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Morphological traits in Portuguese Bordaleira de Entre Douro e Minho sheep: divergence of the breed

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Abstract. Production of the autochthonous Portuguese sheep breed Bordaleira de Entre Douro e Minho (BEDM) is directly associated with the concept of sustainable agriculture. This concept focuses on the adaptation of animal populations to adverse environmental conditions, high biological efficiency and traditional management. Native BEDM sheep can be divided into the following two types on the basis of their geographic location in Portugal and how they are managed: the Várzea, which is found mainly in the lower Entre Douro e Minho region, and the Mountain type, which traditionally prefers common areas. In the present work, we analysed records of liveweight, 15 body measurements and eight indexes of the BEDM sheep, to explore the ability to distinguish different characteristics between BEDM sheep populations. The records that were obtained and analysed by principal component analysis for 412 BEDM sheep (68 males and 344 females) included the following: heights at withers (HW), at back (HB), at rump (HR) and at chest (HC); lengths of trunk (LT), of rump (LR), of head (LH) and of perineum (LP); widths of head (WH), of chest (WC), of biiliac (WBIIL) and of biischiatic (WBIIS); perimeters of the shin (PS), thorax (PT), and abdomen (PA); and finally indexes such as cephalic index (CI), thoracic index (TI), pelvic index (PI), body index (BI), relative chest depth index (RDCI), lateral corporal index (LCI), relative shin thickness index (RTSI) and dactyl–thoracic index (DTI). The Várzea BEDM was morphologically superior to the Mountain variety, with this superiority more evident in females. Height measurements, especially HW in adult females, provided an excellent measurement reference for biometrical breed studies. Functional index values confirmed the BEDM Mountain variety's appropriateness for mountainous regions. Relationships among body measurements suggested that the breed standard needed to be updated. The research presented here was used by the Portuguese Ministery to split BEDM into two new breeds; the traditional variety called Várzea now represents the new BEDM breed, whereas the Mountain variety represents the new Churra do Minho breed.

Additional keywords: Churra do Minho breed, Portugal.

Introduction

The United Nations proclaimed 2010 to be the International Year of Biodiversity, during which human race was called to both safeguard the irreplaceable natural wealth and to reduce biodiversity loss. Wild and exotic animals are not the only creatures facing imminent extinction. Nowadays, many of the European livestock breeds have been greatly altered and three-quarters of local or traditional breeds are extinct or marginalised. About 30% of the farm-animal breeds are currently at high risk of extinction (Scherf 2000). Understanding the diversity, distribution, basic characteristics, comparative performance and the current status of the animal genetic resources for each country is essential for their efficient and sustainable use, development and conservation (FAO 2007). Portugal possesses a very diverse natural heritage, thanks to its geographical location and geophysical conditions (Araújo 1999). Indeed, 21% of its total inland territory has been designated as a protected area for nature conservation, and 61% dedicated to agriculture or forestry (EU 1992).

Forty-five native breeds of livestock from Portugal currently form part of the domestic animal diversity information system (FAO 2009), including 15 sheep breeds. Because of the low numbers of animals within a breed, most of these breeds are considered to be endangered. Lately, there has been an increasing interest in the preservation of hardy, local breeds. There are three main reasons for this. First, these breeds may possess valuable genetic diversity that might otherwise be irreversibly lost; second, they represent part of Portugal's cultural and historical heritage; and finally, they are in higher demand from the consumer, which means that they also have a higher commercial value for the producer (Taberlet *et al*. 2008).

Among the native breeds of sheep found in Portugal, Bordaleira de Entre Douro e Minho (BEDM) is the native sheep breed from the Entre Douro e Minho area in the north of

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Portugal (Pedrosa *et al*. 2007). BEDM sheep can be divided into the following two types according to their geographic location and how they are managed: the Várzea BEDM, which usually accompanies native Minhota cattle in the grazing pastures located in the lower Entre Douro e Minho region, and the Mountain BEDM, which is exclusively used on common areas.

The BEDM was assumed to be on the edge of extinction in the past because of the introduction of foreign breeds that replaced the BEDM flocks and human migration away from rural areas, which reduced the number of farmers and consequently the number of flocks. However, farmers have played an important role in the recovery of the BEDM population and the breed flock book was created in 2001. BEDM has recently been introduced into new areas, such as the eastern regions of Portugal, although the number of BEDM sheep across their dispersion area totalled only 9269 animals in 2005. These values are obviously far removed from the more than 300 000 sheep reared in 1940 (Cerqueira 2006).

Production using the BEDM is directly associated with the concept of sustainable agriculture. This concept focuses on the adaptation of animal populations to adverse environmental conditions, high biological efficiency and traditional management (Pannell *et al*. 2006). BEDM is used principally for meat production and lambs are sold at 2–4 months of age and at 10–14 kg of liveweight for the Várzea variety and at 8–10 kg for the Mountain variety, especially around major holidays (Cerqueira 2006). The 'AGROP Minho' producer group was created in 2005 to market Anho Minhoto protected designation of origin (PDO) meat, which is produced, processed and prepared in a given geographical area by using certified procedures and standards (EU 2006).

Morphological measurements have been used for characterisation of native sheep breeds by several researchers (Degl'Innocenti *et al*. 2003; Riva *et al*. 2004; Traoré *et al*. 2008). Furthermore, external body measurements have been studied to predict bodyweight (Sharples and Dumelow 1990; Aziz and Sharaby 1993; Janssens and Vandepitte 2004; Afolayan *et al*. 2006; Sowande and Sobola 2008; Kunene *et al*. 2009), as well as to predict carcass characteristics (Stanford *et al*. 1998; Kiyanzad 2004). Since none of the morphological parameters for both *várzea* and *mountain* BEDM sheep has previously been studied, in the present work we analysed 15 body measurements and eight indexes, to explore the ability to distinguish among the BEDM sheep populations.

Materials and methods

Sheep population distribution

The region under study included the districts of Viana do Castelo, Braga and Vila Real that covered a total of 12 municipalities (Arcos de Valdevez, Caminha, Melgaço, Monção, Mondim de Basto, Paredes de Coura, Ponte da Barca, Ponte de Lima, Ribeira de Pena, Viana do Castelo, Vieira do Minho and Vila Pouca de Aguiar). Twenty-seven sheep farms were randomly selected from this area (Fig. 1).

Data collection

From October 2004 to March 2005, data were obtained to characterise the morphological variation in the entire BEDM sheep population, including both of the identified BEDM varieties. Body measurements were obtained from 412 adult (>2 years old) BEDM sheep, consisting of 68 males (42 from Várzea and 26 from Mountain varieties) and 344 females (184 from Várzea and 160 from Mountain varieties). For each animal, body measurements were carried out using a Lydthin stick, a tape measure and a vernier calliper. The animals were on an upright plane during the measurements. The exact position of each reference point of measurement was identified on animals just after shearing by palpation on the relevant anatomical bone. The body measurements included (Fig. 2) height at withers (HW), height at back (HB), height at rump (HR), height at chest (HC), length of trunk (LT), length of rump (LR), length of head (LH), length of perineum (LP), width of head (WH), width of chest (WC), width of biiliac (WBIIL), width of biischiatic (WBIIS), perimeter of the shin (PS), perimeter of the thorax (PT) and perimeter of the abdomen (PA). Animal movement and variations in fleece cover may have reduced the accuracy with which measurements were recorded (Stanford *et al*. 1998).

With the data obtained from the body measurements, the following indexes were calculated: cephalic index (CI = WH × 100/LH), thoracic index (TI = WC × 100/HC), pelvic index (PI = WBIIL × 100/LR), body index (BI = LT × 100/PT), relative chest-depth index (RDCI = HC × 100/HW), lateral corporal index (LCI = HW × 100/LT), relative shin-thickness index (RTSI = PS × 100/HW) and dactyl–thoracic index (DTI = PS × 100/PT). The liveweight (LW) was recorded with an electronic weighing machine.

Statistical analyses

Data were analysed using the general linear model (GLM) procedure of the SPSS package version 14 software (SPSS, Chicago, IL, USA). The effects of gender and variety (Várzea or Mountain) were analysed by using the analysis of variance (ANOVA) procedure. The general model used was

$$Y_{ij} = \mu + T_i + S_j + (TS)_{ij} + \varepsilon_{ij},$$

where Y_{ij} is the observation of gender j and variety i for each of the dependent variables; μ is the overall mean; T_i is the effect of variety i (i = 1, 2); S_j is the effect of gender j (j = 1, 2); $(TS)_{ij}$ is the interaction between variety and gender; and ε_{ij} is the random residual error associated with the observation ij. The HSD Tukey's test was applied to compare the mean values obtained. Differences between pair-wise combinations of the least square means were tested for significance ($P < 0.05$). Relationships among body measurements, indexes and liveweight were investigated by principal component analysis. A Varimax rotation was applied to obtain the factor pattern coefficient (Manly 1991).

Results

For Várzea females, all body measurements had significantly higher mean values than those observed for females of the Mountain variety (Table 1). For males, the Várzea variety had higher mean values than did the Mountain variety for HW, HB, HR and HC heights, LR and LT lengths, WC, WBIIL and WBIIS widths, and PT and PA perimeters (Table 2). Also, LW was higher

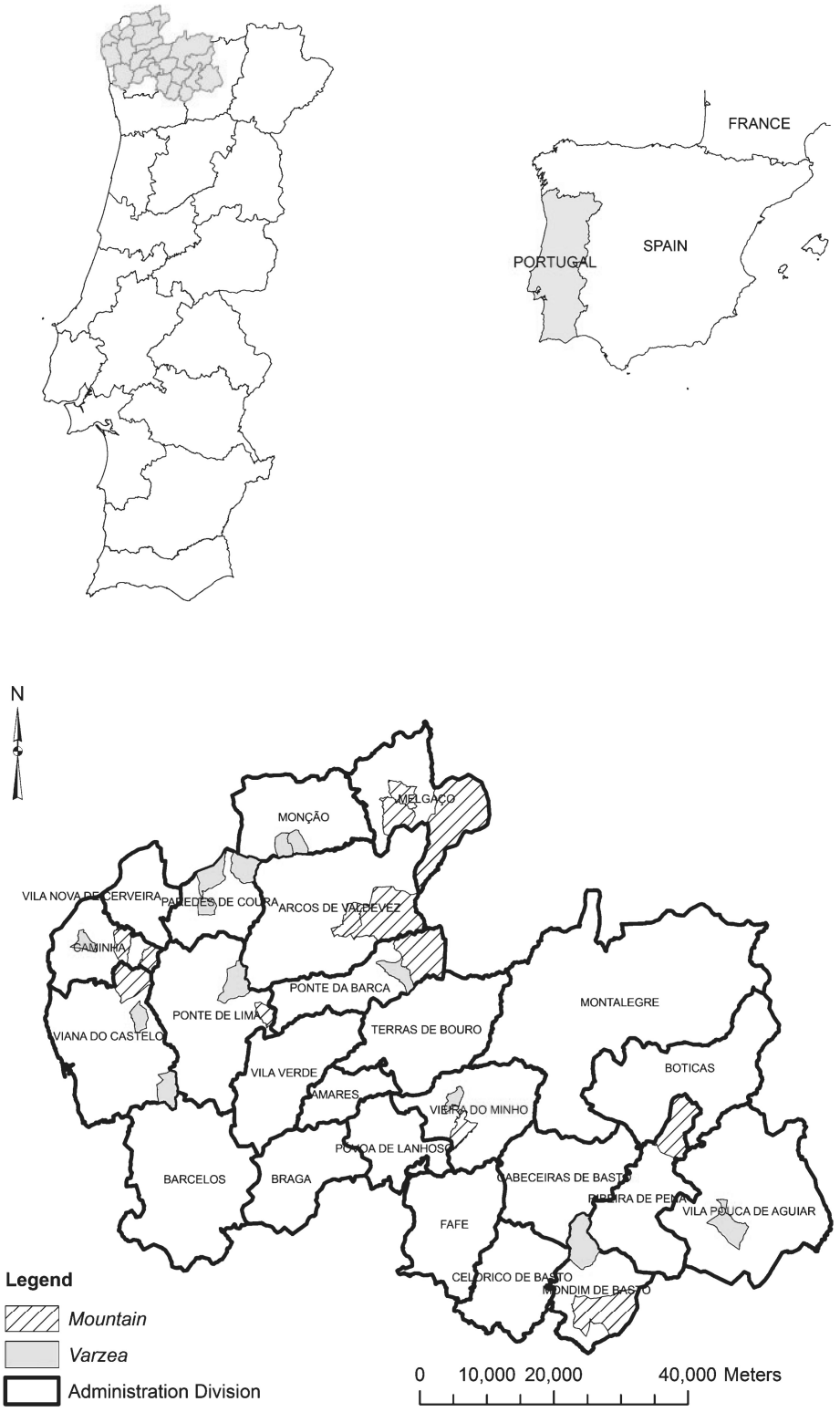


Fig. 1. Geographical distribution of sheep farms sampled in the Entre Douro e Minho region.

in the Várzea variety for both sexes ($P < 0.001$), with least square means of 31.47 ± 5.54 kg and 23.36 ± 4.35 kg for females and 42.74 ± 6.41 kg and 34.09 ± 3.88 kg for males, for the Várzea and the Mountain varieties, respectively. For the biometrical indexes (Table 3), only significant differences existed between female varieties. The Várzea females had higher CI ($P < 0.001$), RTSI (P

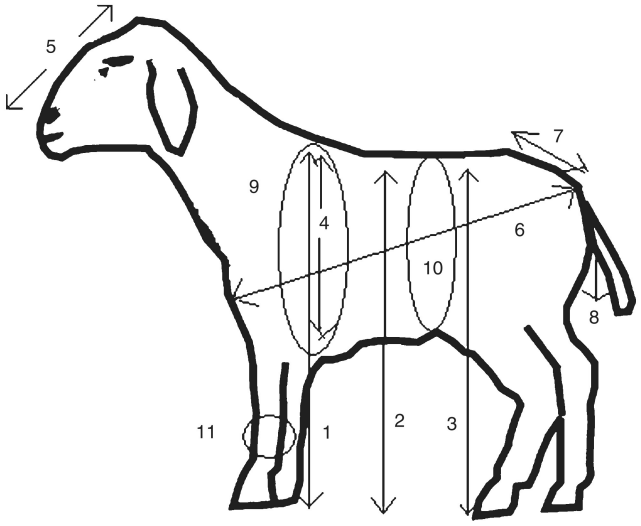


Fig. 2. Zoometrical variables studied (height, length and perimeter) and their reference points. (1) Height at withers (HW). (2) Height at back (HB). (3) Height at rump (HR). (4) Height at chest (HC). (5) Length of head (LH). (6) Length of trunk (LT). (7) Length of rump (LR). (8) Length of perineum (LP). (9) Perimeter of the thorax (PT). (10) Perimeter of the abdomen (PA). (11) Perimeter of the shin (PS).

Table 1. Least square means (μ ± s.d.) for 15 body measurements (cm) and liveweight (kg) of females of each Bordaleira de Entre Douro e Minho (BEDM) variety

HB, height at back; HC, height at chest; HR, height at rump; HW, height at withers; LH, length of head; LP, length of perineum; LR, length of rump; LT, length of trunk; LW, liveweight; PA, perimeter of the abdomen; PS, perimeter of the shin; PT, perimeter of the thorax; WBIIL, width of biiliac; WBIIS, width of biischiatic; WC, width of chest; WH, width of head. *, $P<0.05$; **, $P<0.01$; ***, $P < 0.001$

Parameter	Várzea (n = 184)		Mountain (n = 160)		Significance
	μ ± s.d.	CV (%)	μ ± s.d.	CV (%)	
HW	60.49 ± 3.85	6.36	54.63 ± 3.79	6.94	***
HB	63.55 ± 4.31	6.78	57.39 ± 3.85	6.71	***
HR	60.54 ± 3.91	6.46	53.78 ± 3.84	7.14	***
HC	32.81 ± 2.97	9.05	29.11 ± 3.27	11.23	***
LT	64.53 ± 5.31	8.23	59.07 ± 4.73	8.00	***
LR	20.55 ± 2.62	12.75	16.77 ± 2.17	12.94	***
LH	29.24 ± 1.46	4.99	27.73 ± 1.42	5.12	***
LP	7.54 ± 0.82	10.88	7.23 ± 1.64	22.68	*
WH	13.13 ± 1.19	9.06	11.35 ± 0.99	8.72	***
WC	16.63 ± 2.50	15.03	14.69 ± 2.34	15.93	***
WBIIL	14.60 ± 2.12	14.52	12.44 ± 1.98	15.92	***
WBIIS	9.47 ± 1.41	14.89	7.45 ± 1.02	13.69	***
PS	7.30 ± 0.70	9.59	6.28 ± 0.45	7.17	***
PT	80.39 ± 5.96	7.41	71.18 ± 6.82	9.58	***
PA	87.64 ± 6.21	7.09	77.94 ± 6.73	8.63	***
LW	31.47 ± 5.54	17.60	23.36 ± 4.35	18.62	***

< 0.001), DTI ($P < 0.01$), PI ($P < 0.01$) and BI ($P < 0.001$) than did the Mountain females.

Table 4 presents the principal component analysis, where two main components contributed 70.5% of all variation. The first main component represented 61.4% of the total variation. Body measurements of HW, HB, HR, LT, LH, PS and LW were all positive and contributed most to this variation. The second factor accounted for only 9% of the total variation and was associated with measures on the thorax (HC, WH and PT) and rump (LR and WBIIL). Fig. 3 shows no negative variables and that the body measurements have been separated into the following two groups: one formed by the LW and height measures (HB, HR and HW), where the first main component is more expressive, and the second component including the rump measurements (WBIIL, WBIIS and LR). The principal component analysis for the individual morphometric data (across the varieties and genders) is shown in Fig. 4. The first principal component separated males (positive values) from females (negative values), whereas the second principal component seperated Várzea females from Mountain females. In males, this division was not as obvious.

Table 2. Least square means (μ ± s.d.) for 15 body measurements (cm) and liveweight (kg) of males of each Bordaleira de Entre Douro e Minho (BEDM) variety (Várzea and Mountain)

HB, height at back; HC, height at chest; HR, height at rump; HW, height at withers; LH, length of head; LP, length of perineum; LR, length of rump; LT, length of trunk; LW, liveweight; PA, perimeter of the abdomen; PS, perimeter of the shin; PT, perimeter of the thorax; WBIIL, width of biiliac; WBIIS, width of biischiatic; WC, width of chest; WH, width of head. *, $P<0.05$; **, $P<0.01$; ***, $P < 0.001$; n.s., not significant

Parameter	Várzea (n = 42)		Mountain (n = 26)		Significance
	μ ± s.d.	CV (%)	μ ± s.d.	CV (%)	
HW	65.83 ± 4.97	7.55	61.58 ± 3.51	5.70	***
HB	67.52 ± 5.15	7.63	63.27 ± 3.34	5.28	***
HR	63.71 ± 4.35	6.83	60.27 ± 3.75	6.22	**
HC	32.95 ± 3.82	11.59	30.88 ± 2.39	7.73	*
LT	67.24 ± 6.87	10.22	62.54 ± 3.75	6.00	**
LR	19.00 ± 3.53	18.58	17.00 ± 1.81	10.65	**
LH	30.36 ± 1.25	4.12	30.23 ± 1.92	6.37	n.s.
LP	8.43 ± 1.38	16.37	8.15 ± 1.35	16.52	n.s.
WH	12.62 ± 1.41	11.17	12.46 ± 0.86	6.90	n.s.
WC	17.88 ± 2.68	14.99	15.85 ± 1.97	12.46	**
WBIIL	12.76 ± 2.57	20.14	11.31 ± 1.91	16.92	*
WBIIS	9.26 ± 2.64	28.50	7.85 ± 2.03	25.92	*
PS	7.64 ± 0.62	8.11	7.38 ± 0.57	7.73	n.s.
PT	79.88 ± 7.52	9.41	75.08 ± 4.41	5.87	**
PA	87.02 ± 7.52	8.64	80.77 ± 4.19	5.19	***
LW	42.74 ± 6.41	15.00	34.09 ± 3.88	11.37	***

Discussion

Zoometric indexes are relationships among body measurements that are used to describe the proportions and general size of the parts of animals. In the case of ethnological indexes, which are related to the origins and characterisation of a breed, a BI that is used to determine an animal's proportions was significantly lower in Várzea females than in Mountain females. Lower BI values for an animal indicate that it is closer to being rectangular in shape and is indicative of better conformation for meat production. This is consistent with the phenotypic differences observed in the general conformation of the Várzea and Mountain females. The CI is of

Table 3. Least square means for eight body measurements (cm) and liveweight (kg) of males of each Bordaleira de Entre Douro e Minho (BEDM) variety (Várzea and Mountain)

BI, body index; CI, cephalic index; DTI, dactyl–thoracic index; LCI, lateral corporal index; PI, pelvic index; RDCI, relative chest-depth index; RTSI, relative shin-thickness index; TI, thoracic index. *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; n.s., not significant

Index	Females					Males				
	Várzea (n = 184)		Mountain (n = 160)		Significance	Várzea (n = 42)		Mountain (n = 26)		Significance
	μ ± s.d.	CV	μ ± s.d.	CV		μ ± s.d.	CV	μ ± s.d.	CV	
CI	44.91 ± 3.64	8.10	40.99 ± 3.68	8.98	***	41.58 ± 4.39	10.56	41.38 ± 3.87	9.35	n.s.
TI	50.60 ± 5.17	10.22	50.52 ± 5.66	11.20	n.s.	54.42 ± 6.45	11.85	51.49 ± 6.65	12.91	n.s.
PI	71.39 ± 8.29	11.61	74.49 ± 9.33	12.52	**	67.96 ± 11.23	16.53	66.91 ± 11.53	17.23	n.s.
BI	80.37 ± 4.85	6.03	83.28 ± 5.74	6.90	***	84.25 ± 5.18	6.15	83.39 ± 4.14	4.96	n.s.
RDCI	54.29 ± 4.29	7.89	53.40 ± 5.88	11.01	n.s.	50.04 ± 4.34	8.68	50.21 ± 3.49	6.96	n.s.
LCI	94.08 ± 6.40	6.81	92.78 ± 6.38	6.88	n.s.	98.41 ± 7.29	7.41	98.64 ± 5.60	5.67	n.s.
RTSI	12.08 ± 1.08	8.95	11.54 ± 0.89	7.70	***	11.64 ± 0.93	7.97	12.01 ± 0.86	7.20	n.s.
DTI	9.09 ± 0.69	7.62	8.88 ± 0.79	8.84	**	9.61 ± 0.77	8.00	9.84 ± 0.58	5.87	n.s.

Table 4. Principal component analysis for body measurements (cm) and liveweight (kg) of Bordaleira de Entre Douro e Minho (BEDM) sheep (n = 412 animals)

HB, height at back; HC, height at chest; HR, height at rump; HW, height at withers; LH, length of head; LP, length of perineum; LR, length of rump; LT, length of trunk; LW, liveweight; PA, perimeter of the abdomen; PS, perimeter of the shin; PT, perimeter of the thorax; WC, width of chest; WH, width of head; WBIIL, width of biiliac; WBIIS, width of biischiatic. *, P-values > 0.50

Character	Component 1	Component 2	Communality
HC	0.474	0.765*	0.809
HW	0.915*	0.209	0.881
HB	0.874*	0.340	0.879
HR	0.871*	0.293	0.844
LT	0.644*	0.581*	0.752
LP	0.413	0.275	0.246
LR	0.335	0.797*	0.747
LH	0.673*	0.267	0.524
WH	0.374	0.700*	0.629
WC	0.479	0.652*	0.655
WBIIL	0.061	0.919*	0.849
WBIIS	0.236	0.579*	0.391
PS	0.668*	0.468	0.665
PT	0.562*	0.717*	0.830
PA	0.562*	0.702*	0.809
LW	0.813*	0.321	0.764
Eigenvalue	9.824	1.451	
Explained variable (%)	61.401	9.068	
Accumulated variable (%)	61.401	70.469	

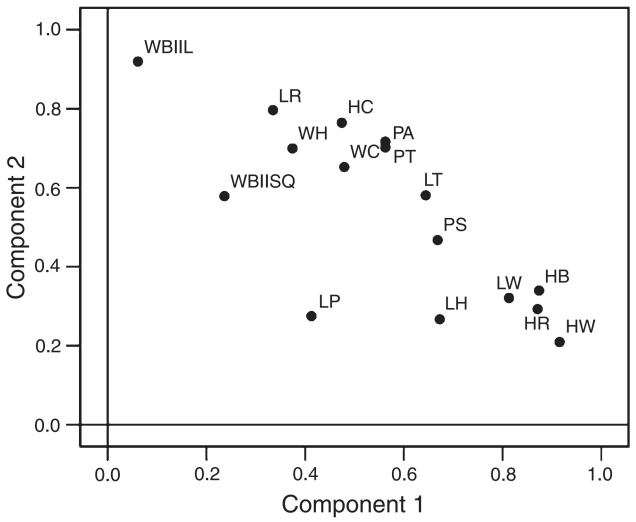


Fig. 3. Scatter plot of Principal Component 1 versus Principal Component 2. Height at withers (HW), height at back (HB), height at rump (HR), height at chest (HC), length of trunk (LT), length of rump (LR), length of head (LH), length of perineum (LP), width of head (WH), width of chest (WC), width of biiliac (WBIIL), width of biischiatic (WBIIS), perimeter of the shin (PS), perimeter of the thorax (PT), perimeter of the abdomen (PA) and liveweight (LW).

ethnological importance, particularly because its variation is not influenced by environmental factors and by the animal's management. In the individuals studied, the length of the head was predominant over the width, so much so that it can be classified as dolichocephalic. The PI, which showed significant differences between the Várzea and Mountain varieties, is a racial diagnosis index used to determine the proportionality of the hindquarters and could be related to reproductive capability. The results for both males and females showed that the length of the hindquarters is predominant over the width. The TI determines the variations in the form of the thorax section. The results indicated no significant differences either for gender or for the two varieties of females. Generally, the transverse section of the animals is more cylindrical than elliptical, which might indicate good muscular capacity and that the animals might be closer to meat-type animals than to those used for dairy production. With respect to the functional indexes that are related to production, the DTI indicates the degree of skeletal fineness and allows us to establish the relationship between the mass of the individual and the limbs that sustain it, so as to determine whether the body volume suits the osseous development. The values obtained, 9.09 ± 0.69 and 8.88 ± 0.79 (μ ± s.d.), indicate that this is a small breed and that there are significant differences between the females of the Várzea and Mountain varieties.

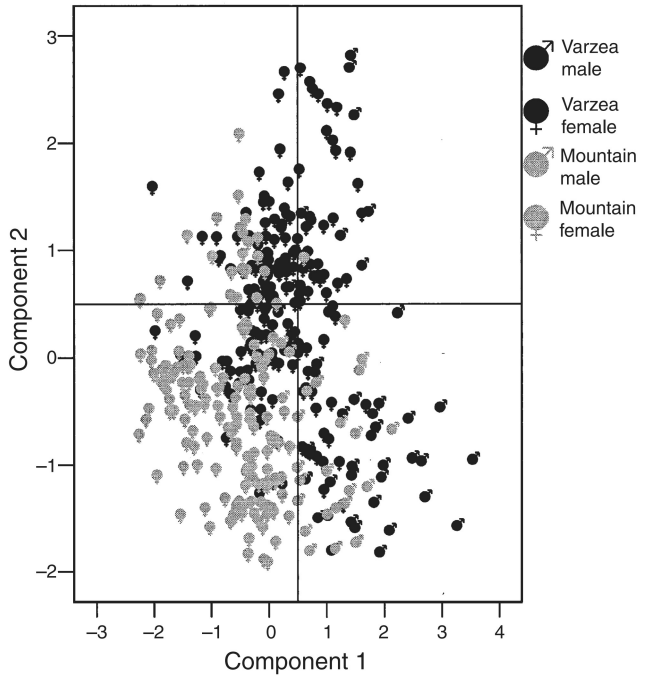


Fig. 4. Distribution of the individual observations for each Bordaleira de Entre Douro e Minho (BEDM) variety (226 Várzea and 186 Mountain) and gender (68 males and 344 females) in relation to the scores for the first two principal components.

In summary, the results obtained have shown the Várzea and Mountain breeds to be of small stature, yet well adapted to their environment. Historically, BEDM animals have been evaluated and selected by using subjective methods primarily based on visual appraisal, and little information has been avalaible on the phenotypic variability among populations of BEDM, whether of Várzea or Mountain variety. Phenotypic differentiation between the two BEDM breeds can now be achieved on the basis of both body measurements and wool characteristics. In fact, the BEDM parameters of genetic variability obtained at microsatellites, such as allele frequencies and heterozygosities, have indicated a considerable level of variation for the complete BEDM population (Oliveira *et al*. 2003). Results for mtDNA haplotypes in BEDM suggested a larger uniformity of genetic maternal inheritance than for the other breeds studied (Oliveira *et al*. 2005). Furthermore, functional index values confirm the BEDM Mountain variety's suitability for mountainous regions. PI values were significantly higher for Mountain females ($P < 0.001$), which were of a more compact type and with long, wide rumps. In this variety, RTSI was associated with strong legs, important to grazing animals in areas with difficult access, and lower withers, back and rump heights.

Small ruminant livestock, both sheep and goats, often are the only possible animal resource for agricultural enterprises of farmers in less favoured areas. They are often fundamental to the maintenance of social and economic dynamism in rural areas (Robertson *et al*. 2009; Williams and Price 2010) and also provide a way to help protect the local vegetation from fires (Rancourt *et al*. 2006). The north of Portugal has been hardly affected by fires, and this is most probably a consequence of modifications in the intensity and type of land use that progressively has taken place since the 1950s (Moreira *et al*. 2009; Carvalho *et al*. 2010). Currently, the grazing of BEDM sheep is used as a strategy to undertake landscape-scale fuel management and to create landscapes with a lower fire hazard.

(*a*)



(*b*)



Fig. 5. Photographs of sheep from the (*a*) Bordaleira de Entre Douro e Minho and (*b*) Churra do Minho breeds.

Conclusions

Biodiverisity is vital for the well being of humans now and in the future. The morphology of the BEDM breed, of both the Várzea and Mountain varieties, has been described. The analysis of the indexes studied suggests that they are well adapted to their environmental conditions and suitable for meat production. In September 2007, as a result of preliminary findings from the present study, the previous BEDM breed was split into two new breeds; the traditional variety called Várzea now represents the new BEDM breed, whereas the other Mountain variety represents the new Churra do Minho breed (Fig. 5) (DGV 2009).

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