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Discrimination ability of Santa Inês and crossbred Santa Inês × Dorper lamb heavy carcasses by the Brazilian and European classification systems

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ABSTRACT - The ability of discriminating carcass characteristics of different fat cover scores of heavy carcasses, according to the European (EUS) and Brazilian (BRS) classification systems, was assessed. Fifty-six lambs, weighing between 26.25 and 46.15 kg, of the Santa Inês and crossbred Santa Inês × Dorper genetic groups were evaluated. The level of adiposity was assessed through color photography of the carcasses after refrigeration according to the EUS and BRS. The carcasses were assigned to four groups by cluster analysis according to 25 variables, namely, cold carcass weight; muscle; bone; fat; and muscle:fat and fat:bone ratios of the carcass and cuts (hindquarter, shoulder, back); kidney, pelvic, and inguinal fat; and subcutaneous fat thickness. Of the four groups obtained by cluster analysis, the scores according to the different classification systems only statistically differed between groups 1 and 4. The BRS had a higher number of variables well correlated with the scores by assessors than the groups classified by the EUS. The BRS was better correlated with tissue composition. However, most variables were better correlated with backfat thickness than the score obtained through the classification systems. Better results were obtained regarding the prediction of carcass fat by the BRS using backfat thickness or cold carcass weight. The Brazilian lamb carcass classification system better predicts tissue composition and is the best method to discriminate intermediate-fat classes when associated with cold carcass weight.

Key Words: conformation, non-specialized breeds, tissue composition

Introduction

The evaluation of lamb carcasses in Brazil employs grading systems that include the fat score as a criterion of quality and price. To evaluate the grease status as a variable that interferes with carcass and meat quality, it influences the appearance, color, succulence, and acceptance of the product by the consumer (Pannier et al., 2014). Such systems assess the carcass fat content subjectively and can help predict its edible portion and fleshiness.

Commonly in Brazil, the classification of ovine carcasses is carried out according to the standards established by the classification system of carcasses EUROP, European Union (EUS), which classifies the carcasses regarding cold carcass weight (CCW) as heavy when CCW≥13 kg and grades them regarding conformation using photographic standards on a scale from 1 to 6, ranging from poor to superior, respectively (European Union, 1994). However, the evaluation of carcasses using that score system leads to difficult distinctions, since the reference images are far apart from one another concerning the level of adiposity, which hinders evaluation using those photographic standards (Miguel et al., 2003).

Although Brazil has its own classification system (BRS), it is little known in lamb slaughterhouses in the country. The BRS classifies carcasses according to categories common to other systems, such as sex, maturity, and weight, grading them according to fat cover on a scale from 1 to 5, corresponding to lean to very fat, respectively (Brasil, 1990). This system was mainly developed to meet the requirements of animals reared in the tropics, which, due to adaptive evolution and even food scarcity, excessive

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amounts of fat stored internally, may compromise the homogenicity traits in external fat cover, therefore, adjustments are required to address the irregularity found in carcasses obtained in Brazil (Medeiros et al., 2011). Regardless of the system, methods based on scores are efficient for being quick and allowing the carcass to be evaluated in few seconds with no damage to it.

This study aimed to assess the discrimination ability of carcass characteristics and tissue composition of the different conformation scores according to the European lamb carcass classification system and the Brazilian lamb carcass classification system for heavy carcasses.

Material and Methods

Fifty-six lambs, weighing between 26.25 and 46.15 kg and having CCW≥13 kg, of the Santa Inês (n = 26) and crossbred Santa Inês × Dorper (n = 30) genetic groups, were evaluated. No significant difference (P>0.05) was observed between the genetic groups evaluated for the variables analyzed in this study, which enabled the two groups to be assessed jointly. The carcasses were kept at 4°C for 24 h and then photographed for later classification by trained assessors.

After refrigeration, the CCW, carcass weight, and pelvic, kidney, and inguinal fat weights were obtained (Table 1). The whole carcasses were photographed for classification, by three trained evaluators, according to the degree of fat cover established by the EUS (1: low, 2: slight, 3: average, 4: high, and 5: very high) (European Union, 1994) and by the BRS (1: lean, 2: slight fat, 3: average fat, 4: uniform fat, and 5: excessive fat) (Brasil, 1990).

The whole carcasses were split into symmetrical half-carcasses, whose backfat thickness (BFT) was measured, in millimeters, between the 12th and 13th ribs. The half-carcasses were then divided into cuts and separated into muscle, fat, and bone (Colomer-Rocher et al., 1984). The percentages of muscle, fat, and bone, as well as the muscle:fat and fat:bone ratios in the carcass and cuts were determined.

The statistical analysis included cluster analysis based on Pearson's dissimilarity and agglomeration method of complete linkage, Spearman's correlation analysis, and variance analysis, using the model:

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij},$$

in which Y_{ij} = observation for tissue composition variables; μ = overall mean; α_i = fixed effect of groups (Cluster (4), EUS (4), or BRS (3)) i observed value in Y_{ij}; and ε_i = random errors ($\varepsilon_{ij} \sim$ IN (0, σ2)), with Tukey's test at 5% significance level, adopted to compare to what extent each classificatory variable influences the response variable, and regression analysis, in which:

$$\text{linear: } y = \alpha + \beta_1 x_1 + \varepsilon \text{ and}$$

$$\text{linear multiple: } y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \varepsilon,$$

in which y = observation for tissue composition variables; x_1 = system of carcass classification, EUS or BRS; x_2 = BFT or CCW; α, β_1, and β_2 = regression coefficients; ε = random error ($\varepsilon \sim IN$ (0, σ2)). The statistical procedures were carried out using the software SAS (Statistical Analysis System, version 9.2).

Results

The carcasses were grouped (Figure 1) into four clusters and a significant statistical effect was observed for the variables CCW, carcass composition, and fat cover, except for inguinal fat (Table 2). Clusters 1 and 4 differed regarding all variables, except inguinal fat. Clusters 2 and 3 differed in CCW, carcass muscle percentage (CaM%), carcass bone percentage (CaB%), carcass fat percentage (CaF%), kidney fat (KiF), and pelvic fat (PelF).

A significant effect was found in the clusters for the score according to the EUS and BRS (Table 3), with a difference (P<0.05) among the carcasses grouped in clusters 4 and 1 for both systems. When those classification methods were used, only the carcasses with low fat content

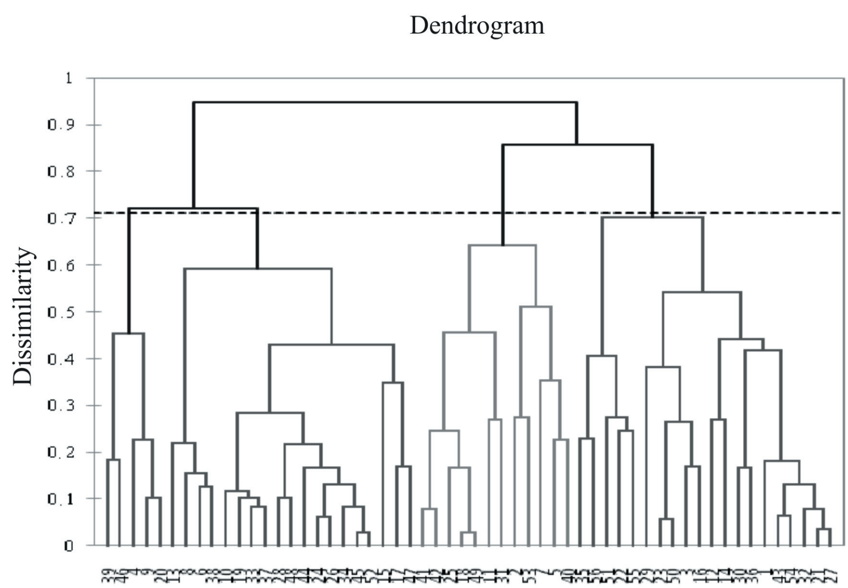
Table 1 - Variables used in the cluster analysis to configure the classification tree

Variable	
CCW	Cold carcass weight (kg)
CaM%	Carcass muscle (%)
CaB%	Carcass bone (%)
CaF%	Carcass fat (%)
CaM:F	Carcass muscle:fat ratio
CaF:B	Carcass fat:bone ratio
KiF	Kidney fat (g)
PelF	Pelvic fat (g)
IngF	Inguinal fat (g)
BFT	Back fat thickness (mm)
HiM%	Hindquarter muscle (%)
HiB%	Hindquarter bone (%)
HiF%	Hindquarter fat (%)
HiM:F	Hindquarter muscle:fat ratio
HiF:B	Hindquarter fat:bone ratio
BaM%	Back muscle (%)
BaB%	Back bone (%)
BaF%	Back fat (%)
BaM:F	Back muscle:fat ratio
BaF:B	Back fat:bone ratio
ShM%	Shoulder muscle (%)
ShB%	Shoulder bone (%)
ShF%	Shoulder fat (%)
ShM:F	Shoulder muscle:fat ratio
ShF:B	Shoulder fat:bone ratio

(≤19%) and those with high fat content (≥28.7%), 20 and 19, respectively, could be discriminated, enabling the discrimination of carcasses grouped at the top and bottom ends of those visual scoring systems: high-adiposity carcasses (cluster 4) from low-adiposity ones (cluster 1). Clusters 2 and 3 did not statistically differ between each other, neither did they differ from the top and bottom clusters (P>0.05), except cluster 3 and 4 from BRS.

Carcass groups were also established as a function of the score in both systems. Under the EUS, four scores (1, 2, 3, and 4) were obtained (Figure 2), while three (1, 2, and 3) were obtained by the BRS (Figure 3).

Using the EUS scale, a significant difference (P<0.05) was found in all carcass tissue composition variables between the poor (1) and very good (4) scores, except for carcass muscle (CaM%), KiF, inguinal fat (IngF), and PelF,



The x axis shows the numbers for carcass identification.

Figure 1 - Dendrogram (dissimilarity) showing the formation of four carcass groups defined by the amounts of fat and tissue composition.

Table 2 - Means and standard deviations of tissue composition and fat cover of carcasses and cuts defined by the four clusters formed by the classification tree

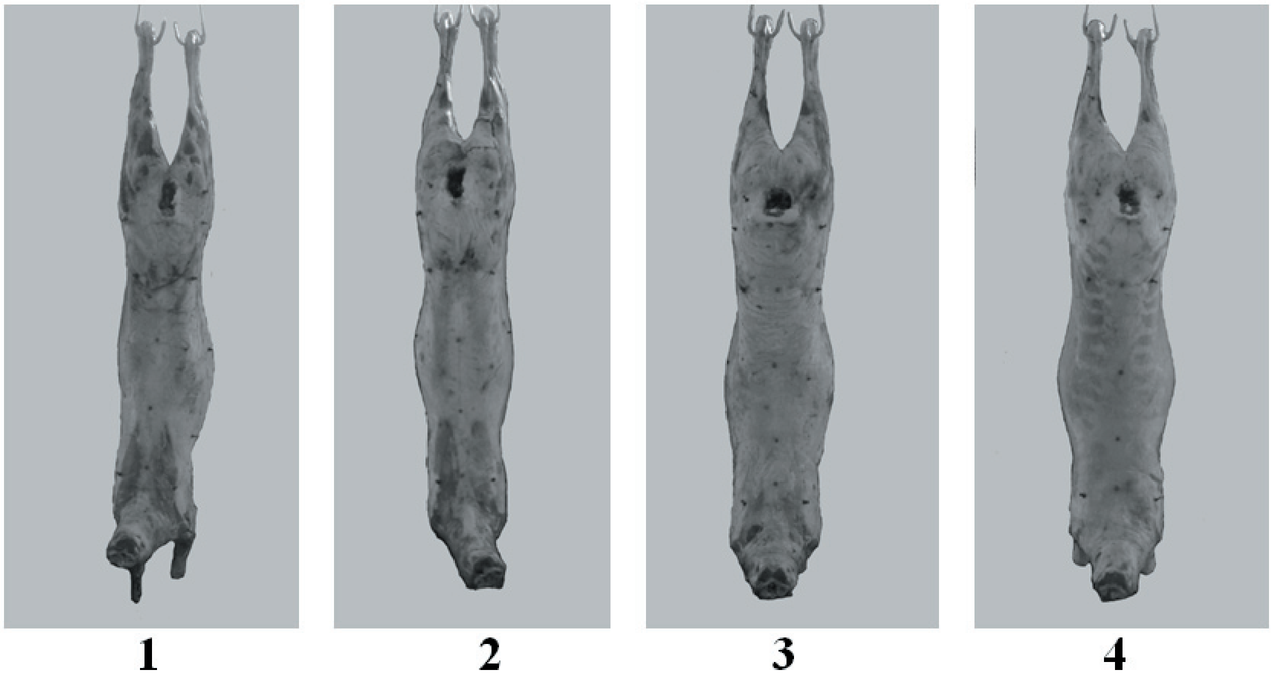
	1 (n = 20)	2 (n = 12)	3 (n = 5)	4 (n = 19)	P-value
CCW	15.59±0.48b	15.16±0.55b	20.10±0.71a	20.19±0.49a	<.0001
ShF%	13.15±0.49b	15.17±1.27b	16.29±1.06b	21.00±0.66a	<.0001
HiF%	11.95±0.51b	14.36±0.83b	14.26±0.39b	17.20±0.49a	<.0001
BaF%	16.95±1.03b	19.09±1.03ab	21.93±1.20a	23.57±0.86a	<.0001
CaM%	59.47±0.63a	54.53±0.79c	57.88±0.25ab	55.81±0.47bc	<.0001
CaB%	19.97±0.47ab	21.44±0.78a	17.8b±0.78c	16.73±0.23c	<.0001
CaF%	19.66±0.68b	22.48±1.12b	27.25±0.81a	28.68±0.67a	<.0001
KiF	0.21±0.02b	0.17±0.02b	0.47±0.02a	0.42±0.04a	<.0001
PelF	0.09b±0.01c	0.06±0.02c	0.28±0.02a	0.18±0.03b	<.0001
IngF	0.06±0.01	0.07±0.02	0.07±0.01	0.12±0.02	NS
BFT	2.14±0.20b	2.45±0.40b	3.55±0.54ab	4.50±0.36a	<.0001

CCW - cold carcass weight (kg); ShF% - shoulder fat (%); HiF% - hindquarter fat (%); BaF% - back fat (%); CaM% - carcass muscle (%); CaB% - carcass bone (%); CaF% - carcass fat (%); KiF - kidney fat (g); PelF - pelvic fat (g); IngF - inguinal fat (g); BFT - back fat thickness (mm); NS - not significant.
The same letters on the same row do not differ (P<0.05) according to Tukey's test.

Table 3 - Means and standard deviations of the scores by the classification systems defined by the four clusters formed by the classification tree

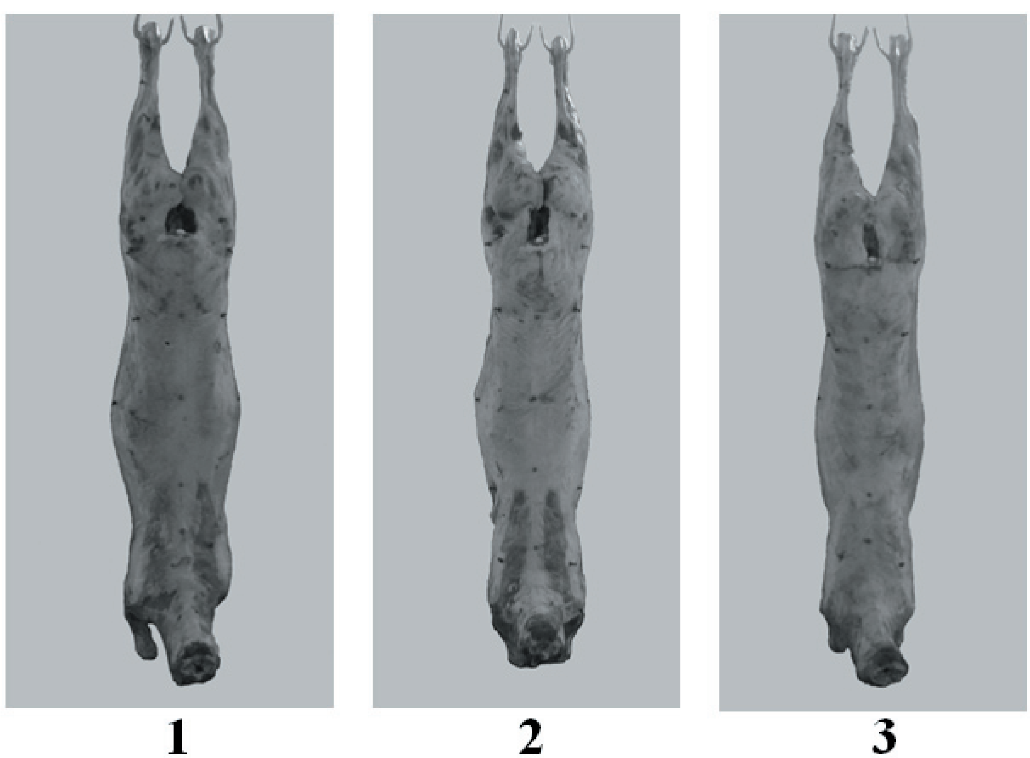
	1 (n = 20)	2 (n = 12)	3 (n = 5)	4 (n = 19)	P-value
EUS	2.00±0.13b	2.33±0.19ab	2.2±0.20ab	2.79±0.18a	0.0052
BRS	1.55±0.11b	2.25±0.33ab	2.00±0.00b	3.05±0.24a	<.0001

EUS - European classification system of lamb carcasses; BRS - Brazilian classification system of lamb carcasses.
The same letters on the same row do not differ (P<0.05) according to Tukey's test.



1: poor; 2: fair; 3: good; 4: very good.

Figure 2 - Photographic standards used in the score scale by the European lamb carcass classification system to assess the degree of fat cover in woolless lambs.



1: lean; 2: slight fat; 3: average fat.

Figure 3 - Photographic standards used in the score scale by the Brazilian lamb carcass classification system to assess the degree of fat cover in woolless lambs.

which were not significant. According to the BRS scale, a significant difference (P<0.05) was found between the lean (1) and average fat (3) for all variables, except for CaM% and IngF (Table 4).

The correlation analysis was performed among scores of both systems and the tissue composition variables of the carcass (Table 5). When the EUS was used, significant correlations were found for all variables, except for inguinal fat. Using the BRS, significant correlations were found for the same variables, except for inguinal fat and CaM%. When the two scales were compared, the BRS method showed the highest correlation coefficients for most variables. When the grouped data were analyzed, nearly all carcass tissue composition variables had higher correlation coefficients with BFT than the subjective fat assessment methods.

The regression analysis (Table 6) confirms that both classification systems were similar regarding carcass tissue composition prediction in slaughter conditions. When CCW was used in the model along with the score obtained by the BRS, 68% of the variation obtained for CaF% was explained.

Both carcass classification systems defined by the EUS and BRS were significantly different (P<0.05) regarding hindquarter fat (HiF%) and the hindquarter muscle:fat (HiM:F) and hindquarter fat:bone (HiF:B) ratios (Table 7).

Significant differences were found for those variables between the poor (1) and very good (4) scores for HiF%. The groups very good (4) and good (3) were similar to each other, but significantly different from the group poor (1). No significant differences were found between groups of

Table 4 - Means and standard deviations of carcass weight, tissue composition, and fat cover defined by the groups according to the score obtained by the European (EUS) and Brazilian (BRS) lamb carcass classification systems

	EUS				P-value
	1 (n = 5)	2 (n = 29)	3 (n = 19)	4 (n = 3)	
CCW	14.40±0.74b	17.18±0.57ab	18.3±0.68ab	20.08±1.59a	0.028
CaM%	58.74±24.96	57.45±0.56	56.38±0.53	54.19±0.61	NS
CaB%	21.30±1.14a	19.25±0.51ab	18.1±0.46ab	16.44±0.60b	0.0225
CaF%	18.67±1.76c	22.88±0.78bc	26.14±1.13ab	30.25±1.09a	0.0007
CaM:F	3.24±0.27a	2.60±0.10ab	2.25±0.13bc	1.79±0.05c	0.0007
CaF:B	0.90±0.14c	1.23±0.06bc	1.48±0.09ab	1.85±0.14a	0.0008
BFT	1.30±0.19c	2.61±0.19bc	3.99±0.36ab	5.86±1.45a	<.0001
KiF	0.19±0.06	0.27±0.03	0.35±0.04	0.34±0.07	NS
PelF	0.06±0.02	0.12±0.02	0.16±0.03	0.21±0.03	NS
IngF	0.08±0.05	0.08±0.01	0.09±0.02	0.03±0.01	NS
	BRS				
	1 (n = 12)	2 (n = 31)	3 (n = 13)		P-value
CCW	14.39±0.49b	17.81±0.52a	19.48±0.67a		<.0001
CaM%	57.79±1.39	57.27±0.47	55.74±0.50		NS
CaB%	20.34±0.78a	19.02±0.47ab	17.26±0.47b		0.01
CaF%	19.09±0.88c	23.91±0.78b	28.75±0.89a		<.0001
CaM:F	30.84±0.13a	24.89±0.10b	19.68±0.08c		<.0001
CaF:B	0.96±0.06c	1.30±0.06b	1.69±0.09a		<.0001
BFT	1.76±0.22c	2.91±0.22b	4.93±0.45a		<.0002
KiF	0.18±0.02b	0.29±0.03ab	0.40±0.06a		0.0019
PelF	0.08±0.01b	0.13±0.02ab	0.18±0.04a		0.0454
IngF	0.04±0.018	0.09±0.01	0.11±0.03		NS

CCW - cold carcass weight (kg); CaM% - carcass muscle (%); CaB% - carcass bone (%); CaF% - carcass fat (%); CaM:F - carcass muscle:fat ratio; CaF:B - carcass fat:bone ratio; BFT - back fat thickness (mm); KiF - kidney fat (g); PelF - pelvic fat (g); IngF - inguinal fat (g); NS - not significant.
The same letters on the same row do not differ (P<0.05) according to Tukey's test.

Table 5 - Correlation coefficients between the scores obtained by the European (EUS) and Brazilian (BRS) classification systems and by back fat thickness and carcass tissue and fat compositions

	CCW	CaM%	CaB%	CaF%	CaM:F	CaF:B	KiF	IngF	PelF
EUS	0.38**	−0.31*	−0.40**	0.53***	−0.52***	0.52***	0.30*	−0.02NS	0.34**
BRS	0.50***	−0.24NS	−0.40**	0.63***	−0.59***	0.61***	0.44***	0.26NS	0.32*
BFT	0.72***	−0.19NS	−0.62***	0.74***	−0.67***	0.78***	0.6***	0.16***	0.56***

CCW - cold carcass weight (kg); CaM% - carcass muscle (%); CaB% - carcass bone (%); CaF% - carcass fat (%); CaM:F - carcass muscle:fat ratio; CaF:B - carcass fat:bone ratio; KiF - kidney fat (g); IngF - inguinal fat (g); PelF - pelvic fat (g); BFT - back fat thickness (mm); NS - not significant.
* P≤0.05.
** P≤0.01.
*** P≤0.001.

Table 6 - Regression coefficient (R), coefficient of determination (R^2), and probability (P) between the classification systems associated with back fat thickness (BFT), cold carcass weight (CCW), and carcass measurements

		CaM%	CaB%	CaF%
y = EUS	R	0.30	0.40	0.53
	R^2	0.09	0.16	0.28
	P	0.02	<.0001	<.0001
y = EUS+BFT	R	0.30	0.62	0.75
	R^2	0.09	0.39	0.56
	P	0.07	<.0001	<.0001
y = EUS+CCW	R	0.30	0.69	0.81
	R^2	0.09	0.47	0.66
	P	0.07	<.0001	<.0001
y = BRS	R	0.24	0.40	0.63
	R^2	0.06	0.16	0.40
	P	0.08	0.00	<.0001
y = BRS+BFT	R	0.24	0.62	0.77
	R^2	0.06	0.39	0.59
	P	0.20	<.0001	<.0001
y = BRS+CCW	R	0.24	0.67	0.82
	R^2	0.06	0.45	0.68
	P	0.22	<.0001	<.0001

EUS - European classification system of lamb carcasses; BRS - Brazilian classification system of lamb carcasses; CaM% - carcass muscle (%); CaB% - carcass bone (%); CaF% - carcass fat (%).

scores 4 and 3 (good) for HiM:F and HIF:B according to the EUS. In BRS, significant differences were found for those variables between the lean (1) and average fat (3) scores for hindquarter bone (HiB%) and the group slight fat (2) was significantly different from the group poor (1).

The correlation analysis (Table 8) showed that both methods were good predictors of hindquarter tissue compositions. The BRS yielded higher correlation coefficients for most variables. Backfat thickness correlated well with all hindquarter variables, except for hindquarter muscle (HiM%), which was not significant.

Both groups showed significant difference for shoulder fat (ShF%) and shoulder muscle:fat (ShM:F) and shoulder fat:bone ratios (ShF:B), while only the BRS showed difference for shoulder bone (ShB%) (Table 9). The groups of extreme scores significantly differed for all variables in both classification systems. The groups with scores fair (2) and good (3) did not differ for any variables in the EUS. For the BRS system, no statistically significant difference was found between the groups lean (1) and slight fat (2) for the variables ShB%, ShM:F, and ShF:B.

Table 7 - Means and standard deviations of hindquarter tissue composition defined by the groups according to the score obtained by the European (EUS) and Brazilian (BRS) lamb carcass classification systems

	EUS				P-value
	1 (n = 5)	2 (n = 29)	3 (n = 19)	4 (n = 3)	
HiM%	64.77±2.36	65.05±0.83	64.13±0.81	61.32±0.83	NS
HiB%	19.23±0.94	17.02±0.49	17.02±0.31	15.99±0.39	NS
HiF%	10.97±1.2c	13.59±0.47bc	15.89±0.62ab	19.51±0.67a	<.0001
HiM:F	6.17±0.65a	4.99±0.22ab	4.2±0.22bc	3.15±0.11c	0.0009
HiF:B	0.58±0.08c	0.82±0.04bc	0.97±0.05ab	1.20±0.06a	0.0002
	BRS				
	1 (n = 12)	2 (n = 31)	3 (n = 13)		P-value
HiM%	65.79±2.03	64.89±0.55	62.43±0.49		NS
HiB%	18.86±0.75a	16.63±0.38b	16.3±0.36b		0.004
HiF%	11.83±0.69c	14.17±0.49b	17.56±0.51a		<.0001
HiF:B	0.64±0.05c	0.87±0.04b	1.09±0.05a		<.0001
HiM:F	57.58±0.35a	48.03±0.22b	35.95±0.12c		<.0001

HiM% - hindquarter muscle (%); HiB% - hindquarter bone (%); HiF% - hindquarter fat (%); HiF:B - hindquarter fat:bone ratio; HiM:F - hindquarter muscle:fat ratio; NS = not significant.
The same letters in the same column do not differ (P<0.05) according to Tukey's test.

Table 8 - Correlation coefficients between the scores obtained by the European (EUS) and Brazilian (BRS) classification systems and by back fat thickness (BFT) and hindquarter tissue compositions

	HiM%	HiB%	HiF%	HiM:F	HiF:B
EUS	−0.17NS	−0.28*	0.60***	−0.52***	0.56***
BRS	−0.29*	−0.32**	0.62***	−0.56***	0.60***
BFT	−0.19NS	−0.41**	0.67***	−0.59***	0.69***

HiM% - hindquarter muscle (%); HiB% - hindquarter bone (%); HiF% - hindquarter fat (%); HiM:F - hindquarter muscle:fat ratio; HiF:B - hindquarter fat:bone ratio; NS - not significant.
* P≤0.05.
** P≤0.01.
*** P≤0.001.

The correlation analysis (Table 10) showed a significant correlation for all shoulder tissue composition variables, except for ShM% in both classification systems. The BRS was the best predictor of shoulder tissue composition, with higher correlation coefficients. When the correlation coefficients of the shoulder were compared with those of the hindquarter according to the EUS, the latter were higher. However, in the BRS, the correlation coefficients were higher for the shoulder. Backfat thickness was the best predictor only for ShF:B and ShB%, while the BRS was the best predictor for the remaining variables.

Both groups of systems significantly differed for backfat (BaF%), back muscle:fat ratio (BaM:F), and backfat:bone ratio (BaF:B) (Table 11). The Brazilian and

Table 9 - Means and standard deviations of shoulder tissue composition defined by the groups according to the score obtained by the European (EUS) and Brazilian (BRS) lamb carcass classification systems

	EUS				P-value
	1 (n = 5)	2 (n = 29)	3 (n = 19)	4 (n = 3)	
ShM%	59.43±2.76	59.61±0.86	59.27±0.88	57.64±0.72	NS
ShB%	22.66±1.36	22.66±0.57	20.31±0.53	17.47±0.76	NS
ShF%	13.22±1.66b	14.99±0.64bc	18.73±1.05b	23.04±0.51a	0.0002
ShM:F	4.74±0.53a	4.18±0.18a	3.43±0.28ab	2.5±0.07b	0.0065
ShF:B	0.60±0.10b	0.73±0.04b	0.95±0.07ab	1.32±0.03a	0.0002
	BRS				
	1 (n = 12)	2 (n = 31)	3 (n = 13)		P-value
ShM%	57.73±1.81	60.85±0.65	57.37±0.59		NS
ShB%	21.92±0.10a	21.08±0.48ab	19.15±0.61b		0.0382
ShF%	12.68±0.72c	15.96±0.67b	21.46±0.87a		<.0001
ShM:F	46.71±0.23a	40.59±0.21a	27.43±0.14b		<.0001
ShF:B	0.60±0.05b	0.78±0.05b	1.14±0.07a		<.0001

ShM% - shoulder muscle (%); ShB% - shoulder bone (%); ShF% - shoulder fat (%); ShM:F - shoulder muscle:fat ratio; ShF:B - shoulder fat:bone ratio; NS - not significant.
The same letters in the same column do not differ (P<0.05) according to Tukey's test.

Table 10 - Correlation coefficients between the scores obtained by the European (EUS) and Brazilian (BRS) classification systems and by back fat thickness (BFT) and shoulder tissue compositions

	ShM%	ShB%	ShF%	ShM:F	ShF:B
EUS	−0.07NS	−0.33*	0.55***	−0.45***	0.54***
BRS	−0.13NS	−0.34**	0.67***	−0.58***	0.63***
BFT	−0.04NS	−0.47***	0.65***	−0.56***	0.67***

ShM% - shoulder muscle (%); ShB% - shoulder bone (%); ShF% - shoulder fat (%); ShF:B - shoulder fat:bone ratio; ShM:F - shoulder muscle:fat ratio; NS - not significant.
* P≤0.05.
** P≤0.01.
*** P≤0.001.

Table 11 - Means and standard deviations of back tissue composition defined by the groups according to the score obtained by the European (EUS) and Brazilian (BRS) lamb carcass classification systems

	EUS				P-value
	1 (n = 5)	2 (n = 29)	3 (n = 19)	4 (n = 3)	
BaM%	56.24±4.12	55.55±1.65	56.54±1.39	56.57±4.59	NS
BaB%	20.11±2.27	18.19±0.87	18.09±1.53	17.47±0.55	NS
BaF%	14.3±1.90b	19.41±0.77ab	21.9±1.04a	25.04±2.8a	0.0019
BaM:F	4.37±0.91a	3.00±0.17ab	2.71±0.17b	2.36±0.44b	0.01
BaF:B	0.76±0.13b	1.16±0.08ab	1.37±0.12ab	1.44±0.18a	0.0491
	BRS				
	1 (n = 12)	2 (n = 31)	3 (n = 13)		P-value
BaM%	57.62±2.63	55.15±1.45	56.53±0.88		NS
BaB%	16.99±1.48	19.91±1.00	15.63±0.88		NS
BaF%	16.24±1.46c	19.79±0.69b	24.4±0.95a		<.0001
BaM:F	39.43±0.46a	28.77±0.12b	23.84±0.16b		0.0004
BaF:B	1.07±0.17b	1.09±0.07b	1.62±0.09a		0.0013

BaM% - back muscle (%); BaB% - back bone (%); BaF% - back fat (%); BaF:B - back fat:bone ratio; BaM:F - back muscle:fat ratio; NS - not significant.
The same letters on the same row do not differ (P<0.05) according to Tukey's test.

Table 12 - Correlation coefficients between the scores obtained by the European (EUS) and Brazilian (BRS) classification systems and by the back fat thickness (BFT) and back tissue composition

	ShM%	ShB%	ShF%	ShM:F	ShF:B
EUS	0.04NS	−0.08NS	0.48***	−0.38**	0.35**
BRS	−0.01 NS	−0.18NS	0.57***	−0.44***	0.44***
BFT	0.06 NS	−0.34**	0.62***	−0.44***	0.51***

BaM% - back muscle (%); BaB% - back bone (%); BaF% - back fat (%); BaF:B - back fat:bone ratio; BaM:F - back muscle:fat ratio; NS - not significant.
* P≤0.05.
** P≤0.01.
*** P≤0.001.

European classification systems enabled differentiating back tissue composition classified for carcasses with score extremes, while no such distinction was possible between the intermediate levels for those parameters.

Groups 1, 2, and 3 differed regarding BaF%, while for BaM:F, groups 2 and 3 did not differ. For BaF:B, no difference was found between groups 1 and 2 for the BRS. None of the groups differed in muscle percentage or bone percentage. The correlation analysis (Table 12) showed that the EUS and BRS were significantly correlated with fat percentage (BaF%) and with BaM:F and BaF:B. Neither method of classification was significantly correlated with back muscle (BaM%) or back bone (BaB%). Backfat thickness was better correlated with BaF%, BaF:B, and BaB% than any score of the classification systems.

Discussion

Based on 25 carcass tissue composition variables and three cuts, the clustering analysis found four carcass groups, which significantly differed for most variables. Even clusters 2 and 3 were similar to the top and bottom (1 and 4) groups for the characteristics evaluated, which suggests difficulty in discriminating intermediate carcasses regarding tissue composition.

The use of specialized meat sheep breeds provides good carcass conformation, with higher scores according to classification and grading systems, unlike hair sheep breeds. Although the latter have low carcass conformation, Souza et al. (2016) found no difference in body score of Santa Inês, ½ Dorper × Santa Inês and ¾ Dorper × Santa Inês lambs. Garcia et al. (2010) reported similarity between quantitative variables of Santa Inês, Texel × Santa Inês, and Dorper × Santa Inês lambs, corroborating the results obtained in the present study, which found no difference among the groups analyzed regarding CCW, tissue composition, or fat cover.

Carcass classification methods based on photographic standards have been used for a long time and are precise enough to set carcass prices based on muscle, fat, and bone percentages (Johansen et al., 2006). However, the European method was developed to assess carcasses of breeds more specialized in meat production and is not specific for carcasses from hair sheep animals commonly found in Brazil, which are little studied and evaluated compared with the number of studies on specialized breeds (Araújo Filho et al., 2010). The degree of fat cover is measured mainly in the shoulder and hindquarter, which explains why the scores using the BRS are better correlated with the amounts of fat in those areas than the EUS.

The evaluation of this development may be described by allometric lines, which are quite similar to actual values when assessed from birth to maturity or over long periods, based on growth as a function of weight and not necessarily time (Berg and Butterfield, 1966). Physiological maturity of each tissue differs at distinct animal development phases, with earlier development of bone, intermediate development of muscle, and late development of fat (Hammond, 1965). In lambs, growth is influenced by weight at birth and quality of the milk consumed in the suckling phase (Boucinhas et al., 2006), as well as the rearing system and post-weaning diet.

The visual standards used by either method in this study allow for good discrimination between lean and fat carcasses, but not for carcasses with intermediate degrees of fat cover. Along with subcutaneous fat development, they are good predictors of fat deposits and total fat development.

Despite the European system featuring four carcass score groups, no significant difference was obtained for carcass or cut tissue composition between the intermediate groups. The correlation with those variables was not as substantial as that obtained by the Brazilian classification system, which matches Huidobro et al. (2004), who obtained lower correlations with tissue composition using the European photographic scale for light lamb carcasses.

Both methods were able to predict carcass fat percentage; however, when BFT and CCW are included in the model, carcass tissue composition prediction becomes more viable, particularly for CaF%. It must be pointed out that establishing quality and profitability parameters for carcasses using BFT is desirable, since this is a usual and simple characteristic that can be measured *in vivo* through ultrasound. However, carcass fat must be assessed in abattoirs in a simple and quick fashion without using destructive methods. Although this measurement may be a better predictor when associated with subjective methods of tissue composition evaluation (Miguel et al., 2003), it is difficult to be applied, since it requires refrigeration for 24 h, besides carcass handling and cutting, which becomes costly for the slaughter line.

Using BFT enabled a better discrimination of carcasses, with high significant correlation with nearly all tissue compositions, both of carcasses and cuts. Nonetheless, this attribute required prior carcass refrigeration for at least 24 h and a cut made in the backfat. This evaluation is difficult and costly for slaughter conditions, which makes the use of visual standards and cold carcass weight more accurate to discriminate intermediate fat cover classes.

Given that fat percentage increases with CCW, further studies using weight classes are suggested to better understand the scores by both the EUS and BRS for woolless lamb carcasses. Russo et al. (2003), in a study on light lamb carcasses (≤13 kg), observed that CCW significantly differed regarding tissue composition variables when using photographic parameters. Those authors also stated that heavier carcasses have more adiposity than lighter ones. Miguel et al. (2007) found a statistically significant difference among CCW classes regarding carcass conformation scores when using the EUS (0.25-point scale), with higher scores for the heavier class (14 kg). Moreover, the results obtained show that better prediction of lamb carcass tissue composition would be achieved if the BRS and CCW were used.

Conclusions

The inclusion of objective methods (backfat thickness and cold carcass weight) in the subjective evaluation to determine the tissue composition of sheep carcasses allows a better classification without compromising the dynamics of the slaughter line. The Brazilian classification system of lamb carcasses is the best predictor of carcass tissue composition when associated with cold carcass weight for carcasses from hair sheep (Santa Inês) and crossbred (Santa Inês × Dorper) animals.

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