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Morphological characterization of sheep breeds in Brazil, Uruguay and Colombia

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ABSTRACT

Several naturalized sheep breeds in the South American continent have little objective information available and as population size is becoming smaller the need for this information becomes more critical. The objective of this study was to differentiate between naturalized breeds in Brazil, Uruguay and Colombia using morphological descriptors and compare them with commercial breeds. The amount of 928 morphometric measurements and 2918 weights were collected. Phenotypic characterization was carried out using size, weight, colour and conformation of the animals, as well as 16 morphometric measurements of the animals. Phenotypic data were analysed using PROC GLM, CORR and PRINCOMP of Statistical Analysis System (SAS®). The distance between breeds was carried out using morphometric and morphological data using UPGMA (Unweighted Pair Group Method Arithmetic Mean) method to create a dendrogram. Phenotypic characterization was shown to be an accessible and easy to use tool in conservation and breeding programs. The breed was the most important factor to differentiate between the animals measured, and adult weight most influenced by the environment. Commercial breeds were larger and Santa Inês animals from the Center-west and Southwest closer to Bergamasca than in other regions.

1. Introduction

Several animal species were brought to the Americas at the time of colonization by Portuguese and Spanish travelers. These animals underwent natural selection for several hundred years in certain environments thereby acquiring singular traits such as rusticity, prolificacy and resistance to endo- and ectoparasites as well as diseases found in these regions (Egito et al., 2002).

More productive exotic breeds have been introduced into these environments from the 20th century. These breeds were selected in temperate climates and do not show the same adaptive features as naturalized breeds. Nevertheless the substitution has led to the almost extinction of some naturalized breeds in these countries (Mariante and Egito, 2002). At present many countries are losing their genetic resources which may have lasting effects on food security and sustainable development especially in light of global warming changes. More than 20% of documented breeds are classified as at risk of extinction and in the last five years over 60 breeds were lost, approximately one per month (FAO, 2007). Further, an estimated 70% of breeds which do not have information on their extinction risk are to be found in developing countries (Kenene et al., 2009).

The use of quantitative information in livestock breeding programmes has become more sophisticated over time. This allows breeders to make faster progress in a chosen set of traits. Phenotypic information was initially used in mass

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Table 1
Breeds, localities and number of observations of phenotypic traits collected in sheep.

Breed	Farm type[a]	Local[b]	Number of animals				Farms[c]
			Weight		Measurements		
			Males	Females	Males	Females	
Barriga Preta	E	NE		25			1
Bergamasca	SI, I	CW	27	356	15	36	3
Bergamasca	SI	SE	23	215	25	25	1
Blackface	E	NE		21	20	24	1
Corriedale	I	Colombia	10	36	1	4	2
Corriedale	I	South	12	19	1	4	1
Crioula Lanada	E	Colombia	14	55	1	5	2
Crioula Lanada	SI, E	Uruguay	17	39	42	42	6
Crioula Lanada	SI, E	South	15	54	31	34	4
Damara	E	NE	10	28	1	4	1
Dorper	I	SE	10	36	24	51	1
Hampshire	SI	Colombia	14	28	1	6	1
Hampshire	I	SE	10	27		4	1
Ideal	I	South	14	29		6	1
Ile de France	I	SE	10	28	1	5	1
Merino	I	Colombia	10	17	1	8	1
Mora	E	Colombia	10	23		7	1
Morada Nova	E	NE	10	17	41	61	1
Morada Nova	SI	CW	27	347	17	15	2
Morada Nova	SI	SE	10	19	10	14	1
Romney Marsh	I	South	14	25		6	1
Santa Inês	SI, I	SE	65	254	84		3
Santa Inês	SI, I	CW	42	183	52		3
Santa Inês	E, SI	NE	29	365	37		3
Somali	E	NE	11	29	5		1
Suffolk	I	South	21	47	20	26	2
Texel	I	South	25	100	17	52	2
Vermelha Colombia	E	Colombia	10	26	17	25	1
Total			2918		928		

[a] Farm types: I—intensive with concentrate feeding and cultivated pastures; SI—semi-intensive on mixed cultivated and native pastures with some concentrate feeding after lambing; E—extensive on native pastures and no concentrate feeding.
[b] Brazilian regions—CW: Center-west; NE: Northeast; SE: Southeast.
[c] Numbers of farms on which data was collected.

selection, whereby individuals with better trait values were chosen to be parents of the next generation. This model has worked remarkably well, and has allowed much progress in genetic merit (Dodds et al., 2007).

Most traits of biological, biomedical and agricultural importance are complex—they are under the control of an interacting net-work of genes, each with a small effect, and of environmental factors (Wu and Lin, 2006). Many quantitative trait loci (QTLs) that affect a broad range of phenotypes have already been mapped with high confidence in the different livestock species and are awaiting further characterization (Andersson and Georges, 2004).

Moreover, several years of selective breeding of these species has led to marked phenotypic changes and genetic adaptation to various environmental conditions (Andersson and Georges, 2004). According to these authors, populations of domestic animals have a rich collection of mutations that affect phenotypic traits.

According to Rodero and Herrera (2000), studies are necessary to characterize, identify and differentiate populations, while origin and history of breeds should be documented, as well as their geographical distribution, qualities and aptitudes, phenotypic description and morphostructural traits (Mariante and McManus, 2004). This is highlighted by Philling et al. (2008) in relation to Production Environment Descriptors (PEDs) and the need to combine production and environmental information on all breeds available worldwide so that informed management decisions about breed choice and substitution can be made.

Different breeds of domestic animals are in many cases as phenotypically diverse as separate species. However, the recent origin of these breeds from their wild ancestors (∼10.000 years before present) makes it possible to make specific crosses and use segregation analysis to map the genes that underlie phenotypic traits (Andersson and Georges, 2004).

Native sheep genetic resources are a large source of income and are of great cultural value in many countries. In South America the situation is different as many local breeds of sheep are not recognised or characterized. Brazil has the largest number of hair sheep breeds on the continent which have an important role especially for small farmers in the northeast of the country (Paiva et al., 2005).

The objective of this study was to differentiate between naturalized breeds in Brazil, Uruguay and Colombia using morphological descriptors and compare them with commercial breeds.

Table 2
Minimum square means for liveweight in sheep breeds from Brazil, Uruguay and Colombia.

Raça	BW	W60	W90	W120	W180	W365	WA
Barriga Preta	2.50^{a}	9.95^{c}	11.75^{a}	13.42^{a}	19.24^{ab}	29.35^{cd}	62.50^{d}
Bergamasca	3.65^{c}	12.17^{gh}	16.47^{e}	17.82^{c}	28.05^{ef}	32.08^{de}	70.00^{de}
Blackface	2.40^{a}	10.19^{d}	14.09^{b}	16.69^{b}	22.94^{bc}	33.04^{ef}	48.92^{bc}
Cheviot	3.89^{d}	12.18^{gh}	16.33^{e}	19.09^{cd}	24.87^{de}	30.81^{d}	51.08^{bc}
Corriedale Brazil	3.84^{d}	12.85^{i}	15.08^{c}	20.36^{d}	27.12^{e}	31.98^{de}	47.98^{bc}
Corriedale Colombia	3.92^{d}	11.03^{f}	14.59^{bc}	16.96^{b}	20.29^{b}	27.67^{c}	49.01^{bc}
Criolla Colombia	3.29^{b}	10.52^{de}	14.14^{b}	16.55^{b}	19.25^{ab}	24.41^{b}	39.96^{a}
Criolla Uruguay	2.91^{ab}	9.15^{b}	12.27^{a}	14.35^{a}	23.82^{cd}	29.81^{cd}	46.23^{ab}
Crioula Lanada	3.25^{b}	13.59^{ij}	18.68^{ef}	19.86^{d}	20.82^{b}	28.31^{cd}	37.64^{a}
Damara	3.81^{cd}	8.31^{a}	17.56^{e}	23.71^{d}	27.32^{e}	35.42^{f}	65.00^{d}
Dorper	3.93^{d}	17.69^{k}	26.14^{h}	30.23^{ef}	32.03^{g}	41.98^{h}	68.95^{d}
Hampshire Brazil	4.23^{e}	20.28^{l}	27.88^{h}	32.24^{f}	34.23^{gh}	43.11^{i}	52.49^{bcd}
Hampshire Colombia	3.66^{c}	11.53^{g}	15.46^{cd}	18.08^{c}	23.76^{cd}	32.32^{e}	53.44^{bcd}
Ideal	4.00^{de}	11.28^{f}	23.49^{g}	31.53^{f}	33.21^{g}	37.51^{gh}	87.32^{f}
Ile de France	4.21^{e}	12.74^{h}	32.08^{i}	36.83^{g}	38.41^{h}	43.52i	87.12^{f}
Merino	3.97^{d}	10.87^{e}	14.32^{b}	16.62^{b}	19.22^{ab}	25.97^{bc}	43.62^{ab}
Mora	3.60^{bc}	10.96e	14.64^{bc}	17.09^{bc}	24.78^{cde}	26.12^{c}	40.73^{ab}
Morada Nova	2.43^{a}	10.71^{e}	15.33^{cd}	16.41^{b}	16.35^{a}	19.86^{a}	39.73^{a}
Romney Colombia	3.72^{cd}	11.59^{g}	15.52^{cd}	18.14^{c}	22.95^{bcd}	29.09^{cd}	46.4^{abc}
Santa Inês	3.72^{cd}	11.61^{g}	15.89^{d}	18.73^{c}	28.53^{ef}	37.05^{g}	76.08^{e}
Somali	2.51^{a}	9.95^{c}	13.47^{ab}	15.38^{ab}	18.65^{ab}	25.72^{b}	45.5^{ab}
Suffolk	4.11^{e}	16.21^{j}	23.64^{g}	28.60^{e}	31.42^{g}	39.02^{h}	80.01^{ef}
Texel	3.92^{d}	21.12^{l}	29.15^{h}	40.13^{g}	49.32^{i}	54.32^{j}	90.34^{f}
Vermelha Colombia	2.50^{a}	10.14^{d}	13.95^{b}	16.51^{b}	20.22^{b}	37.52^{gh}	80.12^{ef}

Different letters in the same column meant significant differences between breeds (Tukey $P < 0.05$). Birth weight (BW); weight at 60 (W60), 90 (W90), 120 (W120), 180 (W180), 365 (W365) days of age, adult weight (WA).

2. Materials and methods

The present study was carried out using animals from Brazil, Uruguay and Colombia (Table 1). The breeds included: Brazilian—Santa Inês (hair), Morada Nova (hair), Brazilian Bergamasca (wool), Crioula Lanada (wool), Barriga Preta (Black Belly) and Brazilian Somali (hair); Colombia: Blackface, Mora (wool), Colombian Criolla (wool), Colombian Vermelho or Camuro (hair); Uruguay–Uruguayan Criolla (wool). The commercial breeds included Merino, Suffolk, Cheviot, Dorper, Damara, Romney Marsh, Ideal, Corriedale, Hampshire Down, Texel and Ile de France. The term “Criollo” or “Crioulo” is widely used in various countries in South America. The expression refers to descendents of crosses between breeds brought by European settlers during colonization (Montaldo et al., 2010).

Data collection was standardized in a meeting in Mexico in 2005 and data were collected in the second semester of 2006 on private and public farms (Conservation Nuclei and Experimental farms). 928 morphometric measurements and 2918 weights were collected. Some data on growing animals (such as birth and weaning weights) had been collected earlier by the farmers. Single morphometric measurements were taken on adult animals showing good body condition (2.5–3.5 on a five point scale). Breeds with less than 10 observations were not included in the final analysis (Table 1).

On farm, climatic and management conditions were very different between countries, regions within countries and breed type (commercial versus naturalized). Most naturalized breeds (except Santa Ines and Bergamasca) were reared on native pastures in their country of origin, while commercial breeds were raised on cultivated pasture. Measurements were adjusted by least squares means for farm type.

The three countries in this study have distinct climates. Brazil has six climatic subtypes: equatorial, tropical, semi-arid, high altitude tropical, temperate and subtropical but the major part is tropical. Different climatic conditions produce environments which vary from equatorial forests in the North and semi-arid deserts in the Northeast to temperate coniferous forests in the South and savanna in the Center-west. Colombian territory is marked by regions of high altitude, especially in the western region. Along the coast the climate is tropical but in higher regions temperatures may be low. The Uruguayan climate is temperate but relatively hot, and temperatures rarely below zero.

Sixteen measurements were taken on the animals as described in McManus et al. (2005), using a metric tape, hipometer and paquimeter:

Shoulder height (SH): vertical distance from highest point of the interscapular region to the soil.
Hip height (HH): vertical distance from highest point of the hip, in the space defined by the spinal process T5–T6 over the sacral tuber of the ileum to the soil.
Hip length (HL): distance between cranial parts of the iliac tuber and caudal parts of the ischium tuber.
Hip width (HW): distance between points of the hips.
Body length (BL): distance between the cranial part of the larger tuber of the humerus and the ischium tuber.
Heart girth (HG): largest circumference of the thorax, passing by the sternum.
Thorax height (TH): vertical distance between the sternum and the shoulder.
Body score (BS): scale of one to five where one is very thin and five very fat.
Cannon bone circumference (CBC): circumference of this bone at thinnest point.
Head length (HeL): distance between the proximal end of the head which coincides with the crest of the neck and medial (central) part of the inferior incisor arch.
Head width (HeW): distance between free parts of the right supra-orbital border and left supra-orbital border.
Ear length (EL): distance from the base to the point of the ear.
Dorsal-sterna diameter (DD): lowest point of the shoulder to the sternum.

Phenotypic data were analysed using simple descriptive analyses (mean, standard deviation, coefficient of variation), analysis of variance, correlations between traits, and principal component relations using PROC GLM, CORR and PRINCOMP procedures of Statistical Analysis System (SAS®). Two discriminatory analyses were carried out, one with weights and one with morphometric measures to verify which traits were important in separation of breeds and see if these types of analyses could be useful in breed characterization. The analysis of variance used breed, sex, region (Uruguay, Colombia and Brazil by region—Center-west, Northeast, South, and Southwest), as well as type of farm (extensive, semi-intensive or intensive). Weights were adjusted to standardized ages: birth, 60, 90, 120, 180 days, one year and adult. The Euclidean distance between breeds was calculated by sex and the UPGMA (Unweighted Pair Group Method Arithmetic Mean) algorithm was used to generate clusters and then dendograms. In this case, only adults were considered.

Table 3
Adjusted means for body measurements in sheep breeds from Brazil, Uruguay and Colombia.

Breed	HH	BL	SH	HG	HW	CG	BS	HeW	CBC	HeL	DD	EL	TH
Bergamasca	71.12^{a}	79.48^{a}	73.14^{a}	92.05^{a}	17.17^{b}	–	2.76^{b}	16.48^{a}	9.24^{b}	24.57^{a}	–	19.98^{a}	–
Blackface	68.40^{a}	60.70^{e}	74.80^{a}	75.45^{b}	12.54^{d}	–	–	–	–	-	–	–	–
Criolla Uruguay	68.54^{a}	73.82^{ab}	70.55^{b}	91.34^{a}	14.40^{cd}	22.13^{ab}	4.29$^{\underline{a}}$	9.01^{d}	8.22^{d}	24.35^{a}	–	10.92^{c}	29.56^{a}
Crioula Lanada	59.12^{b}	69.14^{b}	61.19^{d}	77.97^{b}	15.21^{c}	23.10$^{\underline{a}}$	2.87^{b}	8.62^{d}	9.13^{b}	20.30^{c}	20.72^{d}	12.21^{c}	31.11^{a}
Dorper	69.50^{a}	79.10^{a}	68.00^{bc}	95.47^{a}	21.69^{a}	–	–	–	–	–	–	–	–
Morada Nova	63.14^{b}	66.46^{cd}	64.40^{cd}	73.12^{b}	15.65^{c}	-	–	-	7.28^{a}	-	–	11.28^{c}	25.59^{b}
Santa Inês	72.76^{a}	79.34^{a}	70.81^{b}	92.09^{a}	14.88^{cd}	22.42^{ab}	2.88^{b}	13.02^{bc}	8.39^{cd}	21.09^{c}	26.15^{a}	16.98^{b}	–
Somalis	56.12^{b}	61.70^{e}	58.20^{e}	69.99^{b}	13.21^{d}	–	–	–	–	–	–	15.23^{b}	–
Suffolk	70.35^{a}	79.23^{a}	74.00^{a}	90.65^{a}	21.78^{a}	21.71^{b}	2.63^{b}	12.38^{c}	8.65^{cd}	22.73^{b}	23.04^{b}	–	–
Texel	61.98^{b}	68.76^{bc}	70.74^{b}	89.62^{a}	22.00^{a}	21.56^{b}	3.83^{a}	13.13^{b}	8.87^{c}	20.38^{c}	21.68^{c}	–	–
Vermelha Colômbia	59.87^{b}	63.12^{d}	56.00^{e}	68.00^{b}	12.68^{d}	–	–	–	–	–	–	–	–

Different letters in the same column meant significant differences between breeds (Tukey $P < 0.05$). HH: hip height; BL: body length; SH: shoulder height; HG: heart girth; HW: hip width; CG: hip length; BS: body condition score; HeL: head length; HeW: head width; CBC: cannon bone circumference; DD: dorsal-sternum diameter; EL: ear length; TH: thorax height.

3. Results and discussion

The analysis of variance for weight traits showed that breed was a significant source of variance for these traits. For the other factors studied, there was evidence of sexual dimorphism between males and females. The effects of type of farm and locality may be confounded, as some breeds were reared in a single type of system (Table 1).

As expected animals from breeds reared for meat production especially in intensive systems were heavier at all ages, while animals from local breeds reared in extensive systems were lighter (Table 2). The naturalized Brazilian Bergamasca and Santa Inês breeds were closest in adult weight to exotic breeds.

Table 3 shows the analysis of variance for body measurements and means per breed. Breed influenced all measures studied, while sex did not influence body condition, head width, dorsal-sternum diameter, thorax height and anterior hip width. In general type of system and locality affected the measurements except for cannon bone perimeter dorsal-sternum diameter. According to Miserani et al. (2002), the general shape of the body is called conformation and is the result of many heritable traits. Working with sheep, Traoré et al. (2008), observed a bi-dimensional plot illustrating the relationships between body measurements, separating clearly body measurements as head length, height at withers, tail length and thorax depth from nose perimeter (head profile).

Once again, in general the exotic breeds had larger measurements than naturalized breeds (Table 3), showing better skeletal and muscle development and indicating that they are better for meat production. Once again the naturalized breeds which were closest were the Bergamasca and Santa Inês.

The evaluation of body measurements for meat producers is important as they indicate carcass production as well as respiratory and digestive capacity in animals (Santana, 2001). Nevertheless, according to Costa et al. (2006), it is not certain whether larger or smaller animals determine greater productivity, but there is consensus that certain types or sizes are more adequate for specific management conditions.

Discriminant analyses were used to differentiate groups of animals depending on weight at different ages. Fig. 1 shows the presence of two large groups of females reared in extensive systems. The first group consists mainly of medium and large size such as Bergamasca and Corriedale. It can be seen that animals reared in Colombia, except for Hampshire and Mora, are in the first group. This probably occurred as data collected in this country were all from the same region. The exception here is the Ile de France, which is in the second group and the small sized Morada Nova in the first group. This may be due to sampling.

Paiva (2005) observed that the populations within each breed in Brazil were close to each other when DNA markers were analysed. This was not true here with the exception of Santa Ines from the Center-west and Southeast of Brazil. For example, the Criolla from Colombia and from Uruguay were well separated as were Morada Nova from the Northeast and Center-west of Brazil (Fig. 1). The same author found a clear division between populations of Santa Inês in the Northeast, where the population from Maranhão state was placed furthest from the others and those from Sergipe state were close to the animals from the Center-west. This is in agreement with the approximation of populations of Santa Inês from the Center-west with Southeast. This author also found that populations of Morada Nova were close to wool breeds such as Corriedale and Ile de France. This is in agreement with that found here, where Morada Nova from the Center-west were close to Ile de France from the Southeast and Corriedale from the South, while Morada Nova from the Northeast were not close to these breeds. The environmental conditions can also affect these results as farms in the Center-west, South and Southeast tend to better structured and have better management.

From the analysis based on morphometric measures (not shown), there is an approximation between Crioula lanada breed in Brazil and Criolla in Uruguay, which is in accordance with Paiva (2005), who working with molecular markers, found that naturalized breeds of wool sheep found in Latin America have a common ancestor, probably a breed from the Iberian Peninsula.

In Fig. 2 males from commercial and naturalized breeds reared extensively were divided in two groups except for Crioula which were in a separate branch. When males and females in the same system are compared (Figs. 1 and 3) it can be seen that groups were similar except for Bergamasca

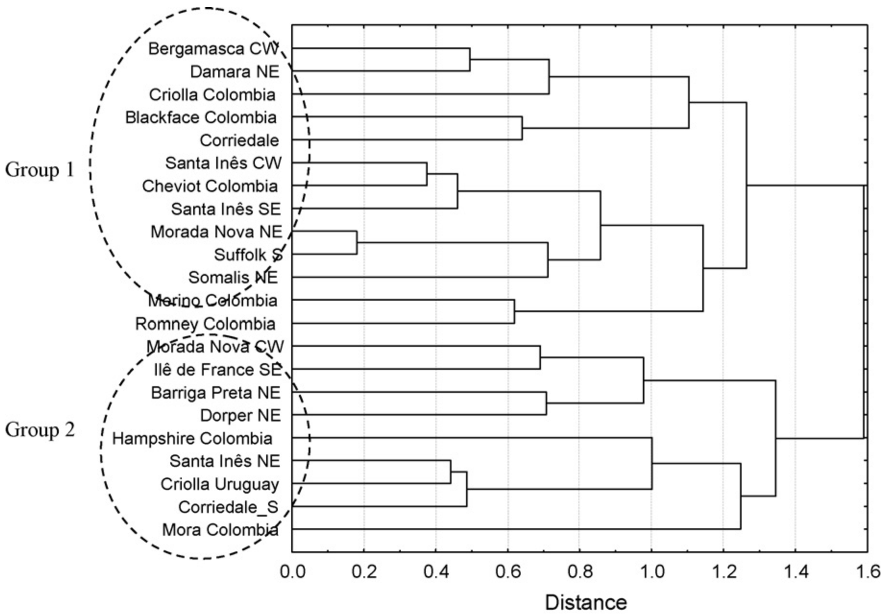

Fig. 1. Dendogram based on distances between naturalized and commercial breeds of sheep calculated from weights from birth to adult.

in the Center-west which in Fig. 2 were together with Santa Inês from the Northeast, Barriga Preta and Dorper; Corriedale which was in the Santa Inês from the Center-west and Somali and Morada Nova from the northeast. These differences may be due to a smaller sampling of males and differential treatment that males receive on farm.

The discriminate analysis showed that all weights had practically the same partial R^2 (Table 4). Therefore in terms of breed separation only one trait needs to be measured. The partial R^2 for morphometric data varied much more (Table 4). Shoulder height showed the best discriminatory value while CBC the lowest. Therefore shoulder height as well as head width and length are of the most use for breed discrimination, in agreement with Herrera et al. (1996). This same author observed that heart girth, thorax height and posterior hip width should not be taken into consid-

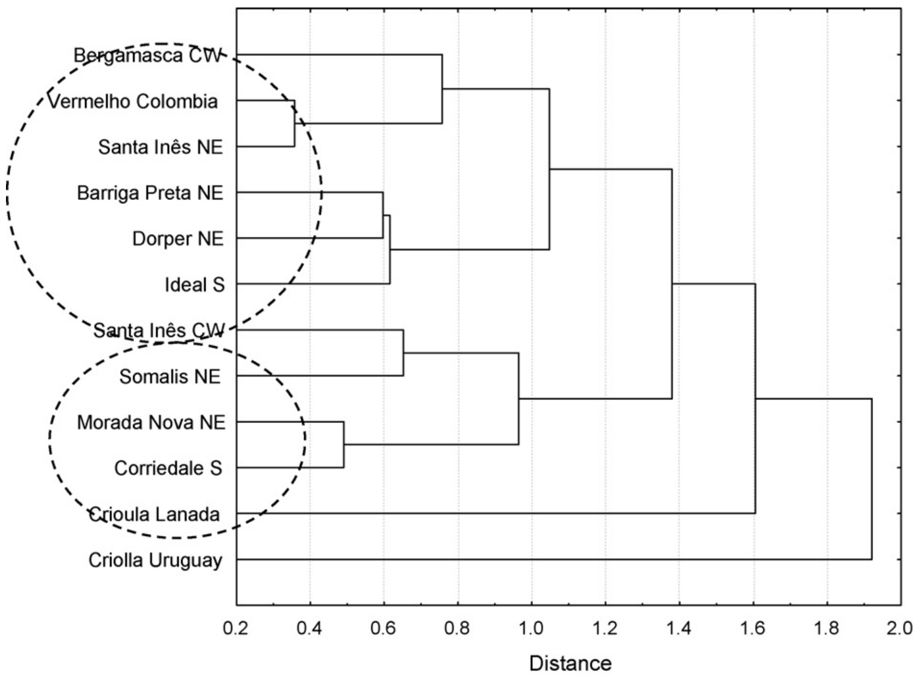

Fig. 2. UPGMA dendogram based on distances between male sheep reared in naturalized and commercial breeds reared in extensive systems in Brazil, Uruguay and Colombia.

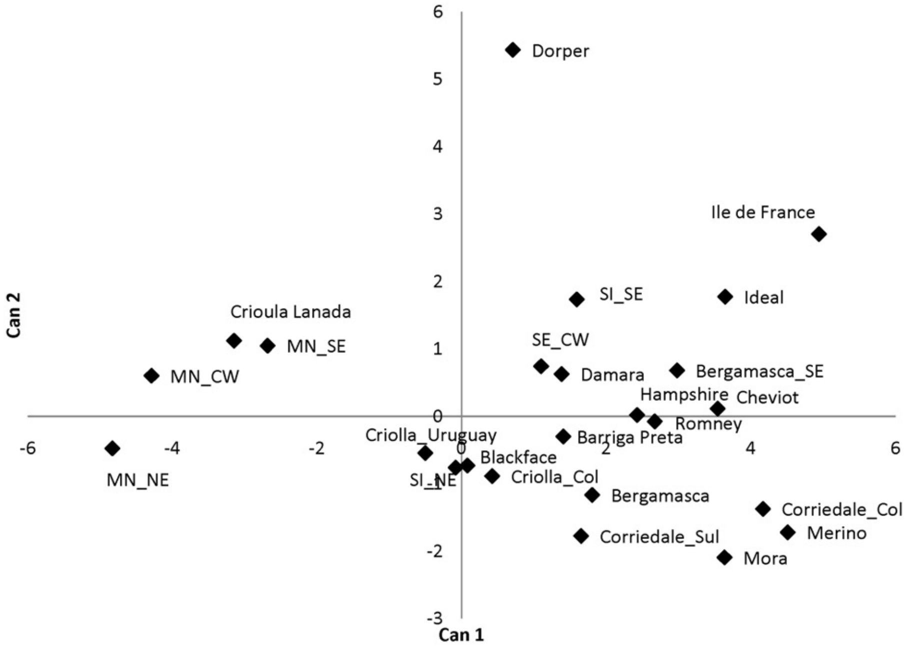

Fig. 3. Canonical analysis for weights in Morada Nova (MN), Merino, Santa Inês (SI), Corriedale, Crioula Lanada, Romney, Cheviot, Hampshire Down and Blackface sheep, including regions Southeast (SE), South (Sul), Center-west (CW) and Northeast (NE) of Brazil, Uruguay and Colombia (Col).

eration in establishing studies of racial differences. Similar results were found in this study for heart girth (Table 4).

Dossa et al. (2007) working with goats showed that the best discriminate model used only five morphological measures from 12 pre-selected, thereby indicating that only a few measurements are needed to separate breeds. In this same study it was seen that there is a significant morphological variation between goat populations depending on local environmental conditions. These results are not in agreement with Lisboa and Fernandos (1988), who found when working with Charolês cattle that a large number of morphometric measures were needed when working with aggressive animals in the Field.

Herrera et al. (1996) observed the influence of two possible factors on the distribution of the breeds in the dendogram, one of different productive ability and other of different breed origins. According to the same author, the head profile is the most important in determining different racial origin, those which were convex corresponding to one origin and the straight and subconcave to another.

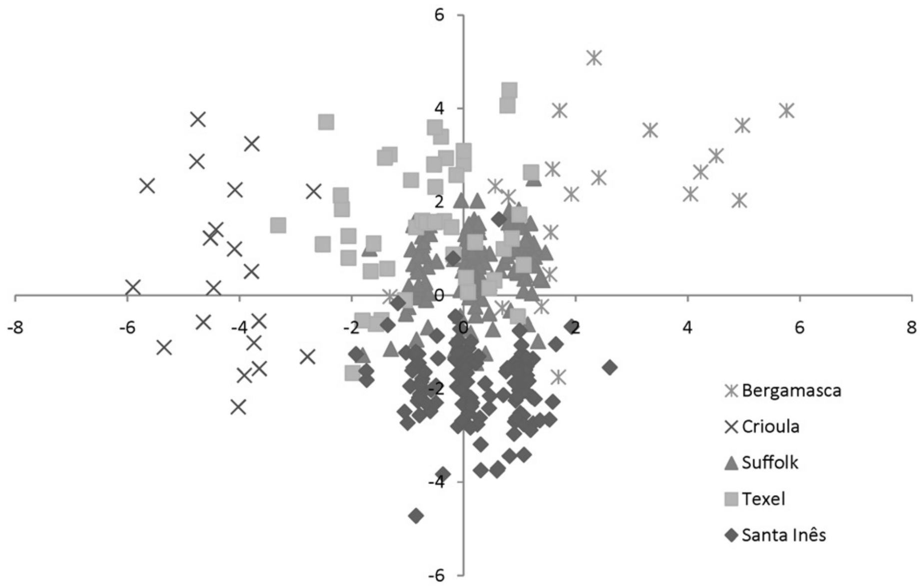

Fig. 4. Canonical analysis for individual morphometric measures in Crioula, Bergamasca, Suffolk, Santa Inês and Texel sheep.

Table 4
Summary of discriminatory analysis for significant weight and morphometric data.

Trait	Partial R^2	Trait	Partial R^2
W365	0.99	SH	0.71
BW	0.99	HeW	0.56
W180	0.99	HeL	0.29
W110	1.00	BL	0.24
		HG	0.14
		CBC	0.13

Weights at birth (BW), 110 (W110), 180 (W180) and one year (W365) of age; SH: shoulder height; HeW: head width; HeL: head length; BL: body length; HG: heart girth; CBC: cannon bone circumference.

The canonical analysis for weight traits (Fig. 3) shows a separation of commercial (Dorper, Ideal, Ile) from naturalized breeds (Morada Nova, Crioula). Many breeds were not well separated in this analysis but some tendencies can be seen, such as the closeness between Santa Ines in the Center-west and southeast regions, as well as the closeness between Bergamasca and Santa Ines with the commercial breeds.

The canonical analysis for morphometric data (Fig. 4) shows individuals within breeds for five breeds and separated Crioula and Bergamasca breeds from Suffolk, Santa Inês and Texel. Of special interest in Brazil is the Santa Ines breed. Fig. 4 shows a clear overlay of the Santa Ines with Suffolk bred in terms of morphological traits. Paiva et al. (2005) showed that naturalized sheep breeds in Brazil were closely related which may be due to crossbreeding in the past in association with genetic drift. Nevertheless these breeds showed higher genetic diversity than commercial breeds. There were cases where within breed population distances were greater than distances between breeds such as with the Santa Inês. This pattern is consistent with the hypothesis of existence of the "old Santa Inês" versus the "New Santa Inês". Breeders and technicians classify the old Santa Ines as smaller more rustic animals which were predominant in the 1980s and 1990s. The New Santa Inês are more prevalent at present and have a large, well developed rump which appeared in a large portion of the population in only a few years. This is more likely to be due to crossbreeding (with Suffolk) than within breed selection (McManus et al., 2007). The colour of the breed also changed and is now predominantly brown or black whereas before animals of various coat colours could be found. The overlaying of Suffolk and Santa Ines can be clearly seen in Fig. 4.

This breed is an interesting alternative for sheep production in Brazil (Costa et al., 2006), being the breed whose numbers are growing in the country (Farnel, 2008) through absorbing crosses (McManus et al., 2007). No other breed shows such strong growth, even in other species (Morais, 2008). Selection for this breed is based almost solely on size (Costa et al., 2006). According to Madelena (2008), selection for a single trait such as size is anti-economic as it has an almost zero correlation with production but increases maintenance requirements.

To investigate the evolution of Bergamasca sheep breed over the last two decades in Italy, Riva et al. (2004) took body measurements and compared with other studies performed in 1984 and 1987. According to this authors, the comparison of these studies suggests some changes in size and shape of this breed, which may be due to environment (higher pasture production, better health status) and selection (animals with a larger thorax and lower wither height). Bergamasca sheep population in Italy, tends to demonstrate an increase in thorax dimensions and a decrease in height at withers and at rump, this improvement of rump dimensions may be considered as a selection criterion (Riva et al., 2004). Data on Bergamasca sheep here show smaller animals compared to those in Italy, probably because of the adverse conditions in which they are reared.

Experiments which involve naturalized breeds and the development of selection programs based on field data are necessary for the improvement of production systems in the region. Comparative analyses of the genomes of different domestic breeds might prove to be one of the most efficient ways of dissecting the genetic basis of phenotypic variation. Domestic animals will also contribute to basic biology as they provide unique opportunities for unraveling the genetic basis of phenotypic variation (Andersson and Georges, 2004).

4. Conclusions

Phenotypic characterization is an accessible tool and results are in agreement with genetic and phenotypic analyses found in the literature. Breed significantly influenced weight and body measurements, with Bergamasca and Santa Inês being the naturalized breeds that were closest to commercial breeds. A clear division in Santa Ines population was seen while Crioula and Criolla breeds from different countries were closely grouped.

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References

Andersson, L., Georges, M., 2004. Domestic-animal genomics: deciphering the genetics of complex traits. Nat. Rev. Genet. 5, 202–212.
Costa, G.S.J., Campelo, J.E.G., Azevêdo, D.M.M.R., Martins, R.F., Cavalcante, R.R., Lopes, J.B., Oliveira, M.E., 2006. Caracterização morfométrica de ovinos da raça Santa Inês criados nas microrregiões de Teresina e Campo Maior. Piauí. Rev. Bras. Zoot. 35, 2260–2267.
Dodds, G.K., McEwan, J.C., Davis, G.H., 2007. Integration of molecular and quantitative information in sheep and goat industry breeding programmes. Small Ruminant Res. 70, 32–41.
Dossa, L.H., Wollny, C., Gauly, M., 2007. Spatial variation in goat populations from Benin as revealed by multivariate analysis of morphological traits. Small Ruminant Res. 73, 150–159.
Egito, A.A., Mariante, A.S., Albuquerque, M.S.M., 2002. Programa brasileiro de conservação de recursos genéticos animais. Arch. Zoot. 51, 193–194.
FAO, Food and Agriculture Organization of the United Nations, Protecting Animal Genetic Diversity for Food and Agriculture—Time for Action. Available in: <www.fao.or/dad-is> (accessed in 1.10.2007).
Farnel, L., Rumo ao Sul. Available in: <http://www.ripa.com.br> (accessed in 19.2.2008).
Herrera, M., Rodero, E., Gutierrez, M.J., Pena, F., Rodero, J.M., 1996. Application of multifactorial discriminant analysis in the morphostructural differentiation of Andalusian caprine breeds. Small Ruminant Res. 22, 39–47.
Kenene, N.W., Bezuidenhout, C.C., Nsahlai, I.V., 2009. Genetic and phenotypic diversity in Zulu Sheep populations: implications for explotation and conservation. Small Ruminant Res. 84, 100–107.

Lisboa, S.R., Fernandos, L.C.O., 1988. Efeito do tamanho corporal na fertilidade da primeira e segunda estação de monta e na produtividade de fêmeas cruza Charolês. Rev. Bras. Zoot. 16, 204–214.

Madalena, F.E., 2008. Efeitos colaterais da genética de alta produção. Available in: <www.milkpoint.com.br> (accessed in 11.2.2008).

Mariante, A.S., Egito, A.A., 2002. Animal genetic resources in Brazil: result of five centuries of natural selection. Theriogenology 57, 223–235.

Mariante, A.S., McManus, C., 2004. Conservação de bovinos de raças naturalizadas, visando a sua inserção em sistemas de produção. In: Proceedings of the 41st Reunião Anual da Sociedade Brasileira de Zootecnia, Campo Grande, Brazil, pp. 335–342.

McManus, C.M., Falcao, R.A., Spritze, A., Elsta, D., Louvandini, H., Dias, L.T., Teixeira, R.A., Rezende, M.J.M., Garcia, J.A.S., 2005. Caracterização morfológica de Eqüinos da Raça Campeiro. Rev. Bras. Zoot. 34, 1553–1562.

McManus, C., Paiva, S., Macedo, F., Louvadini, H., Castro, G., Cubilos, G.B., Ddllshasa, M.S.L., 2007. Final Report: Genetic and Phenotypic characterization of naturalized sheep and pigs in South America, CNPq (Research division report, 75), p. 75.

Miserani, M.G., McManus, C., Santos, S.A., Silva, J.A., Mariante, A.S., Abreu, U.G.P., Mazza, M.C., Sereno, J.R.B., 2002. Heritability estimates for biometric measures of the pantaneiro horse. Arch. Zoot. 51, 107–112.

Montaldo, H.H., Torres-Hernández, G., Valencia-Posadas, M., 2010. Goat breeding research in Mexico. Small Ruminant Res. 89, 155–163.

Morais, O., 2008. O melhoramento genético de ovinos no Brasil: situação atual e perspectivas para o futuro. Available in <http://www.ovinocultura.com.br/artigo3.htm> (accessed in 19.2.2008).

Paiva, S.R., 2005 Caracterização da diversidade genética de ovinos no Brasil com quatro técnicas moleculares. Docortae Thesis, University of Viçosa, Brazil. 118 p.

Paiva, S.R., Silvério, V.C., Egito, A.A., Mcmanus, C., Faria, D.A., Mariante, A.S., Castro, S.R., Albuquerque, M.S.M., Dgram, J.A., 2005. Genetic variability of the Brazilian hair sheep breeds. Pesq. Agropec. Bras. 40, 887–893.

Philling, D., Rischkowsky, B., Scherf, B. (Eds.), 2008. Report of the FAO/WAAP Workshop on Production Environment Descriptors for Animal Genetic Resources, p. 97 p.

Riva, J., Rizzi, R., Marelli, S., Cavalchini, L.G., 2004. Body measurements in Bergamasca sheep. Small Ruminant Res. 55, 221–227.

Rodero, E., Herrera, M., 2000. El concepto de raza, Un enfoque epistemológico. Arch. Zoot. 49, 5–16.

Santana, A.F.de., 2001. Correlação entre peso e medidas corporais em ovinos jovens da raça Santa Inês. Rev. Bras. Saúde Prod. Anim. 1, 27–30.

Traoré, A., Tamboura, H.H., Kaboré, A., Royo, L.J., Fernandez, I., Lavarez, I., Sangaré, M., Bouchel, D., Oivey, J.P., Francois, D., Toguyeni, A., Sawadogo, L., Goyache, F., 2008. Multivariate characterization fo morphological traits in Burkina Faso sheep. Small Ruminant Res. 80, 62–67.

Wu, R., Lin, M., 2006. Functional mapping—how to map and study the genetic architecture of dynamic complex traits. Nat. Rev. Genet. 7, 229–237.