

Analysis of Qualitative Morphological Characteristics of N'Dama Cattle (*Bos Taurus Linneaus*, 1758) from the Marahoué Ranch and Farming Environment (Ivory Coast)

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How to cite this paper: Atta, A.M.D., N'Goran, K.E., Kanh, K.H.M., Yao, F.D.A. and Tre, U.B. (2025) Analysis of Qualitative Morphological Characteristics of N'Dama Cattle (*Bos Taurus Linneaus*, 1758) from the Marahoué Ranch and Farming Environment (Ivory Coast). *Open Journal of Animal Sciences*, 15, 283-300.

<https://doi.org/10.4236/ojas.2025.154020>

Received: May 31, 2025

Accepted: August 23, 2025

Published: August 26, 2025

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Abstract

The physical characteristics of N'Dama cattle are a major issue in the recognition of the breed for both scientists and breeders. To resolve this ambiguity, a comparative study of the physical characteristics of 94 N'Dama cattle from the Marahoué ranch and 107 others farming system in three agro-ecological zones (Central, North-Western and North-East) of Côte d'Ivoire was carried out by the Chi-square test. Analysis showed that the N'Dama from the farming environment has, in addition to the fawn-colored coat (68.2%), other types of coat color (white, black, grey, pi-black). They have mostly lyre horn (58.9%), bicolored horns (91%) and convex back (75.7%). The N'Dama from the Marahoué ranch, on the other hand, has only a fawn-colored coat (100%), a straight back (100%), and ears carried horizontally (100%). It has mostly eyelids (91.5%) and an unpigmented muzzle (91.5%). Multiple correspondence analysis, show that factor 1 with 64.44% of inertia, alone described the essential variability of the population. This factor allows us to qualitatively differentiate cattle through coat color (Rbe), horn shape (Fcn), eyelid color (Cpp) and muzzle color (Cmu). On the basis of discriminating characteristics, the N'Dama studied separated into two (2) groups. The group 1 is made up mainly of cattle from the Marahoué ranch (57.51%). It is characterized by fawn-colored coats (96.73%), lyre-shaped horns (49.67%), unpigmented eyelids (97.38%) and unpigmented muzzles (90.1%). Group 2, on the other hand, is made up of N'Dama farmers (87.5%). They are characterized by other coat colors (60.41%), and crescent horns (52.08%). Their eyelids are pigmented (95.83%), as is their muzzle

(97.91%). Projection of the individuals in the factorial planes of the MCA (1; 2) shows that the N'Dama from the ranch and those from the farming environment constitute a more or less physically homogeneous population.

Keywords

Bovin N'Dama, Physical Traits, Environmental Effects, Ivory Coast

1. Introduction

Livestock farming plays a fundamental role in the socioeconomic and cultural systems of human societies. According to FAO [1], it represents nearly 40% of total agricultural production in developed countries and about 20% in developing countries. Globally, nearly 1.3 billion people depend on livestock, which provides about 34% of the protein consumed by humans. In West Africa, and particularly in Côte d'Ivoire, livestock farming does not yet cover national needs in animal protein. The country remains heavily dependent on imports, which cost nearly 400 billion FCFA annually [2]. This situation is explained in particular by the low productivity of local breeds, often poorly selected, and by the strong pressure of animal diseases [3]. To address this deficit, the Ivorian government has implemented several livestock development projects, particularly those focused on the genetic improvement of local breeds and the promotion of modern livestock farming aimed at increasing national meat and milk production.

The N'Dama is one of the local cattle breeds of Côte d'Ivoire. It is an animal that is well adapted to the climate of this country where African animal trypanosomiasis is prevalent. It is resistant to various animal pathologies and difficult breeding conditions [4] [5]. The N'Dama has superior reproductive performance to some West African cattle breeds, notably the Zebu [6]. These characteristics have earned this breed special attention in livestock development programs and projects in Côte d'Ivoire. The N'Dama breed is also attracting interest in the West African sub-region, as evidenced by its use in crossbreeding programs in most West African countries [7]. However, the integration of the N'Dama breed into these projects has not been without consequences. Indeed, these projects for the genetic improvement of N'Dama by crossing with exotic breeds have not integrated sustainable and efficient management strategies (identification, conservation, characterization) that could guarantee its protection. This situation raises questions about the evolution of the genetic status of the N'Dama breed, and more broadly about the implications of these changes for the sustainability of livestock farming. As part of the National Development Plan (NDP) which aims to strengthen food sovereignty and modernize the agricultural sector, the preservation and development of animal genetic resources such as the N'Dama breed, appear today as major issues. The loss of genetic diversity or the dilution of the adaptive traits of this breed could compromise the sustainability of Ivorian livestock

systems in the long term. It is therefore imperative to characterize the N'Dama breed for a better understanding of these physical characteristics. This would help for better management of the breed at national, sub-regional and global levels [8]. Several phenotypic characterization studies of the N'Dama breed have already been conducted in Ivory Coast [5]-[10]. However, the majority of these studies have focused on the breeding areas of the Center and the North-West of the country. This study broadens the scope of analysis by also integrating the North-East areas as well as the Marahoué ranch, which houses one of the largest numbers of purebred N'Dama cattle. Furthermore, this study focuses exclusively on qualitative phenotypic traits due to their lower sensitivity to environmental variations which allows a better appreciation of the genetic basis of these traits.

2. Material and Methods

2.1. Study Site

The study was conducted in rural areas in the agroecological zones of the Center, Center-West, Northwest, and Northeast of Côte d'Ivoire. The choice of these areas is justified by the fact that they are the main breeding areas for N'Dama bulls. The Marahoué ranch has the largest population of purebred N'Dama cattle.

The agroecological zone of the Centre, covered 4 administrative localities (Bouaké, Brobo, Toumodi and Dimbokro) of three regions (Gbêkê, Bélier, N'Zi). This part of the country has a relatively flat relief, with a succession of high plateaus known as the Baoulé Chain. The vegetation is composed of wooded savannah, grassland savannah and mesophilic gallery forests along the watercourses. The hydrographic network of the Centre is mainly made up of the Bandama river and its tributary the N'Zi. There are also lakes and rivers [10]. In the Center of the country, rainfall is less abundant (from 1000 to 2500 mm).

The Northwest region covers the administrative districts of Ouaninou and Touba in the Bafing region, and Sipilou in the Tonkpi region. The Bafing region is crossed by rivers and the relief is made up of mountains, plateaus, valleys and plains. The vegetation consists of a transition zone straddling the forest and the savannah. The annual rainfall is around 1127 mm. The region has a humid tropical Sudano-Guinean climate. Its rainy season runs from April to October and the dry season from November to March [10]. The Tonkpi Region is located in the far west in the mountain district. In this region, the series of lowlands is linked in places with very rugged areas with contours varying between medium slopes and altitudes sometimes exceeding 1000 m [10]. Rainfall levels vary between 1300 and 2400 mm per year. Temperatures are mild and average 24°C. The Tonkpi region is irrigated by the Sassandra river in the east and the Cavally river in the west, each with numerous tributaries that promote vegetation consisting of 80% rainforest [10].

The Northeast region covers the Bouna department in the Bounkani region. The Bounkani region exhibits a very pronounced geomorphological diversity. The peaks of the ridges, often blunt, can reach 700 meters high [11]. The region, once made up of grassy and wooded savannahs, is now heavily shrubby, with gallery

forests along the region's rivers and streams. Comoé park made up of savannahs and open forests with an area of 11,090 km² covers almost half of the territory. The region has a Sudanese climate. It is characterized by a dry season that runs from November to March, a rainy season that lasts from April to October, and a harmattan that lasts from November to February [11]. The region is bordered to the west by the Comoé river and to the northeast by the black volta river.

Created in 1975, the Marahoué ranch's mission is the selection, multiplication, conservation and distribution of N'Dama cattle only. It is located in the center-west of Côte d'Ivoire between the Worodougou and Béré regions. The vegetation is a savannah with *Andropogon macrophyllus* on the plateaus with dense forests and gallery forests along the Marahoué River and its tributaries. The vegetation is being invaded by woody and thorny plants (*Solannum verbacifolium*, *Harungana madagascariensis*, *Trema guineensis*, *Dicrostakis gomerata*, *Acacia ataxantha*, *Mimosa pigra*) [12]. The climate is Baoulean with a long rainy season (from March to June) and a long dry season (from July to August). The average annual rainfall is 1182 mm [13].

2.2. Choice of Breeding

Through documentation and support from agents of the Ministry of Animal and Fisheries Resources, the N'Dama cattle breeding areas in Côte d'Ivoire were determined. These are the Northwest region which borders Guinea (cradle of the Guinean type N'Dama), the Central region which concentrates the majority of N'Dama cattle improvement projects, the Northeast region where the N'Dama is used in plantations and the Marahoué ranch. The accessibility of the farms, the availability of breeders and the size of the herd were the criteria for selecting the farms. The size of the herds ranged from 15 to 50 head of N'Dama cattle.

2.3. Animal Management and Conduct

In real livestock farming, cattle led by herdsman travel long distances in search of pasture. They are very often in conflict with farmers. The animals are periodically distributed salt and not given any vitamin supplements. At nightfall, they return to the camp where they are kept in night pens. The animals are most often cared for by the herdsman themselves. Most of the animals do not receive any external deworming. Internal deworming of cattle is the most common practice on these farms. As for the Marahoué ranch, the animals are led to pasture, to water, and to night pens every day from 8 a.m. to 4 p.m. The Marahoué river and its tributaries, are the watering sites for the herds. During the dry season, the animals' feed is supplemented with cottonseed. The animals are treated weekly during the rainy season and fortnightly during the dry season. They are treated for external parasites with Aphypermethrin. Internal deworming is mostly performed on young animals.

2.4. Data Collection

The phenotypic description of N'Dama cattle was carried out in two phases. A

total of 201 cattle, including 22 males and 179 females aged four years and older, were sampled. The first phase took place from December 2016 to January 2017 in rural areas in the regions of Bafing, Gbêkê, N'Zi, Bélier and Tonpki. This part of the data has been the subject of a previous study carried out by [3]. The second phase took place from January to February 2024 at the Marahoué ranch and then in farming system in the Bounkani region. Qualitative traits such as ear orientation, eyelid color, muzzle color, coat color, back profile, horn orientation, presence of frontal spot and dewlap development were the variables used to describe the cattle. Each animal was observed once and described using these qualitative variables with the naked eye. The age of the animals was determined based on their dentition and the number of striations on their horns (**Table 1**).

Table 1. Number and origin of herds and cattle used in this study.

Farming regions	Administrative regions	Town	Numbers of farms	Numbers of animal
Centre	Gbêkê	Bouaké	1	9
		Brobo	1	9
	Bélier	Toumodi	1	7
	N'Zi	Dimbokro	1	9
	Sous total		4	34
Northwest	Bafing	Ouaninou	3	26
		Touba	2	17
	Tonpki	Sipilou	1	6
	Sous total		6	49
Northeast	Bounkani	Bouna	5	24
		Sous total	5	24
Ranch	Worodougou	Séguéla	4	94
		Sous total	4	94
		Total	19	201

2.5. Data Analysis

Data were entered into Excel 2016 software. Variable modalities were expressed as percentages. The chi-square goodness-of-fit test was used to compare the proportions between the different modalities of a variable in order to determine which modalities, appear frequently in each type of system. A multiple correspondence analysis (MCA) was performed to verify the segregation of individuals

in a factorial design based on categorical variables. The optimal number of groups was determined using fastcluster software. The typology of these different groups was performed by crossing the most discriminating variables, the system variable and the group variable, using a Chi-square test. The significance level used for the interpretation of statistical tests is 5%. All analyses were performed using R 4.4.2 (R Core Team, 2024) and XLSAT 2024 software.

3. Results

3.1. N'Dama Description of the Two Types of System

Table 2 shows the frequencies of occurrence of qualitative trait modalities production system. The N'Dama described in this study shows phenotype variability for all descriptors. It has a coat of various colors (fawn, white, sandy, gray and black), five different horn shapes (lyre, crescent, cup, crown, back), three phenotypes describing the profile of the back (straight, concave, convex), and two modalities for the rest of the characters (**Figure 1**, **Figure 2** and **Figure 3**). The Chi-square test comparing the different proportions of the modalities tells us that some phenotypes are more frequent than others ($p < 0.001$). Thus, in the general study population, the N'Dama frequently has a fawn-colored coat (83.1%), ears carried horizontally (95.1%), lyre shaped horns (44.3%), a straight back (87.1%), unpigmented eyelids (75.1%), bicolored horns (86.6%) and is without a forehead spot (94.5%). Specifically, the N'Dama from the farming environment has, in addition to the fawn-colored coat (68.2%), other types of coat color (piebald-black, black, white, grey) at 31.8%. They have all types of horn, but mostly lyre horn (58.9%). Some subjects in this population have pigmented eyelids (39%) and others do not (61%). In this population, the N'Dama has a straight, concave and convex back at frequencies of 75.7%, 15.8% and 8.4% respectively. It has bicolored horns and horizontal ears in general (91%). The N'Dama from the Marahoué ranch, on the other hand, has only a fawn-colored coat (100%), a straight back (100%), and ears carried horizontally (100%). Like the farming system N'Dama, the N'Dama from the ranch has all horn types, but in roughly equal proportions. It has mostly eyelids (91.5%) and an unpigmented muzzle (91.5%). In particular, all the cattle on the ranch with pigmented muzzle have pigmented eyelids (8.5%). Those with unpigmented muzzle also had unpigmented eyelids (91.5%). Dewlap is medium and low in 43.6% and 56.4% of cattle in this system respectively.

Table 2. Frequency of occurrence of qualitative characteristics according to the farming system.

Variables	Modality	T. system	Ranch	Total
Coat color	Fawn*	73 (68.2)	94 (100)	167 (83.1)
	Other color*	34 (31.8)	0 (0)	34 (16.9)
	χ^2 (df = 1)	$p < 0.001$	$p < 0.001$	$p < 0.001$

Continued

	Lyre	63 (58.9)	26 (27.7)	89 (44.3)
	Crescent	29 (27.1)	20 (21.3)	49 (24.4)
Horn shape	Cup	4 (3.7)	27 (28.7)	31 (15.4)
	Other shape*	11 (10.3)	21 (22.3)	32 (15.9)
	χ^2 (df = 3)	p < 0.001	P = 0.665	p < 0.001
	<hr/>			
Muzzle color	Unpigmented	53 (49.5)	86 (91.5)	139 (69.2)
	Pigmenté	54 (50.5)	8 (8.5)	62 (30.8)
	χ^2 (df = 1)	p = 0.259	p < 0.001	p < 0.001
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Eyeslids color	Unpigmented	65 (61)	86 (91.5)	151 (75.1)
	Pigmented	42 (39)	8 (8.5)	50 (24.9)
	χ^2 (df = 1)	p = 0.026	p < 0.001	p < 0.001
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Horn color	Bicolor*	97 (91)	77 (81.9)	174 (86.6)
	Unicolor*	10 (9)	17 (18.1)	27 (13.4)
	χ^2 (df = 1)	p < 0.001	p < 0.001	p < 0.001
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Forehead spot	No	105 (98)	85 (90.4)	190 (94.5)
	Yes	2 (2)	9 (9.6)	11 (5.5)
	χ^2 (df = 1)	p < 0.001	p < 0.001	p < 0.001
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Back profile	Straight	81 (75.7)	94 (100)	175 (87.1)
	Concave	17 (15.8)	0 (0)	17 (8.5)
	Convex	9 (8.4)	0 (0)	9 (4.5)
	χ^2 (df = 2)	p < 0.001	p < 0.001	p < 0.001
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Dewlap	Medium	60 (56.1)	41 (43.6)	101 (50.2)
	low	47 (43.9)	53 (56.4)	100 (49.8)
	χ^2 (df = 1)	p = 0.2	P = 0.215	P = 0.943
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Ear orientation	Horizontale	97 (91)	94 (100)	191 (95.1)
	right	10 (9)	0 (0)	10 (4.9)
	χ^2 (df = 1)	p < 0.001	p < 0.001	p < 0.001

The values outside the brackets represent the number of cattle. The values inside the brackets represent the frequencies (%). Fawn* = ginger fawn, wheaten fawn, red fawn; Other color* = piebald-black, black, white, grey, sand; χ^2 = Chi-square; p = probability; df = degree of liberty; Other shape* = crown, back; Bi-colour* = black and white; unicolour* = black, white; T. system = traditional system.



Figure 1. Coat color (a) fawn, (b) sand, (c) white, (d) black.

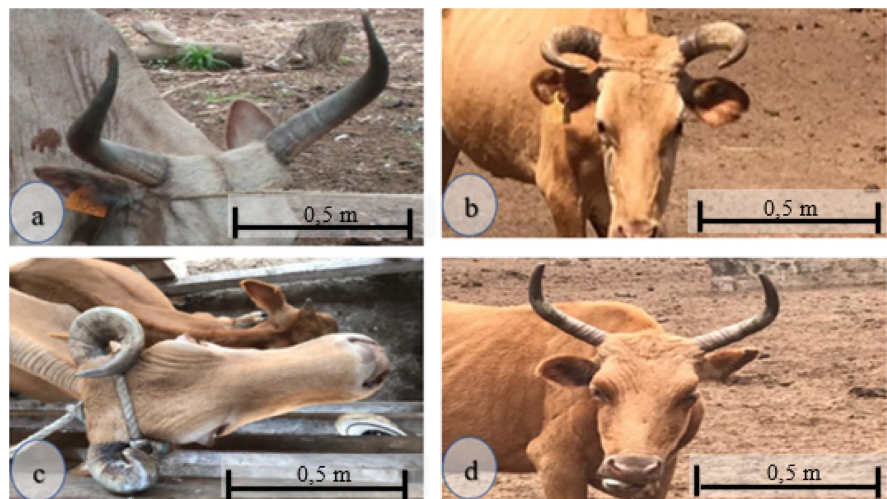


Figure 2. Different types of horns (a) lyre, (b) crescent, (c) back, (d) cup.



Figure 3. Different type of feature (a) pigmented muzzle, (b) unpigmented eyelid, (c) horizontal ears, (d) pigmented muzzle.

3.2. Morphological Variability Factors of the N'Dama According to Qualitative Parameters

Multiple correspondence analysis (MCA) was used to determine the factors of morphological variability in N'Dama cattle according to qualitative variables. The results of this analysis show that factor 1 alone summarizes 64.44% of the information contained in the study population (Table 3). Factor 1 allows us to qualitatively differentiate cattle through four variables. These variables are coat color (Rbe), horn shape (Fcn), eyelid color (Cpp) and muzzle color (Cmu). Eyelid color, with a contribution of 33.88%, is the most important in defining factor 1 followed by muzzle color (30.70%), coat color (24.48%) and horn shape (10.2%). Factor 1 therefore described cattle according to eyelid, muzzle and coat color. It also identifies them to horn shape. The modalities fawn coat (Rbe-1), other coat color (Rbe-2), unpigmented muzzle (Cmu-1), pigmented muzzle (Cmu-2), unpigmented eyelids (Cpp-1), crescent-shaped horn (Fcn-2) and pigmented eyelids (Cpp-2) are well represented on the factor. Axis 1 therefore perfectly explains the variability brought about by these modalities. With negative test values significantly different from zero ($p < 0.05$), the tawny coat (-3.835), unpigmented muzzle (-4.295) and unpigmented eyelids (-4.512) characters form a group of variables at the extreme left of the factor. Opposite this variable group, the characters other color type coat (3.835), crescent-shaped horn (2.371), pigmented muzzle (4.295) and pigmented eyelids (4.512) also form another variable group (Figure 4). Fawn-colored N'Dama therefore tend to have unpigmented muzzles and eyelids. N'Dama with other coat colors (piebald-black, black, white, grey) tend to have crescent-shaped horns and pigmented muzzles and eyelids.

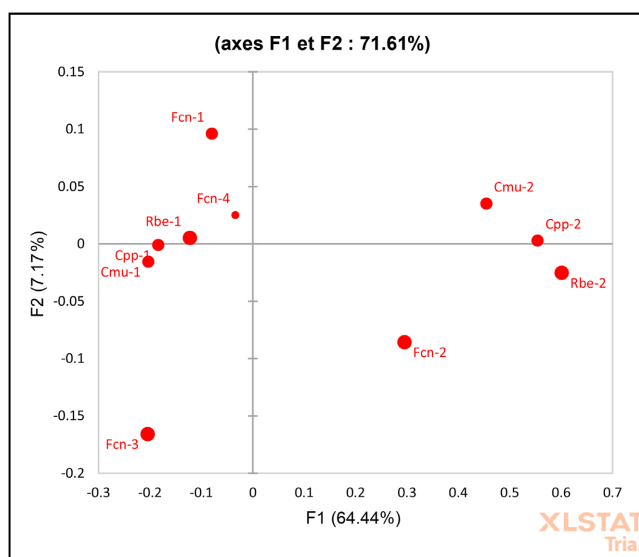


Figure 4. Projection of variables in the plane (F1; F2) of MCA. Rbe-1: fawn coat; Rbe-2: coat of another colour (white, black, grey, sandy, black and white); Fcn-1: lyre-shaped horns; Fcn-2: crescent-shaped horns; Fcn-3: cup-shaped horns; Fcn-4: crown- or wheel-shaped horns; Cmu-1: non-pigmented muzzle; Cmu-2: pigmented muzzle; Cpp-1: non-pigmented eyelids; Cpp-2: pigmented eyelids.

Table 3. Contributions and qualities of representation of the modalities.

Active variables	Modality	F1 (64.44%)	Cos ²	F2 (7.17%)	Cos ²
Coat color	1 = fawn	4.141	0.827	0.066	0.001
	2 = white, black, gray, sand	20.340	0.827	0.322	0.001
	<i>Total</i>	24.481		0.387	
Horne shape	1 = lyre	0.926	0.247	12.204	0.363
	2 = crescent	7.075	0.835	5.366	0.071
	3 = cup	2.144	0.485	12.692	0.363
	4 = crow, wheel	0.060	0.027	0.299	0.015
	<i>Total</i>	10.205		30.560	
Horne color	1 = bicolor	0.003	0.009	1.754	0.567
	2 = unicolor	0.02	0.009	11.303	0.567
	<i>Total</i>	0.023		13.056	
Forehead spot	1 = no	0.018	0.185	0.365	0.418
	2 = yes	0.311	0.185	6.310	0.418
	<i>Total</i>	0.329		6.675	
Eylids color	1 = unpigmented	8.428	0.725	0.002	0
	2 = pigmented	25.453	0.725	0.006	0
	<i>Total</i>	33.881		0.008	
Muzzle color	1 = unpigmented	9.470	0.723	0.504	0.004
	2 = pigmented	21.231	0.723	1.131	0.004
	<i>Total</i>	30.701		1.635	
Back profile	1 = straight	0.009	0.02	0.493	0.114
	2 = concave	0.002	0.001	6.497	0.291
	3 = convex	0.232	0.115	0.165	0.009
	<i>Total</i>	0.243		7.115	
Dewlap	1 = medium	0.028	0.014	10.152	0.541
	2 = low	0.029	0.014	10.254	0.541
	<i>Total</i>	0.057		20.405	
Ear orientation	1 = horizontal	0.004	0.02	1.001	0.560
	2 = right	0.076	0.02	19.117	
	<i>Total</i>	0.08		20.118	0.560

Cos²: square cosine; The values in bold represent the Cos² and the largest contribution, F: factor.

3.3. Determination and Typology Groups Highlighted by MCA

Determination of the optimal classes was performed with a partitioning algorithm using the higher inertia relative loss criteria method. **Figure 5** shows the inertia jumps obtained from the transformation of the categorical variable matrix into *hclust* class objects. Analysis of this figure shows that the optimum number of hierarchical groups is two. Cross-referencing these groups with the overall study population gives us the composition of each group (**Table 4**). **Figure 6** shows the projection of these groups in the factorial plane of the MCA (F1; F2). Group 1, located in the negative part of axis 1, is made up of 153 N'Dama cattle. The second group, opposite group 1, comprises 48 cattle. The factors farming system had a significant effect on group formation ($p < 0.001$). Group 1 comprises 65 cattle from the farming environment (42.48%) and 88 cattle from the Marahoué ranch (57.51%). The second group comprises 42 cattle from the farming system (87.5%) and 6 from the ranch (12.5%). The most discriminating variables determined by the MCA all had significant effects on the variation of individuals in the different groups (**Table 3**). The first group is made up of N'Dama with fawn-colored coats (96.73%), lyre-shaped horns (49.67%), unpigmented eyelids (97.38%) and unpigmented muzzles (90.1%). The second group is characterized by N'Dama with piebald-black, black, white, and grey coat color (60.41%), and crescent horns (52.08%). Their eyelids are pigmented (95.83%), as is their muzzle (97.91%).

Table 4. Typology of the different groups obtained.

Variable	Modality	Group 1	Group 2	df	p
System	Ranch	88 (57.52)	6 (12.5)	1	<0.001
	T. system	65 (42.48)	42 (87.5)		
Coat color	Fawn*	148 (96.74)	19 (39.58)	1	<0.001
	Other color*	5 (3.26)	29 (60.42)		
Horn shape	Lyre	76 (49.67)	13 (27.08)	3	<0.001
	Crescent	24 (15.69)	25 (52.08)		
	Cup	28 (18.3)	3 (6.26)		
	Other shape*	25 (16.34)	7 (14.58)		
Eyelids color	Unpigmented	149 (97.39)	2 (4.2)	1	<0.001
	Pigmented	4 (2.61)	46 (95.8)		
Muzzle color	Unpigmented	138 (90.2)	1 (2.08)	1	
	Pigmented	15 (9.8)	47 (97.92)		<0.001

The values outside the brackets represent the number of cattle. The values inside the brackets represent the frequencies (%). Fawn* = ginger fawn, wheaten fawn, red fawn; Other color* = piebald-black, black, white, grey, sand; df = degree of liberty; p = probability; Other shape* = crown, back; Bi-colour* = black and white; unicolour* = black, white; T. system = traditional system; % = percentage.

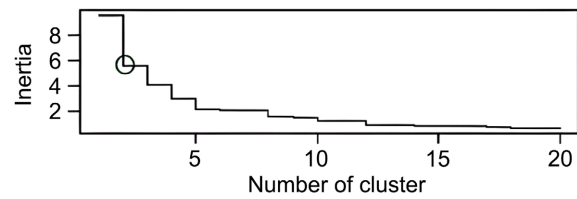


Figure 5. Determanation of optimal group.

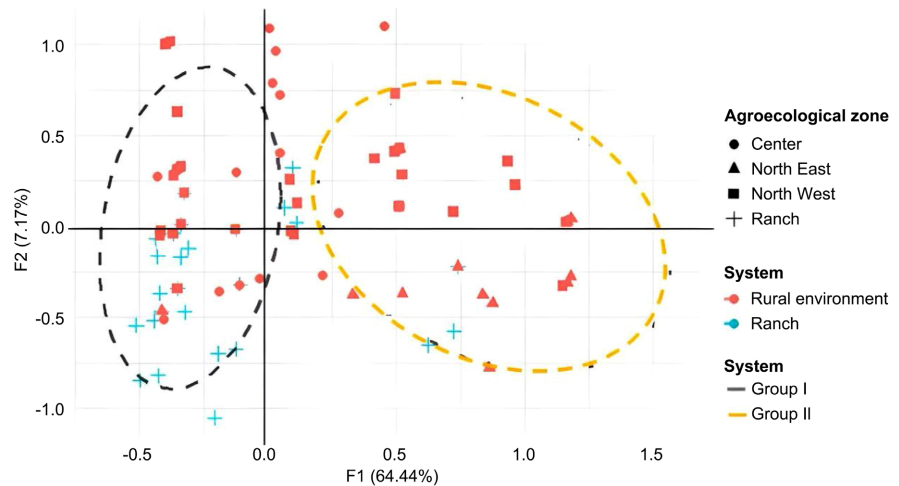


Figure 6. Projection of individual groups into the MCA plane (F1; F2).

4. Discussion

The N'Dama described in these two types of exploitation (extensive and traditional), shows similarities in the distribution of morphological traits with its congeners described in Côte d'Ivoire [5] [9] [14], Senegal [15] [16], and Congo [17]. Indeed, these authors have shown that the N'Dama has variable characteristics, but some of which appear more frequently. According to these authors, the N'Dama has frequently a fawn-colored coat, horizontal ears, lyre-shaped horns and an unpigmented muzzle. Variations in these traits depend on several factors such as genetic factor, environmental and herders' preferences [18]-[20]. The N'Dama on the ranch has only a fawn-colored coat, a straight back and horizontal ears. This similar appearance of coat colour is initially the consequence of selection pressure and the application of the closed-core selection scheme undertaken at the ranch since its creation; the fawn-colored coat being part of the selection criteria [14]. On the other hand, the first nucleus N'Dama cattle at the Marahoué ranch came from Guinea (Figure 7). These animals are known for their distinctive fawn-colored coat [21]. In the farming system, we find the N'Dama with a fawn-coloured dress and those with another colors (white, sand and black). The N'Dama coat color can be very dark, up to and including solid black, piebald black, fawn, but very rarely completely white [9] [17]. This variability in coat color has also been highlighted by other authors in rural [22] and controlled environments [16]. The coat color, mucous membranes, and other body parts of cattle are determined by complex molecular mechanisms involving multiple genes and their

interactions [19] [23] [24]. The synthesis of pigments responsible for coat color, for example, are regulated by several genes. The most important being the melanocortin 1 receptor gene (MC1R) and the agouti signaling protein gene (ASIP) [23] [25] [26]. Activation of the MC1R gene promotes the production of eumelanin, leading to dark coat colors. Conversely, inactivation or mutation of this gene can result in increased production of pheomelanin, leading to light coat colors [23] [27]. Although specific studies on MC1R and ASIP gene polymorphisms in the N'Dama breed are limited, it is likely that the coat color diversity observed in this breed can also be explained by variations in these genes. Indeed, Kunene *et al.* [25] and Wang *et al.* [26] demonstrated through transcriptomic analyses that MC1R genes are highly expressed in dark-coated Nguni and Angus cattle, whereas the ASIP gene is more expressed in brown-coated individuals. Almathen *et al.* [27] also showed that a mutation in the coding region of the MC1R gene is associated with the white coat color observed in dromedaries, while a single base pair deletion and a SNP in exon 2 of the ASIP gene are associated with both black and dark brown coat colors. In the Kolda region, white-coated N'Dama cattle represented 20.17% of the study population [28], a proportion significantly higher than that observed in the present study. According to Gueye *et al.* [22], the presence of white or light-grey coats in N'Dama cattle is associated with Zebu blood introgression; an observation later confirmed by MacHugh *et al.* [29]. Through molecular characterization, these authors demonstrated that N'Dama cattle from Kolda exhibit a higher level of Zebu gene introgression compared to those from Guinea. In contrast, several studies have reported the absence of white coat color in N'Dama populations from Côte d'Ivoire [5] [9] [14]. Furthermore, traditional breeders involved in this study are known for their crossbreeding practices [30]. The presence of white and rare coat colors observed in the local farming systems can be explained by the introgression of the zebu gene, but this remains to be verified by molecular analysis. In traditional farming systems, the N'Dama breed has an equal proportion of individuals with pigmented and non-pigmented muzzles. At the ranch, most cattle have non-pigmented muzzles (91.5%). In Congo on the Abo cattle ranch, Akouango *et al.* [17] describe the N'Dama as having an almost black muzzle in all subjects. In Côte d'Ivoire, Gbodjo *et al.* [9] observed clear mucous membranes in 97.4% of N'Dama cattle. In Senegal, Kanh [31] observed pigmented mucous membranes in 60.92% of subjects, compared with 30.58% with clear mucous membranes. The variation in muzzle color frequency distribution is well known [14] [32]. Like coat color, the variation observed in the frequency distribution of muzzle color in cattle has a genetic origin [33] [34]. The genetic structure of these different N'Dama populations, based on the genes involved in muzzle pigmentation, could therefore explain this variation. The phenotypic structure analysis of the N'Dama cattle in this study allowed us to identify two groups. The study of the effect of the farming system on the formation of these groups revealed a highly significant influence ($p < 0.001$). The selection program implemented at the Marahoué ranch may be the cause of this effect. Varia-

bles related to muzzle color (30%) and eyelid color (33%) contributed most to the discrimination between the two populations. The first group, composed mainly of cattle from the ranch, is characterized by light-colored mucous membranes. The main genes responsible for coat color in cattle are the same ones involved in muzzle pigmentation [23] [27] [33] [34]. Perhaps by selecting fawn-colored cattle at the Marahoué ranch, individuals with light muzzles were indirectly selected. Further genetic studies may confirm this hypothesis. Although the farming system influences the structure of the N'Dama population, neither system is specific to a single group. This may be due to the fact that N'Dama cattle from the ranch are distributed to farmers in rural areas to improve the national herd.



Figure 7. N'Dama herd at Marahoué Ranch.



Figure 8. N'Dama in farming system.

5. Conclusion and Outlook

This study has shown that the N'Dama of Côte d'Ivoire frequently has a fawn-colored coat, horizontal ears, lyre-shaped horns and an unpigmented muzzle. There is little variability in morphological traits in the N'Dama cattle on the Marahoué ranch, unlike those on the farm (**Figure 8**). The N'Dama cattle population on the ranch tends to be homogenized. The tawny coat color, horizontal ears and straight topline are the traits for which it expresses a single phenotype. The N'Dama bulls on the Marahoué ranch are a small population of animals that have been preserved from interbreeding with trypanosensitive breeds. However, there are no major differences between these animals and those from the farming environment. A molecular characterization study is needed to refine our conclusion as to the genetic purity of the N'Dama from both systems.

Acknowledgements

The authors would like to thank the IAEA for their financial support. They would also like to thank the Marahoué Ranch and Peleforo Gon Coulibaly-Korhogo University in Côte d'Ivoire for their cooperation and scientific and technological contributions.

Author's Contribution

AMDA: Documentary research, data collection, statistical analysis and writing of the article. KHMK: Data collection, statistical analysis and writing of the article. FDAY: Data collection. UBT: Data collection. KEN: General supervision of the writing of the article corrections and amendments.

Conflicts of Interest

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

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