Archivos de Zootecnia
Journal website: https://www.uco.es/ucopress/az/index.php/az/

Can individual daily dry matter intake be replaced by morphological or performance traits in sheep?

Freitas, A.C.B.[1], Costa, R.L.D.[2@], Quirino, C.R.[1], Bartholazzi-Junior, A.[1]

[1]Universidade Estadual do Norte Fluminense, Centro de Ciências e Tecnologias Agropecuária Laboratório de Reprodução e Melhoramento Genético Animal, Campos dos Goytacazes, Rio de Janeiro, Brazil.
[2]Centro de Pesquisa em Zootecnia Diversificada, Instituto de Zootecnia, Nova Odessa, São Paulo, Brazil

SUMMARY

Measuring individual daily feed intake (DMI) is difficult and expensive due to the facilities, equipment and labor. Thus, many researchers have been looking for alternative traits, cheaper and easier, to replace feed intake mensuration. The objective of this study was to evaluate the relationships between dry matter intake and body measures, morphometric indices, testicular measurements, carcass traits by ultrasound and performance traits in sheep. Thirty-two lambs with 3 months of age, males and females, Santa Ines purebred and crossbreed Dorper with Santa Ines, were used. The food was provided in automated feed stations and productive performance traits, body and testicular measures, morphometric indices and carcass traits were measured. Correlation coefficients between DMI and all traits were calculated ($p \leq 0.05$). The results showed correlation between DMI and morphometric measures/indices ($0.36<r<0.58$), testicular measures ($0.44<r<0.47$), carcass traits ($0.45<r<0.56$) and performance traits ($0.48<r<0.70$). The DMI was positively correlated with live weight, weight gain, muscle accumulation in the carcass, aptitude for meat, compactness, and stronger growth in sheep. Therefore, the increase in DMI can increase the yield of the carcass in sheep..

ADDITIONAL KEYWORDS

body measures.
carcass.
feed intake.
indices.
testicular measures.

¿Se puede reemplazar lo consumo diario individual de materia seca por rasgos morfológicos o de rendimiento en las ovejas?

RESUMEN

Medir la ingesta diaria de alimento individual (DMI) es difícil y costoso debido el tipo de instalaciones, equipos y la mano de obra necesários. Por lo tanto, muchos investigadores han estado buscando características alternativas, más baratas y fáciles de medir, para reemplazar la medición de la ingesta de alimento. El objetivo de este estudio fue evaluar las relaciones entre la ingesta de materia seca y las medidas corporales, índices morfométricos, medidas testiculares, rasgos de la canal por ultrasonido y rasgos de rendimiento en ovinos. Se utilizaron 32 corderos de 3 meses de edad, machos y hembras, de la raza Santa Inés y cruza dos Dorper con Santa Inés. El alimento se proporcionó en estaciones de alimentación automatizadas y se midieron los rasgos de desempeño productivo, medidas corporales y testiculares, índices morfométricos y rasgos de la canal. Se calcularon los coeficientes de correlación entre DMI y todas las características ($p \leq 0.05$). Los resultados mostraron correlación entre DMI y medidas / índices morfométricos ($0,36 < r < 0,58$), medidas testiculares ($0,44 < r < 0,47$), rasgos de la canal ($0,45 < r < 0,56$) y rasgos de rendimiento ($0,48 < r < 0,70$). El DMI se correlacionó positivamente con el peso vivo, el aumento de peso, la acumulación de músculo en la canal, la aptitud para la carne, la compacidad y el crecimiento más fuerte en las ovejas. Por tanto, el aumento de DMI puede incrementar el rendimiento de la canal en ovinos.

PALABRAS CLAVE

medidas corporales.
canal.
ingesta de alimento.
índices.
medidas testiculares.

INFORMATION

Cronología del artículo.
Recibido/Received: 11.04.2019
Aceptado/Accepted: 10.04.2022
On-line: 15.04.2022
Correspondencia a los autores/Contact e-mail:
rldcosta@sp.gov.br

INTRODUCTION

Livestock feed costs have risen rapidly over the last decade, impacting profitability of livestock producers and whetting the interest by breeders and researchers in feed efficiency (Meyer et al., 2015, pp 85). Determining the feed efficiency of animals allows identifying and selecting animals with better ability to convert feed into animal product, decreasing feed costs (De Paula et al., 2013, pp 806). Traditionally several feed efficiency measures (equations) have been used.

Many of them consider the feed intake of animals in relation to the efficiency, so the feed intake must be transformed into daily dry matter intake (DMI), which is all food without the water (Gomes et al., 2012, pp 35).

Measuring individual daily feed intake under commercial conditions is usually impractical, because it is expensive due to modifications in the facilities. In addition, handling sheep in individual pens requires extra work (weighing the amount of food offered and the leftover) and can be negative for feeding behavior of sheep (Nowak and Boivin, 2015, pp 15). Whereas domestic sheep form large gregarious groups and spend long periods in close proximity with each other (Tamioso et al., 2017, pp 28), collective pens with automated feed stations are a great alternative to remedy the problems with labor and with sheep behavior during the measurements of daily feed intake.

Many researchers have been looking for cheaper and easier traits to replace the measure of daily feed intake, mainly performance, reproductive and carcass traits. So far, however, no manuscript measured body traits and morphometric indices for that purpose. Therefore, the objective of this study was to evaluate the relationships between dry matter intake and body measures, morphometric indices, feed efficiency traits (considering or not DMI in the equations), testicular measurements and carcass traits by ultrasound in sheep, trying to replace the individual feed intake measure with a simpler and cheaper measure. If any alternative trait is identified, indirect selection to improve feed efficiency would be more practical.

MATERIAL AND METHODS

This study was approved by the ethics committee on animal use of the Instituto de Zootecnia (CEUA-IZ), finding number 224-16.

The experiment was conducted at Instituto de Zootecnia, Nova Odessa, São Paulo state, Brazil (latitude - 47″ 19′ 51″ W and longitude - 22″ 47′ 20″ S). Thirty-two not castrated lambs (Ovis aries) with 3 months of age (soon after weaning) and average initial weight of 18±3.7 kg were used. Sixteen lambs were of the Santa Ines breed (8 males and 8 females) and 16 were crossbred 7/8 Dorper x Santa Ines sheep (8 males and 8 females).

The animals were allowed to adjust to the facilities and feeding system for 15 days and were tested for 65 days. They were housed in two indoor pens (males x females), bedded with sugar cane bagasse, 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 of them providing only hay and the other two only concentrate. There was an electronic scale in each pen linked to the automatic waterers, where the animals were weighted every time they drank water.

Each animal was fitted with an electronic identification device (EID) held by a neck collar. Each time an animal inserted its head into the feeder, the INTERGADO® device scanned the EID to record the amount of feed consumed in relation to its disappearance and feeding behavior events during each day (24 hours/day). The automated feeder recorded the daily consumption of concentrate (DCC) and hay (DCH), in kg. These data were transformed into daily dry matter intake (DMI), where DMI = (roughage intake x dry matter roughage content) + (concentrate intake x dry matter concentrate intake) (Gomes et al., 2012, pp 38). We also considered the dry matter intake of concentrate (DMIC) and the dry matter intake of hay (DMIH).

Traditionally several productive performance traits (equations) have been used, many of them considering the DMI of each animal to relate this with efficiency. The productive performance traits without DMI in the equations were: average body weight (ABW) during the feeding period (Gomes et al., 2012, pp 14); mid-trial metabolic body weight (MMBW) = [(initial body weight + final

Table I. Chemical composition of the hay and concentrate in % of dry matter (Composición química del heno y concentrado em % de materia seca).

Chemical composition	Commercial concentrate	Hay
Dry matter (%)	88.9	93.0
Crude protein (%)	19.8	13.4
Ether extract (%)	1.9	1.4
Mineral matter[a]	13.5	6.9
Nitrogen-free extract (%)	54.0	47.0
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 (NDT) (%)	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.
Dry matter, ether extract, mineral matter and crude protein according to AOAC (2005); neutral detergent fiber, acid detergent fiber, hemicellulose, cellulose and lignin according to Goering and Van Soest (1991); NDT according to Kearl (1982).

body weight/2]0.75 (Koch et al., 1963. pp 488) and average daily gain (ADG) = (final weight – initial weight)/ days on feed.

The productive performance traits with DMI in the equations used in this study were: dry matter intake/ body weight (DMI/BW) and dry matter intake of concentrate/body weight (DMIC/BW).

Every 14 days we obtained body and testicular morphometric measurements. The linear body measurements were (in cm) withers height (WH); body length (BL); and thoracic perimeter (TP) (Costa et al., 2014, pp 1371). The testicular measurements were scrotal circumference (SC), in cm; right testicular length (RTL), in mm; and right testicular diameter (RTD), in mm (Toe et al., 2000, pp 230).

Morphometric indices were calculated as the ratio between morphometric measures and/or body weight (Costa et al., 2014, pp 1371): body capacity (BCin) = weight/ thoracic perimeter; body side index (BSin) = withers height/body length x 100; compactness index (Cin) = weight/withers height x 100; body proportionality index (BPin) = compactness index/body index x 100. Other indices used was proportionality index (Pin) = body length/withers height x 100 (Bravo et al, 2010, pp 1108) and anamorphosis index (Ain) = thoracic perimeter2/ withers height x 100 (Rezende et al., 2014, pp 552).

On the last day of the experiment, ultrasound pictures were taken at the 12th to 13th intercostal space, using a Chison D600VET ultrasound system (China) coupled to a linear transducer rated at 7.5 MHz. The ImageJ® software was used to measure, in mm, height of the Longissimus lumborum muscle (Hldm); ribeye area in Longissimus lumborum muscle (RAldm) and subcutaneous fat thickness (SFT) (Menezes et al., 2013, pp 429).

Correlation coefficients between DMI and all traits (body morphometric, index measurements, productive performance traits, testicular parameters and carcass ultrasound) were calculated using the CORR procedure (Pearson method). Results were considered statistically significant when P≤0.05.

RESULTS

The descriptive statistics of all traits studied are presented in **Table II.**

The dry matter intake was compared with 23 other traits and there was no significant correlation only with

Table II: Mean, standard deviation, minimum and maximum of body morphometric, index measures, productive performance traits, testicular parameters and carcass ultrasound. Final trial (Media, desviación estándar, mínimo y máximo de morfometría corporal, medidas de índice, rasgos de desempeño productivo, parámetros testiculares y ecografía de la canal. Ensayo final)

Variable	Mean	Standard Deviation	Minimum	Maximum
Dry matter intake (kg/day)	1.34	0.44	1.08	4.58
Dry matter intake/body weight (%BW)	4.55	1.21	1.43	8.00
Dry matter intake of concentrate (kg/day)	1.23	0.42	1.06	4.53
Dry matter intake of concentrate/body weight (%BW/day)	3.93	1.42	2.01	4.99
Dry matter intake of hay (kg/day)	0.11	0.09	0.2	1.23
Dry matter intake of hay/body weight (%BW)	0.62	0.29	0.5	4.23
Average body weight (kg)	28.89	4.54	18.75	37.00
Mid-trial metabolic body weight (kg)	12.43	1.49	9.01	15.00
Average daily gain (kg/day)	0.24	0.05	0.14	0.35
Withers height (cm)	59.12	3.88	47.00	71.00
Thoracic perimeter (cm)	74.86	7.19	54.00	90.00
Body length (cm)	66.20	6.46	45.00	79.00
Body capacity	0.36	0.06	0.22	0.51
Proportionality index	112.01	8.86	81.82	135.09
Body side index	89.85	7.25	74.03	122.22
Anamorphosis index	95.60	16.80	59.07	139.66
Compactness index	45.38	8.75	24.00	68.97
Body proportionality index	51.51	10.73	25.87	77.60
Right testicular length (mm)	66.01	20.94	20.50	124.2
Right testicular diameter (mm)	45.19	13.85	10.00	83.00
Scrotal circumference (cm)	22.65	4.44	10.00	30.00
Height of Longissimus lumborum muscle (cm)	2.56	0.38	1.73	3.61
Ribeye area in Longissimus lumborum muscle (cm)	10.18	2.36	6.36	16.63
Subcutaneous fat thickness (mm)	1.57	0.44	0.92	2.77

subcutaneous fat thickness. Of the 23 traits with significant correlation with DMI, 65.2% (15 traits) showed correlation higher than 0.43 (moderate to strong correlation) (**Figure 1**).

A very great majority of body morphometric and index measures, testicular and carcass (except subcutaneous fat thickness) showed moderate to strong correlations with DMI (0.44 < r < 0.58). Only withers height (r=0.29), body side index (r=-0.36), proportionality index (r=0.36) and anamorphosis index (r=0.39) showed weak correlations with DMI.

Considering the productive performance traits that do not take into account DMI in the equations, we noted strong correlations between DMI and average body weight (r=0.57) and mid-trial metabolic body weight (r=0.48). But there was a weak correlation between DMI and average daily gain (r=0.36).

DISCUSSION

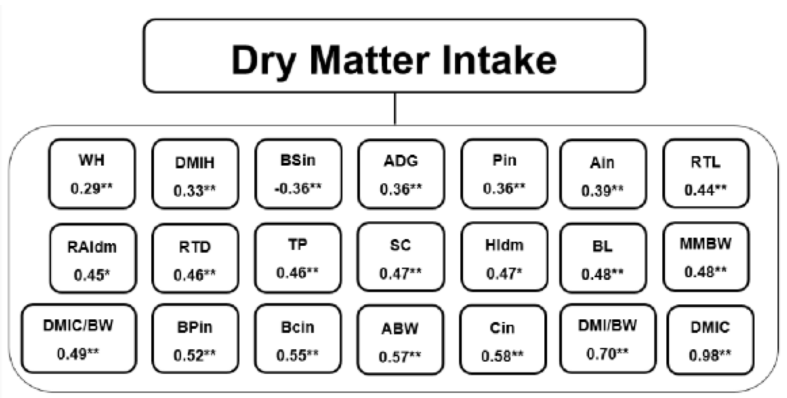
Efficiency traits in sheep are measured using equations and DMI is used in some of them. Due to the high costs and the difficulty involved in measuring the DMI, traits that do not use it are more practical and used frequently for commercial livestock, such as body weight at different ages and average daily gain. However, selection programs based on these traits can increase the DMI and, consequently, livestock feed costs (Koch et al., 1963, pp 493). In addition, little is known about the variability in body morphometric and index measurements related to production and efficiency in sheep.

The body measurements are very simple and quickly executed. Withers height, body length and thoracic perimeter are useful to identify superior individuals for carcass traits (Cezar and Sousa, 2010, pp 42). The increase in thoracic perimeter is closely linked to the live weight, weight gain and yield of the carcass (Lima et al., 2010, pp 2). The genetic improvement of specialized meat breeds selects animals with a more compact conformation, that is, with smaller withers height and body length in relation to their body depth, thus having a greater percentage of the trunk in detriment to body extremities, since the greatest proportion of the carcass comes from the trunk and not from appendicular regions of the body (Cartaxo et al., 2017, pp 395).

Morphometric indices are used to describe the size and proportion of an animal, which are the relationship among various linear body measurements or between these traits and body weight (Khargharia et al., 2015, pp 1256). Body capacity indicates the muscle accumulation in the carcass and allows estimating or classifying animals as to the potential for body development (Araújo Filho et al., 2007, pp 399). Animals with higher value of proportionality index show more aptitude for meat (Casanova and Pere-miquel, 2007, pp 8). The increase in compactness index means more compact animals (body weight increase and withers height decrease) (Costa et al., 2014, pp 1375).

The body proportionality index refers to the animal's conformation, i.e., to what extent the animal is compact or longilineal (Costa et al., 2014, pp 1375). According to the anamorphosis index, also called "conformation Index" or "Baron & Crevat measure", the greater the index, the more robust the animal (Chacón et al., 2011, pp 1673). The body side index indicates that animals with lower value are closer to a rectangle, a predominant form in animals with aptitude for meat production (Casanova and Pere-miquel, 2007, pp 5).

Our results related to the body and index measurements showed moderate to strong correlations between DMI and live weight, weight gain, muscle accumulation in the carcass, aptitude for meat, compactness, and stronger growth. Those results are very



** P<0.001; *P<0.05.

ABW=average body weight; ADG=average daily gain; Ain=anamorphosis index; Bcin= body capacity index; BSin= body side index; BL= body length; BPin= body proportionality index; Cin= compactness index; DMI=dry matter intake; DMI/BW= dry matter intake/body weight; DMIC=dry matter intake of concentrate; DMIC/BW= dry matter intake of concentrate/body weight; Hldm= height of Longissimus dorsi muscle; MMBW= mid-trial metabolic body weight; Pin= proportionality index; RAldm= ribeye area in Longissimus dorsi muscle; RTD= right testicular diameter; RTL= right testicular length; SC= scrotal circumference; TP= thoracic perimeter; WH= withers height.

Figure 1. Significative correlations between dry matter intake (DMI) and body morphometric, index measurements, productive performance traits, testicular parameters and carcass ultrasound (correlaciones significativas entre la ingesta de materia seca (DMI) y la morfometría corporal, las mediciones del índice, los rasgos de desempeño productivo, los parámetros testiculares y la ecografía de la canal).

interesting, since the increase in DMI can increase the yield of the carcass.

From an economic viewpoint, this increase in DMI may or may not be a desirable situation. The direct selection against DMI was favored for low lamb prices with high feed costs (Snowder and Van Vleck, 2003, pp 2710). On the other hand, animals with higher growth velocity and that reach maturity as early as possible are very interesting for producers of sheep meat, because it reduces the reproductive age and improves the rate velocity and that reach maturity as early as possible are very interesting for producers of sheep meat, because it reduces the reproductive age and improves the rate of economic return (Teixeira Neto et al., 2016, pp 32). Hence, in environments with limited feed resources, heavier sheep may be undesirable (Snowder and Van Vleck, 2003, pp 2712), especially in larger and later breeds (Paula et al., 2013, pp 570).

In our study, the animals with higher DMI showed higher muscularity. The distribution of muscularity can be estimated by ultrasound to measure the height and ribeye area in Longissimus lumborum muscle. These measures are directly correlated with the muscle:bone ratio in the most valuable cuts of the carcass (Cezar and Sousa, 2010, pp 42).

There were strong positive correlations between DMI, testicular measures ($0.44<r<0.47$) and body weight ($0.68<r<0.73$). The scrotal circumference, age at puberty and sexual behavior of young lambs can be influenced by body weight (Lima et al., 2010, pp 2) and testicular development is greater in heavier animals than in lighter ones (Fraga et al., 2015, pp 751). Nutritional factors can also act in scrotal circumference, since it was higher in lambs that consumed a high-energy feed than a high-fiber feed (Macedo Junior et al., 2014, pp 393).

CONCLUSIONS

The DMI showed a significant correlation with body measures, morphometric indices, productive performance traits, testicular measurements and carcass traits by ultrasound in sheep. DMI was positively correlated with the increase of live weight, weight gain, muscle accumulation in the carcass, aptitude for meat, compactness, and stronger growth. Therefore, the increase in DMI can increase the yield of the carcass in sheep.

ACKOWLEGMENTS

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

BIBLIOGRAPHY

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' *Revista Brasileira de Saúde e Produção Animal*, vol.8, pp. 394–404. (https://periodicos.ufba.br/index.php/rbspa/article/view/39619/22209).

Bravo S, Fabres M, Schnettler B & Sepúlveda N 2010, 'Índices Zoométricos en Ovejas Criollas Araucanas' *International Journal of Morphology*, vol. 28, pp. 489–95. (https://www.researchgate.net/publication/235734532_Corporal_Composition_and_Characteristics_of_Carcass_of_Araucano_Creole_Lambs).

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' *Revista Brasileira de Saúde e Produção Animal*, vol. 1, pp. 388–401. (https://www.scielo.br/pdf/rbspa/v18n2/1519-9940-rbspa-18-02-0388.pdf).

Casanova P & Pere-Miquel LSD 2007, 'Análisis biométrico y funcional de la raza ovina aranesa' *Revista Electrónica Veterinaria*, vol. 8, pp. 1–8. (https://www.redalyc.org/pdf/636/63613304003.pdf).

Cezar MF & Sousa WH 2010, 'Proposta de avaliação e classificação de carcaças de ovinos deslanados e caprinos' *Revista Tecnologia & Ciência Agropecuária*, vol. 4, pp. 41–51. (https://zeoserver.pb.gov.br/gestaounificada/gu/emepa/publicacoes/revista-tca-emepa/edicoes/volume-04-2010/volume-4-numero-4-dezembro-2010/tca05_proposta.pdf).

Chacón E, Macedo F, Velázquez F, Paiva SR, Pineda E & McManus C 2011, 'Morphological measurements and body indices for Cuban Creole goats and their crossbreds' *Revista Brasileira de Zootecnia*, vol. 40, pp. 1671–79. (https://www.scielo.br/pdf/rbz/v40n8/07.pdf).

Costa RLD, Quirino CR, Afonso VAC, Pacheco A, Beltrame RT, Madella-Oliveira AF, Costa, AM & Silva, RMC 2014, 'Morphometric indices in santa ines sheep' *International Journal of Morphology*, vol. 32, pp. 1370–76. (https://scielo.conicyt.cl/pdf/ijmorphol/v32n4/art39.pdf).

De Paula EFE, Souza DF, Monteiro ALG, Santana MHA, Gilaverte S, Rossi Junior P & Dittrich, RL 2013 'Residual feed intake and hematological and metabolic blood profiles of Ile de France lambs' *Revista Brasileira de Zootecnia*, vol. 42, pp. 806–812. (https://www.rbz.org.br/wp-content/uploads/articles_xml/1516-3598-rbz-S1516-35982013001100007/1516-3598-rbz-S1516-35982013001100007.pdf).

Fraga ALCR, Hatamoto-Zervoudakis LK, Silva Júnior LS, Cabral LS, Souza JR, Barros DS & Angreves, GM 2015 'Puberty beginning in lambs from hairless ewe submitted to caloric or protein restriction' *Revista Brasileira de Saúde e Produção Animal*, vol. 16, pp. 746–57. (https://www.scielo.br/pdf/rbspa/v16n3/1519-9940-rbspa-16-3-0746.pdf).

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 (SP): FUNPEC Editora; 2012, (https://www.researchgate.net/publication/259097386_Ingestao_de_alimentos_e_eficiencia_alimentar_de_bovinos_e_ovinos_de_corte#fullTextFileContent).

Khargharia G, Kadirvel G, Kumar S, Doley S, Bharti PK & Das M 2015, 'Principal component analysis of morphological traits of assam hill goat in esatern Himalayan India' *Journal of Animal and Plant Sciences*, vol. 25, pp. 1251–8. (file:///D:/Downloads/PrincipalcomponentanalysisofmorphologicaltraitsofAssamhillgoatineasternHimalayanIndia.pdf).

Koch RM, Swiger LA, Chambers D & Gregory KE 1963, 'Efficiency of feed use in beef cattle' *Journal of Animal Science*, vol. 22, pp. 486–494. (https://academic.oup.com/jas/article-abstract/22/2/486/4699113).

Lima CJA, Santos ADF, Oliveira VS, Moura CN, Carvalho CTG & Fraga Junior AM 2010, 'Perímetro escrotal, peso e medidas corporais em ovinos da raça Santa Inês e mestiços Santa Inês x Dorper criados no sertão sergipano' In: 47a Reunião Anual da Sociedade Brasileira de Zootecnia. Salvador, BA; 2010.

Macedo Junior GL, Assis RM, Perez JRO, Paula OJ, França PM & Almeida TRV 2014, 'Biometria testicular de cordeiros em diferentes idades e alimentados com níveis crescentes de fibra em detergente neutro oriunda da forragem' *Ciência Animal Brasileira*, vol. 15, pp. 384–99. (https://www.scielo.br/pdf/cab/v15n4/a02v15n4.pdf).

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' *Revista Brasileira de Zootecnia*, vol. 42, pp. 428–437. (https://www.rbz.org.br/pt-br/article/performance-and-carcass-traits-of-santa-ines-lambs-finished-with-different-sources-of-forage/).

Meyer AM, Vraspir RA, Ellison MJ & Cammack KM 2015, 'The relationship of residual feed intake and visceral organ size in growing lambs fed a concentrate or forage based diet' *Livestock Science*, vol. 176, pp. 85–90. (https://www.sciencedirect.com/science/article/pii/S187114131500147X?via%3Dihub).

Nowak R & Boivin X 2015, 'Filial attachment in sheep: Similarities and differences between ewe-lamb and human-lamb relationships' *Applied Animal Behaviour Science*, vol. 164, pp. 12–28. (https://www.sciencedirect.com/science/article/pii/S0168159114002470?via%3Dihub).

Paula EFE, Monteiro ALG, Souza DF, Prado OR, Nomura TM, Stivari TSS, Silva, CJA & Santana, MHA 2013, 'Consumo alimentar residual e sua relação com medidas de desempenho e eficiência e características in vivo da carcaça de cordeiros' *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, vol. 65, pp. 566–572. (https://www.scielo.br/pdf/abmvz/v65n2/37.pdf).

Rezende MPG, Luz DF, Ramires GG & Oliveira MVM 2014, 'Índices zootécnicos de novilhas da raça pantaneira' *Veterinária e Zootecnia*, vol. 21, pp. 550–555. (file:///D:/Downloads/bovinopantaneiro%20(1).pdf).

Snowder GD & Van Vleck LD 2003, 'Estimates of genetic parameters and selection strategies to improve the economic efficiency of postweaning growth in lambs' *Journal of Animal Science*, vol. 81, pp. 2704–2713. (https://academic.oup.com/jas/article-abstract/81/11/2704/4789890?redirectedFrom=fulltext).

Tamioso PR, Rucinque DS, Taconeli CA, da Silva GP & Molento CFM 2017, 'Behavior and body surface temperature as welfare indicators in selected sheep regularly brushed by a familiar observer' *Journal of Veterinary Behaviour*, vol. 19, pp. 27–34. (https://www.sciencedirect.com/science/article/pii/S1558787817300138?via%3Dihub).

Teixeira Neto MR, Cruz JF, Faria HHN, Souza ES, Carneiro PLS & Malhado CHM 2016, 'Descrição do crescimento de ovinos Santa Inês utilizando modelos não-lineares selecionados por análise multivariada' *Revista Brasileira de Saude e Produção Animal*, vol. 17, pp. 26–36. (https://www.scielo.br/pdf/rbspa/v17n1/1519-9940-rbspa-17-1-0026.pdf).

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 Ruminant Research*, vol. 36, pp. 227–240. (file:///D:/Downloads/1-s2.0-S0921448899001170-main.pdf).