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Research Article

Phenotypic Characteristics of Indigenous Goats in Benin

Milognon B. Behingan[1,*], Pascal V. Houndonougbo[2], Aubin Amagnide[2], Gédéon O. Kouato[1], Firmin Adjonoumakpe[1], and Christophe A.A.M. Chrysostome[1]

[1] Faculty of Agronomic Sciences, University of Abomey-Calavi, 01 BP 509, Benin
[2] Laboratory of Biomathematics and Forest Estimation, University of Abomey-Calavi, 04 BP 1525, Benin

*** Corresponding author:** Milognon B. Behingan, Faculty of Agronomic Sciences, University of Abomey-Calavi, 01 BP 509, Benin. Tel: +22996277056; Email: begboris88@gmail.com

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ABSTRACT

Introduction: Phenotypic characterization contributes to the knowledge of breeds and their sustainable use. The present study assessed the possibility of using factorial analysis of mixed data (FAMD) combined with hierarchical clusters on principal components to manage goat characteristics.

Materials and methods: A total of 1644 adult male and female indigenous goats were randomly sampled across different climate zones (Guinean, Sudanian-Guinean, and Sudanian zone) of Benin. The samples were investigated in terms of 20 body measurements (head length, right and left horn length, right and left ear length, neck girth, neck length, cannon length, cannon bone circumference, body length, heart girth, tail length, body weight, Rump width, withers height, chest depth, back height, rump height, rump depth, and age) and 12 qualitative traits (sex, coat color, color pattern, horn presence, horn shape, horn orientation, ear orientation, head profile, beard presence, wattles presence, back profile, and rump profile). Data analysis was performed using FAMD and hierarchical clusters on principal components.

Results: The findings indicated three types of goats with distinct characteristics. The first goat type had a small size (35.65 cm in withers and 38.29 cm in back height), while the third type had a large size (57.02 cm in withers and 59.08 in back height). The second genetic type had a medium size (47.31 cm and 50.01 cm for withers and back height, respectively) resulting from the previous types of genetic crosses.

Conclusion: The results indicate the efficiency of FAMD-based cluster analysis in handling phenotypic data.

1. Introduction

The characterization of animal genetic resources is the first step to their sustainable use[1,2]. Among animal genetic resources, goat is an important economic species, affecting the livelihood of farmers in many countries, including Benin. The phenotypic characterization of goats is the first way of improving their productivity, as indicated in previous studies of Benin[3–7]. Phenotypic characterization involves the collection of data on body measurements and qualitative traits. To present goat's characteristics, data was treated by researchers using descriptive statistics[6–10] and multivariate statistical techniques, such as principal component analysis[6,8,11], multiple correspondence analysis[7], canonical discriminant analysis[7,8,10,11], multivariate analysis of variance[6], and cluster analysis[6,7,10]. Analyzing phenotypic characterization data does not enable the treatment of both qualitative and quantitative variables in a single model. Thus, the potential relationship between body measurements and the qualitative traits of goats is barely considered in the classification process. Previous studies performed phenotypic characterization of goats through statistical techniques that simultaneously include qualitative and quantitative variables scarcely in Benin. Hence, there is a need to use more advanced statistical techniques that allow the treatment of both qualitative

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and quantitative variables in a single model. A statistical technique that deals with both quantitative and qualitative variables is factorial analysis of mixed data (FAMD). The current study aimed to explore goat characteristics using FAMD and hierarchical cluster analysis on principal components.

2. Materials and Methods

2.1. Ethical approval

To carry out the study, the authors adhered strictly to the guidelines on the care and use of animals in research, teaching, and testing by the Canadian Council on Animal Care[12]. Moreover, the committee involved in the project implementation and the School of Science and Technique of Animal Production at the University of Abomey-Calavi, Benin, have approved the study. The authors obtained verbal consent from farmers before recording the body measurements.

2.2. Study area and data collection

The present study investigated 16 districts distributed in three climate zones of Benin, including Guinean, Sudano-Guinean, and Sudanian. These districts were selected based on the abundance of goat flocks (Figure 1).

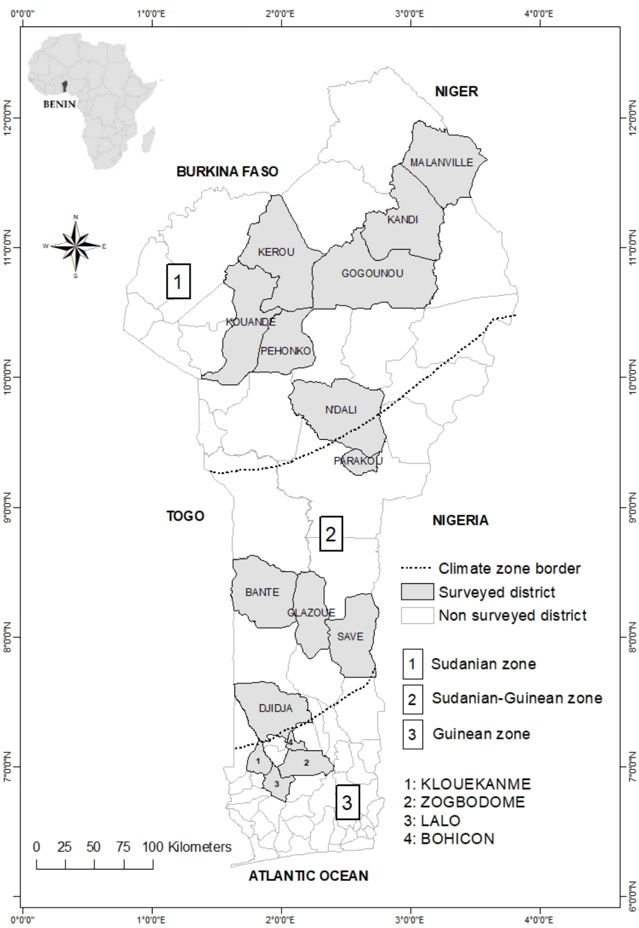

Figure 1. Study locations[13]

The data of adult animals were collected through a survey from October 2020 to March 2021, and phenotypic reared in an extensive system. As suggested by Food and Agriculture Organization (FAO)[14], the characterization of the small ruminants can be investigated using 100-300 female and 10-30 male animals. This guideline was applied to each district of the study area, and 5 to 10 animals were randomly sampled at each farm surveyed, leading to 1644 goats. The collected data which were described by FAO and previous studies are summarized in Table 1[7,14,15]. Body weight, height, and the remaining measurements were measured using a portable electronic scale (maximum load: 50kg, sensitivity: 10g), a measuring stick, and a measuring tape. Moreover, based on the FAO guideline, age of the goats was estimated from their dentition[14]. To avoid biases that might arise from varying enumerators and feed intake, all measurements were taken by the same person in the morning before the animals were fed.

2.3. Statistical analysis

Statistical analysis was conducted by R project, version (4.1.0)[16]. A linear fixed effect model was performed using sex as a fixed factor to analyze the relationships between sex and morphometric traits. In case this relation was significant ($p < 0.05$), a Student-Newman-Keuls was performed using Agrico ale package[17]. A Chi-square test (χ^2) was used to appreciate the relationships between sex and the remaining qualitative variables. Three steps were necessary for the identification of goat characteristics. In the first step, the dimension of the initial data matrix (1644 individuals with 32 traits) was reduced by applying FAMD using FactoMineR package[18]. In the second step, hierarchical cluster on principal component (HCPC) analysis was performed on FAMD outcome. Optimal number of dimensions from FAMD to run in HCPC analysis was identified based on Kaiser criterion[19]. Analysis by HCPC was also performed using FactoMineR package[18]. Plots were drawn using factoextra package[20]. The average value of each variable in each obtained cluster was

Table 1. Collected traits on animals

Type of variable	Descriptor types	Tools/ method used
Quantitative	Head length, right and left horn length, right and left ear length, neck girth, neck length, cannon length, cannon bone circumference, body length, heart girth, tail length,	Measuring stick
	Body weight,	Portable scale
	Rump width, withers height, chest depth, back height, rump height, rump depth	Measuring tape
	Age	Teeth
Qualitative	Sex, coat color, color pattern, horn presence, horn shape, horn orientation, ear orientation, head profile, beard presence, wattles presence, back profile, and rump profile	Visual appraisal

compared to the global mean/proportion for that variable using v-test. A v-test value higher than 1.96 indicates a significant difference ($p < 0.05$) when the mean/proportion of the variable in the cluster is compared to the overall mean/proportion. In the third step, a linear fixed effect model was applied to compare morphometric traits between clusters identified followed by a Student-Newman-Keuls test.

3. Results

3.1. Descriptive analysis of body measurements and qualitative traits

There were significant differences between male and female goats in terms of all quantitative variables except horn length, tail length, withers height, chest depth, back height, rump height, and rump depth ($p < 0.05$, Figure 2).

The male head length (16.50 cm) was greater than that of the female (15.60 cm). The same trend was observed for age, body weight, ear length, canon length, body length, heart girth, and rump width. However, for neck girth and neck length, females recorded higher values than males ($p < 0.05$).

Apart from the head profile, beard, and wattles presence, there was a significant difference between males and females for the other qualitative traits ($p < 0.05$; Figure 3 a-h). Generally, the coat colors of black (33%) and brown (32%) were the most frequently observed characteristics in both sexes, with the dominance of uniform color pattern (46%). Most goats possessed horns (99%) regardless of their sex. Horn had a straight form (52%) with a slanting orientation (51%). Moreover, erected ear (78%) and straight head (75%) were predominant, while beard and wattles were not common (27%). For the back profile, the most dominant was slopes up towards the withers (93%).

3.2. Cluster analysis of goat characteristics based on factorial analysis of mixed data

Hierarchical cluster on principal component analysis revealed the presence of three clusters (Figure 4a-b) as presented in tables 2 and 3.

Significant differences were recorded between the obtained clusters ($p < 0.05$, Table 2). In addition, the mean values of most quantitative variables of each cluster were significant when compared to the global mean ($p < 0.05$). Globally, values taken by variables in cluster 1 were lower than those in cluster 2 which were lower than those of cluster 3. The highest value of wither height was observed in cluster 3 (57.02 cm) while the lowest was in cluster 1

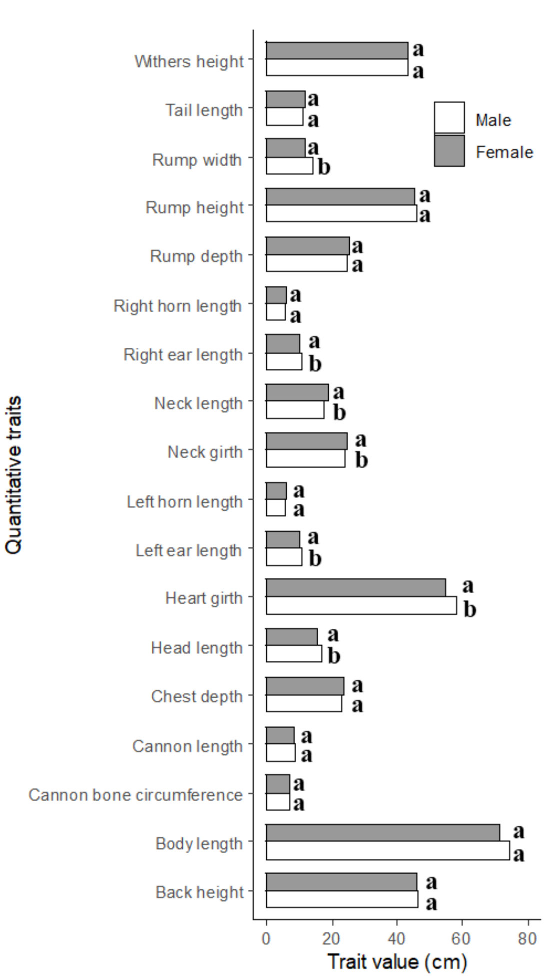

Figure 2. Descriptive statistics of quantitative traits
a and b: Means with different letters are significantly different ($p < 0.05$)

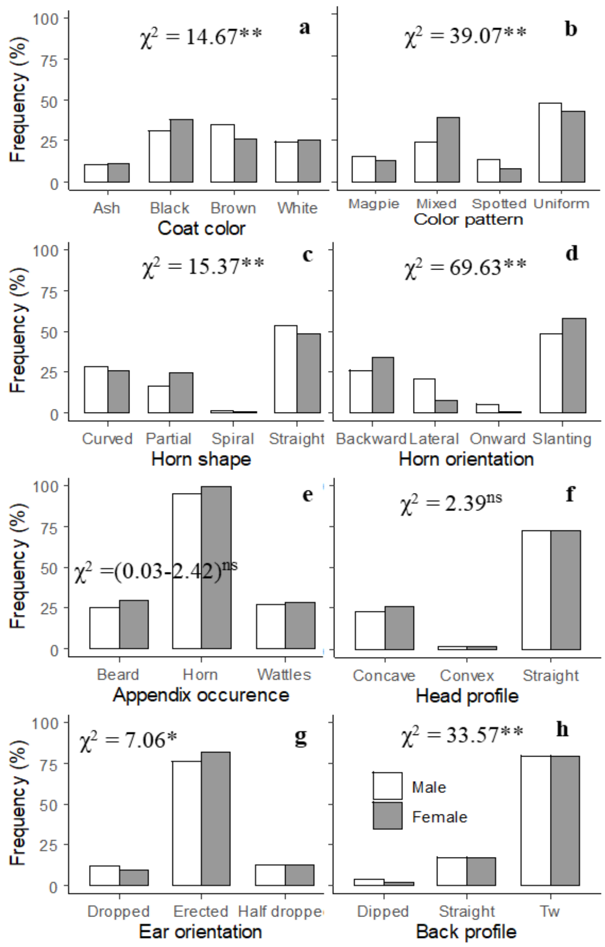

Figure 3. Descriptive statistics of qualitative traits
ns non-significant, ** significant at 0.1%, χ^2: Chi-square statistics, Tw: Slopes up towards the withers

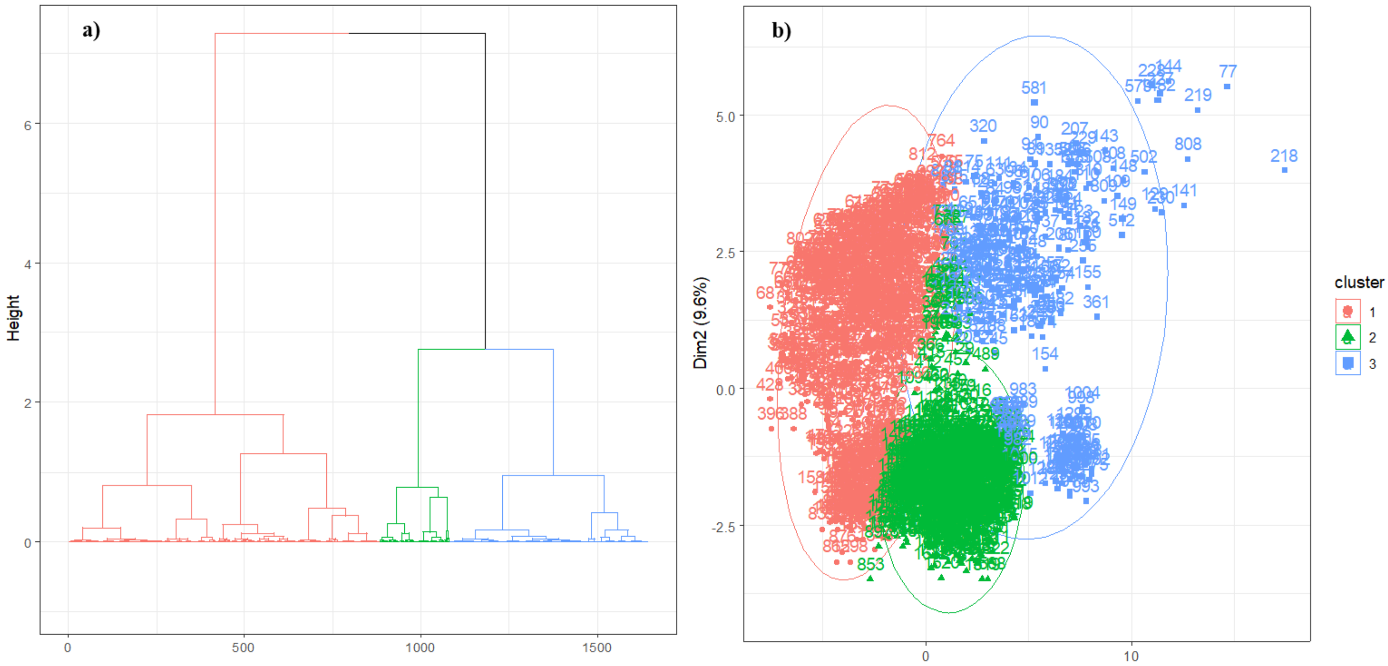

Figure 4. Dendrogram from cluster analysis (a) and biplot from Factorial

(35.65 cm). Goats of cluster 3 (23.30 kg) were the heaviest in comparison to those in cluster 2 (20.71 kg) and cluster 1 (11.61 kg). The same trend was observed for the remaining variables apart from neck length and cannon bone circumference. Neck length for clusters 1 and 2 was approximately similar (17.54 and 17.86 cm, respectively), which was less than the one recorded in cluster 3 (22.81 cm). However, the circumference of the cannon was similar in clusters 2 and 3 (7.49 and 7.50 cm), which were greater than cluster 1 (6.43 cm).

Tables 3 presents the characterization of the clusters according to the categorical variables. The table indicates the frequency of each variable between clusters (Cla/Mod) and the proportion within the cluster (Mod/Cla). Cluster 1 was characterized by goats mainly located in Guinean zone (88.84%). The head profile of these animals was concave (80.51%) with horn oriented most of time laterally (78.34%). The ears were erected (52.50%), with a white coat color (60.93%) and a steep rump (71.47%). However, cluster 2 was characterized by goats generally located in Sudanian-Guinean and Sudanian zone (59.18 and 49.54%). These goats possessed beards (66.21%) and wattles (63.29%). They were black (56.22%) with a straight head and back profile (51.10 and 66.52%, respectively) and

Table 2. Description of obtained clusters according to quantitative traits goat phenotypic characteristics in Benin

Variables	Cluster 1 (n = 747)	Cluster 2 (n = 654)	Cluster 3 (n = 243)	Overall (n = 1644)	F-value
Neck length (cm)	17.54^{b} ± 3.68***	17.86^{b} ± 3.68***	22.81^{a} ± 4.71***	18.44 ± 4.26	225.80***
Age (year)	1.74^{a} ± 1.17***	2.42^{b} ± 1.01***	2.70^{c} ± 1.58***	2.15 ± 1.24	166.90***
Head length (cm)	15.29^{a} ± 2.24***	17.86^{b} ± 3.68***	19.60^{c} ± 2.21***	16.26 ± 2.42	682.20***
Right ear length (cm)	9.55 ±^{a} 1.43***	10.20^{b} ± 1.37***	13.75^{c} ± 2.13***	10.43 ± 2.09	919.30***
Left ear length (cm)	9.46^{a} ± 1.41***	10.32^{b} ± 0.06^{ns}	13.76^{c} ± 2.07***	10.44 ± 2.10	1050.00***
Right horn length (cm)	4.08^{a} ± 2.31***	6.55^{b} ± 2.28***	10.46^{c} ± 3.91***	6.01 ± 3.39	1106.00***
Left horn length (cm)	4.03^{a} ± 2.30***	6.63^{b} ± 2.27***	10.41^{c} ± 4.01***	6.01 ± 3.41	1122.00***
Neck girth (cm)	21.88^{a} ± 3.17***	25.95^{b} ± 2.70***	26.49^{c} ± 3.90***	24.18 ± 3.76	597.60***
Cannon bone circumference (cm)	6.43^{b} ± 0.61***	7.49^{a} ± 0.73***	7.50^{a} ± 0.96***	7.01 ± 0.90	632.70***
Canon length (cm)	7.28^{a} ± 1.33***	8.92^{b} ± 0.86***	11.10^{c} ± 1.81***	8.50 ± 1.83	1773.00***
Heart girth (cm)	50.37^{a} ± 7.72***	60.94^{b} ± 5.69***	66.73^{c} ± 8.33***	56.99 ± 9.50	1244.00***
Tail length (cm)	9.23^{a} ± 2.03***	13.64^{b} ± 2.15***	11.39^{c} ± 0.15^{ns}	11.30 ± 2.93	433.10***
Rump depth (cm)	19.90^{a} ± 5.08***	27.67^{b} ± 3.95***	32.59^{c} ± 7.16***	24.87 ± 6.97	1437.00***
Body weight (kg)	11.61^{a}±4.86***	20.71^{b} ± 4.92***	23.30^{c} ± 7.60***	16.96 ± 7.31	1177.00***
Body length (cm)	64.19^{a} ± 9.09***	78.99^{b} ± 7.57***	87.13^{c} ± 11.04***	73.47 ± 12.54	1557.00***
Chest depth (cm)	18.21^{a}±4.99***	26.19^{b} ± 4.14***	30.47^{c} ± 4.74***	23.19 ± 6.64	1627.00***
Rump height (cm)	37.75^{a} ± 6.19***	48.92^{b} ± 4.99***	60.13^{c} ± 7.34***	45.50 ± 9.94	2960.00***
Withers height (cm)	35.65^{a} ± 6.38***	47.31^{b} ± 5.19***	57.02^{c} ± 7.98***	43.45 ± 9.97	2560.00***
Back height (cm)	38.29^{a} ± 6.21***	50.01^{b} ± 4.83***	59.08^{c} ± 7.22***	46.02 ± 9.66	2743.00***
Rump width (cm)	17.54^{a} ± 0.14^{ns}	11.10^{b} ± 2.61***	19.47^{c} ± 4.51***	13.35 ± 4.43	151.60***

F: Fischer statistic's; ***: Significant difference ($p < 0.05$) when the mean is compared to the overall mean; ns: Non significant, ^{abc} Mean different superscript letters are significantly different ($p < 0.05$)

Table 3. Description of obtained clusters according to qualitative traits of goat phenotypic characteristics in Benin

Variables	Modalities	Cluster 1 (n = 747)		Cluster 2 (n = 654)		Cluster 3 (n = 243)		Overall
		Cla/Mod	Mod/Cla	Cla/Mod	Mod/Cla	Cla/Mod	Mod/Cla	(n = 1644)
Zone	Guinean	88.84	53.28***	4.24	2.91***	6.92	12.76***	27.25
	Sudanian-Guinean	34.24	20.21***	59.18	39.91***	6.58	11.93***	45.92
	Sudanian	26.23	26.51***	49.54	57.19***	24.24	75.31***	26.82
Sex	Male	51.67	33.07***	35.15	25.69***	13.18	25.93^{ns}	70.92
	Female	42.88	66.93***	41.68	74.31***	15.44	74.07^{ns}	29.08
Coat color	Ash	58.72	13.52***	39.95	10.24^{ns}	2.33	1.65***	10.46
	Black	36.18	26.10***	56.22	46.33***	7.61	16.87***	32.79
	Brown	38.59	27.18***	36.88	29.66^{ns}	24.52	53.09***	32.00
	White	60.93	33.20***	22.11	13.76***	16.95	28.40^{ns}	24.76
Color pattern	Magpie	58.58	18.74***	31.38	11.47***	10.04	9.88***	14.54
	Mixed	38.06	23.69***	36.99	26.30^{ns}	24.95	47.74***	28.28
	Spotted	59.47	15.13***	17.37	5.05***	23.16	18.11***	11.56
	Uniform	42.27	42.44***	49.87	57.19***	7.87	24.28***	45.62
Horn presence	Absent	75.00	0.40^{ns}	0.00	0.00^{ns}	25.00	0.41^{ns}	0.24
	Present	45.37	99.60^{ns}	39.88	100.00^{ns}	14.76	99.59^{ns}	99.76
Horn shape	Curved	32.16	19.54***	40.97	28.44^{ns}	26.87	50.21***	27.62
	Partial	47.12	19.68^{ns}	50.64	24.16***	2.24	2.88***	18.98
	Spiral	8.70	0.27***	0.00	0.00***	91.30	8.64***	1.40
	Straight	52.87	60.51***	36.26	47.40***	10.88	38.27***	52.01
Horn orientation	Backward	26.19	16.20***	54.55	38.53***	19.26	36.63***	28.10
	Lateral	78.34	29.05***	1.44	0.61***	20.22	23.05***	16.82
	Onward	40.00	3.48^{ns}	9.23	0.92***	50.77	13.58***	3.95
	Slanting	45.60	51.27^{ns}	46.67	59.94***	7.74	26.75***	51.09
Ear orientation	Dropped	26.82	6.43***	3.35	0.92***	69.83	51.44***	10.89
	Erected	52.50	89.83***	45.31	88.53***	2.19	11.52***	77.74
	Half dropped	14.97	3.75***	36.90	10.55^{ns}	48.13	37.04***	11.37
Head profile	Concave	80.51	42.03***	6.67	3.98***	12.82	20.58^{ns}	23.72
	Convex	8.00	0.27***	0.00	0.00***	92.00	9.47***	1.52
	Straight	35.07	57.70***	51.10	96.02***	13.83	59.96^{ns}	74.76
Beard presence	Absent	55.47	89.56***	30.18	55.66***	14.34	71.19^{ns}	73.36
	Present	17.81	10.44***	66.21	44.34***	15.98	28.81^{ns}	26.64
Wattles presence	Absent	56.67	91.03***	31.08	57.03***	12.25	60.49***	72.99
	Present	15.09	8.97***	63.29	42.97***	21.62	39.51***	27.01
Back profile	Dipped	37.25	2.54^{ns}	9.80	0.76***	52.94	11.11***	3.10
	Straight	26.61	8.30***	66.52	23.70***	6.87	6.58***	14.17
	Slopes up towards the withers	48.97	89.16***	36.32	75.54***	14.71	82.30^{ns}	82.73
Rump profile	Flat	38.47	66.80***	49.88	98.93***	11.65	62.14***	78.89
	Steep	71.47	33.20***	2.02	1.07***	26.51	37.86***	21.11

***: Significant difference (p-value <0.05) when the proportion is compared to the overall proportion; ns: Non significant, Cla/Mod: Frequency between cluster; Mod/Cla: Frequency within a cluster

horn-oriented backward (54.55). Goats in cluster 3 were characterized by dropped (69.83%) or half-dropped (48.13%) ears with the dominance of a convex head profile (92.00%) and a spiral horn form (91.30%). They were mainly found in Sudanian zone (24.24%) but very little in Guinean (6.92%) and Sudanian-Guinean (6.58%) zone.

4. Discussion

The obtained results showed that morphological traits have been influenced by sex. These findings were in concordance with those reported by several authors regarding the effect of sex on quantitative traits of goats[6,21–24].

The black and brown coat colors are dominant in the present study, while the black coat color is dominant for Djallonké goats in Ghana and Nigeria[21,25,26]. In addition, brown coat color is reported to be the most dominant for Bati, Borena, and short-eared Somali goat populations in Ethiopia[27]. Regarding the coat color pattern, the findings of the current study are in line with those found in Ethiopia and Ghana[9,28,29] where uniform coat color is the most dominant coat color pattern of the indigenous goats. The high presence of horns recorded in this study is close to the results obtained in Niger and Ghana, where all goats examined in their research were horned[9,30]. The absence of wattles and beards agrees with past studies in Benin[4,7], Burkina-Faso[10], Ethiopia[24,31], and Ghana[9,21]. In these studies, a frequent absence of wattles and beards in the goat population has been noticed. However, in Nigeria[25,32] and Ethiopia[28], most of the indigenous goats possessed wattles.

The lowest biometric measurements recorded in cluster 1 are associated with the low prevalence of wattles and bears, and the prevalence of erected ears suggests that goats of this group are closely related to the West African Dwarf goat breed, also called Djallonké. The findings of the present research are in line with those recorded on indigenous goat populations of West Africa[4,9,10], which possess a low prevalence of wattles and beards. Moreover, the low presence of wattles associated with the prevalence of erected ears is the characteristic of the West African Dwarf goat in the Guineo Congolese zone[4], where most goats in cluster 1 belong there. A study on comparative analysis of quantitative phenotypic parameters of Djallonké and a crossbreed of Djallonké and Sahelian goats in Benin reported similar results[6]. They revealed that Djallonké goats have the lowest biometric records while hybrids have average values. Bears and wattles are more frequent in Sahelian goat[4,10]. Given this finding and that most of the goats in cluster 3 possess dropping ears and have high values of biometric measurements, it could be argued that these goats are relatively close to the long-legged goats also called Sahelian goats. The second cluster has average values of biometric measurements and possess qualitative traits of both clusters 1 and 2. It is probably the result of crossbreeding between animals of clusters 1 and 2. The differences between body measurements of the current study and previous studies could be explained by environmental (availability of forages, good nutrition, adaptation, and ecotype) and age differences[8,10,24,25,33]. Moreover, animals from different population have different body measurements[34]. Variation of ecological zones associated with a unique climate and vegetation affect morphological variation in the goat population[21]. In addition, the statistical methods used to manage data in the present study produced the same results as a previous study in Benin[7]. The study revealed three goat types. The first type has small size with erected ears, which was located in Guineo-Congolese zone, while the third type is a large size with dropping ears. The second type is an intermediate type, which might be the result of crossbreeding between the previous two types[7]. Instead of using only quantitative traits in the determination of the clusters and describing the qualitative traits with descriptive statistics or multiple correspondence analysis, this method has the advantage to identify clusters with both quantitative and qualitative traits. The analysis process is fast since there is no need to describe separately qualitative and quantitative traits. Furthermore, FAMD-based cluster analysis gives more relevance and accuracy to handling phenotypic data.

5. Conclusion

In this study, the goat population in Benin was divided into three clusters with different characteristics using FAMD-based cluster analysis. It is a novel approach to analyze phenotypic data. The results confirm the existence of three goat types in Benin. The first has low body measurements with a low prevalence of wattles and bears, and erected ears, while the third type of goats possess dropping ears with high values of biometric measurement. The second type processes intermediate characteristics in comparison to types one and three. Therefore, FAMD-based cluster analysis can be used conveniently in characterization of animal genetic resources.

Declarations

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Behingan M. Boris, Kouato O. Gédéon, and Adjonoumakpe Firmin collected the data. Behingan M. Boris performed the statistical analysis and wrote the first draft with Amagnide Aubin. Kouato O. Gédéon, Adjonoumakpe Firmin, Houndonougbo P. Venant, and Chrysostome A.A.M. Christophe contributed to the review of the manuscript. The final manuscript was read and approved by all authors.

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Availability of data and materials

The data used in the current study will be made available by corresponding author on reasonable request.

Ethical considerations

Ethical issues, such as data fabrication, double publication, and submission, redundancy, plagiarism, consent to publish, and misconduct, have been checked by all the authors before publication in this journal.

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