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Environment and biometry in the sheep breeds of North-West Portugal

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Abstract. The North-West region of Portugal has undergone a profound change in its agricultural structure, with the abandonment of agricultural activity but increasing the use of autochthonous sheep breeds. These sheep, which are exploited for meat production, can belong to Bordaleira Entre Douro e Minho (BEDM) breed, usually accompany cattle in the pasture, well-formed and moderately developed or Churra do Minho (CM), small sheep with coarse and long wool, that graze exclusively in herds, traditionally kept in turn by the farmers. The aim of this study is to evaluate the adaptability to different ecosystems and the environment influence, in particular altitude, to the breeds morphometric parameters. A total of 1394 BEDM females and 908 CM females were analysed and conformation, productivity and mobility measures were estimated. Our results present significant differences ($P \leq 0.05$) between breeds and age, with higher values in BEDM, relatively to structure parameters. Significant differences were found, regarding breed in functionality. These biometric differences contribute to explain the geographic distribution of breeds, BEDM occupying the valleys, rarely exceeding 600m in altitude and CM the highest mountains where poor soils predominate, with rocky outcrops and sporadic agricultural crops – scrub, low grass and shrub plants, with low energy levels and poor digestibility.

Keywords. Sheep breeds – Environment – Altitude – Biometric measures – Phenotype – Breeding.

L'environnement et la biométrie chez les Races Ovines du Nord-ouest du Portugal

Résumé. *La région du nord-ouest du Portugal a subi un profond changement dans sa structure agricole, avec l'abandon de l'activité agricole mais en augmentant l'utilisation de races ovines autochtones. Ces ovins exploités pour la production de viande peuvent appartenir à la race Bordaleira Entre Douro e Minho (BEDM), accompagnent généralement les bovins au pâturage, bien formés et moyennement développés ou Churra do Minho (CM), petits ovins à laine grossière et longue, pâturés exclusivement en troupeaux, traditionnellement gardés à leur tour par les agriculteurs. L´objective de cette étude est d'évaluer l'adaptabilité à différents écosystèmes et l'influence de l'environnement, en particulier l'altitude, sur les paramètres morphométriques des races. Un total de 1394 femelles de la race BEDM et 908 femelles de race CM. ont été analysés et les mesures de conformation, de productivité et de mobilité ont été estimées. Nos résultats présentent des différences significatives ($P \leq 0{,}05$) entre races et âge, avec des valeurs plus élevées chez BEDM, par rapport aux paramètres de structure. Des différences significatives ont été trouvées, concernant la race, dans la fonctionnalité. Ces différences biométriques contribuent à expliquer la répartition géographique des races, occupant BEDM les vallées, dépassant rarement 600m d'altitude et CM les plus hautes montagnes où prédominent les sols pauvres, avec des affleurements rocheux et des cultures agricoles sporadiques – broussailles, herbes basses et arbustes, à faible niveaux d'énergie et mauvaise digestibilité.*

Mots-clés. *Races ovines – Environnement – Altitude – Biométrie – Phénotype – Elevage.*

I – Introduction

The domestication of animals and plants represented one of the most important technological transformations in the history of mankind (Arbuckle & Atici, 2013) and appears to have started after the end of the last ice age. Archaeological findings document that the domestication of small ruminants started (approximately 10,000-11,000 BP) in the "Fertile Crescent" and "Levant" region, which today comprises the territory from the Middle East to Turkey, passing through the island of Cyprus (Horwitz *et al.*, 2000; Vigne *et al.*, 2011). Sheep are ubiquitous across pre-historic steppe archaeological contexts dating from the Early Bronze Age, being a small and mobile animal, as part of a pastoral package of horse, cattle, and goats (Haruda *et al.*, 2019).

Archaeological evidence also points to the dispersion of animals from Southwest Asia, along the Mediterranean coast and throughout central Europe (Pereira *et al.*, 2006). In the western part of the Iberian Peninsula, the vestiges date from around 6200 BP and reflect a rapid dispersion, in agreement with the process of maritime colonization by Mediterranean civilizations (Zilhão, 2001).

Genetic studies point out that all the existing domestic sheep have their origin in the Asiatic mouflon (*Ovis orientalis*) from the Taurus and Zagros mountains (Zeder, 2017), and mitochondrial DNA sequencing techniques supported this hypothesis, by excluding the contributions of Urial (*Ovis vignei*) and Argali (*Ovis ammon*) to the existing populations of *Ovis aries* (Hiendleder *et al.*, 2002).

The study the mtDNA of 7 Portuguese breeds, belonging to the 3 main Iberian branches: Merino, Churra, and Bordaleiro, demonstrated an extremely high genetic diversity and found genetic strains that, until then, had only been found in Near East and Asia (Pereira *et al.,* 2006), which reinforces the thesis of dispersion across the Mediterranean by sea (Pedrosa *et al.,* 2007). Archaeological and genetic studies indicate that the territory of the Iberian Peninsula seems to have been an important area for the production and improvement of this species (Davis, 2008), currently illustrated by the 16 indigenous breeds existing in Portugal and the 44 in Spain (BOE, 2019).

In the Northwest of Portugal there are 2 breeds of autochthonous sheep: the "Bordaleira de Entre Douro e Minho" (BEDM) and the "Churra do Minho" (CM). These breeds occupy, preferably, different strata of the orography of this region and are explored in a distinct way. Although BEDM was already mentioned in the 1870 official census, there was no conservation program until officially recognized as an autochthonous breed, in 2003. At that time, CM was only considered as a variety of BEDM and only become recognised officially as an autonomous breed in 2007. Selection programs have been carried out to eradicate the genetic influence of BEDM in this population, by the exclusive use of CM male breeders and selecting new breeders by the size and wool type.

The Bordaleira de Entre Douro e Minho breed is a medium size sheep, belong to the branch of Bordaleiro and occupy the areas of half slope or valleys, which rarely exceed 600m in altitude. This region has a moderate Atlantic climate, characterized by relatively cool summers and mild winters, with annual thermal amplitudes that rarely exceed 10 ºC, and abundant rainfall, especially in autumn and winter. The soils of this region, although poor (generally deficient in phosphorus, magnesium and calcium), allow for a reasonable forage production enabling the obtaining of modest but significant zootechnical results (DGAV, 2013). The profitability of these small size herds is primarily due to its meat production, either by lamb's commercialization or self-consumption. Its manure production is highly valued for fertilizing ornamental gardens and the cleaning and maintenance of the fields are also functions of this breed, that enable its existence and allow the conservation of the typical landscape of the Minho region. Wool, of the Bordaleiro type, with its average quality and devalue, represents more a burden than an asset (Dantas, 2003).

The Churra do Minho is a light-sized sheep breed, with coarse, long and drained wool (Churra type). These animals inhabit the highest areas of the mountains of Northwest Portugal, almost always above 800m altitude, and are raised in free grazing, constituting relatively numerous herds, often accompanied by Bravia goats' breed. This region has an Atlantic climate with markedly continental influences, characterized by very cold winters, with prolonged periods of snow, numerous days of frost and heavy rainfall, which condition the entire vegetation cover of the mountains (DGAV, 2013). CM breed maintains a very homogeneous and unadulterated population, mainly due to its high rusticity and adaptation to this type of production system, characterized by the scarcity of resources and adverse climatic conditions (Teixeira,1994). The higher pastures, where these sheep normally graze, with skeletal soils of granitic origin, have a predominantly shrubby flora and with some poorly developed grasses. This strict and restrictive food base, of low quality and digestibility, greatly conditions the development and survival of the animals that feed on it, as well as the populations that depend on them. Thus, allied to the grazing-pasture practiced in these regions, sporadic agricultural crops (maize, potatoes and vegetables) and spontaneous fodder to complement the livestock on winter days can be found on areas uprooted from the hills and surrounded by immense cliffs (DGAV, 2013).

Several studies of morphometric index are performed worldwide, the vast majority directly related to the breed characterization and conformation (Yunusa *et al*., 2013; Costa *et al*., 2014, Markovic *et al*., 2019). The use of zoometric measures as a strategy to provide a reasonable representation of the differences among breeds and contribute to a better understanding of differences in production systems regarding the environment, nutrition and breeding areas, is an important research topic in sheep populations, particularly in Portugal (SEAIA, 2013; Carolino *et al*., 2013).

The aim of this study is to evaluate the distancing, in morphological terms, of the two breeds and within different age groups, since the separation of the herd book, in order to support the breeding and selection programs.

II – Materials and methods[1]

1. Sample size and distribution

The whole sample comprised 2252 ewes, distributed by 1344 females (F) of BEDM, and 908 females of CM, all over 9 months old and registered in the herd book of the respective breed. The BEDM sheep were selected from 37 herds (representing 21% of the total breeders) and the CM females came from 10 farms (15% of the total) in the region considered to be their breeding area (districts of Braga, Porto, Viana do Castelo and Vila Real).

The BEDM is bred in small agricultural units, normally self-subsistent, constituting small herds that are exploited as a complement to cattle, generally considered as the main production of the farms. These herds, when shepherding together, allow a greater use of forage availability and a profitability of surpluses.

The CM sheep farming system is typically an extensive system. Characterized by medium-sized herds, with about 70 animals per farm, inserted in small mountain agricultural units that take advantage of the large common lands in the region.

2. Zoometric measures

Biometric variables were measured and following procedure, according to FAO (2012) guidelines for adult animals (older than 9 months), is shown in Table 1. Quantitative data (ICCAR, 2008) was obtained using a measure tape and an angle finder.

1. The trial was carried out in accordance with EU Directive 2010/63/EU; it complied with the Portuguese legislation on animal care (DL n. 113, 7 August 2013), and adhered to the internal rules of the Polytechnic Institute of Viana do Castelo.

Table 1. Biometric variables and measuring procedure to obtain them from the animals

	Variable	How to measure It	Units
Standard Traits	Stature (St)	from the top of the spine in between the shoulders to ground	cm
	Chest width (CW)	the inside surface between the top of the front legs	cm
	Body length (BL)	from the cranial point of the humerus greater tuberosity to the ischial tuberosity caudal point	cm
	Bone thickness (BT)	thickness of the cannon bone in the forelegs	cm
	Rump length (RL)	distance between hips to pins	cm
	Thurl width (TW)	distance between thurls	cm
	Rump angle (RA)	the angle of the rump structure from the hooks (hips) to pins	º
Leg Traits	Rear leg set side view (RLSV)	angle measured at the front of the hock	º
	Rear leg set rear view (RLRV)	distance between hocks	cm
	Locomotion (L)	the use of legs and feet, length and the direction of the step	cm
Udder Traits	Rear udder height (RUH)	the distance between the bottom of othe vulva and the milk secreting tissue	cm

3. Data analysis

Descriptive statistics [mean, standard deviation (SD] were generated for all the variables in the dataset. As recommended by ICAR Guidelines, for the quality of data, the animals were grouped in 6 categories of similar age. The first group under 18 months old (group 1), and then considering a productive cycle of 9 years, 5 more categories were established with an interval of 17 months: from 19 to 36 months old (group 2); from 37 to 54 months old (group 3); from 55 to 72 months old (group 4); from 73 to 90 months old (group 5); more than 91 months old (group 6), in order to evaluate biometric modifications between age groups and within breeds.

A Shaphiro-Wilk's test (Shapiro and Wilk,1965) was previously carried out to analyse data distribution normality. Breed and age group effects were determined by Chi-squared or the Tukey's test and ANOVA procedure was used to test differences in age, within breed and between the different data categories, using the general linear model of IBM SPSS Statistics 23.0. All statements of significance were based on testing at the P, 0.05 level. The Pearson phenotypic correlation matrix was estimated for zoometric measures (ZM).

III – Results

1. Breed effect

The morphometric analysis indicated highly significantly ($p \leq 0.05$) breed effect, as shown in Table 2 and 3, with the superiority of the BEDM ewes. Concerning stature analysis, the BEDM breed females were significantly ($p \leq 0.05$) the tallest, largest and biggest (CW and TW), with a greater rump length. Conversely, the CM breed ewes were the significantly ($p \leq 0.05$) less robust (smaller, thinner and shorter), and presented the smallest rump angle and the least bone thickness. The superiority ($p \leq 0.05$) of BEDM females was also verified regarding leg and udder traits, suggesting its higher productive potential.

Table 2. Effect of breed in the different standard traits (cm and º) in BEDM and CM breeds

		Standard traits													
		Stature		Chest width		Body length		Bone thickness		Rump lenght		Thurl width		Rump angle (º)	
Breed	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BEDM	1344	60.4^a	3.5	20.6^a	2.9	67.1^a	5.2	8.1^a	0.5	22.6^a	1.8	19.9^a	2.1	41.8^a	5.9
CM	908	56.4^b	3.4	18.4^b	1.8	63.1^b	5.4	7.8^b	0.5	20.4^b	2.3	17.7^b	2.2	42.6^b	7.1
TOTAL	2252	58.8	4.0	19,7	2.7	65.5	5.6	8,0	0.5	21.7	2.3	19.0	2.4	42.1	6.4

^{a,b} Different letters in the superindex are indicative of the existence of significant differences among breed for the stature measures ($p \leq 0.05$). SD: Standard Deviation.

Table 3. Effect of breed in the different leg and udder traits (cm and º) in BEDM and CM breeds

		Leg traits						Udder traits	
		Rear legs set rear view		Rear legs set side view (º)		Locomotion		Rear udder height	
Breed	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BEDM	1344	10.9^a	2.5	48.2^a	7.5	6.3^a	0.7	5.7^a	2.2
CM	908	10.1^b	2.7	46.5^b	8.3	6.0^b	0.9	5.5^b	1.7
TOTAL	2252	10.5	2.5	47.5	7.9	6.2	0.8	5.6	2.0

^{a,b} Different letters in the superindex are indicative of the existence of significant differences among breed for the leg and udder traits ($p \leq 0.05$). SD: Standard Deviation.

2. Age group effect

To evaluate the breed zoometric variability and the morphological behaviour over age, age group parameters were estimated. When considering the age group effect (Figure 1) in structure traits, significant differences ($p \leq 0.05$) were observed in all parameters, between all age groups and breeds, except for the thurl width, between the first, fourth, and sixth groups. Within breed, zoometric modifications, also with the exception of the thurl width, were observed ($p \leq 0.05$), between the first and second age group, in all the measurements. Also, in this trait, and regarding CM breed, no significant differences ($p > 0.05$) were observed, between all age groups.

3. Phenotypic correlations

The phenotypic correlations between all measurements are given in Table 4, for both breeds. High significant ($p \leq 0.01$) positive correlations were recorded, for all breeds, between the stature and body length (0.56 and 0.51), body length and chest width (0.50 and 0.62), rump length (0.59 and 0.55), rump angle (0.60 and 0.50) and rump length and rump angle (0.67 and 0.78), respectively for BEDM and CM. Similarly, in CM, high significant ($p \leq 0.01$) positive relationships were observed for rump angle and stature (0.52), chest width (0.62) and bone thickness (0.52). Significant ($p \leq 0.01$) negative relationships were obtained for the leg traits, between the rear leg set side view and rump angle (-0.14 and -0.22), rear udder hight (-0.27 and -0.06), rear legs front side view and rump angle (-0.17 and -0.20), rear udder hight (-0.08 and -0.10), for BEDM and CM females, respectively.

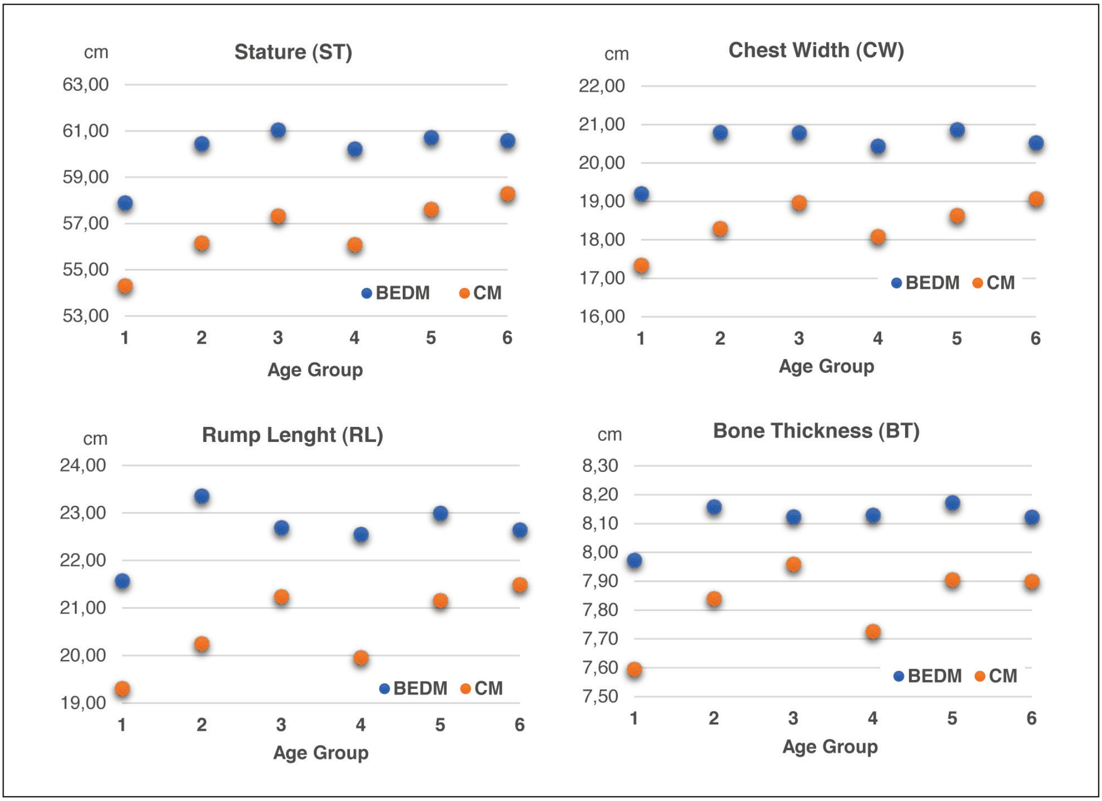

Fig. 1. Effects of age group and breed in the different Standard Traits in BEDM and CM breeds.

Table 4. Pearson's Correlations between traits for BEDM (n:1344, below diagonal) and CM (n: 908, above diagonal) breeds

Breed	Churra do Minho (CM)											
	Trait	**ST**	**CW**	**BL**	**BT**	**RL**	**TW**	**RA**	**RLSV**	**RLFV**	**L**	**RUH**
Bordaleira de Entre Douro e Minho (BEDM)	ST		0.443**	**0.510****	0.468**	0.450**	0.040	**0.523****	-0.250**	-0.177**	0.128**	-0.040
	CW	0.382**		0.501**	0.475**	**0.624****	0.102**	**0.622****	-0.069*	-0.072*	0.120**	0.030
	BL	**0.564****	0.414**		0.414**	**0.549****	-0.083*	0.499**	-0.215**	-0.020	0.114**	0.159**
	BT	0.252**	0.227**	0.381**		0.449**	0.156**	**0.516****	-0.060	-0.134**	0.114**	0.000
	RL	0.444**	**0.498****	**0.591****	0.332**		0.040	**0.785****	-0.153**	-0.084*	0.128**	0.138**
	TW	0.040	0.030	-0.030	0.020	0.010		0.084*	-0.087**	-0.238**	0.095**	-0.030
	RA	0.440**	0.481**	**0.598****	0.360**	**0.666****	0.000		-0.222**	-0.204**	0.143**	0.126**
	RLSV	0.030	-0.101**	-0.040	-0.067*	-0.088**	0.040	-0.143**		0.237**	-0.159**	-0.268**
	RLFV	-0.102**	-0.102**	-0.140**	-0.119**	-0.063*	-0.050	-0.167**	0.249**		-0.084*	-0.106**
	L	0.030	0.030	0.093**	0.107**	0.115**	-0.010	0.020	-0.080**	-0.010		0.010
	RUH	0.000	-0.065*	0.020	0.079**	-0.040	-0.067*	-0.040	-0.063*	-0.083**	0.086**	

ST: stature; CH: chest width; BL: body length; BT: bone thickness; RL: rump length; TW: thurl width; RA: rump angle; RLSV: rear leg set side view; RLFV: rear leg set front view; L: Locomotion; RUH: rear udder hight.

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.001 level (2-tailed). In bold, if high correlated > 0.5.

IV – Discussion

To define and implement breeding programs, morphological traits are essential parameters and dimensions of certain morphological variables could make them suitable, from a productive point of view, for meat (breast measurement) or milk productions (rear leg set side view, rear leg set front view) (Gootwine, 2020).

The studied populations are reared in geographically common areas, with frequent mixing of the breeding animals, which also contributed to the recent breeds genealogic register separation. The phenotypic divergences among them, as body measures differences, imply larger distances among breeds and the zoometric parameters are essential for establishing a morphological breed standard with visual conformation appraisal and, consequentially, to create genetic improvement programs (Gutierrez-Gil *et al.*, 2011).

The morphometric measurements show highly significant ($p \leq 0.05$) breed effect, with the superiority of the conformation traits in the BEDM ewe, being the highest, largest, longest and with the highest bone thickness and thurl width, and the CM females with the higher rump angle, associated to lower fertility and litter size (La Fuente *et al.*, 2011; Haldar *et al.,* 2014). Concerning the leg and udder parameters, significant differentiation ($p \leq 0.05$) between breeds with the superiority of the BEDM, in all traits. These results reflect the higher rusticity of the CM breed, well adapted to the less favourable environment, with low nutritional availability and productivity.

Zoometric measures are, generally, significantly different ($p \leq 0.05$), between breeds, for structure traits, during all age group, with the exception of thurl width (first, fourth and sixth age group), and body length (fifth and sixth age group). Higher variability was observed, regarding the leg and udder traits in both breeds and different group age. Breeding programs are still in an initial period, directed to body conformation traits, and low productivity and double-purpose production has neglected leg and udder traits selection.

The positive and significant correlations among the body measurements observed in all the groups (BEDM, CM) indicate high predictability among the variables (Pundir *et al*., 2011). The lower and negative correlations observed rump angle and rear leg traits and rear udder hight interpret the parameters' weakness in the breeds' productive and functional traits.

Environmental and biological factors can affect animal populations, especially through effects associated with differences in the agro-climatic conditions, natural resources and breed purpose (Bridley, 2011; Vasquez *et al*., 2017; Sérgio *et al*., 2018). The adaptation of the studied breeds to the agro-climatic, ecological and environmental conditions contribute to emphasise their morphological differences and allow to design strategies and improve breeding programs in order to protect and evaluate those autochthonous populations.

The production system, nature and evolution of crop-livestock systems, and cultural, economic and social factors, as cultural preferences, economic opportunities, depopulation and labour bottlenecks (Baltenweck *et al*., 2003), are strongly influenced by general economic environment (markets, agricultural policies, societal demands, trends in other sectors of the economy, global change) but also by environmental and social terms and their ecological, landscape and cultural diversity (Gibon, 2005; Bernués *et al*., 2011; Vouraki *et al*., 2020).

Life history theory suggests an individual morphologic adaptation that will overcome disturbances, minimizing risks during the most vulnerable life stages (Roff, 2002). Disturbance resilience or exploitation may be mediated by physiology and anatomy adaptation, conditioning the morphological characteristics of the new cohort (Grant and Grant, 1993; Astheimer *et al*., 1995). Genetic responses can also be a consequence of environmental disturbances by selective pressures on traits genetically heritable (Grant and Grant, 2003), modulating genetic polymorphisms (Semlitsch and Wilbur, 1989) or changes in genetic structure and diversity (Szczys *et al*., 2012).

Furthermore, habitat components, in particular resources, play a fundamental and important role in shaping the spatial distribution (or space use) and the animal behaviour (Strandburg-Peshkin *et al*., 2017). When behaviours are socially learned, shared within subgroups of the population and persist over time, they are recognised as culture (Laland and Hoppitt, 2003). Considering how learned behaviours can affect individual social decisions reveals the potential for culture to underpin the co-evolution between social structure and behaviour (Farine and Sheldon 2015).

Social behaviour can respond to changes in habitat configuration and the relationship between social structure, animal movement and habitat configuration has important implications for conservation (He *et al*., 2019). Understanding how habitat changes can affect animal movement should be carefully considered in the conservation of social species (Cantor *et al*., 2021), and in the present study, how the border habitat, the social behaviour and the animal movement contribute to their phenotypic characters and productive traits.

Environment, morphology and production are intimately interrelated in the sheep breeds of north-western Portugal. CM breed is extremely archaic, tolerant to harsh climates and poor-quality pastures, characteristic of mountain environments and Bordaleira breed is mostly dairy sheep and used in traditional crop–livestock systems in low-land regions. More studies should be conducted in order to determine the best traits to be used as selection criteria, to increase the animal production systems efficiency and facilitate a breeding programs adjustment to underline their productive potential.

V – Conclusions

New constraints, as climate change, can lead to similar changes in genetic and community structure through the combined effects of selective and neutral processes, and affecting biodiversity, breeds adaptation and productive traits. BEDM and CM are two autochthonous sheep breeds of the Northwest of Portugal, and technical data, such as zoometric measures as a tool in biometric characterization, is mandatory in the implementation of autochthonous breeds selection programs.

The results revealed the high positive differentiation between breeds, with the superiority of BEDM, in structure and functional traits, grazing areas, which rarely exceed 600m in altitude. Positive correlations were obtained between morphometric measurements and its advantages to define conformation, providing a simple practical methodological framework suited for management, characterization and conservation, to be used in selection programs.

Policies that support rural livelihoods, promote local genetic resources and value sustainable products, are a contemporary society requirement, in order to conserve and maintain biodiversity and the environment Sustainability, resilience and adaptive capacity are strategies of autochthons breeds' producers that are guardians of a unique genetic world heritage.

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