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Primary morphological characterization of West African dwarf (Djallonké) ewes from Côte d'Ivoire based on qualitative and quantitative traits

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Phenotypic characterization is used to identify and document diversity within and between distinct breeds, based on their observable attributes. Study to assess the body characteristics and variability of 204 Djallonké (West African dwarf) ewes was conducted in three agro-ecological zones (central, western and northern) of Côte d'Ivoire, from November 2016 to April 2017. Animals were described using visual appreciation of the body hair coat (colour type and pattern), hair length, ear orientation, tail type and the facial (head) profile. The linear body measurements, such as ear and tail length, muzzle length and width, height at wither, chest depth, and chest girth were also described. The data collected were subjected to principal component (PCA) and discriminant analysis. Results showed that the most common Djallonké ewes had erected ear (87.25%), thin tail and straight face. The dominant colour pattern of the body hair coat was patchy (64.22%) followed by plain (32.84%) and spotted (2.94%). The agro-ecological zone had a significant (p<0.01) effect on some linear body measurements (muzzle length, ear length and height wither). Based on PCA performed with all the above morphological variabilities, we were able to segregate the Djallonké ewes' into three clusters (I, II and III). Discriminant analysis revealed that 76.27% sheep of cluster I, 92.80% sheep of cluster II and 90% sheep of cluster III were correctly classified in their original cluster. This result indicated that Ivorian Djallonké sheep population comprises of three well characterized morphological types of animals. This information could constitute a basis for further characterization and development of conservation strategies for Djallonké sheep breeding in Côte d'Ivoire.

Key words: Local, sheep, breed, morphological, variability, West Africa.

INTRODUCTION

West African sub region has a large variety of Animal Genetic Resources (AnGR) that provides food, fibre, transport, fuel, manure and draught power to people. They are important in terms of economic, food, social, religious and cultural values (Boutrais et al., 2014; FAO, 2015; Hounet et al., 2016). However, most West African countries like Côte d'Ivoire are yet to attain self-sufficiency in animal protein production. Therefore, there is a need to increase animal production as the demand for animal protein is increased in Sub-Saharan Africa (SSA), especially in West Africa. (Pangui and Kaboret, 2013).

Djallonké sheep are one of the local breeds of West Africa that play a major role in the maintenance of rural populations living and of major cultural importance due to their traditional use in rites and celebrations (OCDE/CEDEAO (2008). The Djallonké sheep genetic resources in West Africa possess important adaptive traits which make them to cope with harsh agro-pastoral production systems such as lack of quality fodder and disease mainly Trypanosomiasis and ticks (Ammar, 2013; Touré et al., 2014; Acapovi-Yao et al., 2016; Biguezoton, 2017; Diaha-Kouamé et al., 2018). However, the genetic diversity exists between and within breeds which can provide the raw materials for breed improvements and for the adaptation of the populations to changing environments and changing demands (FAO, 2015).

In Côte d'Ivoire, Djallonké sheep have been the subject of genetic improvement studies and zootechnical parameters analysis (SODEPRA, CNO and PNSO) (MIRAH-DPE, 2013). Due to their small body size, they are used in crossbreeding particularly with the Sahelian sheep in different breeding systems (Yapi-Gnaoré, 1992).

However, the introgression of different genes into Djallonké could lead to a serious threat to this AnGR and lead to the loss of some of their adaptive traits. Thus, finding Côte d'Ivoire Djallonké sheep's genetic characteristics would be a huge challenge that we will have to face to set up the genetic improvement of this Ivorian sheep breed.

According to FAO (2013), the development of conservation and production programs requires the implementation of the management strategies and more information about animal genetic resources. The present study aimed to describe the physical and morphological characteristics of the Djallonké sheep breed from three agroecological zones of Côte d'Ivoire.

MATERIALS AND METHODS

Area selected for the study

The study was conducted in seven administrative localities including three in the northern region (Korhogo, Boundiali and Odienné), two in the central region (Bouaké and Toumodi) and two in the western region (Touba and Sipilou) of Côte d'Ivoire (Figure 1).

The northern region is characterized by grassy and wooded savannah vegetation. It is located at 9°30′ North latitude and 5° 30' West longitude).This region has a Sudanese climate, with an annual average warm temperature from 20 to 35°C and a high rainfall of 1500 to 1600 mm. The climate of Sudanese region is divided into two seasons, the rainy from June to October and dry season from November to May (Touré, 1997; MIRAH-DPE, 2013).

The Central region is located at 7°41'37" North latitude and 5°16'36" West longitude. The annual mean temperature and rain fall range from 14 to 39°C and 1200 to 1600 mm, respectively. This central region has a tropical climate with four seasons; a long dry season from December to May and a short dry season from July to October as well as a long rainy season from May to July and a short rainy season from October to November (Eroarome, 2009). The central region is covered by a pre-forest savannah with trees grouped into small forest Island and with galleries of forest in the lowlands.

The Northwest Region is located at 7°55'0" North latitude and 8°4'60" West longitude. It has a Sudano Guinean climate characterized by an annual average temperature and rain fall that range from 20 to 26°C and 1127 to 2400 mm, respectively. This climate has two vegetation including a dense forest and transitional vegetation between forest and savannah, with two seasons; a long wet season from April to October and a dry season from November to March (Viennot, 1983; Eroarome, 2009).

Farm sampling and data collection

Farm sampling

The selected farms were chosen based on an investigative survey on the five (5) important livestock regions (North, Central, West, East and South) of Côte d'Ivoire and discussions with local livestock extension officers and researchers. The discussion aimed to identify the regions where pure Djallonké breed can be found. Based on the outcome, three important regions were selected: the northwest region which is one of the major sheep breeding regions in Côte d'Ivoire, the Central region, where Djallonké sheep breeding has been developed through different national livestock project such as SODEPRA, CNO and PNSO, and the North region which accounts for more than 75% Ivoirian livestock farming (MIRAH-DPE, 2013; Eroarome, 2009). Since the objective of the study was to describe the pure Djallonké sheep breed, 19 farms dealing with pure Djallonké sheep breed and using no others sheep breed in their reproduction system were purposely selected. In these farms, the flock size ranged from 25 to 70 animals which were either raised on fenced natural pastures where they grazed day and night or herded by day and kept in pens at night. The animals had access to mineral salt licks and were dipped or sprayed 2 to 4 times a month.

Data collection

From November 2016 to April 2017 data on qualitative and quantitative morphological traits of 204 Djallonké ewes were collected on 19 traditional farms. For the purpose of even comparison, only animals within the age range of 2 to 6 years were considered. In each farm, the morphological measurements taken on each animal were those advocated by FAO for breed characterization according to the DAD-IS programs (FAO, 2013).

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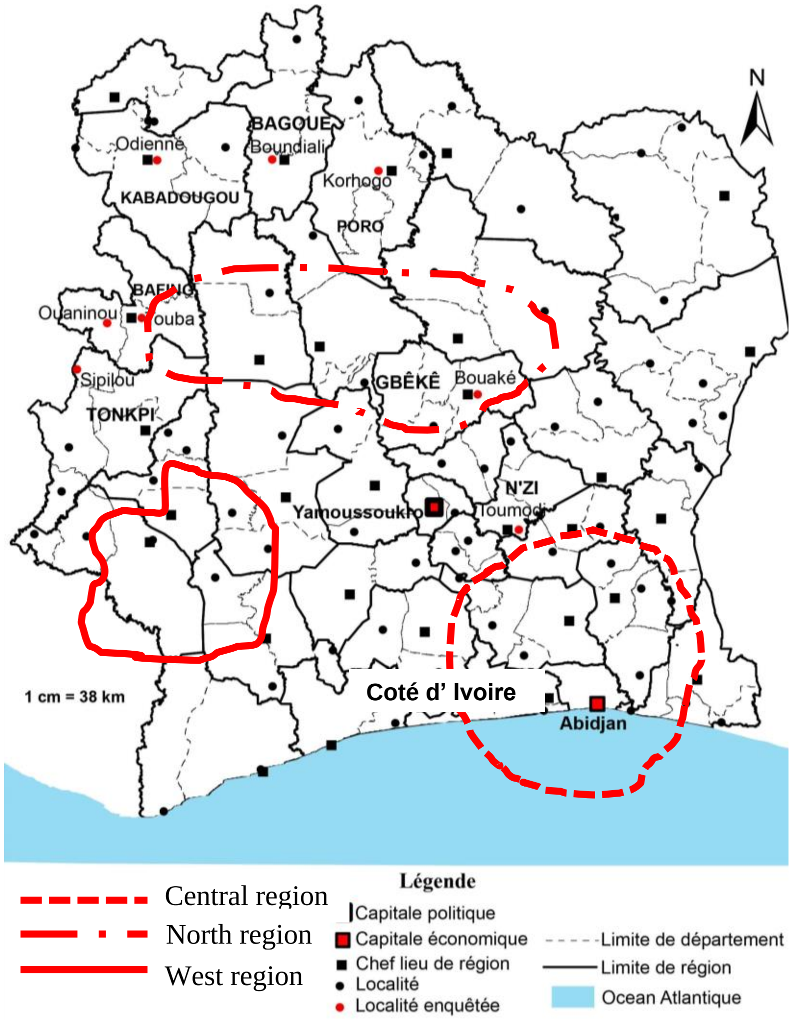

Figure 1. Map of study region. Source: Zouhoula et al. (2018).

The qualitative characters such as colour type and colour pattern of the body hair coat, hair length, ear orientation, tail type and facial (head) profile were recorded based on subjective visual observation. The quantitative morphometrical characters were obtained by measuring the animals with a tape calibrated in centimetres (cm) after restraining and holding them in an unforced position. All measurements were taken by the same team on all farms. The linear body measurements taken were muzzle length (CC), muzzle width (AC), tail length (LQ),ear length (LO), height at wither (HG), chest depth (PT), chest girth (Pt), and body length (LC). The age of the animals was estimated by dentition method suggested by Charray et al. (1992).

Statistical analysis

Descriptive statistics were used to analyse the phenotypic characterization data. Discrete measurement on the form and appearance of the investigated animals was analysed using the frequency procedure of χ^2 test (chi-square test) at 95 % confidence level. Quantitative linear body measurements were analysed using the generalized linear model procedures. Agro-ecological zones were fitted as fixed independent variables, whereas linear body measurements were fitted as dependent variables. Thus, agro-ecological effects on body measurements were assessed using ANOVA. Means were separated using Duncan's multiple range test procedure and values were considered significant at $p<0.05$. To determine the major quantitative variables in the morphological variability and the Pearson's coefficients of correlation (r) between them, principal component factor analysis (PCA) was used. The obtained result was then used to perform the Hierarchical cluster analysis which would allow the construction of the dendrogram and the determination of the Euclidean distances between populations derived from linear body measurement. The different identified cluster sheep were subjected to the discriminant analysis in order to evaluate their differentiation. All analyses were done using XLSTAT 2015.4.01 (Addinsoft, 2015), SPSS (2011) and STATISTICA 7.1. (StatSoft, 2005)

RESULTS

Phenotypic characterization

Qualitative characters

The results of the qualitative characters of all female

Table 1. Percentage values for some morphological qualitative traits observed in Djallonké ewes breed of three agro-ecological zones.

Discrete variable	Trait	Zone 1 (n = 70)		$χ^2$	p	Zone 2 (n = 75)		$χ^2$	p	Zone 3 (n = 59)		$χ^2$	p	TOTAL (n = 204)		$χ^2$	p
		N	%			N	%			N	%			N	%		
Colour pattern of the body hair coat	Plain	9	13	64.66	<0.001	42	56	1.08	0.29	24	41	1.37	0.24	75	37	100.4	<0.001
	Patchy	55	78	-	-	33	44	-	-	35	59	-	-	123	60	-	-
	Spotted	6	9	-	-	0	0	-	-	0	0	-	-	6	3	-	-
Colour type of the body hair coat	White	15	21	35.43	<0.001	26	35	42.6	<0.001	7	12	72.73	<0.001	48	24	186	<0.001
	Black	8	12	-	-	2	3	-	-	6	10	-	-	16	8	-	-
	Fawn	8	11	-	-	0	0	-	-	3	5	-	-	11	8	-	-
	Black + white	32	46	-	-	38	63	-	-	43	73	-	-	113	55	-	-
	White + fawn	7	10	-	-	9	12	-	-	0	0	-	-	16	18	-	-
Hair length	Short	22	31	0.46	0.79	6	8	34.16	<0.001	6	10	21.59	<0.001	32	17	41.06	<0.001
	Medium	27	39	-	-	47	63	-	-	35	60	-	-	109	53	-	-
	Long	21	30	-	-	22	30	-	-	18	30	-	-	61	30	-	-
Ear orientation	Semi-pendulous	0	0	-	-	26	35	7.05	0.008	0	0	-	-	26	13	113.3	<0.001
	Erected	70	100	-	-	49	65	-	-	59	100	-	-	179	87	-	-
Tail type	Thin	70	100	-	-	75	100	-	-	59	100	-	-	204	100	-	-
Facial (head) profile	Straight	70	100	-	-	75	100	-	-	59	100	-	-	204	100	-	-

Zone 1 = northwest region of Côte d'Ivoire, Zone 2 = central region of Côte d'Ivoire, Zone 3 = north region of Côte d'Ivoire.

Djallonké sheep raised in the three agro-ecological zones (west, central and north regions of Côte d'Ivoire) are presented in Table 1.

The colour pattern of the sheep's body hair coat observed in the three agroecological zones was plain (37%), patchy (60%) and spotted (3.94%) (Figure 2). The tail type and facial (head) profile of Djallonké sheep in the three agro-ecological zones were thin and straight, respectively. The colour type of the body hair coat of Djallonké ewes breed was black and white for 55%, white for 24%, white and fawn for 18%, fawn and black for 8%. Most of Djallonké sheep had erected ear (87%) versus semi-pendulous (13 %). Medium hair length was observed for 53% of the sheep. Long and short hairs were noticed, respectively for 30 and 17% of the sheep population.

Morphometrical characterization

Means for body measurements are presented in Table 2. The overall average of CC, AC, LQ, LO, HG, PT, Pt and LC of sampled Djallonké ewes was 14.03, 8.05, 24.66, 10.38, 59.56, 33.3, 70.80 and 57.77 cm, respectively.

In the agro-ecological zone 1, the coefficient of variation of the different measurements was observed bet 7.69% (Pt); in the agro-ecological zone 2 this coefficient of variation varied from 7.32% (HG) to 15.44% (LQ). In the last one (zone 3), this coefficient of variation was found between 6.57% (HG) and 15.79% (AC). The data showed that the agro-ecological zone significantly affected ($p<0.01$) the CC, LO and HG of the sheep but had no effect on AC, LQ, PT, Pt and LC characters. These underlined certain heterogeneity among the Djallonké sheep raised in the three agro-ecological zones.

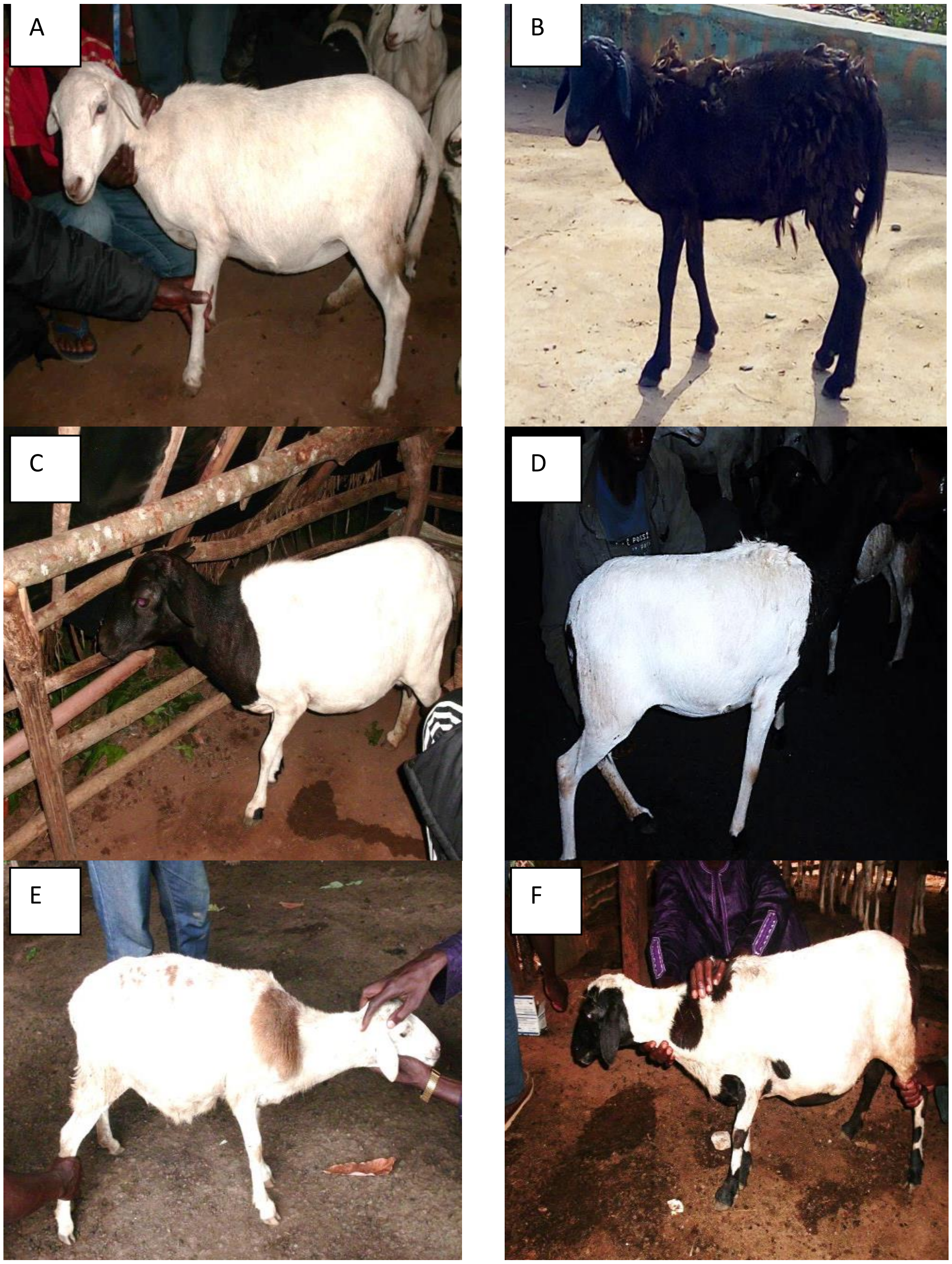

Figure 2. Different colour pattern of the Djallonké ewes body hair coat. a and b (white and black); c and d (patchy black-white); e and f (white spotted of fawn and white spotted of black).

Multivariate analysis

Correlation between body measurements

Pearson's correlation coefficients between all pairs of the various body traits of Djallonké sheep according to PCA are shown in Table 3.

One can see that the significant correlations between the linear body measurements are positive. In addition some values are found to be higher than 0.3. Indeed, a positive correlation was observed between HG, PT, Pt and LC. The LC character correlated with four other linear body measurements such as CC, AC, LQ and LO. The PT and Pt correlated with CC and AC, while HG correlated with CC and LQ. A significant correlation was also noticed between CC and AC.

Morphological variability

Results of the factor and communality of the body measurements of Djallonké sheep breed are reported in

Table 2. Average values (cm) of quantitative morphometrical traits of Djallonké ewes (means ± SD; N = 204).

Trait	Zone 1 (n = 70)		Zone 2 (n = 75)		Zone 3 (n = 59)		Overall means	Fisher test	SIG
	M ±SD	CV (%)	M ±SD	CV (%)	M ±SD	CV (%)	204		
CC	13.7^b ± 1.7	12.2	14.6^a ± 1.7	11.7	13.8^b ± 1.5	10.9	14 ± 1.7	7.057	**
AC	8 ± 1	11.9	8.1 ± 1	12.5	8.1 ± 1.3	15.8	8.1 ± 1.1	0.31	NS
LQ	24.3 ± 3.4	14	24.5 ± 3.8	15.5	25.3 ± 2.9	11.4	24.7 ± 3.4	1.305	NS
LO	10.8^a ± 1.8	16.7	10.1^b ± 1.1	10.9	10.2^b ± 1.1	10.9	10.4 ± 1.4	4.57	**
HG	56.1^b ± 5.6	9.9	60.9^a ± 4.5	7.3	62^a ± 4.1	6.6	59.6 ± 5.4	28.54	***
PT	33.3 ± 2.7	8.2	33.8 ± 3.5	10.2	32.6 ± 2.6	7.9	33.3 ± 3	2.397	NS
Pt	70.8 ± 5.5	7.7	70.4 ± 8.3	11.8	71.3 ± 5.1	7.1	70.8 ± 6.5	0.314	NS
LC	57.8 ± 6.2	10.7	57.5 ± 5.6	9.7	58.1 ± 4.1	7.1	57.8 ± 5.4	0.166	NS

CC : Muzzle length, AC : Muzzle width, LQ : Tail Length, LO : Ear Length, HG : Height at wither, PT : Chest depth, Pt : Chest girth, LC : Body Length, ^{a,b} Means across column between zones with different superscript letters are significantly (P<0,05) different. M = Means, SD = Standard Deviation, CV = Coefficients of Variation, zone1 = agro ecological zone of Central of Côte d'Ivoire, zone2 = agro ecological zone of north, zone3 = agro ecological zone of north-west of Côte d'Ivoire, SIG = Signification level: NS = Not Significant; * p<0.05; ** p<0.01; *** p<0.001.

Table 3. Pearson's correlations among measurements of ewes Djallonké breed populations.

	CC	AC	LQ	LO	HG	PT	Pt	LC
CC	1	-	-	-	-	-	-	-
AC	0.2*	1	-	-	-	-	-	-
LQ	0.13	0.18	1	-	-	-	-	-
LO	0.02	0.03	0.35**	1	-	-	-	-
HG	0.44**	0.18	0.37**	0.06	1	-	-	-
PT	0.39**	0.41**	0.12	0.03	0.25**	1	-	-
Pt	0.39**	0.41**	0.14	0	0.22*	0.76**	1	-
LC	0.39**	0.23**	0.29**	0.29**	0.24**	0.52**	0.46**	1

**Highly significant (p<0.01); *significant (p<0.05), CC : Muzzle length, AC: Muzzle width, LQ : Tail Length, LO : Ear Length, HG : Height at wither, PT : Chest depth, Pt : Chest girth, LC : Body Length.

Table 4. Eigenvalues and percent of total variance along with factor loadings and communalities of the body measurements of three Djallonké ewes breed populations.

Variable	F_1	F_2	F_3	Communality
CC	-0.643	-0.069	-0.466	0,550
AC	-0.555	-0.188	0.200	0,603
LQ	-0.433	0.679	-0.050	0,633
LO	-0.221	0.731	0.437	0,505
HG	-0,542	0.268	-0.664	0,620
PT	0.804	-0.341	0.200	0,617
Pt	-0.785	-0.367	0.186	0,647
LC	-0.727	0.151	0.230	0,735
Eigenvalue	3.04	1.38	1,02	-
Explained variance (%)	38.03	17.26	12.02	-
Cumulative variance (%)	38.03	55.3	68.04	-

CC : Muzzle length, AC : Muzzle width, LQ : Tail Length, LO : Ear Length, HG : Height at wither, PT : Chest depth, Pt : Chest girth, LC : Body Length. Bold values are more associated with the factor.

Table 4. The Kaiser-Meyer-Olkin, which measures the suitability of the sample collection, was equal to 0.69.

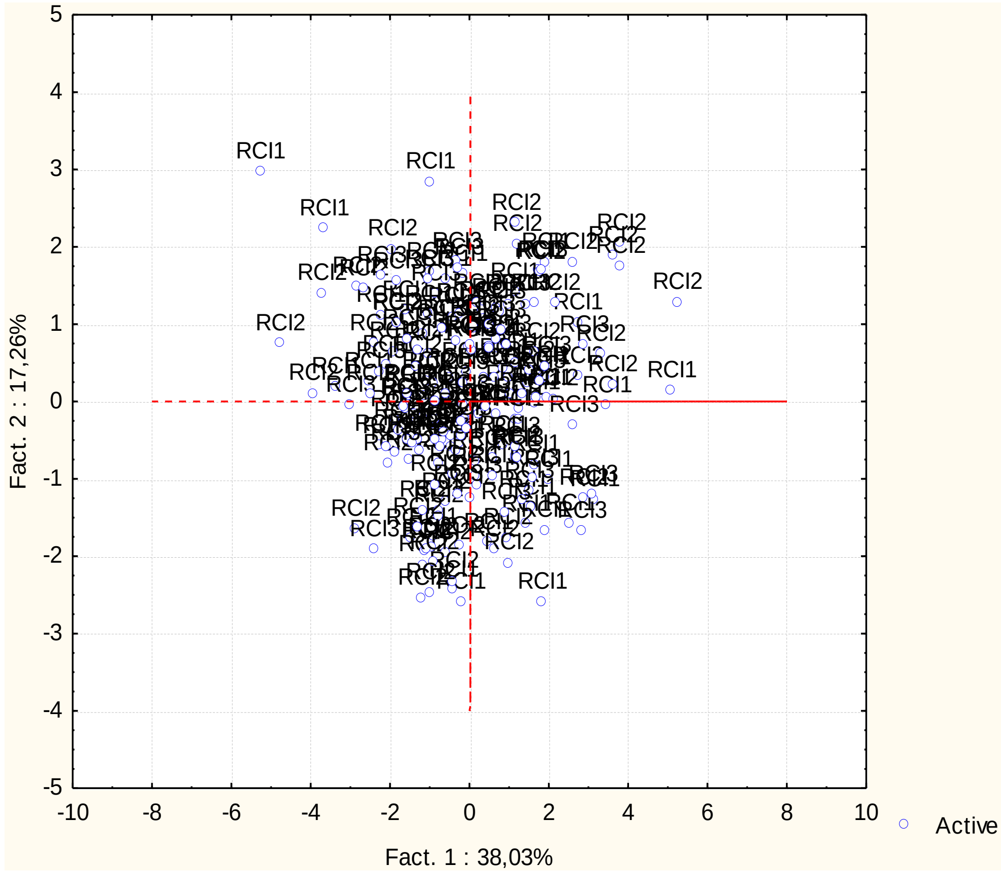

Figure 3. Bi-dimensional representation of individuals of the three agro-ecological zones Djallonké sheep according to PCA for the quantitative traits. RC1 (zone1) = agro-ecological zone of central of Côte d'Ivoire, RC2 (zone2) = agro ecological zone of north of Côte d'Ivoire, RC3 (zone3) = agro ecological zone of west of Côte d'Ivoire.

This value confirmed that the proportion of the variance in difference measurements was caused by the underlying factors. Three factors with eigenvalues superior to 1 were observed (Table 4). They explained 68.04% of total variance. The first factor explained 38.04% of variability, and loadings were negatively high for CC, AC, HG, Pt and LC but positively high for PT. The second factor described 17.26% of the total variability, and loadings were positively high for LQ and LO. The third factor defined 12.02% of variability. It was represented by a significant negative high loading for HG. Likewise, variables communalities, which represent the proportion of variance of each of the eight (8) variables shared by all remaining body measurements, were medium to high. They varied from 0.505 to 0.735 (Table 4).

Animals' plot in bi-dimensional presentation (F_1-F_2), according to PCA, accounting for 50.96% of the total variability, explains better the Djallonké sheep's morphometrical variability (Figure 3). The bi-dimensional presentation of individuals showed that the animals were not separated based on the three agro-ecological zones which were previously found to have a significant effect on the Djallonké sheep's body measurements.

Identification of the Djallonké sheep groups using hierarchical cluster analysis (HCA)

On the basis of the eight (8) major quantitative morphological variables, the cluster analysis revealed the formation of three distinct clusters (Figure 4).

The comparison of the quantitative morphological traits of the three Djallonké ewes clusters is shown in Table 5.

Animals from cluster I are characterized by a smaller size (Figure 2F). The second cluster shows a medium size (Figure 2A and E), with an average HG significantly higher than the data from the others. Except their HG, the cluster III body size is significantly bigger (Figure 2D) than the two previous clusters (Table 5).

The canonical discriminant analysis of the three Djallonké sheep clusters generated two statistically significant ($p<0.05$) canonical variables (axe1 and axe2) that accounted for 75.1 and 24.9% of the total variability, respectively. Lambda-Wilk test (Table 6) obtained by

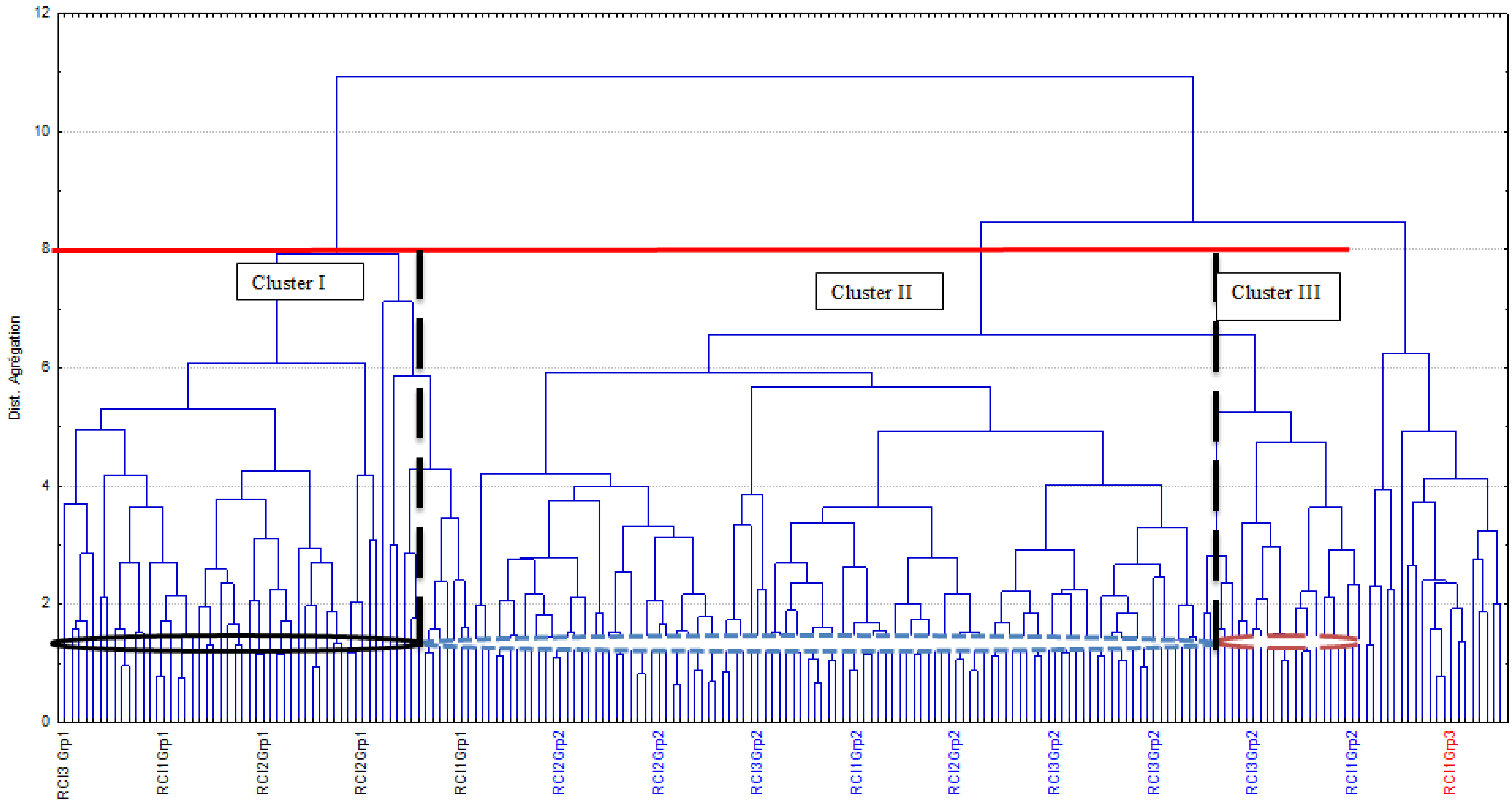

Figure 4. Unweighted pair-group method with arithmetic averaging dendrogram based on 204 ewes population Euclidean differences derived from morphological variables.

discriminant analysis indicated that seven (7) of the eight (8) variables had a most discriminant power. Therefore, these seven (7) variables (CC, AC, LQ, LO, HG, Pt and LC) could be used to differentiate the three Djallonké sheep clusters. Djallonké sheep' plot in bi-dimensional presentation (F_1-F_2) according to discriminant analysis is shown in Figure 5.

The discriminant analysis used to determine the percentage of sheep correctly grouped into their own cluster is presented in Table 7. The analysis revealed that 76.27, 92.80 and 90% of the sheep

Table 5. Arithmetic means for morphological traits of the three Djallonké sheep clusters.

Variable (cm)	Cluster I (n = 59)		Cluster II (n = 125)		Cluster III (n = 20)	
	M ±SD	**CV (%)**	**M ±SD**	**CV (%)**	**M ±SD**	**CV (%)**
CC	12.46^{c} ± 1.31	11.51	14.67^{b} ± 1.40	9.54	14.78^{a} ± 1.19	8.05
AC	7.48^{c} ± 1.07	14.3	8.28^{b} ± 0.99	11.96	8.5^{a} ± 0.69	8.12
LQ	23.61^{c} ± 3.3	14	24.64^{b} ± 3.13	12.7	28.37^{a} ± 3.34	11.77
LO	10.37 ± 1.58	15.24	10.08 ± 1.03	10.22	12.35 ± 1.22	9.89
HG	56.27^{c} ± 5.11	9.08	61.17^{a} ± 4.38	7.16	60.32^{b} ± 7.13	12.82
PT	31.3^{c} ± 2.77	8.85	33.9^{b} ± 2.44	7.2	36.22^{a} ± 2.32	6.41
Pt	65.42^{c} ± 6.96	10.64	72.47^{b} ± 4.65	6.42	76.83^{a} ± 4.96	6.46
LC	53.55^{c} ± 4.25	7.94	58.28^{b} ± 3.44	5.9	67.25^{a} ± 5.14	7.64

CC : Muzzle length, AC : Muzzle width, LQ : Tail Length, LO : Ear Length, HG : Height at wither, PT : Chest depth, Pt : Chest girth, LC : Body Length, M = Means, SD = Standard Deviation, CV = Coefficients of Variation, different superscripts within a row indicate significantly different means (P<0.05).

Table 6. Raw canonical coefficients of canonical discriminant function.

Variable	WILK (Lambda)	Partial (Lambda)	Eigenvalue axe 1	Eigenvalue axe 2	Fisher test	SIG
			1.616	**0.536**		
CC	0.296	0.841	0.398	-0.484	18.302	0.000***
AC	0.257	0.967	0.157	-0.250	3.303	0.039*
LQ	0.26	0.956	0.206	0.280	4.451	0.013**
LO	0.284	0.875	0.143	0.597	13.798	0.000***
HG	0.263	0.947	0.029	-0.430	5.384	0.005***
PT	0.254	0.980	-0.128	0.321	1.980	0.141 NS
Pt	0.268	0.928	0.453	-0.250	7.562	0.001***
LC	0.326	0.764	0.629	0.271	29.982	0.000***

CC: Muzzle length, AC: Muzzle width, LQ: Tail Length, LO: Ear Length, HG: Height at wither, PT: Chest depth, Pt: Chest girth, LC: Body Length, M = Means, SD = Standard Deviation, CV = Coefficients of Variation, SIG = Signification level: NS = Not Significant; *p<0.05; **p<0.01; ***p<0.001.

of the cluster I, II and III, respectively, were correctly classified in their original cluster. Most of the misclassified cluster I was classified as sheep of cluster II (22.03%) and vice versa (6.4%). No misclassified sheep of cluster III were assigned as sheep of cluster I vice versa (1.7%). However, only 1.6% sheep of cluster III were classified as sheep of cluster II.

DISCUSSION

Here we reported the main qualitative characteristics of the North, Central and West Africa agro-ecological Djallonké dwarf sheep, they are straight facial profile (head), thin tail and erected ear. However, one can notice that Djallonké sheep from Côte d'Ivoire are different from those of Africa according to their colour pattern and body hair. These results show that most of the qualitative traits studied for the Djallonké ewes breed found in Côte d'Ivoire are consistent with those found in Togo (Dayo et al., 2015). However, the most qualitative traits of Djallonké sheep investigated in this study were different from the indigenous sheep breed in different areas of Ethiopian (Edea et al., 2010; Tibbo et al., 2004 and Melesse et al., 2013). Those Ethiopian indigenous sheep populations of different areas are characterized by three tail types (fat, thin and docked) and a countless variability of the body hair coat colour type (white, black, red, fawn, brown, roan, grey and any combinations of these colours).

The little issue during this study is that all the ewes examined have different age (from 2 to 6 years old) which could have an influence on the linear body measurements. However the effect of the age could be neglected because, of the fact that in adulthood of the ewes linear body measurement variation is not significant and in any farm the population of ewes is composed of different age. In this study the variation of the coefficients of the eight quantitative characters range from 6.6 to 16.7% indicating no important variation in the ewes

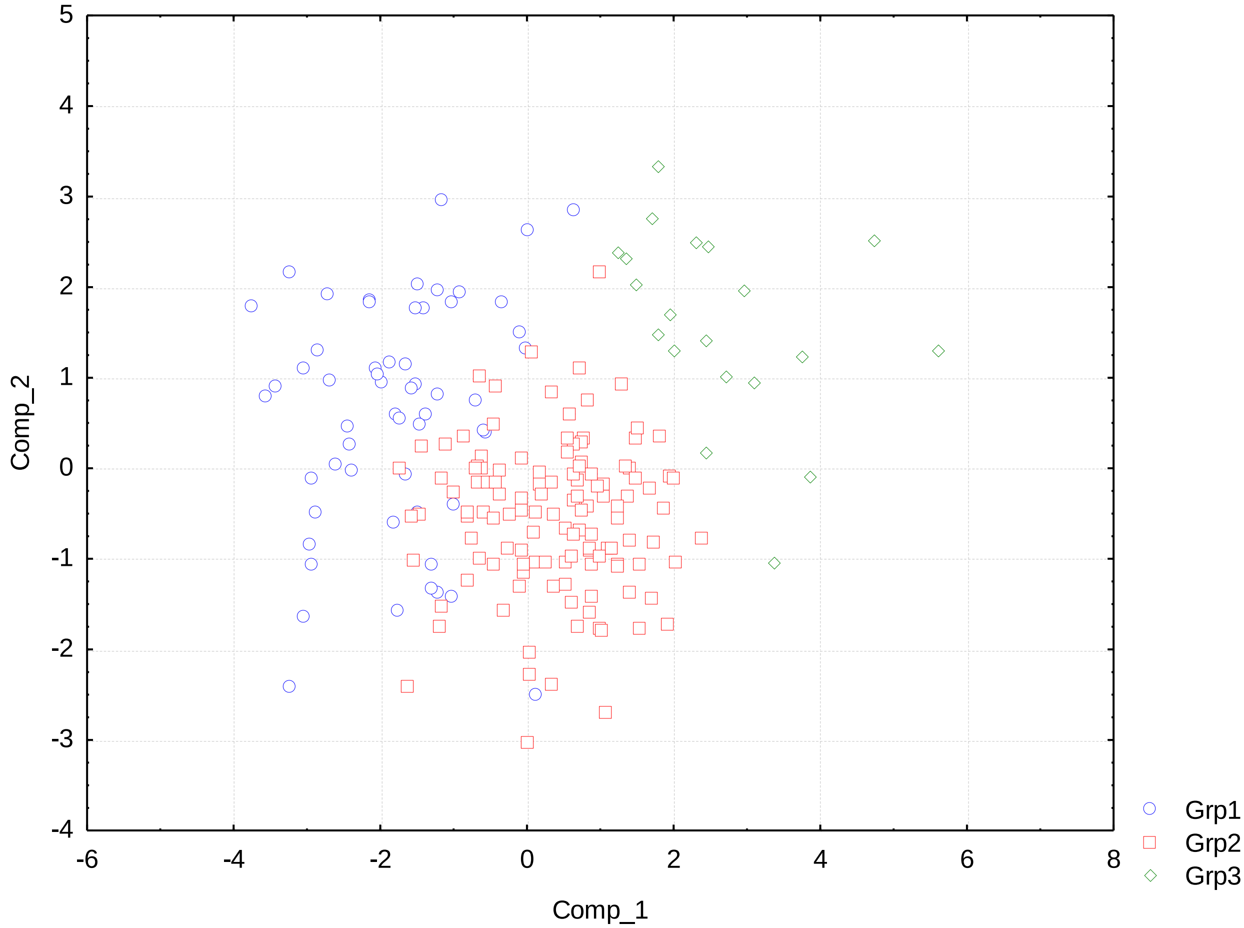

Figure 5. Bi-dimensional plot showing the associations among the clusters of the different Djallonké sheep's morphological variables.

Table 7. Percentage of animal correctly or incorrectly classified in respect with the three clusters.

Group	% de classification	Cluster I	Cluster II	Cluster III
Cluster_I	76.27	45	13	1
Cluster_II	92.8	8	116	1
Cluster_III	90	0	2	18
Total	87.75	53	131	20

analysed.

However, the values for height at withers, body length and chest girth observed–in this present study on the Djallonké ewes were comparable to those reported by Birteeb et al. (2014) for West African dwarf ewes (57.06 ± 0.28 cm, 54.87 ± 0.35 and 65.19 ± 0.41 cm) in Ghana; by Dayo et al. (2015) for Djallonké sheep (54.6 ± 8.2, 58.5 ± 6.3 and 74.72 ± 8.28 cm) in Togo and by Abegaz (2007) and Melesse et al. (2013) for indigenous ewes in Ethiopia (from 57 ± 4 to 64.8 ± 1 cm; from 46.5 ± 3.1 to 68.4 ± 1 cm and from 57.1± 4.3 cm to 65.8 ± 6.3 cm).

The height at withers of Djallonké sheep of present study was similar to those reported by Traoré et al. (2006) for Mossi sheep (59.3 ± 5.5 cm) from Burkina Faso, by Kunene et al. (2007) for ewes Zulu (Nguni) sheep (61 cm) from South Africa, as well as by Abegaz et al. (2011) for Gumuz, Horro and Menz (55 to 70 cm) ewes from Ethiopia.

Higher values for these height at withers, body length and chest girth have been reported by Yakubu and Ibrahim (2011) for Yankasa sheep (75.8 ± 0.48, 70.9 ± 0.37 and 84 ± 0.51 cm), for Uda sheep (83.9 ± 0.21, 76.6

± 0.27 and 91.8 ± 0.26 cm) and for Balami sheep (88.3 ± 0.49, 78.2 ± 0.46 and 100.3 ± 0.81 cm) found in Nigeria. Similar results were also reported by Dayo et al. (2015) for Vogan sheep (71.65±5.79, 71.02 ± 6.03 and 89.3 ± 9.25 cm), for Sahelian sheep (75.43 ± 5.43 cm, 74.83 ± 5.55 cm and 94.57 ± 8.82 cm) in Togo. Likewise, Laoun et al. (2015) reported the same observations for Rambi sheep (77.32 ± 0.12, 107.61 ± 0.25 and 91.89 ± 0.26 cm) from Algeria.

Compared to this study, results from several authors exhibited lower body measurement values for different West Africa indigenous sheep. The height at wither and body length average values for West Africa Dwarf sheep obtained in Ghana were 57.06 ± 0.28, 54.87 ± 0.35 and 65.19 ± 0.41 cm (Birteeb et al., 2014; Asamoah-Boaheng and Sam, 2016). The Ghana Djallonké sheep exhibited values of 52.7 ± 4.1 and 54 ± 4.7 cm.

In this study, the Djallonké ewes examined exhibit morphological traits superior to those reported by other authors; it suggests two major reasons; that uncontrolled crossbreeding of Djallonké sheep of the Sahelian sheep with different breeding in Côte d'Ivoire (Yapi-Gnaoré, 1992; MIRAH-DPE, 2013) had improved some morphological traits. This introgression of sahelian sheep genes with Djallonké sheep breed might explain the higher values observed compared to the indigenous ewes breed of West Africa regions and Since 1989, Djallonké rams have been involved in a selection program (PNSO) in Côte d'Ivoire (MIRAH-DPE, 2013) and the best ones are rented by the farmers to disseminate the genetic gain through the country.

The effect of the agro-ecological zone was statistically significant on CC, LO and HG but not on AC, LQ, PT, Pt and LC. This could suggest that the morphological measurements of the Djallonké sheep populations from the three agro-ecological zones were different from each other for the quantitative characters like CC, LO and HG. This indicates that the breeding area would have an impact on certain morphological measurements of the Djallonké sheep studied.

Our observations are corroborated by different works that have been reported from previous studies such as the cattle in Ethiopia (Chebo et al., 2013) and goat breeds in Ghana (Hanga et al., 2012), in Algeria (Dekhili et al., 2013) and in Morocco (Hilal et al., 2013; 2016) concluding that the morphological measurements variability observed were due to the influence of the environment. The significant morphologic correlations observed are similar with those reported by Cam et al. (2010), Lepaz et al. (2011) and Birteeb et al., 2014).

The significantly high positive correlation coefficient between morphological measurements indicated that Djallonké populations of the three agro ecological zones (central, north, west) of Côte d'Ivoire were very harmoniously conformed, thus reflecting a balanced physical development (growth) and also a good adaptation to their respective environmental conditions. A high correlation usually indicates an interrelationship between the traits and such knowledge is very useful in breeding and management practices of livestock, as it helps in making decision for the selection of the traits by discarding the negatively associated traits. Nevertheless, selection for positively or negatively associated traits is influenced by the production objectives, selection goals and even the socio-cultural demands or conditions of the farmer. Correlation among body traits equally serves as the basis for employment of further multivariate techniques (Birteeb et al., 2012; Yakubu et al., 2011; Birteeb et al., 2014) like Pincipal Component, Factor and Cluster analysis in quantifying trait variability and characterizing breeds.

In present study, the high significant KMO obtained (0.69) implied that the proportion of the variance in the body measurements caused by the underlying factors is high hence true factors existed and the data are factorable. The analysed data show that three factors explained 68.04% of total variance in Djallonké population. The KMO observed was high, but below those reported for indigenous sheep of Nigeria (0.92) (Yakubu and Ibrahim, 2011), northern Ghana (0.91) and by the Djallonké sheep in northern Ghana (0.79) (Birteeb et al., 2012). High KMO values were also reported for cattle (Pundir et al., 2011; N'Goran et al., 2015, 2018). Whereas this result was slightly lower than that of Djallonké sheep reported by Birteeb et al. (2012; 2014), and that of Uda sheep reported by Yakubu and Ibrahim (2011)

Findings in this study are in the range of those reported in Niger by Marichatou et al. (2014) extracted for goat two factors to explain 67.8 % of the total variance, but lower than those reported by Hilal et al. (2016) for the Hamra goat (73.5%) in Morocco where four factors were extracted to explain the total variance.

The communalities found in the current study showed that all the linear body measurement had high loadings on factor 1, which is a good descriptor of general body size. Factors 2 seemed to reflect the ear and tail length while factor 3 seemed to describe the height at withers of the Djallonké sheep. In respect with the Principal Component Analysis (PCA), all used variables in this study can be useful to descript the variability of the Djallonké populations from three agro ecological zones.

The similarity of the results with the other sheep breed differentiation could suggest that the three Djallonké sheep clusters might be the sheep genotype types. Furthermore the discriminant analysis that showed a high degree of correct classification of the sheep in each cluster could mean that the three Ewe clusters could establish well individualized morphological types. Thus if the three clusters were unspecific with the three agro-ecological zones of the study, this could suggest that the differentiation between these clusters would not be due to an adaptation to the breeding environment, but to the subpopulation formation hence the sheep genotype types. There might be two possible main reasons to explain this hypothesis; the Djallonké sheep' cross-breeding with the sahelian sheep in the breeding through country have generated the hybrids. Secondly, the use of improved Djallonké rams obtained from the breeding program (PNSO) in livestock farms in order to promote genetic gain has equally generated various phenotype types.

Conclusion

The present study focused on description of the qualitative characters and quantitative morphometrical traits of Djallonké sheep breed in Côte d'Ivoire. The results revealed the presence of variability in the qualitative and quantitative morphometrical characteristics among the Djallonké sheep breed population that reflect the heterogeneity of the Djallonké sheep population. Djallonké ewes can be classified into three well-characterized sub-populations. This information is quite useful in the designing of sustainable sheep improvement programs in Côte d'Ivoire. To assess the population structure of the Djallonké sheep, further molecular tools should be used to specify the genetic status of this sheep breed in Côte d'Ivoire.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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