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Phenotypic Characterization of Baoule Cattle Raised in Southwest Burkina Faso for Identification and Sustainable Utilization

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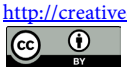


Abstract

This study was conducted on 178 Baoule cattle in five localities in southwest Burkina Faso. Morphobiometric data were collected. The dominant coat colors were black (38.71%) and black piebald (16.13%). The head is generally black. The muzzle is either black or white. The dominant horn shape is the forward-facing crescent moon type. The quantitative variables (horn length, thoracic perimeter, weight, tail length, ear length, height at withers, thorax depth, body length, muzzle circumference) were influenced by age ($p < 0.05$), while sex had no influence on these characteristics ($p > 0.05$). The values obtained showed that these animals are small with a compact conformation. The Baoule taurine of the south is a homogeneous population in the southwest with great phenotypic variability.

Keywords

Baoule Cattle, Burkina Faso, Morphobiometric, Phenotypic Variability

1. Introduction

In Burkina Faso, after agriculture, livestock farming is the second most important primary sector activity. It accounts for 10% - 20% of GDP in the agricultural sector and accounts for approximately 86% of the total population, as stated by the [1]. The sector contributes 12% of GDP and 26% of total exports, ranking it as the second largest exporter of earnings, following cotton, as reported by [2].

A substantial number of animals from various species are being exploited. However, livestock production is struggling to meet the ever-growing population's needs. Baoule cattle constitute the largest bovine population. They are mainly found in the southwest of Burkina Faso, known as Lobi country [3]. Baoule bulls are bred for meat, labour, ritual or customary ceremonies, and rarely for milk [4]. They belong to the group of short-horned Savannah cattle with a dry tropical climate. In southwestern Burkina Faso, Baoule bulls are regarded as pets, kept in small herds and often in homes. Unfortunately, Baoule taurine is often crossed with zebu populations, such as Fulani zebus, because of their small size and relatively low milk production. As with the N'Dama, Baoule bulls are classified as trypanotolerant West African bulls, meaning that they can survive in environments infested with tsetse flies, the vectors of African animal trypanosomosis. Knowledge of Baoule taurines is essential for their preservation.

Studies on the Baoule breed's physical characteristics were carried out in Côte d'Ivoire by [5] and [6], yet detailed research on the physical measurements of Baoule bulls in Burkina Faso is scarce. This study aimed to advance the use of Baoule taurine in Burkina Faso.

2. Materials and Methods

2.1. Study Area

The study area is situated in the Lobi region of Burkina Faso, covering five villages (Batié, Flékora, Gbonkoperou, Gongoblo, and Irnao) in the provinces of Poni and Noumbiel in the southwestern part of the country (**Figure 1**). The Southwest region is bordered by Ghana to the east, Côte d'Ivoire to the south, the Hauts-Bassins and Cascades regions to the west, and the Boucle du Mouhoun, Centre-Ouest, and

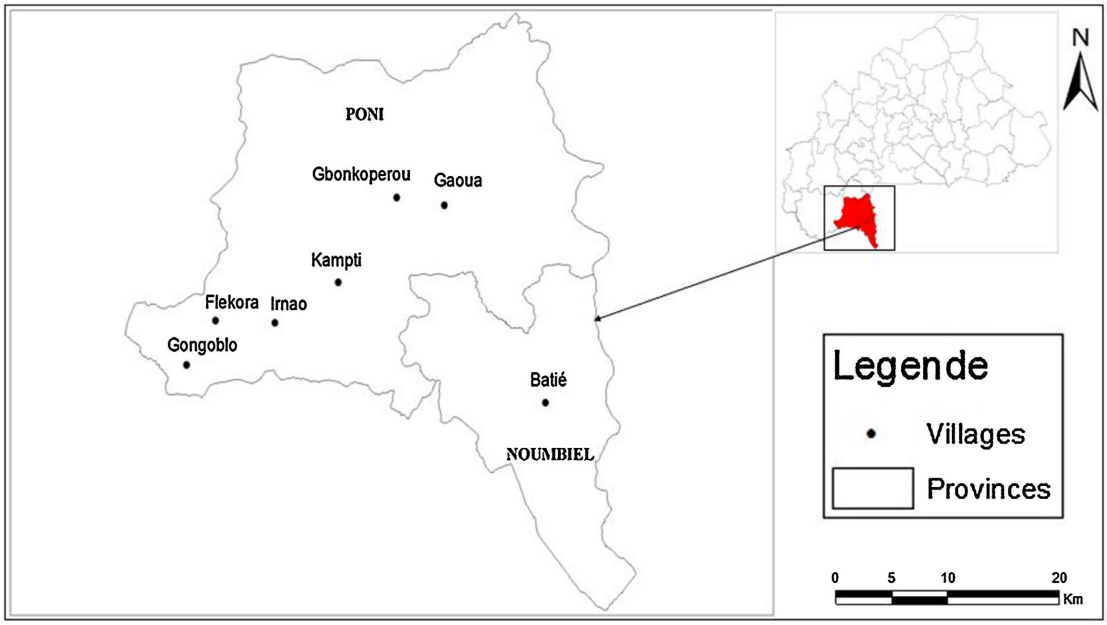


Figure 1. Study area.

Hauts-Bassins regions to the north, according to the information provided by [7]. The Southwest region is very rugged. The majority of the region is made up of hills, mountains, and plateaux with an average altitude of 450 m. The relief comprises vast plains, lowlands, hills, and hillocks. The average altitude of the hills ranges between 300 and 500 m [7]. The region's hydrography is very rich.

The southwest region is covered by two watersheds: the Mouhoun and the Comoé. The Mouhoun River is the most influential river in the region. The main fishing ground in the region is the river basin [7].

2.2. Methodology

2.2.1. Animal Sampling

Surveys were conducted on 32 herders for 178 Baoule taurine in five villages in Lobi country. Table 1 shows the distribution of these numbers. Breeders were essentially linked to the possession of at least 2 Baoule bulls. From each herd, 1 - 10 animals were selected according to the number of animals in the herd.

Table 1. Number of animals sampled based on their locality.

Locality	Cattle Herd		
	Female	Male	Overall
Batié	23	37	60
Flekora	7	1	8
Gbonkoperou	44	10	54
Gongoblo	16	9	25
Irnao	25	6	31
Overall	115	63	178

2.2.2. Body Measurements

A total of 20 variables, including 10 qualitative and 9 quantitative variables, were recorded. Qualitative data were obtained and described by simply observing the participants. Quantitative data were obtained after each animal was restrained. The FAO phenotypic characterisation guide [8] was used to measure morpho-biometric traits. Age was estimated on the basis of the dentition. The same operator took measurements early in the morning to avoid feeding and watering effects on the size and conformation. Visibly pregnant females were excluded from the study.

Quantitative morphometrical characteristics were obtained using a measuring tape calibrated in centimetres (cm) after restraining and holding the animals in an unforced position. All measurements were taken by the same team of personnel on all farms. Linear body measurements recorded included chest perimeter (Pth), horn length (LoC), tail length (Qlo), body length (LoCor), ear length (Olo), muzzle circumference (CM), height at wither (HGa), chest depth (PT), and live weight (Pds). The animals' age was estimated using the dentition method, as suggested

by [8].

Observations of coat colour, eyes, head, muzzle, horn presence, horn shape, ear and horn orientation, dewlap size, head shape, and hair structure were recorded visually.

2.2.3. Statistical Analysis

The collected information was entered into an Excel 2007 database. The effect of locality, gender, and age on the different traits (qualitative and quantitative) was assessed using Pearson's chi-square test, analysis of variance, Student's t-test, and GLM. The level of significance used to interpret the statistical tests was set at 5%. The structuring of the morphological diversity of cattle populations due to quantitative traits was assessed using principal component analysis (PCA). Qualitative and quantitative data analyses were performed using R version 3.1.0 (R Core Team, 2014).

3. Results

3.1. Qualitative Characteristics

3.1.1. Types of Dress Colour and Headwear

Among the Baoule bulls in the zone, coat colours vary greatly (**Figure 2**). The dominant coat colours are black-pie and piebald-black. The dominant head

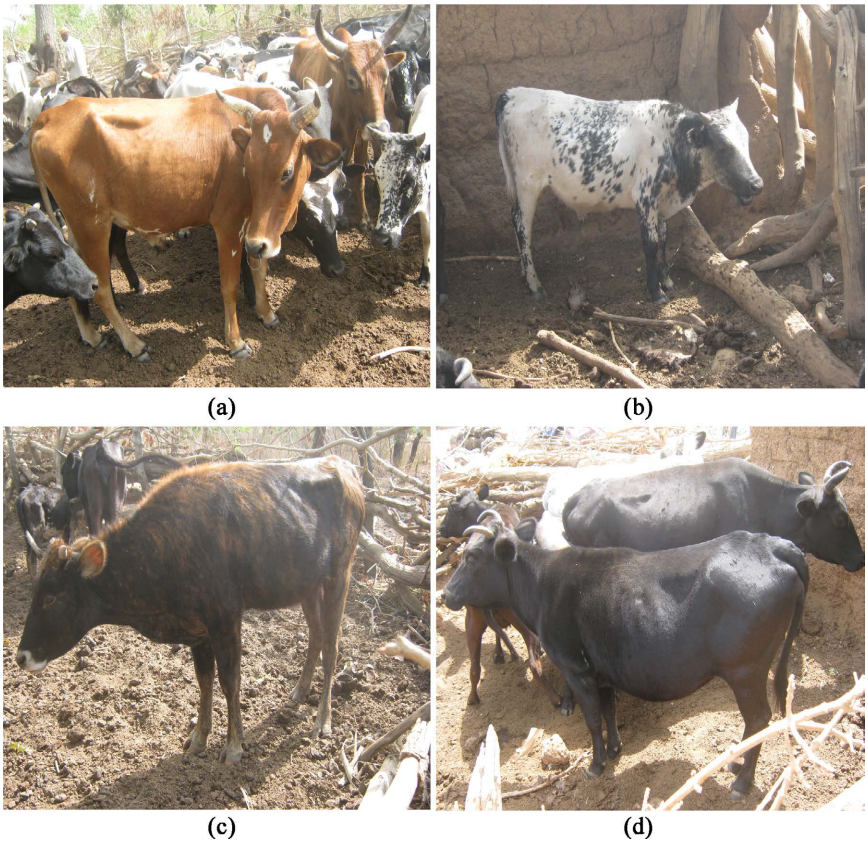


Figure 2. Different colour patterns of the hair coats of Baoule cattle: (a) fawn, (b) black speckled, (c) hyena, (d) black.

colour is black. The frequencies of these different colours calculated are shown in Table 2. In terms of coat colour, the locality had a significant effect (p = 0.018 94, Chi^2 test), whereas no significant difference was observed for head colour (p = 0.4226).

Table 2. Frequency of coat and head colours according to the locality.

Variables						Locality Effect
	Batie	Flekora	Gbonkoperou	Gongoblo	Irnao	
Coat colour (%)						
White (piebald)	8.33	0	0	0	3.22	
Chocolate	8.33	12.5	5.56	4	6.45	
Chocolate-pie	6.67	0	18.52	12	3.23	
Fawn	8.33	12.5	1.85	4	3.23	
Grey	1.67	0	0	4	0	
Hyena	1.67	0	0	8	0	*0.0189***
Black	11.67	12.5	27.78	12	16.13	
Black speckled	1.67	12.5	0	0	3.23	
Black-pie	41.67	12.5	20.37	40	38.71	
Pie-black	3.33	25	18.52	12	16.13	
Red Pie	0	0	7.41	0	6.45	
Pie-red	6.67	12.5	0	4	3.23	
Head colour (%)						
White	8.33	0	0	0	6.45	
Chocolate	0	0	7.41	0	3.23	
Chocolate-pie	0	0	3.7	0	0	
Fawn	11.67	25	7.41	8	6.45	*NS*
Grey	1.67	0	1.85	4	0	
Black	75	75	68.52	72	74.19	
Black speckled	1.67	0	1.85	0	0	
Black-pie	1.67	0	1.85	8	6.45	
Pie-black	0	0	7.41	8	3.23	

**: significant; NS: non-significant.

3.1.2. Types of Eye and Muzzle Colours

The muzzle and around the eyes also varied (white, chocolate, fawn, grey, and black). No significant differences were observed between the localities for snout colour (p-value = 0.4932, Chi^2 test) or eye colour (p-value = 0.3237, Chi^2 test). The dominant muzzle colours were black and white. The dominant colour around the eyes was black (Table 3).

Table 3. Frequency of eye and muzzle colour according to the locality

Variables						Locality effect
	Batie	Flekora	Gbonkoperou	Gongoblo	Irnao	
Eye colour (%)						
White	6.67	0	0	4	6.45	
Chocolate	0	0	5.56	0	3.23	*NS*
Fawn	8.33	25	5.56	4	0	
Grey	3.33	0	1.85	4	0	
Black	81.67	75	87.04	88	90.32	
Muzzle colour (%)						
White	21.67	12.5	16.67	36	25.81	
Chocolate	0	0	3.7	0	0	*NS*
Fawn	8.33	0	5.56	0	0	
Grey	3.33	0	1.85	4	0	
Black	66.67	87.5	72.22	60	74.19	

NS: non-significant.

3.1.3. Influence of Sex on the Horn Shape

In Irnao, 12.90% of the observed animals had no horns (**Table 4**). With regard to horn shape, all shapes were observed in Irnao, with varying frequencies. The dominant type is represented by horns in the "shape of a lunar cross and oriented

Table 4. Wearing frequency and horn shape according to the locality

Variables						Locality Effect
	Batie	Flekora	Gbonkoperou	Gongoblo	Irnao	
Presence of horn (%)						
Absence	0	0	0	0	12.90	*0.000***
Presence	100	100	100	100	87.10	
Horn shape (%)						
Horns crossed in a crescent shape and pointing forward	100	100	94.44	100 (25)	70.97	
Horns crossed in a crescent shape, pointing forward and then downward	0	0	5.56	0	6.45	*0.000***
Horns crossed in a crescent shape and pointing inwards	0	0	0	0	9.68	

**: significant.

forwards". The frequencies differed significantly at the 5% threshold using the Chi² test (Table 4).

All shapes were observed with varying frequencies in the females. However, only the "lyre horn oriented outwards and then forwards" type was observed in males. The dominant type in both sexes is the "lyre horn oriented outwards then forwards" type. The frequencies did not differ significantly at the 5% threshold using the Chi² test (Table 5).

Table 5. Horn shape frequency according to sex.

Variables			Sex Effect
Horn shape (%)	Male	Female	
Cross-shaped and forward-facing	98.41	90.43	
Cross the moon, pointing forward and then downward	0	4.35	*NS*
In a lunar cross and inwardly oriented	0	2.61	

NS: non-significant.

3.2. Quantitative Characteristics

3.2.1. Influence of Locality on the Quantitative Characteristics

Across all localities, the quantitative traits measured in Baoule bulls (Pth, LoC, Q, LCO, LO, HG, and PDS) showed a significant difference at the 5% threshold by analysis of variance (ANOVA) for means calculated with p-value < 0.05; except for muzzle circumference where the means were not significantly different between localities at the 5% threshold by ANOVA (Table 6).

Table 6. Average values (cm) of quantitative morphological traits of Baoule cattle according to locality.

Variables	Calculated parameters	Batie	Flekora	Gbonkoperou	Gongoblo	Irnao	Locality Effect
Pth (cm)	Extremes (min-max)	109 - 146	118 - 144	93 - 148	88 - 152	101 - 146	*0.00*
	Mean ± SD	128.40 ± 7.81	130.88 ± 8.25	122.35 ± 11.63	124.52 ± 13.70	125.26 ± 10.64	
LoC (cm)	Extremes (min-max)	9 - 34	11 - 20	2 - 23	2 - 37	0 - 33	*0.005***
	Mean ± SD	15.72 ± 5.70	14.63 ± 5.13	11.13 ± 5.33	15.68 ± 9.38	14.00 ± 8.72	
Qlo (cm)	Extremes (min-max)	44 - 72	58 - 63	40 - 85	42 - 81	49 - 88	*0.002***
	Mean ± SD	60.4 ± 5.12	60.5 ± 2.20	56.31 ± 8.83	62.8 ± 8.25	59.97 ± 6.93	
LoCor (cm)	Extremes (min-max)	101 - 139	109 - 132	87 - 133	81 - 144	89 - 134	*0.000***
	Mean ± SD	118.77 ± 7.95	120.88 ± 9.43	111.30 ± 11.10	117.68 ± 13.60	112.42 ± 10.02	
Olo (cm)	Extremes (min-max)	11 - 17	12 - 15	12 - 18	13 - 17	12 - 17	*0.000***
	Mean ± SD	13.45 ± 1.14	14.00 ± 1.07	14.11 ± 1.44	14.40 ± 1.15	13.77 ± 1.26	
CM (cm)	Extremes (min-max)	33 - 44	37 - 42	28 - 45	28 - 49	29 - 43	*NS*
	Mean ± SD	38.30 ± 2.40	39.63 ± 2.07	38.19 ± 3.38	38.92 ± 4.42	37.39 ± 3.03	

Continued

HGa (cm)	Extremes (min-max)	80 - 105	88 - 102	70 - 112	79 - 111	76 - 96	*0.000***
	Mean ± SD	92.83 ± 5.24	93.50 ± 4.93	88.09 ± 6.87	91.52 ± 8.22	88.74 ± 4.78	
PT (cm)	Extremes (min-max)	43 - 146	47 - 144	37 - 148	34 - 152	40 - 146	*0.007***
	Mean ± SD	51.48 ± 3.13	50.88 ± 2.85	48.70 ± 4.50	51.00 ± 5.84	49.52 ± 4.02	
Pds (Kg)	Extremes (min-max)	116 - 257	143 - 247	75 - 257	65 - 280	116 - 249	*0.0108***
	Mean ± SD	185.97 ± 32.18	195.00 ± 33.22	162.74 ± 40.14	171.16 ± 49.34	174.06 ± 38.76	

Pth: chest perimeter. LoC: horn length. Qlo: tail length. LoCor: body length. Olo: ear length. CM: muzzle circumference. HGa: height at wither. PT: chest depth. Pds: live weight. **: significant.

3.2.2. Influence of Sex on the Quantitative Characteristics

Sex had no significant effect on the quantitative traits (Pth, LoC, Qlo, LoCor, Olo, CM, HGa, PT, and Pds) (Table 7). The p-values indicate no sexual dimorphism in the cattle studied for these traits.

Table 7. Average values (cm) of quantitative morphological traits of Baoule cattle according to sex.

Variables	Calculated Parameters	Male	Female	Sex Effect
Pth (cm)	Extremes (min-max)	88 - 152	101 - 148	*NS*
	Mean ± SD	125.67 ± 13.91	125.54 ± 8.61	
LoC (cm)	Extremes (min-max)	0 - 37	0 - 34	*NS*
	Mean ± SD	14.17 ± 7.13	13.86 ± 6.98	
Qlo (cm)	Extremes (min-max)	42 - 83	40 - 88	*NS*
	Mean ± SD	59.90 ± 8.37	59.17 ± 6.82	
LoCor (cm)	Extremes (min-max)	81 - 144	89 - 134	*NS*
	Mean ± SD	115.78 ± 13.28	115.10 ± 9.19	
Olo (cm)	Extremes (min-max)	11 - 18	12 - 17	*NS*
	Mean ± SD	13.81 ± 1.41	13.90 ± 1.22	
CM (cm)	Extremes (min-max)	28 - 49	29 - 45	*NS*
	Mean ± SD	38.24 ± 3.85	38.26 ± 2.73	
HGa (cm)	Extremes (min-max)	70 - 112	76 - 102	*NS*
	Mean ± SD	91.68 ± 8.66	89.90 ± 4.82	
PT (cm)	Extremes (min-max)	34 - 152	40 - 148	*NS*
	Mean ± SD	50.25 ± 5.91	50.17 ± 3.11	
Pds (Kg)	Extremes (min-max)	65 - 280	95 - 257	*NS*
	Mean ± SD	176.05 ± 49.55	174.70 ± 33.03	

Pth: chest perimeter, LoC: horn length, Qlo: tail length, LoCor: body length, Olo: ear length, CM: muzzle circumference, HGa: height at wither, PT: chest depth, Pds: live weight. NS: non-significant.

3.2.3. Influence of Age on the Quantitative Traits

The influence of age on these traits was tested using GLM at only 5%. Age had a significant effect on the quantitative variables measured (Table 8).

Table 8. Average values (cm) of quantitative morphological traits of Baoule cattle according to age.

Variables	Calculated parameters	Age ≤ 36 months	Age > 36 months	Age effect
Pth (cm)	Extremes (min-max)	88 - 131	110 - 152	*0.000***
	Mean ± SD	112.33 ± 10.49	128.6 ± 8.25	
LoC (cm)	Extremes (min-max)	0 - 9	0 - 37	*0.000***
	Mean ± SD	8.48 ± 4.82	15.22 ± 6.84	
Qlo (cm)	Extremes (min-max)	42 - 66	40 - 88	*0.000***
	Mean ± SD	54.06 ± 6.38	60.65 ± 7.07	
LoCor (cm)	Extremes (min-max)	81 - 23	98 - 144	*0.000***
	Mean ± SD	104.30 ± 10.77	117.85 ± 9.10	
Olo (cm)	Extremes (min-max)	12 - 16	11 - 18	0.011
	Mean ± SD	13.48 ± 1.12	13.95 ± 1.31	
MC (cm)	Extremes (min-max)	28 - 41	33 - 49	*0.000***
	Mean ± SD	35.09 ± 3.30)	38.97 ± 2.66	
HGa (cm)	Extremes (min-max)	70 - 96	81 - 112	*0.000***
	Mean ± SD	83.61 ± 6.18	92.10 ± 5.44	
PT (cm)	Extremes (min-max)	34 - 54	45 - 63	*0.000***
	Mean ± SD	44.70 ± 4.47	51.46 ± 3.12	
Pds (cm)	Extremes (min-max)	65 - 194	119 - 280	*0.000***
	Mean ± SD	129.24 ± 31.22	185.63[a] ± 33.33	

Pth: chest perimeter. LoC: horn length. Qlo: tail length. LoCor: body length. Olo: ear length. CM: muzzle circumference. HGa: height at wither. PT: chest depth. Pds: live weight. **: significant.

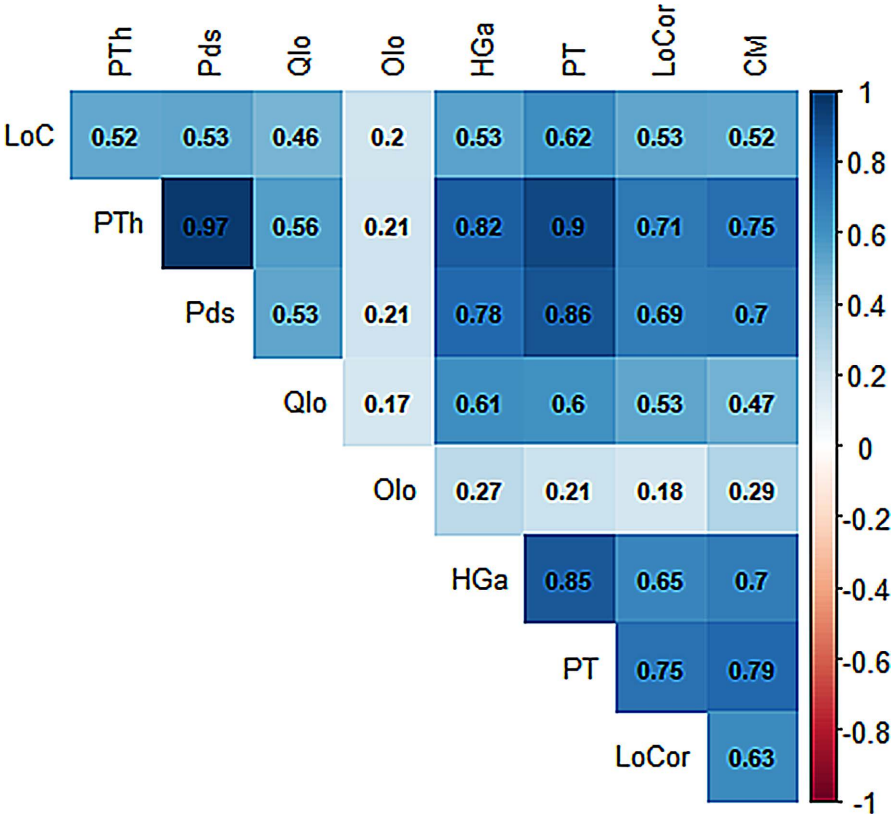
3.3. Multivariate Analysis

3.3.1. Population Structure as Determined by PCA

The KMO index value of 0.89 indicates that the information level accessible through all 9 quantitative variables is compressible. In addition, the highly significant Bartlett's sphericity test (p-value = 0.000) indicates that the data can be subjected to principal component analysis (Table 9). The Pearson correlation matrix for all morphobiometric characteristics is shown in Figure 3. Correlations with a significant p-value at the 5% threshold ranged from 0.2 to 0.9. This matrix indicates that all correlations were positive. Highly significant correlations were observed between several pairs of variables. Except for the correlations between ear length and other traits and tail length and other traits, which were not significant.

Table 9. The KMO index and Bartlett's test results.

Kaiser-Meyer-Olkin Index		0.89
Bartlett's test of sphericity	Chi-square approx.	1493.214
	ddl	36
	Signification (P-value)	0.000



Pth: chest perimeter. LoC: horn length. Qlo: tail length. LoCor: body length. Olo: ear length. CM: muzzle circumference. HGa: height at wither. PT: chest depth. Pds: live weight.

Figure 3. Correlation matrix for all morphometric characteristics.

The PCA results for our entire sample are shown in Figure 4. Principal component analysis revealed the proportion of variability explained by each of the two factorial axes. They express 74.8% of the phenotypic diversity of Baoule cattle. The PCA performed on the entire population did not reveal any discrimination of the study area population along the axes.

3.3.2. Discriminant Analysis of Cattle Populations

Figure 5 supports the conclusion that no distinct groups exist based on geographical location. The confusion matrix in Table 10 indicates that 45.88% of cases were correctly classified and that 93 individuals (54.12%) were reclassified. This high reclassification rate proves that "location" is not a very influential factor in the grouping of Baoule cattle in southern Burkina Faso. Other intrinsic factors related to the animals or the livestock system may explain the differences in the results.

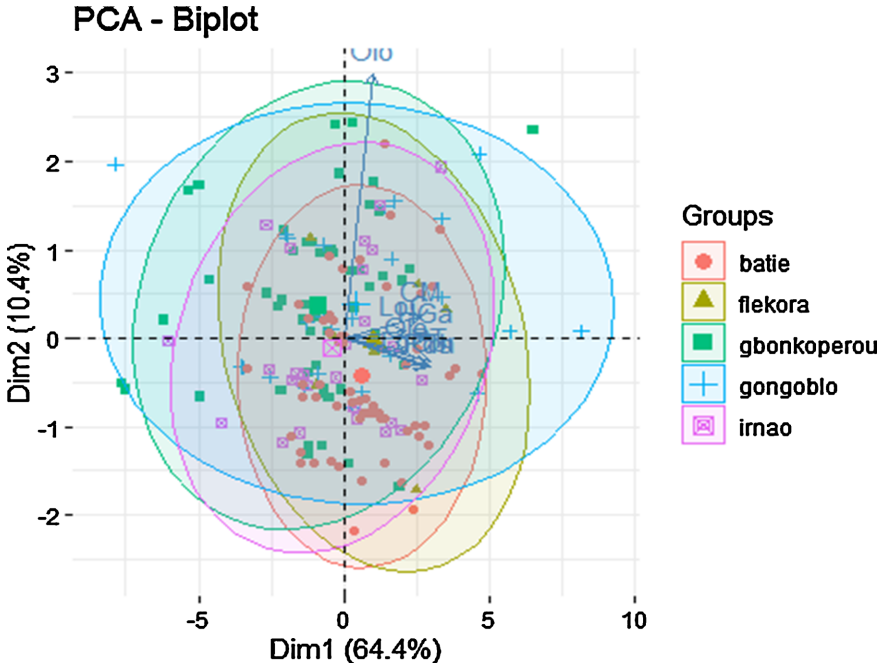


Figure 4. Bidimensional plot of the principal component analysis (PCA).

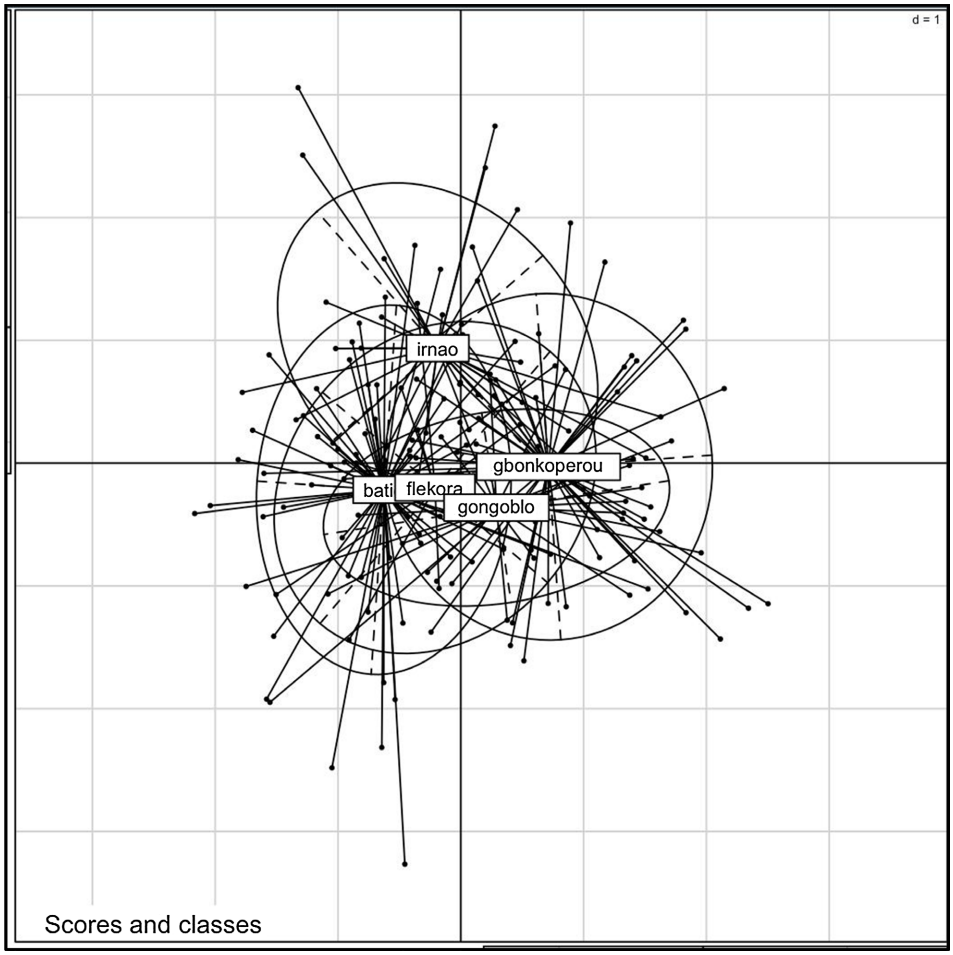


Figure 5. The presentation of different groups was obtained after partitioning using the AFD method.

Table 10. Confusion matrix for sample estimation.

	Batié	Flekora	Gbonkopérou	Gongoblo	Irnao	Total	% Correct
Batié	49	1	5	0	5	60	81.70%
Flekora	4	1	2	0	1	8	12.50%
Gbonkopérou	11	0	37	3	3	54	68.52%
Gongoblo	10	0	7	7	1	25	28%
Irnao	11	0	7	1	12	31	38.70%
Total	85	2	58	11	22	178	45.88%

4. Discussion

Qualitative characteristics that can be used to identify Baoule taurines in south-west Burkina Faso are highly variable. Domination is present across various modalities of specific variables. The Baoule bull of Burkina Faso is characterised by a predominantly black-pie or piebald-black coat, with a black head and black or white muzzle. The horns are in a lunar cross pattern, with the horn pointing forward. Variability in the coat colour of Baoule bulls has also been observed in Côte d'Ivoire bulls [5] [7]. Meanwhile, the colour of the coat may not effectively characterise an individual. One can consider Baoule bulls in comparison to short-horned bulls with piebald-black or black-pie coats in a savannah setting. Furthermore, when animals with these coats have a slightly developed cervico-thoracic hump, they crossbreed with zebus, commonly known as "Méré". Baoule bulls have small, side-set ears, short hair, and a poorly developed dewlap [6]. Baoule males and females are generally horned [9]-[11]. The absence of horns at Irnao could be explained by the practice of dehorning. The "lunar crossing and forward-facing" horn type was the most representative in all localities in both males and females. In other words, no sexual dimorphism exists for the horn shape. [6] described that in males, the horns form a very flared "U" shape oriented laterally, and the crescent-shaped horns are oriented forward.

This study found that the quantitative character values (Pth, LoC, Qlo, LoCor, Olo, CM, HGa, PT, and Pds) vary from one location to another, with the exception of the muzzle's circumference. This could be explained by differences in rearing practices between localities, particularly in terms of feeding and health monitoring. According to [12], the herd is run by unskilled herdsmen, and the animals rarely receive supplementary feed and generally do not receive any veterinary care.

Sex had no influence on these quantitative traits in the cattle studied, as the difference between the values of these traits was not significant between males and females. This non-significance can be explained by the higher number of females compared with males in our study. This result suggests that the Baoule cattle may exhibit low intrinsic sexual dimorphism.

The values for height at the withers (91.68 cm ± 8.66 cm for males and 89.90 cm ± 4.82 cm for females) and body length (115.78 cm ± 13.28 cm for males and 115.10

cm ± 9.19 cm for females) were similar to those reported by [10]. However, in north-eastern Côte d'Ivoire, these values are lower than those reported by [5]. However, for the thoracic perimeter (125.67 cm ± 13.91 cm for males and 125.54 cm ± 8.61 cm for females), there is a difference compared to their work. The average weights are 176.05 kg ± 49.55 kg for males and 174.70 kg ± 33.03 kg for females, which differed from the description by [5], who observed that the average weight was 191 kg for cows and 184 kg for bulls.

The means of the linear traits between the age classes (Age ≤ 36 months and Age > 36 months) differed significantly, indicating that age has an effect on these traits. The weights of the animals, which varied by age (129.24 kg ± 31.22 kg for animals less than or equal to 36 months and 185.63 kg ± 33.33 kg for animals older than 36 months), were lower than those reported by [10] and [5] in Côte d'Ivoire in a traditional environment. Indeed, these authors found that the weight varied from 159 to 162 kg from birth to 2 years; at 3 years, the weight was 212 kg.

Multivariate analyses (principal component analysis and discriminant factor analysis) did not allow this diversity to be structured by grouping the cattle into subsets. In this zone [13], noted a positive overall balance of acts linked to the conservation of Baoule bulls and practices in Burkinabe Lobi country, which would justify the low development of Baoule bull interbreeding in the zone. This may explain the phenotypic homogeneity of Baoule cattle in southwest Burkina Faso observed in this study.

5. Conclusion

Morphobiometric data for the Baoule bull in southwest Burkina Faso show that there is considerable phenotypic variability. However, there is no phenotypic structuring of Baoule cattle into sub-populations in southwest Burkina Faso. However, some differences have been observed between localities, probably linked to differences in husbandry practices. As the Baoule taurine is classified as a trypanotolerant West African cattle breed, action is needed to improve its performance in order to meet the needs of the local population, while at the same time emphasising the need to preserve this genetic heritage. DNA analysis of these cattle will provide a clearer understanding of the observed variations in their physical characteristics and reveal distinct genetic groups.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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