Centro Universitário do Espírito Santo/UNESC, Av. Fioravante Rossi, 2930, 29703-900 Colatina, ES, Brazil

Correspondence to: **Ricardo Lopes Dias da Costa**
E-mail: rldcosta@iz.sp.gov.br

Author contributions

Ana Carolina B. Freitas - collected the data and wrote the manuscript; Ricardo Lopes Dias da Costa - conception of the study, administered the project, reviewed the manuscript and corresponding author; Celia R. Quirino - critical reading of the manuscript, statistical analysis; Aylton Bartholazzi Junior - statistical analysis; Wilder H.O. Vega - reviewed the manuscript; Renato T. Beltrame - critical reading of the manuscript and Fábio P. Campos - conducted laboratory analysis.