Genetics and Biodiversity Journal

Journal homepage: http://ojs.univ-tlemcen.dz/index.php/GABJ
e-ISSN: 2588-185X P-ISSN: 2602-5582

OPEN ACCESS

Original Research Paper

Biometric Assessment of Blackbelly Sheep in Central Africa

Meka Z. II* Martin A. Tadakeng Y. Meutchieye F, Fonteh F.

University of Dschang, Faculty of Agronomy and Agricultural Sciences, Department of Animal Science, Biotechnology and Bioinformatics Research Unit, PoBox. 188. Dschang-Cameroon.

***Corresponding Author**: Meka Zibi II**. Email**: mekaarthur@yahoo.ca

Article history; Received: January 25th 2020 Revised: February 23th 2021 Accepted: March 25th 2021

Abstract

The Genetic and phenotypic characterization of the Central AfricanBlackbelly sheep was carried outfrom April 1st to November 30th2019. A total 288adults sheep were sampled in order to assess the genetic diversity of the Blackbelly population in 3 Central Africa countries (Cameroun, Congo Brazzaville and Gabon).A total of twenty-two (22) body measurements were collected with the aid of metric tools(i.e.,headlength, head width, hornlength, ear length, neck length, neck circumference, total body length, trunk length, height at withers, height at back, height at rump, chest circumference, chest depth, chest width, rump width, rump length, front leg length, rear leg length, tail length, canon bone circumference, nipple length and body weight). The latter was used to calculate twelve (12)indices (sub-sternal gracility, ear-length, format, compactness, massiveness, chest,slenderness, frame, body, dactylo-thoracic, caudal and ear) in a bid to appreciate the functional relationship between measurements. Phenotypic dimorphism ($P \leq 0.05$) has been observed between the Blackbelly sheep of different countries, with the highest and heaviest animals coming from Congo (HW= 62.217 ± 5.288 and BW = 27.44 ± 6.08kg), the longest from Gabon (TBL = 84.69 ± 8.70) and the largest (CW=15.01± 2.531 and RW=14.716 a± 2.351) from Cameroon. A perfect correlation was recorded between BW and TC. Principal Component Analysis reveals that six main components explain 73.1% of the observed variability in the body measurements of Blackbelly sheep population of Central Africa. The first two components which have eigenvalues greater than 3 and explain 25.44% (CP1) and 17.41% (CP2) of the variability in body measurements, can be considered for an improvement and selection program. Hence, the height at back and thethoracic circumference appear to be the most interesting measurements to beconsidered for the selection and conservation of the Blackbelly sheep.

Keywords: Genetic diversity,Phenotype, Blackbelly, sub-Saharan Africa

Introduction

Sheep farming is a key element in the nutritional, economic and socio-cultural security of many countries around the world. Just likemost animals in tropical Africa, sheep have to adapt to a stressful environmentwhich often results to an erosion in animal biodiversity (Wilson, 1992). There exist five common breeds of sheep in Central Africa, including the Djallonké which is found in the Sudano-Guinean zone, the Peuhl, Uda, Kirditypes which are found in the Sahelian Zones, and the Blackbelly breed that is found exclusively in the Forest Zone (Manjeliandal, 2003). This highlights the presence of a large genetic diversity which can be exploited and improved upon for better performances. Studies on these animal populations would help determine the genetic variability between these individuals and their implication in the genetic improvement of sheep breeds.

Indeed, different animal populations allow society to have a wider range of options to meet the challenges of future years (FAO, 2008). But it is true that no animal resource can be efficiently exploited without a qualitative and quantitative zoo-genetic characterization. To this end, several indicators of genetic diversity are commonly used, namely: breed inventories, inbreeding measures and genetic markers (Ollivier and Foulley, 2013). These inventories include the collection of information on each breed, fora phenotypic characterization with theaim is to assessing differences between breeds and to detect, ifpossible,the genetic origin of these differences (FAO, 2012).

These studies find their roots in population genetics which, according to Hartl and Clark (1997) is the study of the distribution and changes in the frequency of a gene (allele) in populations of living beings, under the influence of evolutionary pressures (natural selection, genetic drift, recombination, mutations, and migration). These evolutionary forces are generally the source of the variability observed within a population. In Africa, one of the greatest forces of variability is migration, which is the transfer of individuals (and thus, genes) from one population to another. While it actually decreases interspecific variability, migration has been accused for the worldwide spread of the Blackbelly sheep. Several genetic types of the Blackbelly sheep around the world have been subjected to genetic characterization and performance evaluation. However, very little is known about those in Central Africa despite the fact that their performance and qualities are appreciated by breeders around the world.The Blackbelly sheep is recognized as the main breed of sheep in Barbados (BBSAI, 2011).The American type Blackbelly sheep appears to be heavier than the Cameroonian type because the former has been subjected to various improvement programs (Speller and al., 2013).The Pelibuey sheep breed which constitutes one of the most important breeds for sheep production in Colombia and Mexico (Romualdo and al., 2004; Macedo and al., 2011) is said to have originated fromthe Blackbelly sheep (Victalinaand al., 2012). Indeed, the Blackbelly sheep which is known for its prolificity and its resistance to diseases has been widely studied in more than 26 countries in the world. Thus, its presence throughout the world highlights the importance and the interest given to this zoo-genetic resource by developed countries(Meka andal., 2019). However, the scarcity of information about this breed in its native land, the Central Africa sub-region and Cameroon in particular, is a factor hindering its efficient exploitation and thus theprofitabilityof its production.

Hence, the necessityto assess precise information on the genetic diversity of the Blackbelly sheep in Central Africa. As pointed out by Delgado and al. (2001), variationsinmorphological characteristicsarethe basis for phenotypic characterization of animal genetic resources. However, the laws of population genetics are only applicablein defining a primary breed within a context of random mating, a characteristic common in Sub-Saharan Africa (Lauvergne and al., 2011). The objective of this study is therefore to assess the morphometric and biometric variations that exist between Blackbelly sheep populations in different countries of Central Africain order to establish more adequate management and improvement models

Materials and methods

Study Area

The current study was carried out in 3 countries of the Central African sub-region (Figure 1): Cameroon, Congo Brazzavilleand Gabon. Thesecountries fall within the Sudano-Sahelian, Bimodal and Monomodal forest agroecological zones. For each of these countries, different administrative regions were sampled as study zones. In Cameroon, we have the South, the Littoral, the East, and the Central regions. In Gabon, two regions were studied;the WouleuNtem and Estuary regions. Meanwhile in Congo Brazzaville, the Kouilou and Nairi regions constituted the zone of study. The bimodal rainforest agroecological zones of these countries are characterized by 4 seasons, 2 rainy seasons and 2 dry seasons. while the monomodal zonesare characterized by 2 seasons, 1 rainy season and 1 dry season

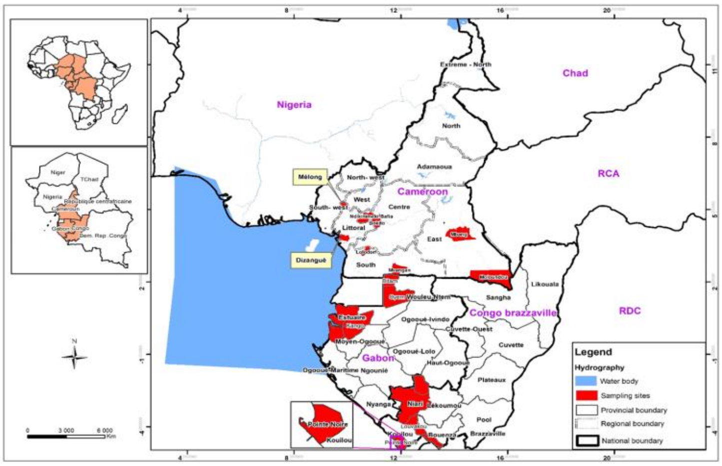

Figure 1. Study sites location

Measurement and Data Collection

This study wasbased on biometrics measurements collected from 288 Blackbelly sheep. Atotal sample of 204 females and 84 males reared in different production systems wererandomly selected. To prevent any form of bias in measurements, the animals were subjected to screening and crossbreds, pregnant and unhealthy animals were eliminated from the sample. The ageof the animals was determined by examination of dentition as well as direct interview with the owner.

A total of 22 measurements were collected on each animal according to the FAO (2013) and AU-IBAR (2015) guidelines as illustrated on the Figure 2.

Cephalic measurements:Head length (HL), Ear Length (EL),Head width (HWh), Horn Length(HLh). Body measurements: Height at withers (HW), Height at the Back (HB), Height at the rump (HR), Total body length (TBL), Neck length (NL), Trunk length (TrL), ThoracicCircumference (TC), Neck Circumference (CN), Chest depth (CD), Chest width (CW), Rump Width(RW), Rump length (RL).

Measurements of the Limbs and Extremities: Length of the front leg (LFL), The length of the hind leg (LHL), Tail length (TL), Canon bone circumference(CB), Length of the Nipple (LN), body weight (BW).

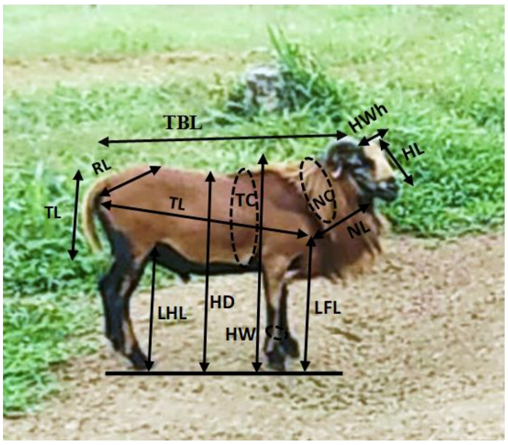

Figure 2. Some of the body measurements of Black belly in this study.

Body indices were determined from the 22 measurements following the methodologies of Victalina(2012) and Ngonoand al. (2019) in order to appreciate the functional relationship that exists betweenthe measurements. Subsequently, the following 12 indices were calculated:Substernal gracility index (SGI), Ear Length index (ELI), Format index (IF), Compactness index (CI), Massiveness index (MI), Chest index (ChI), Slenderness index (SI), Frame index (FI), Body index (BI),Dactylo-thoracic index (DTI), The caudal index (ICa), The Ear index (EI).

Statistical analyses

Descriptive statistics was used to calculate the means, standard deviations, variation coefficient ofthe different measurements as well as the indices. Analysis of variance was used to test the influence of country on body measurementswhile the t-testwas usedto evaluate the influence of sex on measurement and index.The following statistical model was adopted:

$$\mathbf{Y_{ijk} = \mu + \alpha_i + \beta_j + e_{ijk}.}$$

where:Y_{ijk} is the performance (measurement) of the kanimal ofcountry iand sex j;μis the population mean;αiis the effect of the country i (i varying from 1 to 3); βjis the effect of the sexj(j varying from 1 to 2);eijkis the residual error on the kindividual of countryiand sex j.

Duncan's Multiple Range Test was used to separate the means when the effects of the country and the sex was significant ($p \leq 0.05$). The 22 biometric measurements were subjected to Principal component analysis (PCA) in order to assess the cause of genetic variability in the studied Blackbelly population. This made it possible to determine the linear relationship that exists between these different characteristics (FAO, 2013). The overall adequacy of the Principal Component Analysis (PCA) was established by Kaiser-Meyer-Olkin (KMO) test of sampling and Bartlett's test of sphericity (Kaiser, 1960; Eyduranand al. 2010).

Based on the 22 body measurements, Discriminant Factor Analysis (DFA) was used to identify the genetic types found within the studied population (Faye, 2012; FAO, 2013) in a bid to assess and or validate the purity of this breed.The genetic relationship that exists between the different genetic types was established through Ascendance Hierarchical Clustering (AHC) (Roux,2006 and Carpentier 2007).

The different statistical analysis was carried out with the aid of the following statistical tools: SPSS 21.0 (2018), R-Software version 3.6.1 (2018) and XLSTAT 2014.

Results

Descriptive Analysis of Biometric Measurements

Tables 1, 2 and 3 present the descriptive statistics of the body measurements according to the countries studied.With respect to cephalic measurements (Table 1)the highestHWh, NL and EL were recordedfor the blackbelly population of Congo Brazzaville,meanwhile those in Gabon presented a higher HLh and CN.Only the Ear Lengthand neck circumference were influenced ($p \leq 0.05$) by countries.Ear Lengthwas significantly higher inthe blackbelly population of Congo (11.23 ± 1.16cm) compared those in Gabon (9.09 ± 1.80 cm), which presents a large dispersion value (18.96%). A statistically higher Neck Circumference (34.355 ± 8.324 cm) was obtained for the blackbelly sheep population of Gabon with a 23.10% coefficient of variation compared to its Congo Brazzaville counterparts. Analysis of variance(Table 2) reveals that, except for HWh, TC andRW, every other body measurement(TBL, TrL, HB, HR, CD, CW, RL) was influenced ($p \leq 0.05$) by the country.The highestaverage body length (84.691± 8.704cm) and trunk length (62.57 ± 5.88cm)were recorded for the Gabon population, meanwhile the highest HWh, HB, TC and CD were observed for those in Congo Brazzaville. However, the average CW, RL and RW were highest in Cameroon. With respect to the measurements of the limbs, extremities and body weights (Table 3), significant ($p \leq 0.05$) differences were observed only for LFL, TL and CB. The average LFL, LHL, CBand LN were highest in the blackbelly sheep population of Cameroon but the highest Bodyweight was recorded in favor of their Congo Brazzaville counterparts.

Table 1. Head Width,HeadLength,Horn length, Neck length, ,Circumference of neck and Ear length of Blackbelly sheep in Central Africa

	Country	n	Mean± SD	CV (%)
HWh	Cameroon	252	$10.829^{a} \pm 1.466$	13.51
	Congo	24	$11.450^{a} \pm 0.926$	7.81
	Gabon	11	$10.791^{a} \pm 1.158$	10.23
	Average	**287**	**10.880 ± 1.425**	**13.05**
HL	Cameroon	252	$18.756^{a} \pm 9.962$	53.1
	Congo	24	$17.\ 621^{a} \pm 1.736$	9.56
	Gabon	11	$16.664^{a} \pm 1.218$	6.97
	Average	**287**	**18.581 ± 9.361**	**50.37**
HLh	Cameroon	252	$4.405^{a} \pm 7.5545$	171.17
	Congo	24	$4.058^{a} \pm 8.100$	178.73
	Gabon	11	$8.009^{a} \pm 10.732$	127.76
	Average	**287**	**4.514 ± 7.7387**	**171.39**
NL	Cameroon	252	$25.167^{a} \pm 6.892$	27.33
	Congo	24	$26.867^{a} \pm 6.111$	22.58
	Gabon	11	$26.527^{a} \pm 2.355$	8.47
	Average	**287**	**25.361 ± 6.720**	**26.49**
CN	Cameroon	252	$32.282^{ab} \pm 4.574$	14.14
	Congo	24	$30.488^{a} \pm 6.018$	18.95
	Gabon	11	$34.355^{b} \pm 8.324$	23.10
	Average	**287**	**32.211 ± 4.9120**	**15.43**
EL	Cameroon	252	$9.657^{ab} \pm 1.550$	16.02
	Congo	24	$11.233^{b} \pm 1.165$	10.36
	Gabon	11	$9.091^{a} \pm 1.807$	18.96
	Average	**287**	**9.767 ± 1.594**	**16.29**

a, b: the means assigned the same letter in the same column indicate that there are no significant differences between countries ($p > 0.05$). HL = Head Length, HWh= Head Width, HLh = Horns Length, EL = Ear Length, NL = Neck Length, CN = The Circumference of the Neck

Table 2. Length of body and trunk, height at withers, back and rump, circumference, depth, width of the chest and length, width of the rump of the Blackbelly in Central Africa

	Country	n	Mean± SD	CV (%)
TBL	Cameroon	252	78.563 ^{a}± 8.982	11.41
	Congo	24	83.321 ^{ab}± 7.384	8.50
	Gabon	11	84.691 ^{b}± 8.704	9.80
	Average	**287**	**79.196± 8.988**	**11.34**
TRL	Cameroon	252	52.421 ^{a}± 10.280	19.57
	Congo	24	60.000 ^{b}± 7.431	11.91
	Gabon	11	62.573 ^{b}± 5.885	8.97
	Average	**287**	**53.444± 10.302**	**19.27**
HW	Cameroon	252	59.315 ^{a}± 7.142	12.02
	Congo	24	62.217 ^{a}± 5.288	8.18
	Gabon	11	57.855 ^{a}± 6.288	10.36
	Average	**287**	**59.502± 7.011**	**11.78**
HB	Cameroon	252	58.075 ^{ab}± 7.158	12.30
	Congo	24	59.229 ^{b}± 5.221	8.45
	Gabon	11	54.418 ^{a}± 4.992	8.75
	Average	**287**	**58.032± 6.976**	**11.88**
HR	Cameroon	252	58.897 ^{b}± 6.580	11.15
	Congo	24	58.383 ^{b}± 4.720	**7.77**
	Gabon	11	53.727 ^{a}± 3.983	**7.07**
	Average	**287**	**58.656± 6.429**	**10.94**
TC	Cameroon	252	71.508 ^{a}± 9.023	12.59
	Congo	24	72.096 ^{a}± 6.864	9.30
	Gabon	11	69.155 ^{a}± 8.397	11.58
	Average	**287**	**71.467± 8.829**	**12.34**
CD	Cameroon	252	25.919 ^{a}± 4.845	18.66
	Congo	24	36.713 ^{b}± 3.455	9.50
	Gabon	11	34.200 ^{b}± 3.806	10.61
	Average	**287**	**27.139± 5.744**	**21.15**
CW	Cameroon	252	15.016 ^{b}± 2.531	**16.82**
	Congo	24	11.804 ^{a}± 2.544	**20.75**
	Gabon	11	12.436 ^{a}± 2.045	**15.68**
	Average	**287**	**14.648± 2.697**	**18.41**
RL	Cameroon	252	20.331 ^{b}± 6.480	31.81
	Congo	24	17.517 ^{ab}± 2.409	13.21
	Gabon	11	16.164 ^{a}± 2.522	14.88
	Average	**287**	**19.936± 6.223**	**31.19**
RW	Cameroon	252	14.716 ^{a}± 2.351	15.95
	Congo	24	14.233 ^{a}± 1.876	12.73
	Gabon	11	14.155 ^{a}± 2.582	17.40
	Average	**287**	**14.654± 2.323**	**15.83**

a, b: the means assigned the same letter in the same column indicate that there are no significant differences between countries (p > 0.05). TBL = Total body length, TrL = Trunk length, HW = Height at withers, HB = Height at back, HR = Height at rump, TC = Chest circumference, CD = Depth of chest, CW = Width of chest, RW = Rump width, RL = Rump length

Correlations Between Body Measurements in Black Belly Sheep From Central Africa

As presented on Table 6, there exists significant correlations between the biometricmeasurements of the Blackbelly sheep population of Central Africa. The correlation coefficients range from -0.297 (i.e., between Neck lengthand the height at the back) to 1.00 (i.e., Thoracic Circumferenceand the Body weight). A very strong correlation (0.94) can be observed between the height at the withers and the height at the back. Body weight is significantly ($p < 0.01$) correlated with height at withers (0.72), height at the back (0.70) and Height at rump (0.66).

Table 3. Length of the front leg, Length of the hind leg, TailLength,Canon bone circumferences, Length of the nipple, Body weightof the Blackbelly in Central Africa

	Country	n	Mean ±SD	CV (%)
LFL	Cameroon	252	42.885 ^{b}± 7.405	17.23
	Congo	24	37.733 ^{ab}± 4.863	12.38
	Gabon	11	35.709 ^{a}± 2.587	6.91
	Average	**287**	**42.179± 7.346**	**17.40**
LHL	Cameroon	252	45.008 ^{a}± 7.352	16.30
	Congo	24	44.663 ^{a}± 3.988	8.65
	Gabon	11	42.255 ^{a}± 2.504	5.65
	Average	**287**	**44.874± 7.015**	**15.62**
TL	Cameroon	252	22.448 ^{ab}± 5.729	25.47
	Congo	24	24.871 ^{b}± 4.017	15.48
	Gabon	11	21.100 ^{a}± 4.021	18.17
	Average	**287**	**22.599± 5.586**	**24.70**
CB	Cameroon	252	7.823 ^{b}± 0.798	10.18
	Congo	24	7.254 ^{a}± 0.747	9.92
	Gabon	11	7.164 ^{b}± 0.815	10.85
	Average	**287**	**7.751± 0.816**	**10.45**
LN	Cameroon	252	1.637 ^{a}± 1.369	83.48
	Congo	24	1.538 ^{a}± 1.435	95.49
	Gabon	11	1.145 ^{a}± 1.121	93.31
	Average	**287**	**1.610± 1.365**	**84.47**
BW	Cameroon	252	26.926 ^{a}± 7.994	29.63
	Congo	24	27.447 ^{a}± 6.081	21.74
	Gabon	11	24.841 ^{a}± 7.439	28.56
	Average	**287**	**26.890± 7.822**	**29.08**

*a, b: the means assigned the same letter in the same column indicate that there are no significant differences between countries (p >0.05). **LFL** = Length of the front leg, **LHL** = Length of the hind leg, **TL** = TailLength **CB** = Canon bone circumferences, **LN** = Length of the nipple, **BW** = Body weight.*

Table 4. Variation of sub-sternal gracility index, Ear Length index, format index, compactness index massiveness index, thoracic index of Black belly per country in Central Africa

Index	Country	n	Mean± SD	CV (%)
SGI	Cameroon	252	1.375 ^{b} ± 0.5476	39.75
	Congo	24	0.699 ^{a} ± 0.0999	14
	Gabon	11	0.702 ^{a} ± 0.1893	25.70
	Total	**287**	**1.293 ± 0.5605**	**43.41**
ELI	Cameroon	252	0.389 ^{b} ± 0.1133	28.56
	Congo	24	0.307 ^{a} ± 0.0315	9.84
	Gabon	11	0.269 ^{a} ± 0.0657	23.28
	Total	**287**	**0.377 ± 0.1099**	**27.02**
IF	Cameroon	252	1.334 ^{a} ± 0.1553	11.62
	Congo	24	1.345 ^{a} ± 0.1316	9.39
	Gabon	11	1.472 ^{b} ± 0.1613	10.45
	Total	**287**	**1.340 ± 0.1555**	**11.19**
CI	Cameroon	252	0.914 ^{b} ± 0.1014	11.07
	Congo	24	0.867 ^{ab} ± 0.0648	7.39
	Gabon	11	0.819 ^{a} ± 0.0901	10.48
	Total	**287**	**0.907 ± 0.1006**	**11.11**
MI	Cameroon	252	1.209 ^{a} ± 0.1255	9.29
	Congo	24	1.160 ^{a} ± 0.0807	6.78
	Gabon	11	1.198 ^{a} ± 0.1168	9.29
	Total	**287**	**1.205 ± 0.1109**	**9.16**
ChI	Cameroon	252	0.213 ^{b} ± 0.0402	18.87
	Congo	24	0.166 ^{a} ± 0.0479	27.61
	Gabon	11	0.180 ^{a} ± 0.0238	12.57
	Total	**287**	**0.207 ± 0.0426**	**19.32**

*a, b: the indices affected by the same letter in the same column indicate that there are no significant differences between the countries (p>0.05). **SGI** = Substernal gracility index, **ELI** = Ear Length index, **IF** = Format index, **CI** = Compactness index, **MI** = Massiveness index,**ChI**= Chest index*

Table 6. Correlations between body measurements of Black belly sheep in Central Africa

	HWh	**HL**	**HLh**	**NL**	**CN**	**EL**	**TBL**	**TrL**	**HW**	**HB**	**HR**	**TC**	**CD**	**CW**	**RL**	**RW**	**LFL**	**LHL**	**TL**	**CB**	**LN**	**BW**
HWh	1																					
HL	0.133*	1																				
HLh	0.118*	-0,013	1																			
NL	-0.039	0.007	-0.248**	1																		
CN	0.451**	0.084	0.442**	0.021	1																	
EL	0.317**	0.023	0.026	-0.068	0.077	1																
TBL	0.365**	0.116*	0.135*	-0.269**	0.275**	0.273**	1															
TrL	0.420**	0.120*	-0.052	0.353**	0.330**	0.152**	0.232**	1														
HW	0.345**	0.086	0.129*	-0.253**	0.373**	0.328**	0.482**	-0.064	1													
HB	0.415**	0.090	0.151*	**-0.297****	0.412**	0.359**	0.460**	0.002	**0.943****	1												
HR	0.279**	0.091	0.058	-0.151*	0.354**	0.301**	0.391**	-0.082	**0.912****	**0.884****	1											
TC	0.287**	0.109	0.106	-0.324**	0.335**	0.166**	0.586**	-0.087	**0.727****	**0.708****	**0.666****	1										
CD	0.080	0.048	-0.087	0.581**	0.106	0.049	0.093	0.358**	0.110	-0.016	0.078	0.016	1									
CW	0.020	0.091	-0.022	0.240**	0.124*	-0.250**	0.030	-0.017	0.021	-0.024	0.120*	0.145*	0.149*	1								
RL	0.497**	0.084	0.093	-0.236**	0.377**	0.222**	0.296**	0.499**	0.161**	0.358**	0.143*	0.234**	-0.340**	-0.174**	1							
RW	0.291**	0.117*	-0.068	0.461**	0.269**	-0.023	0.142*	0.572**	-0.063	-0.062	0.030	-0.013	0.375**	0.427**	0.220**	1						
LFL	0.071	0.016	-0.092	0.536**	0.179**	0.036	-0.360**	0.279**	-0.0125*	-0.038	-0.015	-0.235**	0.141*	0.167**	0.115	0.225**	1					
LHL	0.066	0.015	-0.046	0.550**	0.192**	0.026	-0.315**	0.299**	-0.103	-0.050	-0.031	-0.218**	0.293**	0.108	0.041	0.211**	0.914**	1				
TL	0.128*	0.100	-0.013	0.292**	0.289**	0.184**	0.102	0.181**	0.337**	0.309**	0.420**	0.140*	0.386**	0.076	0.083	0.273**	0.192**	0.234**	1			
CB	0.222**	0.115	0.104	0.191**	0.430**	0.106	0.037	0.184**	0.167**	0.173**	0.241**	0.123*	0.098	0.220**	0.178**	0.303**	0.312**	0.280**	0.331**	1		
LN	-0.026	0.067	-0.501**	-0.089	-0.193**	0.105	0.171**	0.014	0.124*	0.131*	0.093	0.253**	-0.038	-0.010	0.096	0.007	-0.104	-0.140*	-0.106	-0.074	1	
BW	0.287**	0.109	0.106	-0.324**	0.335**	0.166**	0.586**	-0.087	**0.727****	**0.708****	**0.666****	**1.000****	0.016	0.145*	.234**	**-0.013**	**-0.235****	-0.0218**	0.140*	0.123*	0.253**	1

HL : Length of the head, **HWh**: Width of the head, **HLh** : Length of the Horns, **EL** : Ear Length, **NL** : Neck Length, **CN** : Circumference of the neck, **TBL** : Total body length,**TrL**: Trunk length, **HW** : Height at withers, **HB** : Height at back, **HR** : Height at rump, **TC :** Thoracic Circumference, **CD** : Chest Depth, **CW** : Chest Width, **RW** : Rump width, **RL** : Rump length, **LFL** : Length of the front leg, **LHL** : Length of the hind leg, **TL** : Length of the tail, **CB** : Canon bone circumferences, **LN** : Length of the nipple, **BW** : Body weight

Table 5. Variation of Slenderness Index, Frame index, Body Index, Dactylo-thoracic Index, CaudalIndex, Ear index of Blackbelly sheep in Central Africa

Index	Country	n	Mean±SD	CV (%)
SI	Cameroon	252	0.557 ^{b}± 0.0970	**17.38**
	Congo	24	0.410 ^{a}± 0.0329	**8.34**
	Gabon	11	0.407 ^{a}± 0.0582	**13.65**
	Average	**287**	**0.539± 0.1041**	**18.86**
FI	Cameroon	252	0.133 ^{b}± 0.0188	**14.03**
	Congo	24	0.117 ^{a}± 0.0104	**8.53**
	Gabon	11	0.125 ^{ab}± 0.0191	**14.57**
	Average	**287**	**0.132± 0.0188**	**7.69**
BI	Cameroon	252	0.747 ^{a}± 0.1736	**23.20**
	Congo	24	0.833 ^{ab}± 0.0709	**8.21**
	Gabon	11	0.911 ^{b}± 0.0819	**8.58**
	Average	**287**	**0.760± 0.1690**	**21.05**
DTI	Cameroon	252	0.111 ^{a}± 0.0172	**15.46**
	Congo	24	0.101 ^{a}± 0.0101	**9.62**
	Gabon	11	0.104 ^{a}± 0.0115	**10.47**
	Average	**287**	**0.110± 0.0168**	**14.54**
ICa	Cameroon	252	0.381 ^{a}± 0.0915	**23.99**
	Congo	24	0.400 ^{a}± 0.0557	**13.377**
	Gabon	11	0.364 ^{a}± 0.0496	**13,00**
	Average	**287**	**0.382± 0.0879**	**20.94**
EI	Cameroon	252	0.164 ^{ab}± 0.0274	**16.67**
	Congo	24	0.181 ^{b}± 0.0156	**8.59**
	Gabon	11	0.157 ^{a}± 0.0305	**18.51**
	Average	**287**	**0.165± 0.0271**	**12.12**

a, b: the indices affected by the same letter in the same column indicate that there are no significant differences between the countries (p>0.05). **SI** = Slendernessindex, **FI** = Frame index, **BI** = Body index, **DTI** = Dactylo-thoracic index, **ICa**= Caudal index, **EI** = Ear index

Genetic Variability according to Body Measurements

The total explained variance and the component matrix forthe different body measurements are presented on tables 7and 8 respectively. The Kaiser-Meyer-Olkin (KMO) index for the efficiency of the sample for PCA of biometric measurements was 0.741. The test for the total significance of the correlation between body measurements (X2 = 4251. 603 p <0.01) as well as the sphericitytest of Bartlett were significant, thus further supporting the validity of the factor analysis for our data.

Table 7. Distribution of the total Variance explained according to body measurements

Component	Initial own values			Extraction Sum of squares of the factors selected			Sum of squares of the factors retained for the rotation		
	Total	% of variance	% Accumulated	Total	% of variance	% accumulated	Total	% of variance	% accumulated
1	5.598	25.446	25.446	5.598	25.446	25.446	5.054	22.974	22.974
2	3.835	17.431	42.877	3.835	17.431	42.877	2.791	12.689	35.663
3	1.996	9.073	51.950	1.996	9.073	51.950	2.610	11.863	47.525
4	1.786	8.119	60.069	1.786	8.119	60.069	2.250	10.225	57.750
5	1.569	7.134	67.203	1.569	7.134	67.203	1.795	8.157	65.908
6	1.299	5.907	73.109	1.299	5.907	73.109	1.584	7.201	73.109
7	0.956	4.347	77.456	-	-	-	-	-	-
8	0.822	3.735	81.191						
9	0.709	3.224	84.415						
10	0.653	2.966	87.381						
11	0.532	2.419	89.801						
12	0.431	1.959	91.759						
13	0.390	1.775	93.534						
14	0.353	1.606	95.140						
15	0.299	1.359	96.499						
16	0.261	1.187	97.686						
17	0.222	1.008	98.694						
18	0.128	0.580	99.274						
19	0.070	0.317	99.591						
20	0.061	0.278	99.870						
21	0.029	0.130	100.000						

A total of 6 principal components with eigenvalues greater than 1 were obtained after PCA (see table 7). Components 1 and 2 with eigenvalues of5.598 and 3.835 respectively, cumulatively represent 42.87% of the phenotypic variability observed within the Blackbelly sheep population of Central Africa. However, components 3, 4, 5 and 6 equally have eigenvalues greater than 1and together with the components 1 and 2, cumulatively, 73.10% of the phenotypic variability observed within this population.

According to table 8, the height at withers, the height at the back, the height at the rump, the thoracic circumference and the bodyweight are positively and strongly correlated to factor 1, and thus contributes to the total variability observed in factor 1. While the rump length, front leg length and hind leg length best explain and positively relate to the variability in factor F2.

Table 8. Matrix of components for the different body measurements of Black belly sheep from Central Africa

Variable	Component					
	1	2	3	4	5	6
HWh(cm)	0.534	0.307	-0.425	0.172	0.011	-0.046
HL (cm)	0.166	0.126	-0.002	0.172	0.128	0.156
HLh(cm)	0.206	-0.043	-0.416	-0.626	0.374	-0.176
NL (cm)	-0.313	**0.752**	0.332	0.093	0.005	-0.138
CN (cm)	0.543	0.411	-0.315	-0.300	0.230	0.061
EL (cm)	0.386	0.067	-0.160	0.114	-0.479	-0.389
TBL (cm)	0.675	-0.118	-0.113	0.330	0.262	-0.200
TrL(cm)	0.121	0 **644**	-0.413	0.445	0.053	-0.164
HW (cm)	**0.890**	-0.071	0.249	-0.152	-0.148	-0.090
HB (cm)	**0.903**	-0.044	0.082	-0.144	-0.240	0.010
HR (cm)	**0.835**	0.027	0.322	-0.186	-0.163	-0.002
TC (cm)	**0.853**	-0.196	0.209	0.052	0.111	0.166
CD (cm)	0.043	0.540	0.445	0.148	0.190	-0.530
CW (cm)	0.065	0.301	0.383	-0.012	0.536	0.449
RL (cm)	0.430	0.162	**-0.690**	0.231	-0.181	0.251
RW (cm)	0.100	**0.670**	-0.032	0.361	0.404	0.049
LFL (cm)	-0.156	**0.733**	0.024	-0.232	-0. 416	0.329
LHL (cm)	-0.150	**0.751**	0.065	-0.249	-0.379	0.187
TL (cm)	0.342	0.478	0.262	-0.138	-0.083	-0.304
CB (cm)	0.277	0.501	-0.033	-0.216	0.054	0.254
LN (cm)	0.159	-0.180	0.262	0. **667**	-0.287	0.300
BW (kg)	**0.853**	-0.196	0.209	0.052	0.111	0.166

Projection in Figure 3 discriminates between two main groups of variables that are negatively correlated with each other (NL, LFL, LHL on the F2 axis and HW, HB, HR, BW, TC on the F1 axis)

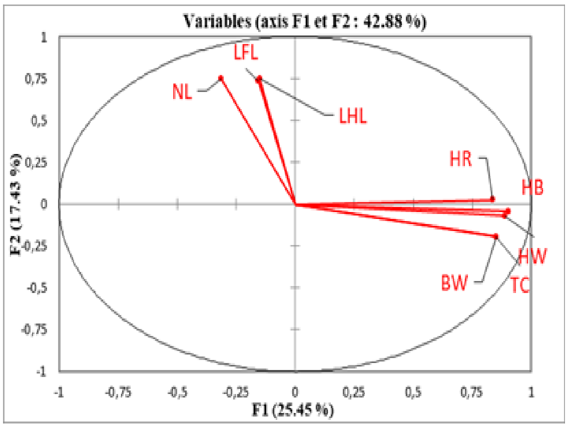

Figure 3: Correlation circle of the initial variables by PCA for body measurements of Blackbelly sheep in Central Africa

NL= Neck length, LFL= Length of the front Leg, LHL= length of the Hind Leg, HW=height at withers, HB= Height at the back, HR= Height at the rump, TC= Thoracic Circumference and BW=Body weight

It appears that, the height at withers, the height at the back, the height at the rump, the thoracic circumference and the bodyweight are positively and strongly correlated as well as with to the F1 axis. However, necklength, length of the front leg and length of the hind leg are strongly correlated with each other and with the F2 axis.

Population Structure Based on Body Measurements in Black Belly Sheep FromCentral Africa.

Table 9 further highlights the distinction that exists between theBlackbelly sheep populations. The various explanatory variables of this study made it possible to determine 3 Classes and the average biometric characteristics of these three genetic types (Table 9). The most discriminating factors that characterizethe class 1 sheep are NL, LFL and LHL. The population which constitutes the 2ndclass are discriminated by HWh,HL, DC, EL, TBL, TrL, HB, CD, RL, RW, TL, CB and LN. Finally, the following biometric measurements discriminate class 3 sheep; HLh, HW, HB, TC, CW and BW. Except for the best average, body weight and chest circumference can be seen to be in favor of the class 3 population; the highest mean measurements were observed in blackbelly sheep population of class 2.

Table 9. Biometric characteristics of the 3 genetic types of Blackbelly sheep in Central Africa

Variables	**Classes**		
	1	**2**	**3**
HWh(cm)	10.451	**11.**937	10.272
HL (cm)	16.941	**21.284**	18.075
HLh(cm)	3.745	5.1626	**5.325**
NL (cm)	**29.183**	23.743	19.924
CN (cm)	31.204	**34.427**	31.121
EL (cm)	9.3854	**10.442**	9.590
TBL (cm)	73.831	**86.108**	80.378
TrL(cm)	55.083	**61.895**	38.606
HW (cm)	54.856	62.905	**64.045**
HB (cm)	53.551	**62.234**	61.151
HR (cm)	55.458	60.485	**62.5**
TC (cm)	64.464	76.442	**78.424**
CD (cm)	27.855	**28.1123**	24.424
CW (cm)	**14.904**	13.89	15.121
RL (cm)	18.515	**25.491**	15.075
RW (cm)	15.190	15.430	12.5
LFL (cm)	**44.618**	41.914	37.666
LHL (cm)	46.929	**45.162**	40.439
TL (cm)	23.132	23.276	20.65
CB (cm)	7.783	**7.827**	7.568
LN (cm)	1.133	**2.0494**	1.924
BW (kg)	20.685	31.298	**33.053**

HL : Length of the head, HWh: Width of the head, HLh : Length of the Horns, EL : Ear Length, NL : Neck Length, CN : Circumference of the neck, TBL : Total body length,TrL: Trunk length, HW : Height at withers, HB : Height at back, HR : Height at rump, TC : Thoracic Circumference, CD : Chest Depth, CW : Chest Width, RW : Rump width, RL : Rump length, LFL : Length of the front leg, LHL : Length of the hind leg, TL : Length of the tail, CB : Canon bone circumferences, LN : Length of the nipple, BW : Body weight

Figure 4reveals that the Length and width measurements (TrL,NL, RL,RW) are most correlated to the F1 axis. The Bodyweight, canon bone circumference, height at withers and height at the back are more correlated to the F2 axis. The trunk length and the Bodyweight seem to be the most discriminating variables.

The Phylogenetic Relationships Between the Genetic Types of Blackbelly Sheep Populations in Central Africa according to Body Measurements

As shown on figure 5, the Blackbelly sheeppopulation is constituted of two (2) subgroups. The first subgroupis composed of genetic type T3 meanwhile genetic types T2 and T1 constitutes the second subgroup. Therefore, T1 is more closely related to T2 but distantly related to T3, probably due of the genetic distances that exist between the two subgroups. This suggests that the distance between the barycenter of the genetic types T1 and T3 is greater than that between T2 and T3. Hence, this could hint to the fact that T1 and T2 share a large genetic heritage.

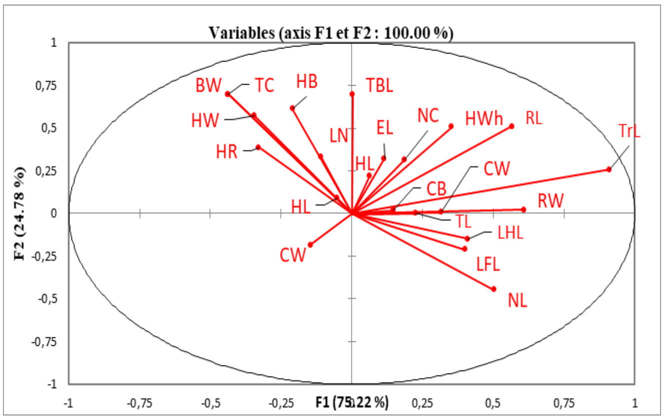

Figure 4. variable-factor correlations of the three class of Black belly in Central Africa.

HL : Length of the head, HWh: Width of the head, HLh : Length of the Horns, EL : Ear Length,NL : Neck Length, CN : Circumference of the neck, TBL : Total body length,TrL: Trunk length, HW : Height at withers, HB : Height at back, HR : Height at rump, TC : Thoracic Circumference, CD : Chest Depth, CW : Chest Width, RW : Rump width, RL : Rump length, LFL : Length of the front leg, LHL : Length of the hind leg, TL : Length of the tail, CB : Canon bone circumferences, LN : Length of the nipple, BW : Body weight

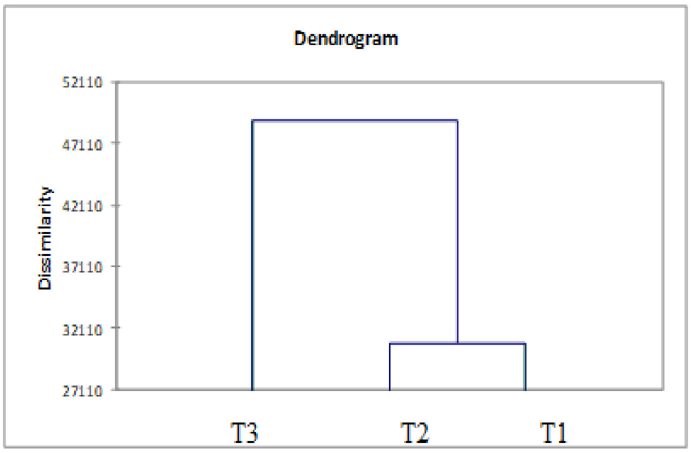

Figure 4. Dendrogram of the Blackbelly sheep population morphotypes in Central Africa

Legends: T1: Morphotype 1. T2: Morphotype 2. T3 : Morphotype 3

According to Table 10,intraclass variations are greater than interclass variations. This could indicate kinship within the population with a high inbreeding rate

Table 10. Decomposition of variance for optimal classification

Variance category	Absolute	Percentage
Intra-class	632.2764	69.79%
Inter-classes	273.6858	30.21%
Total	905.9623	100.00%

Discussion

Results from the analysis of biometric data obtained from the Blackbelly population in the different countries studied reveals a great phenotypic variability ($p \leq 0.05$). This could point to the existence of a significant genetic diversity (Gaouar et al., 2015).On a general note, the length and width of the head in this study are of 18.581 ± 9.361 cm and 10.880 ± 1.425 cm respectively.Furthermore, these averages remain comparable between countries. This result is similar to that reported by Tadakeng (2015) on the West Cameroon sheep (20.04 ± 3.34 cm). The Congo Brazzaville Blackbelly sheep population has significantly longer ears (11.233 ± 1.165 cm) compared to those in other countries. Similar results were obtained by Dayo and al., (2015) on Djallonke sheep in Togo (11.613 ± 2.61 cm). However, thesevalues are low comparedthose obtained by Dayo (2015) in Togo on the Vogon (18.45 ± 2.08 cm) and Sahelian (21.631 ± 2.48 cm) breeds. These differences can be explained by the fact that, the Vogon and Sahelian breeds possess characteristic droopy or semi pendulous ears which is probably an adaptative mechanism for efficient thermoregulation in hot zones. The overall mean body length obtained for the different countries studied is 79.196 ± 8.98 cm. These values arehoweverhigher than those obtained by Aroraet al. (2010) on Ganjam sheep in India (76.75 ± 12.28 cm) and Wilson (1992) on the Djallonké sheep (60-65 cm). Nevertheless, they are comparable to thoseobtained by Tadakeng (2015) on the West Cameroon sheep (76.75 ± 12.28 cm).

Although significantly ($p < 0.05$) higher for the Congo blackbelly population, the overall mean trunk length obtained in this study (53.44 ± 10.302 cm) is close to thatreported by Tadakeng (2015) on West Cameroon sheep (54.96 ± 9.06 cm). Though comparable between the countries studied, an overall average height at the withers of 59.502 ± 7.011 was recorded. Aroraand al. (2010) and Rodrigo and al. (2015) reported lower values for the Ganjam (67.7 ± 0.48 cm)and Merinos (67.88 ± 3.53cm) sheep in India and Chilierespectively. Withal, this result remains comparable to that obtained by Vallerand and Brankaert (1975) on the Djallonké sheep (59 cm) and Tadakeng (60.59 ± 8.30 cm) sheep breedof the Cameroon Western Highlands. The height at the back and rump were significantly higher in the Congo sheep. This isfurther corroborated bythe fact that the Congo Blackbelly presented the largest sizes. A mean chest circumference of 71.467 ± 8.829cm was obtained, but no statistical difference ($p > 0.05$) between countries. Quasi-similar values have been reported by Arora et al., (2010) for the Ganjam sheep (72.7 ± 0.68 cm) of India. The Congo Brazzaville sheep populationpresented the highest chest circumferences (72.096±6.864cm),thereby justifying the highest bodyweight recorded in their favor. The relationship between chest circumference and body weight can be explained by the rule of Bergam evoked by Lamotte (1994), stated by Brody (1964) in“Small Ruminants”, who explained that the chest circumference gives the first estimate of the metabolic potential, which is proportional to the volume of the body and therefore to the weight of the animal.

Results revealed a mean rump length and rump width of 19. 936 ± 6.22 cm and 14.644 ± 2.323 cm respectively. A lesser mean rump width was reported by Denis (1975) for the Peul sheep ofSenegal (14.4 ± 0.5 cm) and Sibomana (1998) for the local Rwandan and Burundian breeds (16.89 ± 4.68 cm). Indeed, a larger rump would appear to be a characteristic of good motheringquality in the ewe, which further confirms the observations of Manjeli and al. (1991) on the prolificity of the Blackbelly sheep in Cameroon. An overall meanbodyweight of 26.89 ±7.82kg was observed with the highest value being recorded for the Blackbelly sheep population of Congo (27.447 ± 6.081 kg). Traoré and al., (2006) in Burkina and Birteeb and al., (2014) in northern Ghana reported lower body weights for the Mossi sheep (23.3 ± 5.0 kg) and Djallonke sheep (26.92 ±0.89kg) respectively. The practice ofsheep fattening production systems in Congo Brazzaville could explain the difference in Bodyweight observed in the aforementioned studies. With a bodyweight lower than 35kg, we can therefore conclude that the Blackbelly Sheep of Central Africa is small in size.

The analysis of indicesreveals a significant ($p \leq 0.05$) viability between the blackbelly sheep population of the countries studied. A mean substernal gracility index (SGI) and ear length index (ELI) of 1.29 ± 0, 56and 0.37 ± 0.10 respectively, suggests that the Blackbelly sheep population of this area is of intermediate type. Gueye (1997) however reports dissimilar results for the following sheep breeds: 0.59 for the Djallonké sheep, 1.61 for the Touabire sheepand 1.51 for the Peuhlsheep. The high indices reported for the sheep breedsof the Sahelian zone is equally an adaptation for efficient thermoregulation. This is because an increase in height of legs with a corresponding increase in SGI, enables the animal to reduce the thermal impact of the infrared radiation from the ground as well as the solar radiation reflected by the soil on the body (Zeuh and al., 1997). The sheep from Cameroon presented a significantly higher Compactness Index (0.914). Similar results were obtained in Tadakeng (2015) on the West Cameroon sheep. The Body Massiveness Index (MI) gives an appraisal of the relationship between the body extremities and body mass. Results reveal a mean MI of 1.20 ± 0.11which is close to the findings of Tadakeng (2015) obtained for the West Cameroon sheep (1.13). However, authors who worked on closely related ruminant species reported quasi-dissimilar findings in the instar of Edilberto and al., (2011)and Ngonoand al., (2019) who recorded a MI of 0.57 and 2.72 for the Creole goat of Chile and 2.72 for the White Fulani cattle of Cameroon. The massiveness index is a functional index that plays a role in the animal’s adaptation to its milieu.Results show that the mean thoracic index of the studied blackbelly sheep population is 0.2 ± 0.0426 with a significantly higher value recorded in favor of the Cameroon sheep (0.213). Victalina(2010) on the other handrecorded a higher mean ChI(0.5)for the Peliluey sheep population in Mexico.

The body index enables us to have an overall appraisal of the size of the animal. Following the classification model adopted by Eliberto and al., in 2011 (where ifthe BI > 0.90:"long", BI = 0.86 0.88: "medium" and BI < 0.85: "stocky), we could conclude that the blackbelly sheep of Central Africa is generally brevilineal(0.760). However, the subset of Gabon presenteda longer linear body conformation (0.911). According to the dactylo-thoracic index, sheep can be classified into four categories; lightweight (DTI <0.105), intermediary (DTI = 0.1060.108), lightweight (DIT = 0.109 0.11) and heavy (0.111 < DTI <0.115) breeds.From the aforesaid classification, it is safe to say that the Blackbelly sheep of Central Africa is alightweight meat type (DIT = 0.110) albeit those of Cameroon were predominantly of the heavy meat type (DIT = 0.111 ± 0.017). Putra and al. (2010) obtained different values in his studies carried out on the Katjang goat of Indonesia. The reports of Victalina (2012) indicates lower values for both sexes (0.0974 in male and 0.0952 in female) of the Pelibuyebreed in Mexico. The DIT values obtained for the Cameroon blackbelly sheep are similar to the findings of Tadakeng (2015) who recorded a DIT of 0.12 for the West Cameroon sheep.The dactilo-thoracic index equally provides information on the dairy capability of breeds (Álvarezand et al., 2009).

There are significant correlations (p<0.01) between the different body measurements of Blackbelly sheep population of Central Africa. The correlation coefficients range from -0.297 (between RL and HB) to 1.00 (between TC and BW). Gueye (1997) and Olatunji (2009) equally reported a positive correlation between BW and TC for the Senegalese Peuhl-Peuhl sheep andthe South-West Nigerian breed respectively. A strong and positive correlation can equally be observed between the height measurements (e.g., r = 0.94 between HW and HB; r = 0.912 between HW and HR; r = 0.884 between HB and HR) as well as betweenTC and HW (r = 0.727), HB (r = 0.708) and HR (r = 0.666). The overall mean Bodyweight of the studied sheep population is significantly (p<0.01) correlated to HW (r = 0.72),HB (r = 0.70) and HR (r = 0.66). A perfect correlation was obtained betweenBW and TC (r=1). These results confirm the "theory of Bergam" on animal growth. The highly positive correlations between the biometric parameters of Blackbelly sheep population of Central Africa are similar to those reported by Victalina and al., (2012) for the Pelibuye sheep of Mexico. This concurrence could highlight a common origin for both breeds (Meka and al., 2019).

Principal component analysis revealed that 6 major components account for73.1% of the total phenotypic variability observed within studied population and components CP1 and CP2 explaining for 25.44% and 17.41% of the observed variability in body measurements respectively. Contrarily, divergent results have been reported by several authors. Yakubu (2013) extracted three (3), while Osaiyuwu (2010)reported two (2)main components after subjecting the body measurements collected from theYankasa sheep andBalami sheep populations of Nigeria respectively to PCA. In the same line, Putra et al., (2019) reported four(4) main components to be responsible for the overall variability observed in the Katjang goat population of Indonesia. Nonetheless, the results of this study agree with the findings of Rodrigo (2015) whoreported that6 main componentsexplained the phenotypic variability observed in the sheep population of Chile. Nevertheless, the common denominator in all these results is the fact that the first component (CP1) explains a major part of observed phenotypic variability and thus can be used for selection programs to obtain more stables breeds. PCA distinguishes the height variables (HW, HB, HR, plus BW and TC) which explain the maximum variation in CP1, and the length and width variables (NL, TrL,RL,RW,LFL,LHL)which accounts for the variations in CP2. The thoracic circumference (TC) has been reported to have the greatest contribution to the rotating CP1 for studies carried out on the Yankassa sheep population of Nigeria (Yakubu, 2013), a result which contrasts the findings of this study where the greatest contribution to the same rotating CP1 is in favor of HB. This could equally serve for selection purposes, because TC which has the greatest contribution in CP1 is highly correlated to body weight.

Three (3) classes within the studied Blackbelly sheep population can be distinguished after Discriminant Factor Analysis (DFA). Class 1 is characterized by small-sized sheep with an elongated neck. Class 2 is comprised of the longest sheep (TBL = 86.108 cm) within the population with a long and large head; their body and trunk are longer than that of their counterparts of the other subsets.They equally possess long ears and tail with more developed nipples. The last class (Class 3)is made up of large sheep with voluminous chests (TC =78.42cm and CW = 15.12cm) and heavy weight (BW=33.05kg). Two subgroups were obtained after AscendanceHierarchical Clustering (AHC)of body measurements. The first subgroupconsists of the type T3 only while the second is made up of types T2 and T1. This confirms the results of DFA and shows that T1 and T2 are therefore closer while T3 is more distant, probably due to the genetic distances that exist between these three morphotypes.

Conclusion

This study reveals theexistence of a great phenotypic variation between the blackbelly sheep populations of Congo Brazzaville, Gabon and Cameroon. The longest sheep are found in Gabon while the tallest, largest and heaviest were from Congo Brazzaville. The Blackbelly sheep of Central Africahas an overall small size and is classified as lightweight meat type.The perfect correlation obtained between the thoraciccircumference and Bodyweight suggests that the former can be used to efficiently select for the latter.Two components (CP1 and CP2) out of sixcumulatively explain 42.85% of the total variability observed within the blackbelly populationof Central Africa. The height at back significantly contributes to the F1 factor of the first componentwhich explains the greatest portion of the phenotypic variability, thus can be adopted within the context of a selection and improvement program. Discriminant Factor Analysis revealed three (3)classes thereby highlighting the presence of a higher heterogeneity within the Blackbelly population. Furthermore,the highest mean measurements were observed for the class 2 subset, although the population of class 3 presenting the best Bodyweight. However, in order to increase the efficiency of selection, improvement and conservation of the Blackbelly population of Central Africa, biometric characterization has to be coupled with genomics and other emerging biotechnologies.

References

Álvarez R. J. Ferrer J. Revilla R. Sanz A. 2009. Estudiobiométrico de la raza Churra Tensina. In :Diputación Provincial de Huesca (ed), XXXIV CongresoNacional de la SEOC (Sociedad Española de Ovinotecnia y Caprinotecnia, Barbastro, España), 555–561.

Arora R. Bhatia S. Jain A. 2010. Morphological and genetic characterization of Ganjam sheep. Animal Genetic Resources, 2010, 46, 1–9. © Food and Agriculture Organization of the United Nations, 2010 doi:10.1017/S2078633610000627

AU-IBAR. 2015. Strategic Plan 2014–2017, Nairobi, Kenya

Barbados Blackbelly Sheep Association International. 2011. Children’s Zoo Barnyard. Barbados Blackbelly sheep description. 2p

Birteeb P. T. Peters S. O. Ozoje M. O. 2014. Analysis of the body structure of Djallonke sheep using a multideterminant approach. Animal Genetic Resources, 54, pp65 – 72.

Brody S. 1964. Bioenergetic and grouth, Hafner Publishing Company, New-York, second edition, 1023 p.

Carpentier, F.G. 2007. Introduction aux analyses multidimensionnelles : 135p.

Dayo G-K. Alfa E. E. Talaki K. Soedji S. Sylla Dao B. 2015. Caractérisation phénotypique du mouton de Vogan du Togo et relation avec le mouton Djallonké et le mouton sahélien. Animal Genetic Resources, 2015, 56, 63–78. © Food and Agriculture Organization of the United Nations, 2015 doi:10.1017/S207863361500003X

Delgado J. V. Barba C. Camacho M. E. Sereno F. T. P. S. Martinez A. Vega-Pla J. L. 2001. Livestockcharacterization in Spain. Animal GeneticResearch. Information. 29: 7–18.

Denis J. P. 1975. L'élevage ovin au Sénégal - ln compte rendu des Journées techniques : "Productions animales", 15-19 sept. 1975 ; - Maisons Alfort : Revue d’élevage et Médécine VétérinairePays tropicaux ; pp.77-109.

Edilberto C. Fernando M. Francisco V. Samuel R. P. Eliecer P. Concepta M. 2012. Morphological measurements and body indices for Cuban Creole goats and their crossbreds. R. Bras. Zootec., v.40, n.8, pp.1671-1679

Eyduran E. Topal M. Sonmez A. Y. 2010. Use of factor scores in multiple regression analysis for estimation of body weight by several body measurements in brown trouts (Salmo trutta fario). International Journal of Agriculture and Biology, 12, 611-615.

FAO. 2008. L’état des ressources zoogénétiques pour l’alimentation et l’agriculture dans le monde, édité par Barbara Rischkowsky et DafyddPilling. Rome.392p.

FAO. 2013. Caractérisation phénotypiques des ressources génétiques animales. FAO sur la production et la santé animale. N° 11. Rome.152p.

Gaouars B. S. Da Silva A. Ciani E. Kdidi S. Aouissat M. Dhimi I. Lafri M. Maftah A. And Mehtarn. 2015. admixture and local breed marginalization threaten algerian sheep diversity. plos one,10 (4) pp. 1-13.

Gueye A. 1997. Moutons et Chèvres du Sénégal : Caractérisation morpho-biométrique et typage sanguin. Écoles inter-états des sciences et médicine vétérinaires. Thèse Médecine.Vétérinaaire. Dakar, 6, 79p.

Hartl Daniel L. and Clack Andrew G. 1997. Principle of genetic population.Sinauer Associates, Inc.1997, 542 p.

Kaiser H. F. 1960. The application of electronic computers to factor analysis. Educational and PsychologicalMeasurement, 20, 141-151.

Lamotte M. 1994. Théorie actuelle de l'Evolution. Hachette, Paris.444 p.

Lauvergne J. J. MillarP. Meutchieye F. Bouchel D. 2011. Visible genetic polymorphisms in domesticated animal species.CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 2011 6, No. 060.

Macedo, B. R. J. Arredondo R. V. Cruz E. C. A. 2011. Caracterización de los ovinocultoresasociadosdelestado de Colima. I. Estudiodescriptivo. In : AMMVEB (ed), XXXV CongresoNacional de Buiatría, (AsociaciónMexicana de MédicosVeterinariosEspecialistas en Bovinos, México), 1–7.

Manjeli Y. Njwe R. Thoumboué J. 2003. Phenotypic and geneticparameter of body weight of Blackbelleysheep. Journal of the Cameron Academy of sciences. Vol 03, N°02 (2003).

Meka Z. II Meutchieye A. M. Ntsoli F. Tadakeng J. Fonteh Y. 2019. Factors affecting the global diffusion of an African animal genetic resource: the case study of the Cameroon Blackbelly sheep.PKFokam Journal of Applied Science and Technology, inaugural Edition, June 2019. ISSN 2707 – 2843. pp. 26-35.

Ngono E. P. J. Meutchieye F. Manjeli Y. 2019. Biometric assessment of White Fulani cattle in a semi-intensive production system in Northern Cameroon using principal components analysis.Gen. Biodiv. J: 3(2), 62-71.

Olatunji-Akioye A. O. & Adeyemo O. K. 2009 Liveweight and chest girth correlation in commercial sheep and goat herds in southwestern Nigeria. International Journal Morphol., 27(1):49-52.

Ollivier L. and Foulley J-L. 2013. Mesure et évolution de la diversité génétique des plantes cultivées et des animaux domestiques. Institut de Mathématiques et Modélisation de Montpellier, UMR-CNRS 5149 Université de Montpellier II, 34095 Montpellier Cedex 05, France.

Osaiyuwu O. H. Akinyemi M. O. Salako A. E. 2010. Factor analysis of the morphostructure of mature Balami sheep. Res J Anim Sci. 2010;4(2):63–65.

Putra W. P. B. Ilham F. 2019. Principal component analysis of body measurements and body indices and their correlation with body weight in Katjang does of Indonesia. J Dairy Vet Anim Res.;8(3):124–134. DOI: 10.15406/jdvar.2019.08.00254

R Core Team 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rodrigo B. Andrés C. Cecilia C. Fernando S. 2015. Body arquitecture of main sheep breeds in chile: Journal of Animal Ethnology (2015) 1: 1-9

Romualdo J. Ortíz J. Hernández Zepeda J. 2004.Caracterizaciónmorfométrica del ovinoPelibuey local en Yucatán, México (Morphological characterization of the Pelibuey sheep of Yucatan, Mexico).ArchivosLatinoamericanos de Producción Animal, 12 (Supl. 1), 26–31.

Sibomana J. B. 1998. Elevage du mouton à queue grasse dans la région de Byumba (Rwanda) : Aspects socio-économiques et zootechniques. ThèseMéd.vét: Dakar, 15p.

Speller C. F. Burley D. V. Woodward R. P. Yang D. Y. 2013. Ancient mtDNA Analysis of Early 16th Century Caribbean Cattle Provides Insight into Founding Populations of New World Creole Cattle Breeds. PLoS ONE 8(7): e69584. doi: 10.1371/journal.pone.0069584.

SPSS 21. IBM Corp. Released 2018. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp

Tadankeng Djoufack Y. 2015. Biodiversité des ovins (ovisaries) des hautesterres de l'ouest-Cameroun. Département des science Animales, Université de Dschang.

Traore Tounkara K. A. Traore A.P. Sidibe S. Samake K. Diallo B. O. Diallo A. 1996. Epidemiología de la peste de los pequeñosrumiantes (PPR) y de la peste bovina en Mali :encuestasserológicas. Revue Élevage et Médecine véterinaire des Pays tropicaux. 49 (4) : 273-277

Vallerand and Branckaert R. 1975. La race ovine Djallonké au Cameroun Potentialités zootechniques, conditions d'élevage, avenir. Rev. Elev. Med. vét. Pays trop.,1975, 28 (4) : 523-545

Victalina AR. Rafael MB. Jaime MC. Julio M. Á. Omar P. R. Luis JG. Alejandra HC Héctor LR 2012. Morphological characterization of Pelibuey sheep in Colima, México. Tropical Animal Health and Production. 45, 895–900. https://doi.org/10.1007/s11250-012-0303-1Corpus ID: 14076700.

Wilson TR 1992. Petits ruminants : productions et resources génétiques en Afrique tropicale, FAO, Rome. 193p.

Yakubu A. 2013. Principal component analysis of the conformation traits of Yankasa sheep. Biotech Anim Husband. 2013;29(1):65–74.