Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/sjar
http://dx.doi.org/10.5424/sjar/2014121-4673

Spanish Journal of Agricultural Research 2014 12(1): 117-124
ISSN: 1695-971-X
eISSN: 2171-9292

# Influence of farming system and production purpose on the morphostructure of Spanish goat breeds

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## Abstract

The aim of this study was to examine the possible influence of farming systems, based on the morphostructure of 1,571 female goats drawn from 40 flocks containing seven Spanish breeds (Blanca Andaluza, Blanca Celtiberica, Negra Serrana, Pirenaica, Payoya, Murciano-Granadina and Malagueña) raised under four different farming systems. Analysis of morphometric variables showed that the morphostructure of native Spanish goat breeds was linked to the farming system used and thus to the production purpose. The morphostructure of grazing breeds may be more influenced by natural selection within the physical environment and less by human selection. That of stall-fed breeds, by contrast, reflects intense artificial selection aimed at achieving a highly-productive dairy type. For this reason, morphological evaluation systems used in breeding programmes for meat or dual-purpose goat breeds farmed extensively or semi-extensively should be specific, and should reflect the influence of the environment in which these goats are farmed.

**Additional key words**: morphologic traits; caprine; discriminant; aptitude.

## Introduction

Over recent decades, the selective breeding of goats has given rise to such highly-specialized meat or dairy morphotypes that one single meat or dairy model applies to several breeds of each type and species. However, this high degree of specialization requires intensive rearing conditions. In contrast, breeds currently in danger of extinction are not subjected to this selective pressure, and retain the characteristics adapted to the environment in which they are located.

The application of selection programs based on high-productivity criteria for these endangered breeds may seriously impair their ability to graze and to adapt to different environments. The *in situ* conservation of endangered breeds therefore requires the application of specific selection criteria based on those traits which enhance their adaptation to the farming system in which they are raised, since both environment and production purposes appear to influence breed morphostructure.

Rodero *et al.* (2003) compared the morphostructural features of two Spanish dairy goat breeds with a view to identifying common selection criteria in terms of conformation, and applying valuation morphological lineal (VML), proposing two different models for each. For this purpose, as they commented, it is necessary to include traits of rump, chest and different perimeters.

The growth of animals is influenced by environmental conditions such as food availability, climate, and ecological aspects, among others. On the other hand, the aptitude of a breed is closely linked to its origin, history and evolution in the environment where it was raised.

In a previous study to identify native goat breeds in Jordan using morphostructural variables, Zaitoun *et al.* (2005) found that breeds tended to cluster as a function of purpose and farming system: dual-purpose breeds raised intensively were close to each other but distant from meat breeds raised under wholly-extensive farming systems.

Morphostructural differences by location of herd have also been reported by Macciota *et al.* (2002) in the Sarda goat breed. Goats in coastal areas (*i.e.* 71.7 ± 2.9 cm of height at withers) displayed greater morphostructural measurements than those raised in

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Received: 28-06-13. Accepted: 19-02-14.

Abbreviations used: BL (body length); ChD (chest depth); ChG (chest girth); HaW (height at withers); HL (head length); HW (head width); RL (rump length); RW (rump width); SC (shin circumference); VML (valuation morphological lineal).

the hills (*i.e.* 70.5 ± 3.1 cm of height at withers), which were in turn greater than those raised in the mountains (*i.e.* 69.7 ± 2.8 cm of height at withers).

Dossa *et al.* (2007) found that morphostructural differences among goats in Benin were associated both with vegetation and with the altitude at which the herd lived, arguing that breeding programs should reflect the specific features of each ecological area.

Research aimed at characterizing Spanish goat-farming systems has highlighted the existence of various models, ranging from minimal human intervention through grazing management and selection to the use of a totally-controlled environment. Thus Vert & García-Trujillo (2006) classified farming systems into four types-extensive, semi-extensive, semi-intensive and intensive-as a function of concentrate intake (kg goat$^{-1}$ yr$^{-1}$; *i.e.* < 75 in the extensive system) and stocking rate (number of animals ha$^{-1}$; *i.e.* > 6 in the intensive system).

The present study aimed to examine the possible influence of these four farming systems, and thus of production purpose, on the morphostructure of several Spanish goat breeds.

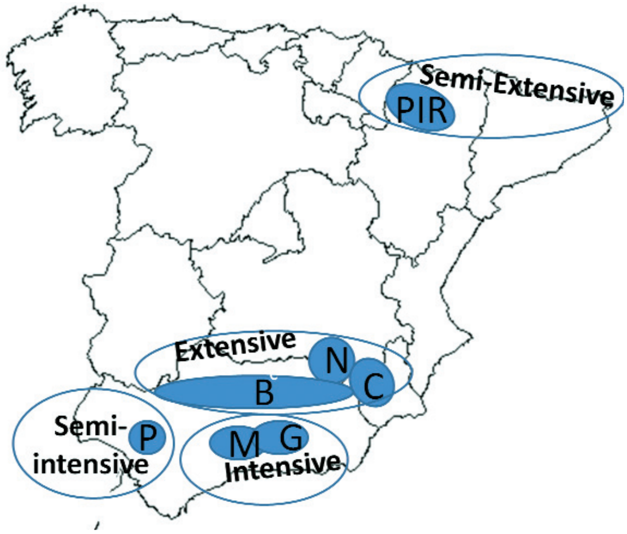


**Figure 1.** Distribution of the breeds studied (B, Blanca Andaluza; C, Blanca Celtiberica; N, Negra Serrana; PIR, Pirenaica; P, Payoya; G, Murciano-Granadina; M, Malagueña), according to their farming system.

## Material and methods

### Data collection

One thousand five hundred and seventy-one females were drawn from 40 flocks containing seven Spanish goat breeds located in the Autonomous Communities of Andalusia, Castilla-La Mancha and Aragon [Malagueña (142), Murciano-Granadina (102), Payoya (237), Pirenaica (152), Negra Serrana (266), Blanca Andaluza (274) and Blanca Celtiberica (398)] (Fig. 1). The number of herds raised under the four farming systems were: intensive (244), semi-intensive (237), semi-extensive (152) and extensive (938). The sample size was obtained by applying a coefficient that relates the homogeneity of the herds studied, expressed through external qualitative traits (coat color, head profile, rump angle, etc.), and the number of animals in each of them. The sample size differences are explained by the fact that some breeds are endangered, with a population size of under 10,000 breeding females (OJ, 2004), and the variability of these breeds in higher than the variability of non-endangered breeds. The endangered breeds included in this study were Payoya, Pirenaica, Negra Serrana, Blanca Andaluza and Blanca Celtiberica. The other two breeds, Malagueña and Murciano-Granadina, had a large number of heads, over 10,000. All animals had given birth at least twice and completed their development.

Murciano-Granadina and Malagueña breeds present a lactic aptitude and showed higher milk production levels (310 and 484 kg per lactation period, respectively; Sánchez, 2008). Generally, they are farmed intensively and kept in stalls throughout the year. The herds studied were located in southern Spain.

The Payoya breed is traditionally classified under double aptitude, milk and meat. The level of its milk production is around 412.59 kg per lactation period (Herrera & Luque, 2008) and it is raised under a semi-intensive regime; the goats are grazed but also receive feed supplements appropriate to their milk yield, with a concentrate supply of over 150 kg goat$^{-1}$ yr$^{-1}$. The herd studied was located in the southern Spanish province of Cadiz.

The Pirenaica breed is also classified by double aptitude (milk-meat) although it is now more widely used for meat production. This breed is raised under semi-extensive conditions where periods of grazing alternate with periods of more abundant stall-feeding. The study herds were located in the northern Spanish province of Huesca.

Those breeds raised under extensive production systems, Blanca Andaluza, Negra Serrana and Blanca Celtiberica, are not milked, as they are required to produce one kid $yr^{-1}$. They are fed wholly on natural resources, by direct grazing, and receive less than 75 kg of concentrate $goat^{-1}$ $yr^{-1}$ during pasture-deficit. The Blanca Andaluza and Negra Serrana herds were located in southern Spain (Morena Mountain and Mountain of Alcaraz), and the Blanca Celtiberica herd in the east of the country.

### Morphometric traits

To evaluate and differentiate the morphostructural models of seven breeds and four farming systems, the nine morphometric variables used by Herrera *et al.* (1996) were used with the exception of width of shoulders, which could not be taken into account. These zoometric traits are studied by measuring the bony prominences using a measuring stick, calipers and a tape measure, are not affected by the animal's conformation and are independent of lactation stage and season. In this way, the following measurements were obtained: head length (HL), height at withers (HaW), body length (BL), rump length (RL), head width (HW), rump width (RW), chest depth (ChD), shin circumference (SC), and chest girth (ChG).

### Statistical analysis

In order to describe each breed morphometrically, the resulting information from the main descriptive statistics (mean and corresponding standard error) of those nine morphometric variables was used. Differentiation of the seven breeds as a function of morphometric variables was performed by analysis of variance (ANOVA) and Tukey's test was carried out. Discriminate canonical analysis enabled each individual animal to be assigned to a group, and also provided information on the degree of differentiation among groups (Herrera *et al.,* 1996). A Mahalanobis test was carried out for the canonical analysis in order to establish the Euclidean distances among the different populations of goats. The spatial distribution of individuals is represented by canonical coefficients in the form of scatter plots and tree diagrams obtained from Mahalanobis distances.

In order to determine the influence of the farming system, the same procedure was carried out to check the differentiation according to breed. Breeds were grouped by production system using canonical procedures and Mahalanobis distances (Mahalanobis, 1936).

A multivariate analysis of variance (MANOVA) was performed too on the data with the four multivariate test statistics of Statistica software output (Wilks' lambda, Pillai's trace, Hotelling-Lawley and Roy's maximum root) for breed and farming system effects. The interaction of both effects did not possible include.

Statistical analysis was carried out using the Statistica software package for Windows 7.0 (Statsoft, Inc.®, Tulsa, OK, USA).

## Results

Spanish breeds raised extensively displayed an average height at withers of between 71.45 cm for Blanca Celtiberica and 77.12 cm for Blanca Andaluza (Table 1); they are therefore generally large animals, either square or somewhat elongated in shape when height at withers is taken in conjunction with body length. Heads tend to be large, with head length accounting for roughly one third of height. They are slender, as deduced from mean rump width, and very bony, with high values for chest girth, which does not favour an ideal meat conformation for kids. Goats raised under semi-intensive and semi-extensive systems displayed values for height at withers similar to those recorded for extensively raised goats (78.43 cm and 73.33 cm, respectively); heads were smaller, and width values slightly higher. In contrast, intensively-raised highly-specialised dairy breeds were shorter than the rest, with smaller heads; widths, however, were similar to those of goats raised under extensive and semi-extensive systems. Small shin girth was characteristic of dairy breeds.

The differences across all breeds were highly significant ($p \leq 0.001$). Breeds extensively raised had similar morphometric traits, except for Blanca Celtiberica breed, which had lower values for all traits (Table 1).

Those breeds with a similar aptitude were grouped together. Thus, we formed four groups by farming system, extensive, semi-extensive, semi-intensive and intensive. As in the case of the Payoya breed, which presents the highest of five morphometric measures, the semi-intensive farming system showed the greatest means of five similar variables (Table 2). In contrast, the animals raised under intensive conditions had the smallest means in the case of six variables. The other two farming systems presented intermediate values of morphometric traits.

Generally speaking, goats adapted to each farming system displayed a specific morphostructure, evident

**Table 1.** Descriptive statistics (mean ± standard error) and differentiation of seven Spanish goat breeds (B: Blanca Andaluza; C: Blanca Celtibérica; N: Negra Serrana; PIR: Pirenaica; P: Payoya; G: Murciano-Granadina; M: Malagueña) by morphometric variables

| Traits[1] | B (N = 274) | C (N = 398) | N (N = 266) | PIR (N = 152) | P (N = 237) | G (N = 142) | M (N = 102) | *p*-value |
|---|---|---|---|---|---|---|---|---|
| HaW | $77.12^{a} \pm 0.22$ | $71.45^{b} \pm 0.18$ | $76.25^{a} \pm 0.22$ | $73.33^{c} \pm 0.24$ | $78.43^{d} \pm 0.23$ | $68.22^{e} \pm 0.47$ | $69.44^{ef} \pm 0.28$ | < 0.001 |
| BL | $81.57^{a} \pm 0.25$ | $75.45^{b} \pm 0.20$ | $82.12^{a} \pm 0.29$ | $76.57^{bc} \pm 0.30$ | $89.46^{d} \pm 0.30$ | $73.97^{be} \pm 0.69$ | $71.64^{f} \pm 0.34$ | < 0.001 |
| ChD | $34.13^{a} \pm 0.14$ | $32.64^{b} \pm 0.14$ | $34.46^{a} \pm 0.16$ | $35.45^{c} \pm 0.15$ | $33.37^{d} \pm 0.13$ | $30.98^{e} \pm 0.26$ | $30.97^{ef} \pm 0.16$ | < 0.001 |
| HL | $25.26^{a} \pm 0.11$ | $23.46^{b} \pm 0.06$ | $24.93^{a} \pm 0.10$ | $21.81^{c} \pm 0.09$ | $22.63^{d} \pm 0.10$ | $18.53^{e} \pm 0.14$ | $17.94^{f} \pm 0.08$ | < 0.001 |
| HW | $12.81^{a} \pm 0.05$ | $12.25^{b} \pm 0.03$ | $12.74^{a} \pm 0.05$ | $13.43^{c} \pm 0.06$ | $13.92^{d} \pm 0.06$ | $12.40^{be} \pm 0.09$ | $12.84^{a} \pm 0.05$ | < 0.001 |
| RW | $14.86^{a} \pm 0.11$ | $13.79^{b} \pm 0.11$ | $14.36^{c} \pm 0.11$ | $16.57^{d} \pm 0.09$ | $17.83^{e} \pm 0.09$ | $15.73^{f} \pm 0.20$ | $16.44^{dg} \pm 0.12$ | < 0.001 |
| RL | $23.44^{a} \pm 0.10$ | $21.64^{b} \pm 0.05$ | $22.86^{c} \pm 0.10$ | $23.11^{ac} \pm 0.08$ | $26.10^{d} \pm 0.10$ | $21.87^{bef} \pm 0.14$ | $22.08^{f} \pm 0.16$ | < 0.001 |
| ChG | $95.60^{a} \pm 0.49$ | $85.44^{b} \pm 0.24$ | $96.94^{a} \pm 0.32$ | $91.42^{c} \pm 0.37$ | $89.27^{d} \pm 0.32$ | $85.59^{be} \pm 0.59$ | $88.08^{df} \pm 0.49$ | < 0.001 |
| SC | $9.69^{a} \pm 0.04$ | $8.77^{b} \pm 0.03$ | $10.15^{c} \pm 0.05$ | $9.46^{d} \pm 0.05$ | $8.20^{e} \pm 0.07$ | $7.97^{ef} \pm 0.06$ | $8.72^{bg} \pm 0.05$ | < 0.001 |

[1] Traits: HaW: height at withers; BL: body length; ChD: chest depth; HL: head length; HW: head width; RW: rump width; RL: rump length; ChG: chest girth; SC: shin circumference. Means having different superscript letters within different rows differ statistically ($p < 0.05$).

in the high level of significance observed by ANOVA. Tukey's test revealed similar measurements for certain variables, including chest depth between intensively and semi-intensively farmed animals, head width between extensively and intensively farmed goats, and rump width between semi-extensively and intensively farmed goats. Shin circumference was generally greater in grazing goats, whose legs were sturdier than those of milking goats.

The four multivariate test statistics of Statistica output (Wilks' lambda, Pillai's trace, Hotelling-Lawley and Roy's maximum root) showed a significant effect of breed and farming system, with a *p*-value < 0.001 (data no presented).

We employed the discriminate analysis to obtain the classification of individuals to their breeds (Table 3). The highest rates of correct assignment of individuals to each breed were observed in Blanca Andaluza, Payoya and Pirenaica breeds, with each belonging to a different farming system. The lowest number of correct assignments can be seen in the case of the Negra Serrana goat breed, which presented 82 (30.87%) animals assigned to the Blanca Andaluza goat breed. In the case of animals raised under a semi-extensive and semi-intensive farmer system, represented by the Pirenaica (PIR) and Payoya (P) breeds, respectively, a large proportion of goats were correctly classified (97.89% and 89.47%, respectively), suggesting a morphostructural response to two specific and widely-separated grazing areas, Pirenaica in northern Spain and Payoya in the south of the Iberian Peninsula. In animals raised intensively (Murciano-Granadina and Malagueña), the absence of grazing minimized the effect of herd location and emphasised the effect of se-

**Table 2.** Descriptive statistics (mean ± standard error) and differentiation of four farming systems by morphometric variables

| Traits[1] | Extensive (N = 938) | Semi-extensive (N = 152) | Semi-intensive (N = 237) | Intensive (N = 244) | *p*-value |
|---|---|---|---|---|---|
| HaW | $74.47^{a} \pm 0.14$ | $73.33^{b} \pm 0.24$ | $78.43^{c} \pm 0.23$ | $68.93^{d} \pm 0.26$ | < 0.001 |
| BL | $79.13^{a} \pm 0.17$ | $76.57^{b} \pm 0.30$ | $89.46^{c} \pm 0.30$ | $72.62^{d} \pm 0.36$ | < 0.001 |
| ChD | $33.59^{a} \pm 0.09$ | $35.45^{b} \pm 0.15$ | $33.37^{a} \pm 0.13$ | $30.98^{d} \pm 0.14$ | < 0.001 |
| HL | $24.41^{a} \pm 0.06$ | $21.81^{b} \pm 0.09$ | $22.63^{c} \pm 0.10$ | $18.19^{d} \pm 0.08$ | < 0.001 |
| HW | $12.56^{a} \pm 0.03$ | $13.43^{b} \pm 0.06$ | $13.92^{c} \pm 0.06$ | $12.6^{a} \pm 0.05$ | < 0.001 |
| RW | $14.27^{a} \pm 0.07$ | $16.57^{b} \pm 0.09$ | $17.83^{c} \pm 0.09$ | $16.14^{bd} \pm 0.11$ | < 0.001 |
| RL | $22.5^{a} \pm 0.05$ | $23.11^{b} \pm 0.08$ | $26.10^{c} \pm 0.10$ | $21.99^{d} \pm 0.11$ | < 0.001 |
| ChG | $91.67^{a} \pm 0.27$ | $91.42^{a} \pm 0.37$ | $89.27^{b} \pm 0.32$ | $87.04^{c} \pm 0.39$ | < 0.001 |
| SC | $9.43^{a} \pm 0.03$ | $9.46^{a} \pm 0.05$ | $8.20^{b} \pm 0.07$ | $8.41^{bc} \pm 0.05$ | < 0.001 |

[1] Traits: HaW: height at withers; BL: body length; ChD: chest depth; HL: head length; HW: head width; RW: rump width; RL: rump length; ChG: chest girth; SC: shin circumference. Means having different superscript letters within different rows differ statistically ($p < 0.05$).

**Table 3.** Classification (percentage of accuracy ratio) of goats by breed on the basis of morphostructural variables

| Breeds | % | B p=0.17 | C p=0.25 | N p=0.17 | PIR p=0.10 | P p=0.09 | G p=0.06 | M p=0.15 |
|---|---|---|---|---|---|---|---|---|
| Blanca Andaluza (B) | 58.76 | 161 | 43 | 62 | 4 | 1 | 0 | 3 |
| Blanca Celtibérica (C) | 92.21 | 20 | 367 | 9 | 2 | 0 | 0 | 0 |
| Negra Serrana (N) | 56.77 | 82 | 27 | 151 | 6 | 0 | 0 | 0 |
| Pirenaica (PIR) | 89.47 | 0 | 7 | 1 | 136 | 4 | 2 | 2 |
| Payoya (P) | 97.89 | 1 | 2 | 0 | 1 | 232 | 0 | 1 |
| Murciano-Granadina (G) | 58.41 | 0 | 3 | 0 | 7 | 3 | 59 | 29 |
| Malagueña (M) | 87.94 | 0 | 1 | 0 | 1 | 0 | 15 | 124 |
| Total | 78.39 | 264 | 450 | 223 | 157 | 240 | 76 | 159 |

p: the *a priori* classification probabilities.

lective breeding aimed at a single dairy model. Few goats of these two breeds were misassigned to any of the other breeds, which confirm that intensively-farmed goats were readily distinguishable from those raised under other systems. In this case, the percentage of assignment was of 87.94% for Malagueña and 58.42% for Murciano-Granadina, where the assignment errors occur between both breeds. This fact confirmed the trend towards breeding a single dairy morphotype.

As well as employing discriminate analysis to differentiate animals by the effect of breeds, we applied the same analysis for the farming system effect. Thus, the idea that morphostructure reflects adaptation to one particular farming system is confirmed by the high rate of correct assignment of goats to the farming system in which they were raised (Table 4). In fact, the correct classification of 98.51% of the extensively-farmed goats underlines the fact that the morphostructure is adapted to the grazing system. Similar results can be deduced from Fig. 2, showing that breed, farming system and production purpose were distinguished on the basis of morphometric variables.

The representation of Mahalanobis distances through a cluster tree (Fig. 3) showed that specialized dairy breeds which were raised intensively were grouped at a considerable distance from extensively-raised goats.

## Discussion

### Characteristics of native Spanish goat breeds raised under four different farming systems

In Spain there is a large number of goat breeds, which have different aptitudes according to their origin and geographical localization. Those goat breeds raised in marginal areas are endangered and their principal production orientation is meat. Those breeds with double aptitudes are in a better situation than meat goats, due to the fact that they can produce meat as well as milk, which mean increased profit per animal. These animals, and in particular those goats in the lactation phase, must receive a supplement. While dairy goats present high milk production, they have to be reared under intensive conditions.

Generally speaking, each breed displayed a specific morphostructural type, with quantitative traits reflecting adaptation to the physical environment in which they are grazed, and-though to a lesser extent-

**Table 4.** Classification (percentage of accuracy ratio) of goats by farming system on the basis of morphostructural variables

| Systems | % | E p = 0.60 | SE p = 0.10 | SI p = 0.15 | I p = 0.15 |
|---|---|---|---|---|---|
| Extensive (E) | 98.51 | 924 | 8 | 1 | 5 |
| Semi-Extensive (SE) | 85.53 | 13 | 130 | 3 | 6 |
| Semi-Intensive (SI) | 97.05 | 2 | 3 | 230 | 2 |
| Intensive (I) | 92.56 | 4 | 6 | 8 | 224 |
| Total | 96.11 | 943 | 147 | 242 | 237 |

p: the *a priori* classification probabilities.

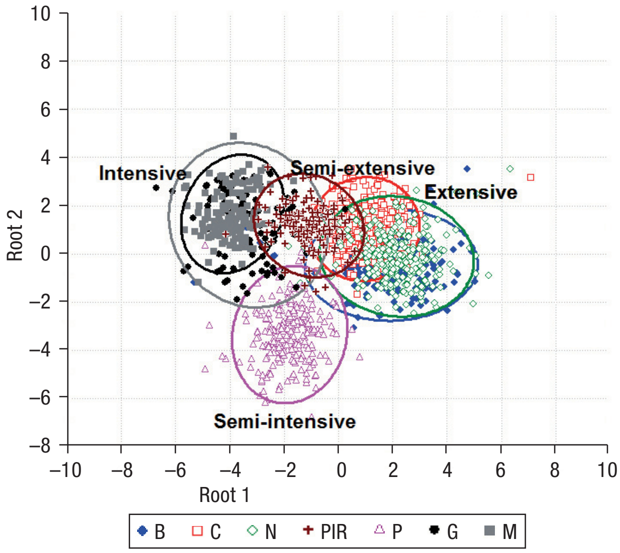


**Figure 2.** Scatter diagram of the animals belonging to the seven Spanish breeds (B, Blanca Andaluza; C, Blanca Celtiberica; N, Negra Serrana; PIR, Pirenaica; P, Payoya; G, Murciano-Granadina; M, Malagueña). The ellipses show the spatial distribution of each goat breed.

reflecting the outcome of breeding efforts, particularly under the extensive system. The variables referring to height and head demonstrated the most correspondences established between breeds and farming systems; and, logically, shin circumference, so typical of milk breeds, is also influenced by both effects. Similar findings are reported by Capote *et al.* (1998) at the *Agrupacion Caprina Canaria* (Canary Goat Populations), who attributed differentiation largely to the environmental conditions of each subarea, and also to cultural and economic factors.

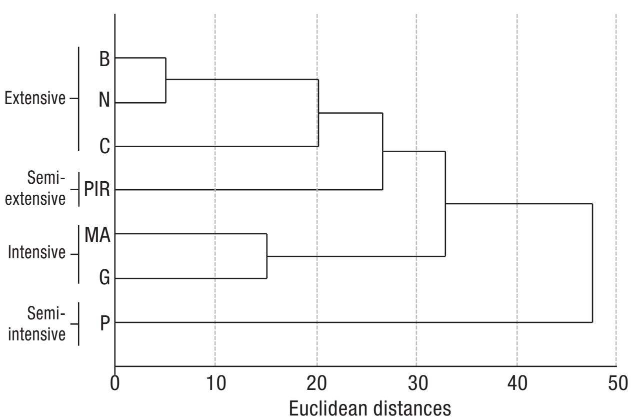


**Figure 3.** Phylogenetic representation of the relationships among the Spanish goat breeds based on Mahalanobis distances (B, Blanca Andaluza; C, Blanca Celtiberica; N, Negra Serrana; PIR, Pirenaica; P, Payoya; G, Murciano-Granadina; M, Malagueña).

The similar morphostructure of extensive breeds can be attributed to an adaptive environmental response, as in the case of the similar geographical location of the Blanca Andaluza and Negra Serrana breeds (Fig. 1), where in some cases they were reared close to each other for at least 15 years but had never been hybridised, their coat colour remaining white and black, respectively. However, previous research did in fact obtain some genetic relationships between both breeds (Tunon *et al.,* 1989; Jordana *et al.,* 1993; Azor *et al.,* 2005; Monteagudo *et al.,* 2006). The great difference between the Blanca Celtiberica breed and the other meat goats, Blanca Andaluza and Negra Serrana, could be explained by the area grazed by each breed, where the former grazes on higher slopes than those areas grazed by the other two meat breeds (Luque *et al.,* 2005). In contrast, the two milk breeds, Murciano-Granadina and Malagueña, only showed differences in height at withers, chest depth and rump length measures. This fact could be due to the high grazing capacity of the Malagueña breed, because before it was raised under intensive conditions, the areas where it grazed had higher slopes than the areas occupied by the Murciano-Granadina breed.

The double-aptitude goat breeds were those which showed the greatest differences in morphometric traits to the other five breeds studied. These differences could be explained by the need to have an intermediate morphostructure between meat and milk breeds. This means that in some morphometric measures, the Pirenaica is similar to some meat breeds, in particular to Blanca Celtiberica for body length and Blanca Andaluza for rump length. The Payoya breed did not show similitude with the other breeds studied, which could be due to the fact that its origin has still not been determined (Herrera & Luque, 2008); some authors believe its origins lie in the Alpine and Pyrenean trunk, with additional influence of the convex trunk, which is necessary for its adaptation to areas where this breed is raised.

Earlier research (Herrera *et al.,* 1996) highlighted differences between Andalusian meat and dairy breeds, as well as between hill-raised and mountain-raised dairy breeds (Rodero *et al.,* 2003). Macciotta *et al.* (2002) noted differences in the morphostructure of Sarda goats depending on geographical location (mountain, hill or coast), showing that morphometric breed analysis can provide information on the morphostructural adaptation of herds to prevailing breeding and management conditions.

## Correlation between morphostructure and farming systems

The highest values of chest depth and girth in goats raised under an extensive or semi-extensive farmer system could be due to the fibre content of the pasture. Obviously, the thinner shafts were found in dairy animals because shin circumference is correlated directly and negatively with the amount of milk produced by the goats (Rodero *et al.,* 2003).

The inter-breed differences in morphometric variables as a function of the farming system and production purpose reflect the type of selection to which goats are subjected. The breeding criteria applied to grazed meat goats differ from those applied to milk goats. Indeed, in some cases, the only criteria applied when breeding grazed goats are aimed at enhancing their ability to adapt to harsh environmental conditions; that ability is evaluated in terms of productive and reproductive success. The morphostructure of grazing goats is largely the result of natural selection for the ability to adapt to given climate conditions and physical-geographical environments (Lauvergne, 1988). Grazing goats thus displayed higher values for height at withers, chest girth and leg length than intensively raised goats (Martini *et al.,* 2010).

## Morphometric differentiation by discriminate analysis of breed and farming system

The comparison between goat breeds according to morphological characteristics is made using multivariate classification techniques based on classical linear methods, such as canonic discrimination (Jordana *et al.,* 1993; Herrera *et al.,* 1996; Capote *et al.,* 1998; Crepaldi *et al.,* 2001; Macciotta *et al.,* 2002; Lanari *et al.,* 2003; Rodero *et al.,* 2003; Nsoso *et al.,* 2004; Zaitoun *et al.,* 2005; Traoré *et al.,* 2006, 2008; Dossa *et al.,* 2007; Vargas *et al.,* 2007).

The results in the individual assignment of Blanca Andaluza and Negra Serrana breeds could only be due to their sharing of a grazing range, which was a large area bounded by the mountains of Alcaraz and Morena (Herrera & Luque, 2008). A similar correct assignment percentage was reported by Dossa *et al.* (2007) in goat herds in Benin, where a large proportion of goats (76.6%) were correctly assigned to the appropriate grazing system, thus demonstrating the considerable discriminating power of the morphometric measurements that were used in this study. Earlier research (Herrera *et al.,* 1996) highlighted differences between Andalusian meat and dairy breeds, as well as between hill-raised and mountain-raised dairy breeds (Rodero *et al.,* 2003). Other authors (Luque *et al.,* 2005) have reported similar results in meat goats, because they found a correlation between morphological structure and altitude and slope of the pasturing areas. Macciotta *et al.* (2002) noted differences in the morphostructure of Sarda goats depending on geographical location (mountain, hill or coast). Crepaldi *et al.* (2001), Macciotta *et al.* (2002), Zaitoun *et al.* (2005) and Dossa *et al.* (2007) also reported the effect of the farming system and production purpose on morphometric variables.

The ordering of "extensive", "semi-extensive", "semi-intensive" and "intensive" in Fig. 3 reflects the influence of the farming system and production purpose for each breed. In theory, therefore, one would expect the Payoya breed to be located at an intermediate point between semi-extensive and intensive, but this was not the case. One possible explanation is that Payoya is a relatively recent breed, and its morphostructure may therefore be influenced by breed origin (Herrera *et al.,* 1996) as well as by the farming system and production purpose.

The confirmation of the adaptation of breed morphostructure to specific farming systems and production purposes underlines the need to ensure that morphological evaluation systems used in breed selection programmes for grazed goats should be specifically designed for those breeds. Application of the same criteria as that used for highly-specialised breeds raised intensively is not feasible.

In farming systems involving grazing, morphostructural models are shaped by environmental factors. The impact of these factors on the conformation of the breeds in question should be evaluated with a view to optimising productivity based on optimum resource use under sustainable production systems.

As final conclusions, the analysis of morphometric variables showed that the morphostructure of native Spanish goat breeds was linked to the farming system used and, thus, to production purpose. The morphostructure of grazing breeds may be more influenced by natural selection for the physical environment and less by human selection; that of stall-fed breeds, in contrast, reflects intense artificial selection aimed at achieving a highly-productive dairy type. For this reason, morphological evaluation systems used in breeding programmes for meat or dual-purpose goat breeds farmed extensively or semi-extensively should be specific, and should reflect the influence of the environment in which these goats are farmed.

## Acknowledgements

The present study was supported by the INIA-FEDER Projects RZ-01-010-C3-1, RZ2004-00010-00-00 and RZ2008-00021-00-00.

## References

Azor PJ, Monteagudo LV, Luque M, Tejedor MT, Rodero E, Sierra I, Herrera M, Rodero A, Arruga MV, 2005. Phylogenetic relationships among Spanish goats breeds. Anim Genet 36: 423-425.

Capote J, Delgado JV, Fresno M, Camacho ME, Molina A, 1998. Morphological variability in the Canary goat population. Small Rumin Res 27: 162-167.

Crepaldi P, Negrini R, Milanesi E, Gorni C, Cicogna M, Ajmone-Marsan P, 2001. Diversity in five goat populations of the Lombardy Alps: comparison of estimates obtained from morphometric traits and molecular markers. J Anim Breed Gen 118: 173-180.

Dossa LH, Wollny C, Gauly M, 2007. Spatial variation in goat populations from Benin as revealed by multivariate analysis of morphological traits. Small Rumin Res 73: 150-159.

Herrera M, Rodero E, Gutiérrez MJ, Peña F, Rodero JM, 1996. Application of multifactorial discriminant analysis in the morphostructural differentiation of Andalusian caprine breeds. Small Rumin Res 22: 39-47.

Herrera M, Luque M, 2008. Las razas caprinas andaluzas de protección especial: Blanca Serrana Andaluza, Negra Serrana o Castiza, Blanca Celtibérica y Payoya. In: Patrimonio Ganadero Andaluz, Vol II: Las razas ganaderas de Andalucía. Junta de Andalucía, Consejería de Agricultura y Pesca. pp: 195-256.

Jordana J, Ribo O, Pelegrin M, 1993. Analysis of genetic relationships from morphological characters in Spanish goat breeds. Small Rumin Res 12: 301-314.

Lanari M, Taddeo H, Domingo E, Pérez-Centeno M, Gallo L, 2003. Phenotypic differentiation of Criollo goat popution in Patagonia (Argentina). Archiv Anim Breed 46: 347-356.

Lauvergne JJ, 1988. Populations traditionelles et premieres races standardisées d'Ovicaprinae dans le bassin mediterranéen. In: Colloq INRA Nº 47, INRA, París. pp: 77-94.

Luque M, Rodero E, Peña F, García A, Sierra I, Herrera M, 2005. Application of discriminant analysis to the morphostructural differentiation of 7 extensive goat breeds. 56th Annual Meeting of the European Association for Animal Production, Uppsala, Sweden. pp: 301-301.

Macciotta NPP, Cappio-Borlino A, Steri R, Pulina G, Brandano P, 2002. Somatic variability of Sarda goat breed analysed by multivariate methods. Livest Prod Sci 75: 51-58.

Mahalanobis P, 1936. On the generalised distance in statistics. Proc Nat Inst Sci of India 2: 49-55.

Martini M, Salari F, Altomonte I, Rignanese D, Chessa S, Gigliotti C, Caroli A, 2010. The Garfagnina goat: a zootechnical overview of a local dairy population. J Dairy Sci 93: 4659-4667.

Monteagudo LV, Luque M, Tejedor MT, Peña F, Rodero E, Sierra I, Herrera M, Arruga MV, 2006. Análisis filogenéticos mitocondriales en las cabras domésticas de la Península Ibérica. XXXI Jornadas de la SEOC, Zamora. pp: 174-177.

Nsoso JJ, Podisi B, Otsogie E, Mokhutshwane BS, Ahmadu B, 2004. Phenotypic characterization of indigenous Tswana goats and sheep in Botswana: continuous traits. Trop Anim Health Prod 36: 789-800.

OJ, 2004. Laying down detailed rules for the application of Council Regulation (EC) No. 1257/1999 on support for rural development from the European Agricultural Guidance and Guarantee Fund (EAGGF). Official Journal of the European Union, No 817/2004.

Rodero E, Herrera M, Peña F, Molina A, Valera M, Sepúlveda N, 2003. Morpho-structural model for Florida and Payoya Spanish dairy goats in extensive (grazing) systems (Modelo morfoestructural de los caprinos lecheros Españoles Florida y Payoya en sistemas extensivos). Revista Científica de la Facultad de Ciencias Veterinarias de la Universidad del Zulia 13 (5): 403-412.

Sánchez M, 2008. Las razas caprinas andaluzas de fomento: Murciano-Granadina, Malagueña y Florida. In: Patrimonio Ganadero Andaluz, Vol II: Las razas ganaderas de Andalucía. Junta de Andalucía, Consejería de Agricultura y Pesca. pp: 169-194.

Traoré A, Tamboura HH, Kaboré A, Yaméogo N, Bayala B, Zaré I, 2006. Caractérisation morphologique des petits ruminants de race locale Mossi au Burkina Faso. AGRI 39: 39-50.

Traoré A, Tamboura HH, Kaboré A, Royo LJ, Fernández I, Álvarez I, Sangaré M, Bouchel D, Poivey JP, Francois D, Toguyeni A, Sawadogo L, Goyache F, 2008. Multivariate characterization of morphological traits in Burkina Faso sheep. Small Rumin Res 80: 62-67.

Tunon MJ, González P, Vallejo M, 1989. Genetic relationships between 14 native Spanish breeds of goat. Anim Genet 20: 205-212.

Vargas S, Larbi A, Sánchez M, 2007. Analysis of size and conformation of native Creole goat breeds and crossbreds used in smallholder agrosilvopastoral systems in Puebla, Mexico. Trop Anim Health Prod 39: 279-286.

Vert I, García-Trujillo R, 2006. Estudio del efecto del sistema de producción sobre la cantidad y composición de leche de cabra de la raza Murciano-Granadina. XXXI Jornadas de la SEOC, Zamora, 20-22 Sept, Ed Instituto Tecnológico Agrario de Castilla y León. pp: 195-197.

Windows SRF, 2011. Statsoft. Inc 2300. East 14th Street, Tulsa, OK, 74104, USA, 2011.

Zaitoun IS, Tabbaa MJ, Bdour S, 2005. Differentiation of native goat breeds of Jordan on the basis of morphostructural characteristics. Small Rumin Res 56: 173-182.