Multivariate analysis as a tool for phenotypic characterization of an endangered breed

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ABSTRACT
Goats are important from a socioeconomic perspective for the poor in arid regions, worldwide. Nevertheless, more than half of the local breeds in the world are threatened and have not been fully characterized. The Canindé is one of the main local breeds of northeastern Brazil and, like most, their effective numbers have fallen over the years and needs to be characterized. Many tools are available for assessing the phenotypic profile of a breed and multivariate techniques are important when considering all variables simultaneously. The present study utilized multivariate techniques for phenotypic characterization of the Canindé goat breed from 11 morphometric variables (HL = head length; FW = face width; HW = head width; BL = body length; CG = chest girth; WH = wither height; SRH = sacral region height; CW = croup width; CL = croup length, SP = shin perimeter and ES = ear size) and morphological variables of qualitative character (presence and absence of earrings, horns, beard, abnormal teat number and hair length) collected from herds from different states (populations) in the northeast of Brazil. Multivariate analysis allowed the differentiation and characterization of the evaluated individuals, HL, FW, WH, SRH and BL variables were the most important to define the phenotypic profile of the studied populations. Examined whether spatial organization of individuals was assessed in each state of the Brazil demonstrated considerable diversity of phenotypes within breeds from the different states. These data could be used successfully in a conservation breeding programme.

1. Introduction
Canindé is one of the major local breeds of northeastern Brazil and, like many, still needs to be better characterized. Genetic resource conservation is a set of actions taken in order to protect genetic patrimony, with emphasis on those that are under constant threat (Ribeiro et al. 2010), as in the case of the Canindé breed.

Phenotypic character study is the basis for the differentiation of groups and/or breeds and provides support for conservation programmes; it is a technique used to characterize genetic resources in many countries (Zepeda et al. 2002; Zaitoun et al. 2005; Revidatti et al. 2007; Carneiro et al. 2010; Jimcy et al. 2011; Aziz & AlHur 2013). Many tools are available that can help determine the discriminatory power that variables have in describing breed patterns. These also aid in evaluation of the relative importance of variables, saving time and financial resources invested by researchers. In this field, multivariate analysis techniques have been very useful in support of characterisation studies of breeds, as examples of the studies developed by Yakubu et al. (2011) with African goats, Legaz et al. (2011) in studies with Assaf sheep and Dekhili et al.’s (2013) evaluation of Algerian goats.

According to Ferraudo (1995), multivariate analysis (cluster analysis, main component analysis, canonical analysis, discriminant analysis and correspondence analysis) refers to all statistical methods that simultaneously analyse multiple measurements in a single individual and that are interrelated. It has been widely used in studies of breed characterization and genetic diversity as it provides descriptive analysis of the differences between populations, considering all variables together, providing a data overview (Cazar 2003; Dossa et al. 2007).

Multivariate analysis allows for greater discriminating power, eliminating those difficult to measure variables and those that contribute little towards explaining variation.

Therefore, the aim of this study was to reduce data dimensionality, eliminate redundant information and identify similarities by using multivariate analysis.

2. Material and methods
2.1. Data collection
Data used in this study were obtained from 150 Canindé adult female goats (Figure 1) from different herds in Pernambuco (n = 9), Paraíba (n = 39), Rio Grande do Norte (n = 69) and Bahia (n = 33) states (Figure 2) (semi-arid region of Northeast Brazil, covering the largest area of the breed occurrence). The animals were in an extensive rearing system, with local pasture as the basis of herd feeding. Sampling was carried out from June 2011 to January 2012. A form containing...
animal identification and its herd, as well as morphology and morphometry information was used.

Morphometric evaluation was performed with the aid of a measuring tape and considered 11 quantitative characteristics (according to Zepeda methodology 2002): HL = head length; FW = face width; HW = head width; BL = body length; CG = chest girth; WH = wither height; SRH = sacral region height; CW = croup width; CL = croup length; SP = shin perimeter and ES = ear size.

For morphological characterization, the animals were catalogued on the basis of presence or absence of qualitative characteristics such as earrings, horns, beard, abnormal teat number (politetia) and hair length (short or long).

2.2. Data analysis

Morphometric data were subjected to variance and descriptive analysis, using the Statistical Analysis System (SAS 1999). Averages were submitted to Tukey test at 5% probability. Multivariate statistical analysis was performed using the Statistica 2009 software, version 8.0. Hierarchical clustering among morphometric variables was assessed by the nearest neighbour method, performed based on Euclidean distance.

Morphometric variables were subjected to factor analysis based on principal components analysis to identify characteristics best suited to breed characterization. The number of factors was established based on eigenvalues which explained a minimum of 70% of accumulated variation. Those with a value < 70% were discarded, according to the Jolliffe criterion (1972, 1973).

Correspondence analysis was used to verify the association between qualitative morphological traits by plotting individuals in a multi-dimensional plan.

Morphometric and morphologic variables were subjected to canonical and discriminant analyses. Discrimination of individuals based on the Mahalanobis distance and composite variables were called canonical roots or discriminant functions. Each canonical root consisted of a linear combination ($Z$) of the independent variables ($Y_i$) in order to maximize the correlation between $Z$ and $Y_i$. Linear combination of $i$ variables $Y$, forming a discriminant function $Z$, can be represented in the following model:

$$Z = \mu_0 + \mu_1 Y_1 + \mu_2 Y_2 + \mu_3 Y_3 + \cdots + \mu_i Y_i.$$ 

In this model, $\mu_1, \mu_2 \ldots \mu_i$ are estimated canonical coefficients for the data and $Y_1, Y_2 \ldots Y_i$ represent independent variables, which are the different groups according to the states.
3. Results and discussion

Averages (cm) and their respective standard deviations for the evaluated morphometric characteristics (according to state; populations) are shown in Table 1. A significant difference in the studied variables in different states was observed ($p < .05$), except for the BL characteristic (Table 1).

Animals raised in the states of Pernambuco and Bahia presented the highest averages of CG, WH, SRH and SP, showing that animals belonging to these states are taller than the animals raised in Paraíba and Rio Grande do Norte. However, these populations have similar body length (Table 1). In general, the local goats in the Northeast of Brazil are small animals, this result differs from the results obtained in the present study. This difference can be associated with the influence of crossbreeding with exotic mating and management techniques often adopted in the region. This highlights the need for a genetic management plan for the Canindé breed as a way of maintaining intrabreed genetic variability.

Discriminant analysis was adopted to classify individuals into statistically different groups per state, based on morphometric and morphological characteristics. This type of analysis allows us to understand the differences between populations and predict the class or group which an individual belongs to (Hair et al. 1998).

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Table 1. Averages (cm) and their respective deviant-pattern for evaluated morphometric characteristics (Canindé breed), according to the state.

| Variables | Rio Grande do Norte N° 69 | Pernambuco N° 09 | Paraíba N° 39 | Bahia N° 33 |
|-----------|---------------------------|-----------------|--------------|------------|
| Head length | 21.71 ± 1.22** | 19.94 ± 0.73** | 20.52 ± 0.88** | 20.59 ± 0.73** |
| Face width | 12.75 ± 1.42** | 11.77 ± 0.66** | 12.00 ± 1.01** | 12.57 ± 0.76** |
| Head width | 11.39 ± 0.73** | 11.39 ± 1.05** | 9.80 ± 0.90** | 11.03 ± 0.66** |
| Body length | 67.17 ± 4.54** | 68.33 ± 3.27** | 65.71 ± 3.99** | 67.75 ± 3.48** |
| Chest girth | 76.49 ± 5.10** | 78.88 ± 4.51** | 78.50 ± 5.35** | 87.66 ± 5.27** |
| Wither height | 67.19 ± 3.07** | 67.44 ± 2.69** | 66.34 ± 3.44** | 70.68 ± 3.09** |
| Sacral region | 66.86 ± 4.00** | 69.00 ± 3.08** | 66.20 ± 3.32** | 70.31 ± 3.56** |
| Croup width | 15.04 ± 1.46** | 13.44 ± 1.58** | 13.67 ± 1.81** | 13.21 ± 1.06** |
| Croup length | 16.56 ± 1.13** | 14.72 ± 1.09** | 15.16 ± 1.00** | 15.45 ± 0.82** |
| Shin | 8.53 ± 0.55** | 9.11 ± 0.60** | 8.69 ± 0.65** | 9.57 ± 1.75** |

Table 2. Frequency distribution of morphologic traits in Canindé goats in Pernambuco (PE), Paraíba (PB), Rio Grande do Norte (RN) and Bahia (BA) states, northeastern Brazil.

| Alleles | Phenotype | N° 69 | N° 09 | N° 39 | N° 33 |
|---------|-----------|------|------|------|------|
| Wa** | Presence of earrings | 5 | 0.07 | – | – | 4 | 0.10 | – | – |
| Wa | Absence of earrings | 64 | 0.93 | 9 | 1.00 | 35 | 0.90 | 33 | 1.00 |
| Ho | Presence of horn | 68 | 0.99 | 9 | 1.00 | 39 | 1.00 | 33 | 1.00 |
| Ho | Absence of horn | 1 | 0.01 | – | – | – | – | – | – |
| Br | Presence of beard | 21 | 0.30 | 5 | 0.56 | 32 | 0.82 | 26 | 0.79 |
| Br | Absence of beard | 48 | 0.70 | 4 | 0.44 | 7 | 0.18 | 7 | 0.21 |
| HL | Long hair | 1 | 0.01 | – | – | 5 | 0.13 | – | – |
| HL | Short hair | 68 | 0.99 | 9 | 1.00 | 34 | 0.87 | 33 | 1.00 |
| – | Presence of polieltia | 6 | 0.09 | 1 | 0.11 | 1 | 0.03 | – | – |
| – | Absence of polieltia | 63 | 0.91 | 8 | 0.89 | 38 | 0.97 | 33 | 1.00 |

Notes: Equal letters on the same line do not statistically differ as assessed by Tukey test at 5% ($p < .05$); N°: Observation numbers.

Table 3. Person correlations between the evaluated morphometric variables on Canindé goats.

| Variables | RL | FW | HW | BL | CG | WH | SRH | SRW | CL | SP | ES |
|-----------|----|----|----|----|----|----|-----|-----|----|----|----|
| HL | 1.00000 | 0.69245** | 0.47179** | 0.45868** | 0.36222** | 0.40736** | 0.35025** | 0.52828** | 0.58192** | 0.28343** | 0.22132** |
| FW | 1.00000 | 0.28261** | 0.28668** | 0.27678** | 0.30835** | 0.12588** | 0.45474** | 0.41909** | 0.23488** | 0.14075** |
| HW | 1.00000 | 0.43416 | 0.39576** | 0.39908** | 0.45451** | 0.43591** | 0.52413** | 0.27428** | 0.24871** |
| BL | 1.00000 | 0.64899 | 0.60279** | 0.56788** | 0.27771** | 0.49384** | 0.39364** | 0.11590** |
| CG | 1.00000 | 0.71960** | 0.69610** | 0.61681** | 0.38986** | 0.51240** | 0.07690** |
| WH | 1.00000 | 0.77545** | 0.22616** | 0.49229** | 0.46279** | 0.17692** | 0.40289** | 0.23165** |
| SRH | 1.00000 | 0.57377** | 0.06496** | 0.16706** | 0.30181** | 0.10731** | 0.00000 |

Notes: RL: head length; FW: face width; HW: head width; BL: body length; CG: chest girth; WH: wither height; SRH: sacral region height; CW: croup width; CL: croup length; SP: shin perimeter; ES: ear size.

** Significant correlations.
morbidity similar to those found in the present study. However, animals from Rio Grande do Norte are different from others because of a lack of beard (Br+) in most cases (Table 2). The beard is determined by the locus beard (Br), which contains the Br0 (bearded) and Br+ (wild) alleles, which are autosomal genes linked to sex, dominant in males and recessive in females.

Ozoje (2002) observed 75% of animals with beards in a West African breed, a highly considered characteristic.

Most of the correlations between the assessed variables were significant ($p < .001$) and ranged from 6% to 77% (Table 3).

Low correlations between CG and ES and SP and CW were observed, indicating the independence of these variables. Correlations above 50% were observed for BL, SRH, CG and WH characteristics, related to animal size and length. The correlations found in the present study were higher than those obtained by Ribeiro et al. (2004) which focused on Canindé goats under different environmental conditions and animal numbers. The presence of positive correlations between the assessed variables justifies the use of multivariate analysis. Group analysis (Figure 3) demonstrates relationships between the 11 morphometric variables performed in two distinct groups.

One group was formed by variables which define animal length and height (BL, SRH, WH, and CG) which correlated significantly. Another group comprised the remaining variables.

Five factors explained 76% of total variance of studied morphometric variables (Table 4). Okpeku et al. (2011), studying local goats in southern Nigeria (based on five morphometric measurements), found two factors that explained 94.15% and 97.65% of the total variation in females and males, respectively. Yakubu et al. (2011), evaluating morphometric characteristics of African goats, reported that more than 60% of variation was explained by the first component factor in a West African breed. Herrera et al. (1996), studying local goats in Andalusia, noted that the most discriminant variables were HL, CG, HW, and body weight. Deza et al. (2007), comparing local with exotic goats in Argentina (Anglo Nubian and Saanen), reported that head profile, type and width of ears and type of horn were most discriminating.

All distances between the populations (Table 6) were significant ($p < .001$), indicating that despite belonging to the same breed, there are differences among populations.

The commonalities found in this study ranged from 0.1854 to 0.7571 (Table 5) and explain how much a particular characteristic contributes to explain the number of factors being considered (Morrison 1976). The SP characteristic showed low commonality, that is, contributed little towards explaining the total accumulated variation in the factors.

This may be associated with reduced factor loading of this variable in the first and second factors. HW showed greater commonality, because of the greater association of this variable with the first factor. FW was the second most important variable in the first factor. These characteristics appear to be important for describing breed and define the animal encephalic profile. The second factor could be termed ‘height factor’, since the loading characteristics were WH and SRH and are the most correlated variables. The trait with higher factor loading in the third factor was BL, defining it as ‘length factor’. In the fourth factor, ES was the greatest loading trait. SP was highlighted as the highest factor loading trait in the fifth (Table 5), indicating the lesser importance of these traits in breeding profile. Conversely, Rodero et al. (2003) reported that SP is indicative of animal hardiness and an important trait in studies of local goat characterization. Taking into consideration animal body areas, both the most important features in all five factors are representative of the main areas.

Okpeku et al. (2011), in studies with goats in Nigeria, showed that body size neck length were first and second factors. Herrera et al. (1996), studying local goats in Andalusia, noted that the most discriminant variables were HL, CG, HW, and body weight. Deza et al. (2007), comparing local with exotic goats in Argentina (Anglo Nubian and Saanen), reported that head profile, type and width of ears and type of horn were most discriminatory.

Table 4. Factors, eigenvalues, simple and total accumulated variation of morphometric traits of Canindé goat breed.

| Factors | Eigenvalues | Simple variation (%) | Accumulated variation (%) |
|---------|-------------|----------------------|--------------------------|
| 1       | 2.898203    | 26.34730             | 26.34730                 |
| 2       | 2.466923    | 22.37202             | 48.71932                 |
| 3       | 1.169164    | 10.62876             | 59.34809                 |
| 4       | 0.931672    | 8.46974              | 67.81783                 |
| 5       | 0.910934    | 8.28122              | 76.09095                 |

Table 5. Factor weights for the 11 morphometric measures of Canindé goats.

| Variables | Factor 1          | Factor 2          | Factor 3          | Factor 4          | Factor 5          | C      |
|-----------|-------------------|-------------------|-------------------|-------------------|-------------------|--------|
| HL        | 0.862213          | −0.094577         | 0.026110          | 0.116723          | 0.061232          | 0.7571 |
| FW        | 0.832442          | −0.034278         | −0.078984         | −0.129743         | 0.325747          | 0.7259 |
| HW        | 0.341415          | 0.182131          | 0.558520          | 0.395257          | −0.079635         | 0.20935|
| BL        | 0.034011          | 0.088513          | 0.881892          | −0.101852         | 0.203637          | 0.48650|
| CG        | −0.010751         | 0.673100          | 0.102917          | 0.171096          | 0.471663          | 0.42512|
| WH        | 0.066881          | 0.872399          | 0.073433          | −0.002573         | 0.127353          | 0.62058|
| SRH       | −0.12482          | 0.841857          | 0.090623          | 0.277386          | −0.040914         | 0.61926|
| CW        | 0.709152          | −0.045951         | 0.208467          | 0.071675          | −0.351240         | 0.55741|
| CL        | 0.668240          | 0.198975          | 0.286814          | 0.188946          | −0.328674         | 0.56408|
| SP        | −0.012322         | 0.216486          | 0.176691          | 0.170103          | 0.793540          | 0.18542|
| ES        | 0.075275          | 0.062290          | −0.011739         | 0.921934          | 0.109927          | 0.35125|
| V.T.E.*   | 26.34730          | 48.71932          | 59.34809          | 67.81783          | 76.09095          |        |

Notes: V.T.E.*: Total accumulated variation; C: commonalities; HL: head length; FW: face width; HW: head width; BL: body length; CG: chest girth; WH: wither height; SRH: sacral region height; CW: croup width; CL: croup length; SP: shin perimeter; ES: ear size.

Table 6. Distance of Mahalanobis, based on morphometrical and morphological characteristics of Canindé goats between the states.

| Estados | BA | RN | PE | PB |
|---------|----|----|----|----|
| RN      | 14.50** | 0.00 |    |    |
| PE      | 5.55** | 10.39** | 0.00 |    |
| PB      | 7.48** | 9.31** | 7.58** | 0.00 |    |

Notes: RN: Rio Grande do Norte; PE: Pernambuco; PB: Paraíba; BA: Bahia. **Significative (1% probability).
Each breed corresponds to ecotypes strongly associated to their rearing system, shaping the groups and creating intrabreed diversity, which might be used in conservation programmes.

The longest distance occurred between RN and BA populations (14.0) due to geographical isolation of these herds, consequently breaking the flow of genes across generations. The shortest distance was observed between PE and BA herds (5.55) because these populations are located very close to each other geographically. These groups consumed a similar diet and were more similar with regard to body size and body length (Table 1).

Traoré et al. (2008) evaluated local goats of Bukina Faso (close proximity between evaluated populations) which explains the homogeneity between individuals. Jimcy et al. (2011), with local goats in India, found greater distance between Thrissur goats. Dekhili et al. (2013) found greater distance between local populations of goats in three different environmental areas in the northeast of Algeria.

In the present study, canonical analysis, based on morphometric and morphological characteristics, allowed identification of canonical variables (CAN1 and CAN2), which added 70% and 94% of total variation, respectively (Table 7), indicating large reduction in sample space, with little loss to explain the total variation (6%).

The majority of studies with goats suggest canonical analysis can reduce sample space with loss very close to this value (Zaitoun et al. 2005; Dossa et al. 2007; Traoré et al. 2008; Jimcy et al. 2011). The morphological characteristics showed the greatest contribution in the two canonical variables, which were (in increasing order of importance) hair length, politetia, presence of earring and beard. This suggests that morphology is important in defining breed patterns. A similar observation was reported by Deza et al. (2007) in goats in Argentina.

As shown in Figure 4, despite the trend of subset formation (highlighting the animals of Rio Grande do Norte) a connection between the herds was observed.

The animals of Pernambuco state are diluted among several groups, which explains the fact that these herds are derived from each other. This arrangement comes from gene flow, promoted by the exchange of male between herds, a common practice between breeders. Gene flow is important to keep genetic variability, mainly between herds of the same breed. Rocha et al. (2007), in studies on Moxotó goats from Pernambuco, Paraíba and Rio Grande do Norte, observed the formation of distinct groups, promoted by geographic isolation, also observed by Oliveira et al. (2010) in studies on these herds with molecular markers.

Most individuals of RN were classified according to the original population (95%), indicating reduced gene flow across populations. This is due to the greatest distances observed between individuals from RN (Figure 4). In PE, just

| Variáveis          | CAN 1     | CAN 2     | CAN 3     |
|--------------------|-----------|-----------|-----------|
| Head length        | -0.54712  | 0.16503   | -0.34695  |
| Face width         | 0.27374   | -0.36518  | 0.03180   |
| Head width         | -0.41039  | -1.05903  | 0.49104   |
| Body length        | -0.00635  | 0.00983   | 0.06611   |
| Chest girth        | 0.11900   | -0.02090  | -0.10141  |
| Wither height      | -0.02419  | -0.10088  | -0.07016  |
| Sacral region height | 0.09504 | -0.01245  | 0.07522   |
| Croup width        | -0.17389  | 0.30395   | 0.04049   |
| Croup length       | -0.30163  | -0.02303  | -0.04284  |
| Shin perimeter     | 0.26119   | -0.05321  | 0.10105   |
| Ear size           | -0.37965  | 0.05206   | -0.47953  |
| Horn               | -1.38179  | -0.03645  | 0.43850   |
| Earring            | -0.36851  | -0.48890  | 0.46225   |
| Beard              | -0.57326  | -0.44659  | 0.09337   |
| Hair               | -0.96134  | 0.89696   | -0.88549  |
| Politetia          | 0.93416   | -0.24704  | -0.70288  |
| Eugenvalues        | 2.53100   | 0.84105   | 0.21259   |
| V.T.E.*            | 0.70607   | 0.94069   | 1.00000   |

Note: V.T.E.* – total accumulated variance. Most important variables (WEIGHT) within the CAN1 and CAN 2 given in bold.

Figure 4. Canonical representation of the morphometric and morphological traits associated with individuals by state. RN: Rio Grande do Norte; PE: Pernambuco; PB: Paraíba; BA: Bahía.
We report that animals of different populations have different morphological and morphometric profiles but they are within the breed standard. According to discriminant analysis, the qualitative hair, beard, earring, politetia, horn and morphometric (HL, FW, BL, WH and SRH) characteristics were the most important for breed characterization of Canindé goat breed.

Disclosure statement

No potential conflict of interest was reported by the authors.

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