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ANIMAL PRODUCTION

Berganês, a new sheep breed from the Brazilian semiarid: performance and carcass traits in different sex-classes by univariate and multivariate approaches

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ABSTRACT. Twenty-four lambs between four and five months of age were divided into sex classes: uncastrated males, castrated males and females, eight for each treatment, with an average body weight of 27.00 ± 3.13 kg. dry matter and water intakes were higher for uncastrated males ($p < 0.001$). final body weight, body weight at slaughter, average daily gain and cold carcass weight were greater for uncastrated, intermediate for castrated and lower for females ($p < 0.05$). hot and cold carcass yields were higher for castrated males and females, respectively. ($p < 0.05$). based on principal component analysis, twenty-five variables were selected out of thirty-two, in some of the seven principal components generated, summarizing 21.87% data dimension. Discriminant analysis identified greater discrimination power for body weight at slaughter, thorax width, thorax depth, fatness, dry matter intake and hot carcass weight. All lambs were classified into their respective sex classes. Therefore, uncastrated males have performed better than castrated ones and both showed higher performance than females. Females and castrated males showed higher carcass yield. Discriminant analysis indicated heterogeneity between sex classes.

Keywords: multivariate analysis; native sheep; sheep breeding; cooling loss; commercial cuts.

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Introduction

Berganês sheep is an ecotype emerged in the Brazilian semiarid around 1980 and is derived from a crossbreed between Bergamácia and Santa Inês (Silva Filho et al., 2021a; Soares et al., 2019). These animals have large body size and are highly adapted to semiarid conditions, thus becoming an alternative for meat production (Nogueira Filho & Yamamoto 2017). Male castration and female slaughter are common practices in this region. However, no studies have evaluated sex class effects on performance and carcass traits of this sheep breed.

Sex class can affect productive performance and carcass traits since metabolic and hormonal changes influence growth rate and fattening (Everitt & Jury 1966; Rodrigues et al., 2016). In general, uncastrated males have greater testosterone synthesis, which has an anabolic effect, increasing muscle growth (Schanbacher, Crouse, & Ferrell, 1980; Li et al., 2020).

Araújo et al. (2017) assessed sex class effect on the performance of Morada Nova sheep and reported that dry matter intake, average daily gain, and body weight at slaughter were greater for uncastrated males, intermediate for castrated, and lower for females. Conversely, females and males may have higher carcass yield, which can be explained by early puberty, resulting in lower carcass weight and higher fat deposition than uncastrated males (Facciolongo et al., 2018; Okeudo & Moss, 2008). This result is important since fat serves as a barrier against extravasation of carcass fluids (Costa et al., 2011; Warner, 2017).

Based on the above, this study aimed to evaluate the effect of sex class on performance and carcass traits of Berganês sheep, using univariate and multivariate statistical methods.

Material and methods

Experiment location and date

The experiment was carried out at the Federal Institute of *Sertão Pernambucano* (IF Sertão-PE), municipality of Petrolina, state of Pernambuco - Brazil (9° 23' 39'' S latitude, 40° 30' 35'' W longitude, and 373 m altitude) between July and September 2017. This area has a semiarid climate and total rainfall in 2017 was 140 mm, with an average air temperature of 25°C and relative air humidity of 60%.

Ethical aspects, animals, treatments and experimental design

The study was approved by the Animal Ethics Committee of the IF Sertão, Pernambuco State (under code 029/2017).

We used 24 Berganês lambs, eight of each belonging to one of the following sex classes: uncastrated males, castrated males, and females (eight for each). The animals had an average body weight of 27.00 ± 3.13 kg and aged between four and five months. For evaluations, lambs were distributed in a completely randomized design and housed in 2-m^2 individual pens with a dirt floor and equipped with feeders and drinking fountains.

Diets and chemical analysis

The experiment lasted 70 days, with the first 14 days for adaptation to facilities and handling. Lambs were fed a single diet with a roughage: concentrate ratio of 15:85, containing Buffel grass hay (*Cenchrus ciliaris* L.), ground corn, soybean meal, calcitic limestone, and mineral mixture. Table 1 lists the ingredient proportions and chemical composition of diets. The diet was based on National Research Council (NRC, 2007) to provide 250 g day^{-1} gains. Diets were supplied twice daily (8:00 and 15:00h) and adjusted to allow 10% leftovers.

Table 1. Ingredient proportions and diet chemical composition for Berganês lambs from different sex classes.

Total diet Ingredients	(g kg^{-1})
Ground corn	565.00
Soybean meal	245.00
Buffel grass hay	150.00
Calcitic Limestone	10.00
Mineral mix	30.00
Total	1000.00
Chemical composition Nutrients	(g kg^{-1})
Dry matter	932.00
Crude protein	169.10
Neutral detergent fiber	220.10
Acid detergent fiber	110.90
Ether extract	31.10
Total digestible nutrients	778.40

Contents of dry matter (DM - method 934.01), crude protein (CP - 942.05), and ether extract (EE - 920.39) were determined according to Association of Official Analytical Chemists (AOAC, 2000). Neutral (NDF) and acid (ADF) detergent fiber were obtained according to the method described by Van Soest, Robertson, and Lewis (1991). Total digestible nutrients (TDN) were calculated using the equation described by Weiss (1999).

Dry matter, nutrient and water intakes, and animal productive performance

Dry matter intake was determined as follows: DMI = (diet offered daily - leftovers in the feeder the next day) x dry matter. Nutrient intake [CP (CPI), NDF (NDFI), and EE (EEI)] consisted of the difference between their amounts in diets and leftovers. TDN intake was obtained as follows: TDNI = (CPI – CP in feces) + 2.25 (EEI – EE in feces) + (total carbohydrate intake – total carbohydrate in feces). Water intake (WI) was calculated as WI = water offered daily - leftovers in drinking fountains the next day – evapotranspiration in control drinking fountains.

Initial (IBW) and final (FBW) body weights were obtained on days 1 and 56, respectively, with animals being weighed after 16 hours fasting. We also estimated average daily gain [ADG = (FBW-IBW) /56] and feed conversion (FC = dry matter intake/average total gain).

Carcass traits and morphometric evaluation

After the end of the experiment, lambs were transported to a slaughterhouse in the municipality of Petrolina, where they fasted for 16 hours and were weighed for body weight at slaughter (BWS) and then slaughtered. Slaughter process started with brain concussion, followed by bleeding, skinning, evisceration, and head and feet removal. Carcasses were weighed to obtain hot weight (HCW) and yield (HCY = HCW / BWS

* 100). After 24-hour cooling, carcasses were weighed again for cold weight (CCW), yield (CCY = CCW / BWS * 100), and cooling loss [CL = (HCW - CCW) / HCW * 100] (Cezar & Sousa, 2007). Carcass conformation and fatness were also evaluated using a 0.25-point scale, from 1 to 5, as described by Cezar and Sousa (2007).

Carcasses were also measured for external length (ELC), internal length (ILC), leg length (LL), thorax width (TW), thorax depth (TD), hind width (HW), hind perimeter (HP), compactness indices of carcass (CCI = CCW/ILC) and leg (LCI = HW/LL), according to Cezar and Sousa (2007). Moreover, carcasses were cut lengthwise and then separated into six anatomical regions (neck, shoulder, rib, saw, loin, and leg). These parts were individually weighed for yield determination as follows: Cut (%) = (cut weight / weight of reconstituted left half carcass) × 100 (Cezar & Sousa, 2007).

Statistical Analysis

Data were evaluated using the Statistical Analysis System (SAS, 2002). The Shapiro–Wilk normality test was carried out using the PROC UNIVARIATE at 5% significance ($p < 0.05$). Analysis of variance was run using the PROC GLM, with means subjected to Tukey's test at 5% significance ($p < 0.05$). The variables IBW and HCW were included as covariates for analysis of animal performance and carcass traits, respectively. A principal component analysis (PCA) was performed using PROC PRINCOMP, with principal components retained for analysis by the Kaiser (1960) criterion. A discriminant analysis (DA) was also performed to classify and discriminate individuals for performance and carcass traits. The procedure PROC STEPDISC was used to determine the variables with the greatest discrimination power. The classifier PROC DISCRIM was used to determine the percentages of individual classifications in each sex class. Finally, canonical roots were generated by the PROC CANDISC.

Results

Nutrient intake (DMI, CP, NDF, and TDN) (g day^{-1}) was higher for uncastrated males ($p < 0.001$), while DMI (%BW) was not different (P=0.633) between sex classes (Table 2), averaging 2.97%BW. Water intake (g day^{-1}) was higher for uncastrated males, but WI in %BW (p=0.121) was not different between sex classes. On average, WI for feedlot Berganês lambs was 8.6%BW.

The FBW, BWS, and ADG were higher for uncastrated males, intermediate for castrated males, and lower for females ($p < 0.05$). Uncastrated males showed lower FC, followed by castrated, and both were lower than FC of females (Table 2).

Table 2. Dry matter, nutrient and water intake, and performance of Berganês lambs from different sex classes.

Variable	Uncastrated	Castrated	Females	SEM	*P*-value
		Intake			
Dry matter (g day^{-1})	1460.57^a	1260.66^b	1072.58^b	43.69	<0.001
Dry matter (%BW)	3.02	2.98	2.92	0.05	0.633
Crude protein (g day^{-1})	359.02^a	312.45^b	261.37^b	9.52	<0.001
Neutral detergent fiber (g day^{-1})	291.82^a	227.30^b	202.68^b	16.54	<0.001
Ether extract (g day^{-1})	27.49	26.97	21.37	1.43	0.154
Total digestible nutrients (g day^{-1})	1471.21^a	1278.62^b	1080.95^b	37.15	<0.001
Water (g day^{-1})	4330.95^a	3441.51^b	3181.13^b	133.26	<0.001
Water (%BW)	8.97	8.13	8.70	0.17	0.121
		Performance			
Initial body weight (kg)	28.55	26.71	25.55	0.55	0.168
Final body weight (kg)	48.32^a	42.28^b	36.55^c	1.19	<0.001
Body weight at slaughter (kg)	46.09^a	39.10^b	33.92^c	1.16	<0.001
Average daily gain (g day^{-1})	317.06^a	244.26^b	175.25^c	13.90	<0.001
Feed conversion (kg)	4.56^a	5.27^b	6.28^c	0.20	<0.001

SEM = standard error of the mean; P = probability value; BW = body weight. Means followed by different letters, in the same row, are significantly different by Tukey's test at 5%.

The HCW and CCW were higher for uncastrated males, intermediate for castrated males, and lower for females ($p < 0.001$) (Table 3). Females and castrated males had higher HCY and CCY ($P < 0.05$) On average, HCY and CCY were 52.88 and 50.95%, respectively. Lower CL were found for females, intermediate for castrated males, and higher for uncastrated males (P=0.002) (Table 3).

Better carcass conformation was observed for uncastrated males ($p < 0.001$), but no differences were detected between sex classes for carcass fatness (P=0.099). Regarding carcass morphometry, TD was higher for uncastrated males, intermediate for castrated, and lower for females (P=0.012). However, ELC, ICL, LL, HW, HP, CCI, and LCI were not affected by sex classes (p > 0.05). Commercial meat cuts (neck, shoulder, rib, saw, loin, and leg) in half-carcass (%) were also not affected by sex classes (Table 3). Leg was the most representative commercial meat cut, with on average 31.59% half-carcass.

Table 3. Carcass traits and commercial meat cuts of Berganês lambs in different sex classes.

Variable	Uncastrated	Castrated	females	SEM	P
Hot carcass weight (kg)	23.42[a]	21.31[b]	18.05[c]	0.53	<0.001
Cold carcass weight (kg)	22.31[a]	20.58[b]	17.53[c]	0.48	<0.001
Hot carcass yield (%)	50.90[b]	54.51[a]	53.24[a]	0.51	0.010
Cold carcass yield (%)	48.42[b]	52.63[a]	51.79[a]	0.54	0.001
Cooling loss (%)	4.87[c]	3.45[b]	2.70[a]	0.25	<0.001
Conformation (1-5)	3.82[a]	3.35[b]	3.39[b]	0.06	<0.001
Fatness (1-5)	3.47	3.27	3.44	0.04	0.099
Carcass morphometry					
External length (cm)	63.14	61.64	61.81	0.49	0.135
Internal length (cm)	74.07	72.69	73.83	0.76	0.425
Leg length (cm)	45.07	44.14	46.12	1.17	0.602
Thoracic width (cm)	20.21	20.64	18.43	0.29	0.078
Thoracic depth (cm)	29.09[a]	27.25[b]	26.31[b]	0.34	0.012
Hind width (cm)	22.71	21.71	20.81	0.22	0.628
Hind perimeter (cm)	61.79	59.93	56.69	0.64	0.287
CCI (kg cm^{-1})	0.27	0.28	0.27	0.00	0.160
LCI (kg cm^{-1})	0.51	0.49	0.46	0.01	0.657
Commercial cuts					
Neck (%)	12.01	12.22	11.11	0.48	0.809
Shoulder (%)	20.31	20.17	18.61	0.32	0.437
Rib (%)	16.04	16.91	18.30	0.27	0.256
Saw (%)	12.35	12.15	10.43	0.31	0.143
Loin (%)	9.72	9.80	10.82	0.15	0.108
Leg (%)	31.54	31.35	31.87	0.30	0.869

CCI = Carcass compactness index; LCI = Leg compactness index; SEM = Standard error of the mean; P = Probability value. Means followed by different letters, in the same row, are significantly different by Tukey's test at 5%.

The PCA generated seven principal components (PCs) with eigenvalues > 1, which explained 87.67% total variance (Figure 1). Twenty-five out of the 32 variables analyzed showed greater explanatory power (eigenvector > 0.3 or < -0.3) for some of the generated components.

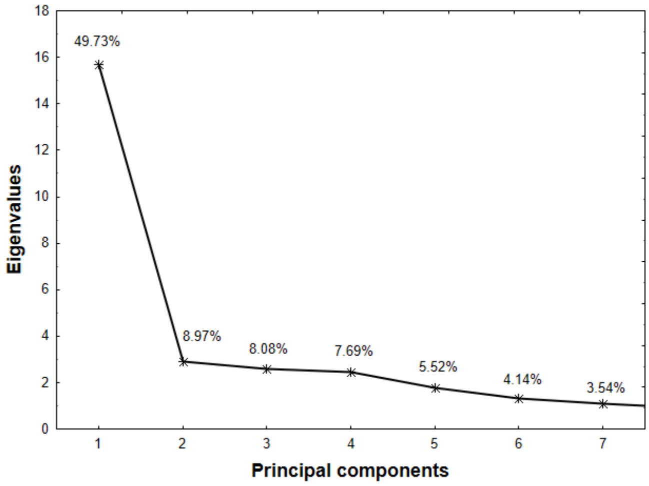

Figure 1. Cumulative variance and eigenvalues (y-axis) generated by principal component analysis for nutrient intake, animal performance, and carcass traits of Berganês lambs from different sex classes.

The PC1 explained 49.73% total variance, in which DMI, CPI, EEI, TDNI, FBW, BWS, ADG, HCW, CCW, HP, and CCI had the largest eigenvectors (> 0.3) (Figure 2). PC2 explained 8.97% total variability, with the greatest explanatory power for FC, HCY, and rib (eigenvectors > 0.3) and for shoulder (eigenvectors <-0.3). PC3 explained 8.08% total variance, with the greatest explanatory power for EEI, HCY, and CCY (eigenvectors > 0.3). PC4 explained 7.69% total variation, for which fatness and LL (eigenvectors > 0.3) and LCI and shoulder (eigenvectors < -0.4) had greater explanatory power. PC5 explained 5.52% cumulative variance, with ELC, loin, and leg having eigenvectors > 0.3 and CL and saw <-0.3. PC6 explained 4.14% total variance, and neck and HCY had eigenvectors <-0.6 and >0.3, respectively. Finally, PC7 explained 3.54% total variability, with EEI, fatness, and leg showing eigenvectors > 0.3 and ELC < -0.3.

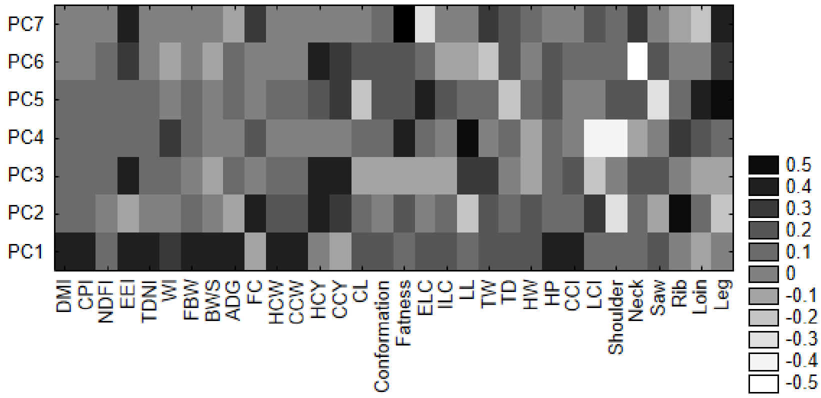

Figure 2. Principal components generated from nutrient intake, animal performance, and carcass traits of Berganês lambs from different sex classes. PC = Principal components; DMI = Dry mater intake; CPI = Crude protein intake; NDFI = Neutral detergent fiber intake; EEI = Ether extract intake = TDNI = Total digestible nutrients intake; WI = Water intake; FBW = Final body weight; BWS = Body weight at slaughter; ADG = Average daily gain; FC = Feed conversion; HCW = Hot carcass weight; CCW = Cold carcass weight; HCY = Hot carcass yield; CCY = Cold carcass yield; CL = Cooling loss; ELC = External length carcass; ILC = Internal length carcass; LL = Leg length; TW = Thoracic width; TD = Thoracic depth; HW = Hind width; HP = Hind perimeter; CCI = Carcass compactness index; LCI = Leg compactness index.

Figure 3 illustrates the interrelationship between the variables and the first two components (PC1 and PC2) through a two-dimensional plane. Variables DMI, CPI, EEI, TDNI, FBW, BWS, ADG, HCW, CCW, HP and CCI all approached each other and positioned themselves better along the PC1. In PC2, HCY, FC, and Rib were positively positioned, while shoulder, negatively.

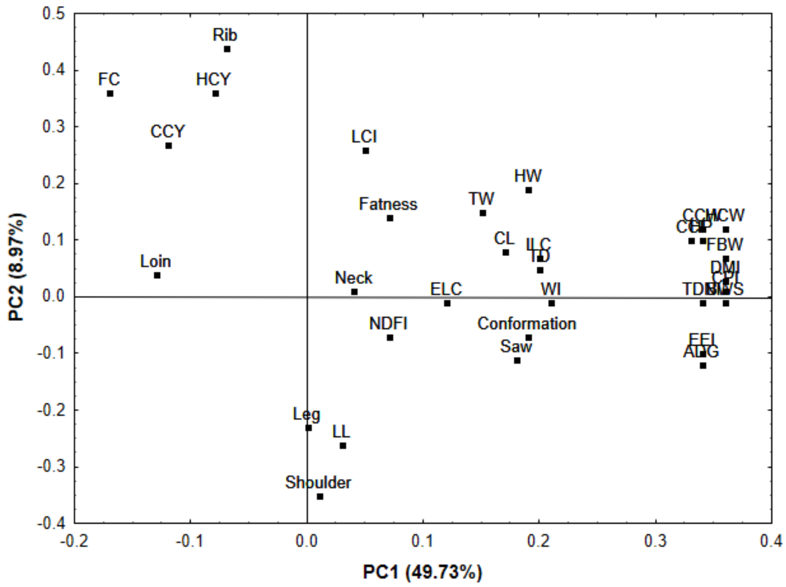

Figure 3. Two-dimensional representation of the first two principal components generated from animal performance and carcass traits of Berganês lambs from different sex classes. PC = Principal components; DMI = Dry mater intake; CPI = Crude protein intake; NDFI = Neutral detergent fiber intake; EEI = Ether extract intake = TDNI = Total digestible nutrients intake; WI = Water intake; FBW = Final body weight; BWS = Body weight at slaughter; ADG = Average daily gain; FC = Feed conversion; HCW = Hot carcass weight; CCW = Cold carcass weight; HCY = Hot carcass yield; CCY = Cold carcass yield; CL = Cooling loss; ELC = External length carcass; ILC = Internal length carcass; LL = Leg length; TW = Thoracic width; TD = Thoracic depth; HW = Hind width; HP = Hind perimeter; CCI = Carcass compactness index; LCI = Leg compactness index.

The variables with the highest discriminating power were BWS, TW, TP, fatness, DMI, and HCW ($p < 0.05$) (Table 4). The remaining others were excluded from the model by Wilks's lambda stepwise method, with values reducing from 0.183 to 0.028. All lambs could be classified into their respective sex classes (Figure 4).

Table 4. Discriminant linear function of the variables selected by the stepwise method and percentages of classification of Berganês lambs of the sex-classes uncastrated males, castrated males and females.

Variable	Uncastrated	Castrated	Females	P-Value	Wilk's Lambda
Body weight at slaughter	100482572	103352757	100331744	<0.001	0.183
Thorax width	92465186	105600646	105945684	0.009	0.114
Thorax depth	390814584	370884130	356540687	0.036	0.083
Fatness	-1.49286E9	-1.46364E9	-1.36577E9	0.033	0.057
Dry matter intake	-4921286	-4758099	-4513379	0.040	0.040
Hot carcass weight	-124664132	-122195762	-123383000	0.028	0.028
Constant	-3.8498E10	-3.739E10	-3.4841E10		
Classification (%)	100	100	100		

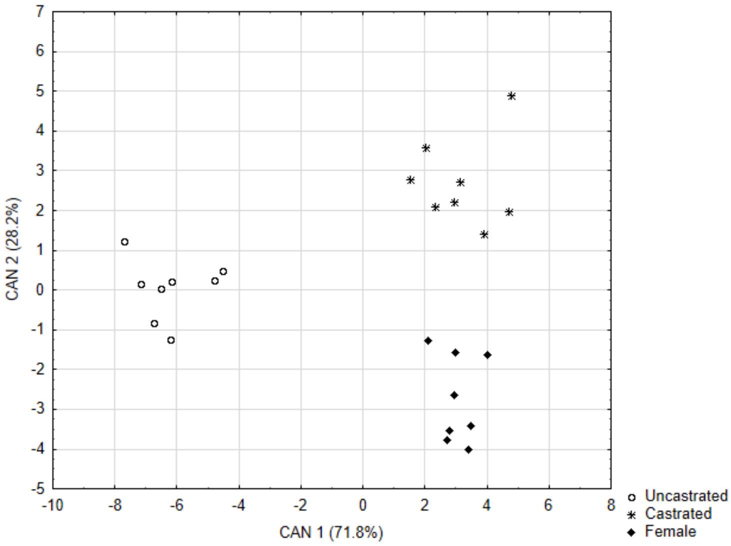

Figure 4. Canonical representation of nutrient intake, animal performance, and carcass traits of Berganês lambs from different sex classes.

Discussion

The highest values for DMI, CPI, NDFI, TDNI, and WI observed for uncastrated males increased FBW, BWS, and ADG but decreased FC. Increases in nutrient intake promote greater ADG and FBW, with water being involved in muscle growth metabolic reactions (Albuquerque et al., 2020). Other authors (Mahgoub & Lodge, 1994; Pereira et al., 2018) also reported that uncastrated males have better productive performance than other sex classes.

Testosterone blood levels in uncastrated male lambs are higher than in castrated males and emales. Many studies have shown that higher testosterone levels are associated with higher growth rates in sheep (Arnold & Meyer 1988; Adam & Findlay 1997; Araújo et al., 2017). When bound to myofibril receptors, testosterone triggers reactions in the cell nucleus through signaling pathways to activate mammalian target protein of rapamycin (mTOR), which plays a role in structural protein synthesis, such as actin and myosin, in muscle fibers (Vingren et al., 2010).

However, castrated males and females had similar DMI and WI, but castrated males had better productive performance. Therefore, muscle growth decreased in females to start fat deposition, which is related to reproductive development (Rodrigues et al., 2016), as females were approaching the reproductive stage by the time of this study.

The highest HCW and CCW for uncastrated males, intermediate for castrated males, and lower for females also reflect testosterone anabolic effect on male muscles and female pregnancy preparation. These findings are in agreement with Everitt and Jury (1966), who evaluated Southdown × Romney crossbred lambs and with Pereira et al. (2018), who evaluated Morada Nova lambs.

The lowest carcass yield for uncastrated males was already expected. However, unexpectedly, it was not associated with carcass fattening since sex classes did not differ for fatness (P=0.099). Similar results were verified by (Araújo et al., 2017). Complementing our study, Silva Filho et al. (2021b) evaluated non-carcass components and found higher total weights of by-products (head, blood, skin, and feet) for uncastrated males than in castrated males and females. Thus, the greater representation of these non-carcass components in BWS of uncastrated males decreased carcass yield.

The CL results suggest that females and non-castrated males may have higher and lower intramuscular fat contents, respectively. Higher intramuscular fat contents indicate greater availability of molecules or free radicals to make bonds with proteins or water, inhibiting fluid extravasation between muscle fibers (Warner, 2017).

Better carcass conformation in uncastrated males corroborates the results of performance and carcass weight. This confirms a greater muscle hyperplasia in this sex class (Butterfield, 1988).

Uncastrated males also had a greater TD. By studying allometric growth in ruminants, Owens, Dubeski, and Hansont (1993) verified that thorax matures in the penultimate stage of life. Therefore, we may suggest that uncastrated males prolonged thorax growth for longer, thus castration anticipated the maturation of this region. Females are also known to mature earlier.

The PCA showed that 25 out of the 32 variables analyzed had high explanatory power in some of the seven principal components generated, summarizing data dimension by 21.87%. Dataset size reduction and explaining variation in a few PCs is a PCA premise (Härdle & Simar, 2015; Macena et al., 2022) and indicates the technique suitability.

In PC1, most of the total variance (49.73%) indicated FBW, BWS, and ADG for performance results and HCW, CCW, HP and CCI for carcass responses. These variables were also associated with nutrient intake (DM, CP, TDN, and EE). Body growth and carcass weight increases result from the supply of ingested nutrients for fat deposition in body tissues (Santos et al., 2019).

The contrast in PC2 indicates that an increase in FC was related to higher HCY and rib yield, and lower shoulder yield in castrated males and females (Tables 2 and 3). This suggests that earliness in castrated males and females increased FC, HCY, and rib yield, reducing shoulder yield. However, an increased FC is not a desirable characteristic. Moreover, HCY in uncastrated males is compatible with those reported by Vargas Junior et al. (2014) for Pantaneiro lambs, and superior to those observed by Araújo et al. (2017) for Morada Nova and by Souza, Selaive-Villarroel, Pereira, Silva, and Oliveira (2016), for Santa Inês lambs. Ribs and shoulder are cuts of lower commercial value (Cezar & Sousa, 2010), therefore, reductions in the yield of the shoulder and rib increases may not lead to losses in carcass economic value.

The results verified in PC3 indicated that increases in EEI improved HCY and CCY. A high bioavailability of lipids in metabolism facilitates their deposition in muscle tissues (Kowalczyk, Orskov, Robinson, & Stewart, 1977; Fan et al., 2019). Consequently, higher lipid contents in muscles increase availability of molecules or free radicals to bind with water and proteins, preventing further cooling losses and improving carcass yield (Warner, 2017; Corazzin, Bianco, Bovolenta, & Piasentier, 2019)

The results verified in PC4 suggest that carcass fatness increase was associated with higher LL. These variables also showed a negative correlation with LCI and shoulder yield. Carcass fatness and LL positive correlation indicates that the ecotype Berganês has long legs and adequate carcass fat cover. Moreover, the high LL was decisive for LCI reduction.

The contrast found in PC5 indicates that the ELC increase was correlated with increases in loin and leg yields, as well as reductions in CL and saw. These are desirable characteristics, since CL reduction increases carcass yield. Similarly, saw reductions, associated increases in with loin, leg, and ELC, improve carcass commercial value (Cezar & Sousa, 2010). Also, the contrast in PC6 is also desired, as indicates that reductions in neck yield increase HCY.

The PC7 indicated that EEI increases enhanced carcass fatness and leg yield, but reduced ELC. As mentioned before, high lipid bioavailability in animal metabolism increases their deposition in body tissues (Fan et al., 2019), which could justify the increase in carcass fattening. As for leg yield, there was an increase in subcutaneous and intramuscular fat contents, reducing its CL and increasing its yield in carcass (Corazzin et al., 2019). Furthermore, an increase in EEI may anticipate fat deposition and tissue growth maturation (Kowalczyk et al., 1977), which may be related to ELC reduction in this study.

The greater discrimination power of BWS, TD, DMI, and HCW can be explained by the statistical difference detected by analysis of variance (Tables 2 and 3). However, selecting thorax width and fatness show the importance of these variables in sex class discrimination in our study. The Wilks's lambda represents the proportion of total variance in discriminant scores not explained by differences between groups (Hair, Black, Anderson, & Tatham, 2009). Therefore, reductions in these values indicate that the model was properly fit to treatment discrimination and classification (Dossa, Wollny, & Gauly, 2007), suggesting heterogeneity between sex classes in our study.

Conclusion

In general, productive performance, carcass weight, and carcass conformation are higher for uncastrated Berganês males, intermediate for castrated males, and lower for females. Uncastrated males have lower carcass yields and higher cooling loss. Except for thoracic length, carcass and meat cut morphometric characteristics are not affected by sex classes in Berganês lambs. Berganês lamb sex classes were heterogeneous, and body weight at slaughter, thorax width, thorax depth, fatness, dry matter intake, and hot carcass weight showed greater discriminatory power.

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