Genetics & Biodiversity Journal

Journal homepage: https://journals.univ tlemcen.dz/GABJ/index.php/GABJ

ISSN: 2588-185X

Original Research Paper

OPEN ACCESS

Biometric assessment of Fulanisheep in Sahelian and Sudanian zones of Chad

DJOMTCHAIGUE Bamaré Herbert [1,2], KOUSSOU Mian-Oundanag [1], TADAKENG Djoufack Yannick [2],OUMAR Mouctar Kodbe [3], ZEUH Vounparet [3], AWAH Ndukum Juluis [2],MEUTCHIEYE Félix [2*]

[1]*Institut de Recherche en Elevage pour le Développement, PoBox. 433. N'Djamena, Chad.*
[2] *University of Dschang, Faculty of Agronomy and Agricultural Sciences, Department of Animal Science, Biotechnology and Bioinformatics Research Unit, PoBox. 188. Dschang-Cameroon.*
[3] *University of N'Djamena, Department of Biology. Chad.*

***Corresponding Author**: Meutchieye, University of Dschang **Email** fmeutchieye@gmail.com.
Article history: Received: May 29th 2022; Revised: December 30th 2022; Accepted: .January 08th 2023

Abstract

A survey was conducted in Sahelian and Sudanian agroecological zones to assess the biometric features of the native Fulani sheep breed. 309 adult Fulani sheep individuals were sampled in the dominant pastoral production system. Seventeen (17) body measurements were recorded using the tape measure: Height at withers at (HW), Rump height (RH), Chest circumference (CC), chest depth (CD), body length (BL), total body length (TBL), rump length (RL), rump width (RW), neck length (NL), head length (HL), head width (HW), ear length (EL), tail length (TL), barrel circumference (BC), testicle length (TesL), testicle circumference (TesC) and body weight (BW). Based on these body measurements, eleven (11) biometric indexes were calculated (sternal slenderness index, auriculo-thoracic index, format index, compactness index, massiveness index, slenderness index, frame index, dactylo-thoracic index, body index, caudal index, and auricular index). Phenotypic dimorphism ($P<0.05$) was observed in the Fulani sheep population. High, long and heavy sheep were recorded in the Sudanian zone (WH= 81.17±4.88; BL = 73.78±6.78 and BW = 39.28±3.03). A high correlation was obtained between BW and WH ($r=0.95$). The principal component analysis revealed that 5 components contribute to 70.94% of the phenotypic variability observed within the Fulani sheep population. The two components explain 48.36% of the variability observed according to body measurements. As well as the WH and RH could be considered for a program of selection and conservation of Fulani sheep.

Keywords: Genetic diversity, Measurement, Fulani, Sahelian and Sudanian zones.

الملخص

وأجريت دراسة استقصائية في المناطق الإيكولوجية الزراعية الساحلية والسودانية بهدف تقييم السمات البيو مترية لسلالة أغنام الفولاني الأصلية. تم أخذ عينات من 309 أفراد من أغنام الفولاني البالغين في نظام الإنتاج الرعوي السائد. تم تسجيل سبعة عشر (17) قياسًا للجسم باستخدام مقياس الشريط: الارتفاع عند ذبول(HW) ، ارتفاع الردف(RH) ، محيط الصدر(CC) ، عمق الصدر(CD) ، طول الجسم(BL) ، طول الجسم الكلي(TBL) ، طول الردف(RL) ، عرض الردف(RW) ، طول الرقبة(NL) ، واستنادا إلى قياسات الجسم هذه، تم حساب أحد عشر (11) مؤشرا للقياسات الحيوية (مؤشر النحافة القصية، ومؤشر الصدر الصدري، ومؤشر الشكل، ومؤشر الانضغاط، ومؤشر الضخامة، ومؤشر النحافة، ومؤشر الإطار، ومؤشر داكتيلو الصدر، ومؤشر الجسم، والمؤشر الذيلي، والمؤشر الأذني). لوحظ ثنائي الشكل الظاهري (P<0.05) في أعداد الأغنام الفولانية. وسجلت أغنام عالية وطويلة وثقيلة في المنطقة السودانية (WH = 81,17 ± 4,88 ؛ BL = 73.78 ± 6.78 و .(BW = 39.28 ± 3.03 يتم الحصول على ارتباط عالي بين BW و .(WH (r = 0.95 كشف تحليل المكون الرئيسي أن 5 مكونات تساهم في 70.94٪ من التباين الظاهري الذي لوحظ داخل مجموعة أغنام الفولاني. يفسر المكونان 48.36٪ من التباين الذي لوحظ وفقًا لقياسات الجسم. بالإضافة إلى WH و RH يمكن النظر في برنامج اختيار وحفظ أغنام الفولاني.

الكلمات المفتاحية :التنوع الجيني، القياس، الفولاني، المناطق الساحلية والسودانية، تشاد.

Introduction

Sheep farming is critical for livelihoods and food security in rural communities, especially in developing countries (Amadou *et al.*, 2012). Maintaining the genetic diversity of livestock is vital to face future challenges such as threats from climate change, emerging diseases, and food security for a growing human population (Barker 2001; Groeneveld *et al.*, 2010). Indigenous African sheep genetic resources

DOI: 10.46325/gabj.v7i1.282

currently contribute about 30% of the agricultural gross domestic product of most African countries (Muigai *et al.,* 2013).

However, a better knowledge of the diversity of sheep species can contribute to the improvement of its productivity and preservation (Traoré *et al.,* 2006). Morpho-biometric characterization has been used to describe and classify wild animal populations as well as domestic animal populations including livestock (Zaitoun *et al.,* 2005; Traoré *et al.,* 2008). In Chad, the native sheep population is made up of Fulani, Arab, Kababish Mayo Kebbi, and Kerdimi breeds, which are all adapted to harsh conditions. The Fulani sheep breed is widely distributed in the country and shows interesting adaptation to all ecological environments of Chad. Animals with a two-tone coat, constituting a genetic type called *Oudah*, have a black or brown colored coat in front and white in back, the separation is done in the middle of the body. The *Waïla* genetic type differs from the first only in its white color (Zeuh, 2000).

Other sheep breeds showing similar characteristics as the Fulani sheep have been described in many parts of Africa including the local Fulani breed in Cameroon (Njoya *et al.,* 1997), Uda and Balami in the Sahelian zones of Nigeria (Otchere *et al*., 1987; Yakubu *et al.,* 2010) and Fulani in Senegal (Ndiaye, 2018). Also, a description of the Mayo Kebbi sheep among other small ruminants has been documented by Dumas (1980), and Zeuh (2000 and 2013). Though the socioeconomic importance and particularly high demand during Muslim ceremonies and rituals of sheep in Chad (Mopaté *et al.,* 2020). There is little information on the biometric and phenotypic features of Fulani sheep in the country. This study is to assess the morphometric characteristics of the Fulani sheep of Chad, which is a prerequisite for any characterization program and the conservation of this genetic resource.

Materials and methods

Study area

This study was conducted in the Sahelian zone (Chari-Baguirmi: 11°7598'5514" Northern and 15°1503'8405" Eastern) and in the Sudanian zone (Mandoul: 8°9418'5169" Northern and 17°4818 '1465" Eastern). The choice of these provinces within the agroecological zones is justified by the relative density of *Fulani* sheep herders. The climate of the Sahelian zone is of the tropical Sahelian type characterized by two seasons; a very short rainy season from May to September and a long dry season from October to May with average annual temperatures of 40°C. Annual rainfall varies from 200 to 600mm and the vegetation is generally savannah grassland and pseudo-steppe dominated by *Acacia raddiana*, *Balanites aegyptiaca*, *Ziziphus mauritania*, *Calotropis procera*, and on the other hand by herbaceous cover with the following species : *Panicum turgidum*, *Aristida mutabilis*, *Cenchrus biflorus*, *Eragrostis tremula* and *Andropogon gayanus*. The climate of the Sudanian zone (which is southern to the above mentioned one) is of the Sudanian tropical type characterized by two seasons: a rainy season from May to November and a dry season from November to April with an average temperature of 40 °C. The annual rainfall varies from 800 to 1200 mm. The vegetation is characterized by open forest and woody savannah, a mixture of legumes *(Parkia biglobosa* and *Vitellaria paradoxa)* and Combretaceae *(Anogeissus leiocarpa, Guiera senegalensis, Combretum collinum, Combretum glutinosum, Combretum nigricans, Terminalia avicennioides, Terminalia glaucescens, Terminalia laxiflora* and *Terminalia macroptera)*. The herbaceous layer is continuous with a predominance of perennial grasses among which *Andropogon gayanus*, *Vitex doniana,* and *Cymbopogon giganteus* (Sougnabe, 2003).

Data collection and body measurement

Biometric data of 309 adult Fulani sheep individuals (229 ewes and 80 rams) made up of two genetic types (237 Oudah sheep and 72 Waïla sheep) raised under pastoral systems were collected. Crossbred and pregnant animals were excluded from the study to avoid bias. The Oudah type is dichromic (black or brown at the front and white at the back), kept by the Oudah transhumant communities (Figure 2). The Waïla types are monochromic (White) and kept by Waïla transhumant groups (Figure 3).

Body measurements were done as previously described by FAO (2008; 2013) and AU-IBAR (2015). The age of the animals was obtained by interviewing the owner and confirmed by the dentition. The following measurements were taken (Figure 4)

DOI: 10.46325/gabj.v7i1.282

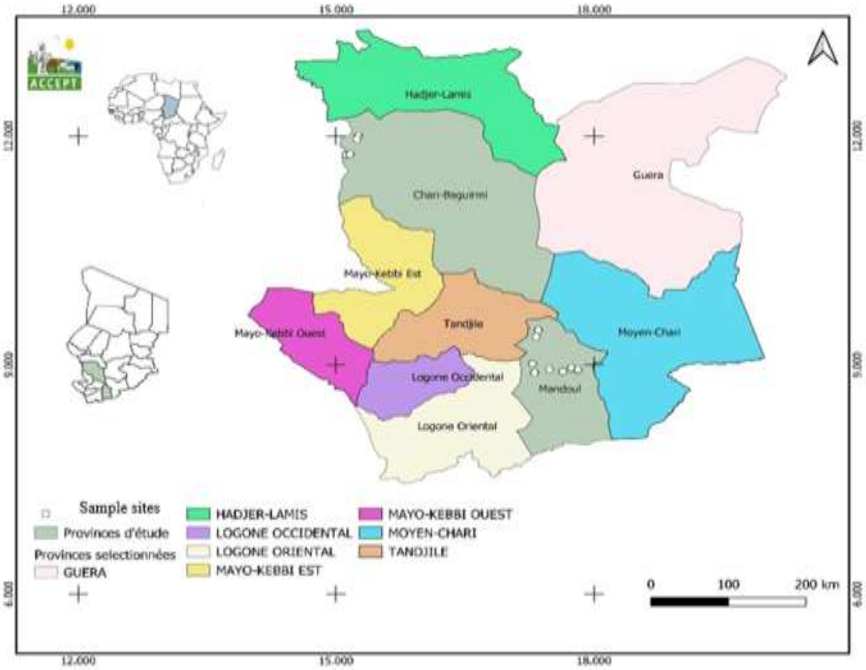

Figure 1: Study area.

Figure 2: Waila sheep

Figure 3: Oudah sheep

Figure 4: Body measurement

Head measurements: Head length (HL), Head Width (HWh) and Ear Length (EL),
Body Measurement: Total Body Length (TBL), Body Length (BL), Height at Withers (HW), Rump Height (RH), Chest Circumference (CC), Chest Depth (CD), Rump Length (RL), Rump Width (RW), Neck Length (NL), Tail Length (TL), Testicle Length (TesL), Testicle Circumference (TesC), Barrel Circumference (BC) and Body Weight (BW).

DOI: 10.46325/gabj.v7i1.282

Biometric indices were calculated to appreciate the relationships between the measurements using previously described formulas (Boujenane *et al.*, 2008; Ngono *et al.*, 2019; Meka *et al.*, 2021).

The following eleven indices were calculated (Table 1)

Table 1: Biometric index evaluation

Index	Calculation	Definition
Subternal Gracility Index (SGI	HW-CD/CD	This index highlights the stocky or wading character of the animal.
Auriculo-thoracic Index (ATI)	EL/CD	It allows to assess the development of the ear of sheep
Format Index (FI)	BL/HW	Determine the format on animal
Compactness Index (CI)	CC/BL	
Massivity Index (MI),	CC/HWh	Determine the mass on animal
Slenderness index (SI)	LP/PT	
Frame Index (FrI)	CB/HWh	
Body Index (BI)	BL/CC	It possible to determine the format of the animal
Finger-Thoracic Index (FTI)	CB/CC	
Caudal Index (CaI)	TL/HW	Determine the height of tail on animal
Ear Index (EI).	EL/HWh	Determine the sizeof ear on animal

HWh: Head Width; CD: Chest Depth; EL: Ear Length;BL: Body Length; CC: Chest Circumference; BC: Barrel Circumference; TL: Tail Length; HW: Heigh at Withers.

Statistical analyses

Descriptive statistics were used to calculate the means, standard deviations, and coefficient of variation of the various measurements and indices. The analysis of variance was used to test the influence of sex, genetic type, and zones on the measurement. The F-test was used to highlight the influence of sex on the measurements and body indices.

Table 2: Sample size according to different factor

Factors	Modalities	Sample size
Sex	Ewe	229
	Ram	80
Genetic type	Oudah	237
	Waïla	72
Zones	Sahelian	146
	Sudanian	163

F-test was used to separate the means when the effect of zone and gender were significant at the threshold ($p<0.05$). The meaning and degree of association between measurements and biometric indices were assessed using Pearson's correlation coefficients.

Principal Component Analysis (PCA) based on measurement and body index was performed to assess the cause of genetic diversity (Faye *et al.*, 2012). Discriminant Factor Analysis (DFA) based on 17 body measurements (FAO, 2013) was used to identify the types of genetic relationships of the studied population. A coefficient of variation of less than 15% is considered to indicate that the population is homogeneous, while a coefficient of more than 15% indicates that the values are relatively dispersed (Peter, 2020; Faria *et al.*, 2010).

The construction of the phylogenetic tree following the Ascending Hierarchical Classification (HAC) protocol was used to establish the genetic relationship between the genetic types (Roux, 2006). These different statistical analyses were done using SPSS 21.0 and XLSTAT 2022 software.

DOI: 10.46325/gabj.v7i1.282

Results

Biometric index in Fulani Sheep in Sahelian and Sudanian zone of Chad

Tables 3 and 4 present the descriptive analyses of the body measurement of Fulani sheep in Chad. According to the sex, NL, EL, and TL were not significantly different (P>0.05). The results showed that HW, RH, CD, CC, HL, BL, TBL, RL, CB, TL, and BW were significantly influenced (P<0.05) by the province of the location of the sheep. While HW, EL, RL, TesL, and TesC were not influenced (P>0.05) by the location of the sheep. The highest WH was obtained in Oudah 81.37±5.32 cm and 78.90 ± 6.56 cm for Waïla). Similar trends were observed for the other measurement. The highest BW was recorded with Oudah sheep (38.78±3.29kg). BC was more dispersed with a coefficient of variance of 20.67 (Table 3).

Correlation between body measurements

Table 5 shows the correlations between body measurements. A strong correlation (r=0.89) was found between WH and RH. BW was significantly (P<0.01) correlated with WH (r=0.95), RH (r=0.89) and CC (r= 0.58). A significantly negative correlation (r=-0.058) was obtained between BL and NL

Genetic variability according to the biometric measurement of Fulani sheep in Chad

The correlation matrix between the biometric measurements and factors is shown in Table 6. The Kayser-Meyer-Olkin (KMO) index for the efficiency of the samples for the Principal Component Analysis (CPA) of the measurements was 0.75. Five (05) components make it possible to better explain phenotypic variability. Components 1 and 2 contribute 39.39% and 8.97% respectively for a cumulative variability of 48.36%. Components 3, 4, and 5 contribute to a cumulative variability of 70.94%.

Figure 5 shows the discrimination between the different variables that are negatively correlated with each other (NL, HWh, EL, RL, CD, RH on the F2 axis). It appears that RW, CC, BL, TBL, BW, BC, and HW are positively and strongly correlated on the F1 axis.

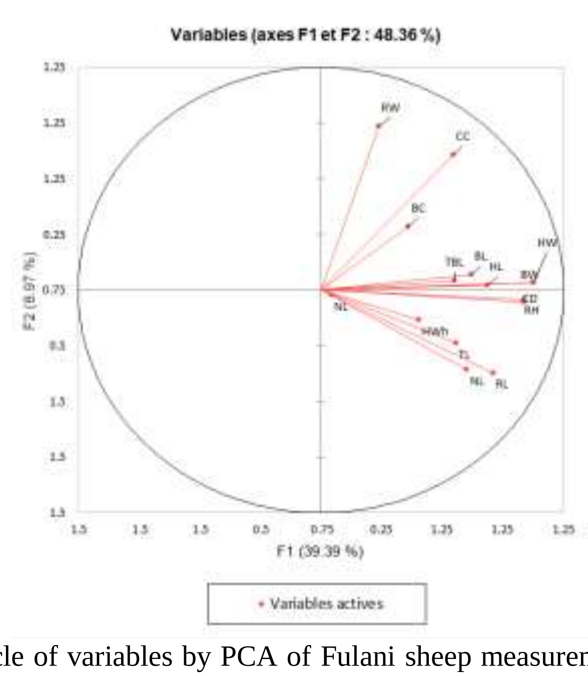

Figure 5: Correlation circle of variables by PCA of Fulani sheep measurement in sahelian and sudanian zones of Chad. *HW: Height at Withers, RH: Rump Height, CC: Chest Circumference, CD: Chest Depth, EL: Ear Length, HL: Head Length, HWh: Head Width, LB: Length Body, NL: Neck length, TBL: Total Body Length; RL: Rump Length; RW: Rump Width; TL: Tail Length; BC: Barrel Circumference; BW: Body Weight.*

Table 3: Biometric measurement of Fulani sheep by sex, genetic typeand zones

Variable	Sex Mean ± SD (CV)		Genetic type Mean ± SD (CV)		Zones Mean ± SD (CV)		Total Mean ± SD (CV) [n = 309]
	Female [n = 229]	Male [n = 80]	Oudah [n = 237]	Waïla [n = 72]	Sahelian [n = 146]	Sudanian [n = 163]	
HW	79.93±4.94^{a}(6.18)	83.26±6.98^{a}(8.38)	81.37±5.32^{a}(6.53)	78.90±6.56^{a}(8.34)	79.25±6.18^{a}(7.79)	82.17±4.88^{a}(5.93)	80.79±5.71(7.06)
RH	79.45±5.38^{a}(6.77)	83.31±5.68^{a}(6.81)	81.00±5.36^{a}(6.67)	78.64±6.45^{a}(8.20)	79.15± 6.56^{a}(8.28)	81.62±4.54^{a}(5.56)	80.45±5.71 (7.09)
CC	83.44±9.04^{a}(10.83)	88.69±9.10^{a}(10.26)	85.25±9.19^{a}(10.78)	83.32±9.68^{b}(11.61)	83.10±11.48^{a}(13.81)	86.32±6.52^{a}(7.55)	84.80±9.33 (11.0)
CD	39.77±4.80^{a}(12.06)	41.52±5.51^{a}(13.27)	40.46±5.01^{a}(12.38)	39.41±5.13^{b}(13.01)	36.94±4.66^{a}(12.61)	43.16±3.26^{a}(7.55)	40.22±5.05(12.55)
EL	20.97±3.05^{a}(14.54)	20,74±2.49^{b}(12.00)	21.09±2.87^{a}(13.60)	20.31±2.98^{a}(14.67)	20.80±3.12^{a} 15.00)	21.01±2.72a (12.94)	20.91±2.91 13.91)
HL	24.66±3.02^{a}(12.24)	27.18±3.10^{a}(11.40)	25.28±3.24^{a}(12.81)	25.40±3.22^{b} 12.67)	23.77±2.92^{a} 12.28)	26.69±2.86^{a} (10.71)	25.31±3.23 12.76)
HWh	10.56±1.44^{a}(13.63)	11.06±1.68^{a}(15.18)	10.61±1.48^{a} 13.94)	10.96±1.60^{b}(14.54)	10.71±1.27^{a}(11.85)	10.67±1.72^{b} (16.12)	10.69±1.52 14.21)
BL	71.89±6.43^{a}(8.94)	73.77±8.18^{a}(11.08)	72.57±6.70^{a}(9.23)	71.75±7.76^{b} 10.81)	71.14±6.98^{a}(9.81)	73.48±6.78^{a}(9.22)	72.38±6.96(9.60)
TBL	100.38±6.75^{a}(6.72)	104.36±8.71^{a}(8.34)	101.54±6.67^{a} 6.56)	101.00±9.78^{b} 9.68)	104.18±6.48^{a}(6.22)	98.93±7.50^{a}(7.58)	101.41±7.50(7.39)
RL	21.11±2.76^{a}(13.07)	22.97±2.32^{a}(10.10)	21.67±2.70^{a} 12.46)	21.35±3.03^{b} 14.19)	21.46±3.26^{a}(15.19)	21.71±2.26^{b} (10.40)	21.59±2.77(12.83)
RW	16.40±2.47^{a}(15.06)	17.55±3.27^{a}(18.63)	16.71±2.93^{a}(17.54)	16.65±2.01^{b} 12.07)	16.67±2.24^{a} 13.43)	16.72±3.13^{b} (18.72)	16.70±2.74 16.40)
BC	8.95±1.85^{a}(20.67)	9.51±1.00^{a}(10.51)	9.11±1.79^{a}(19.64)	9.06±1.28^{b}(14.12)	8.79±1.67^{a}(18.79)	9.37±1.65^{a}(17.60)	9.10±1.68(18.46)
TL	47.52±7.36^{a}(15.48)	48.79±7.17^{b}(14.69)	47.97±7.72^{a} 16.09)	47.44±5.86^{b}(12.35)	46.85±7.05^{a}(15.04)	48.75±7.47^{a}(15.32)	47.85±7.32(15.29)
NL	25.55±3.06^{a}(11.97)	25.72±4.09^{b}(15.90)	25.77±3.35^{a} 12.99)	25.04±3.29^{b} 13.13)	25.33±3.02^{a}(11.92)	25.84±3.61^{a}(13.97)	25.60±3.34 13.04)
TesL		22.20±3.64 (16.39)	22.94±3.07^{a} 13.38)	19.63±3.51^{a} 17.88)	23.15±4.15^{a} 17.92)	21.64±3.05^{a}(14.09)	22.11±3.47 15.69)
TesC		30.21±4.85 (16.05)	31.44±4.21^{a} 13.39)	27.56±5.21^{a} 18.90)	32.60±5.32^{a} 16.32)	29.50±4.17^{a} (14.13)	30.47±4.75(15.58)
BW	37.89±3.06^{a}(8.07)	39.96±4.33^{a}(10.83)	38.78±3.29^{a}(8.48)	37.25±4.06^{a}(10.89)	37.47±3.83^{a}(10.28)	39.28±3.03^{a} (7.71)	38.43±3.54(9.21)

^{a,b} means with the same letter on the line differ significantly (P<0.05), N: Number; SD: Standard Deviation; CV: Coefficient Variance
HW: Height at Withers, RH: Rump Height, CC: Chest Circumference, CD: Chest Depth, EL: Ear Length, HL: Head Length, HWh: Head Width, LB: Length Body, NL: Neck length, TBL: Total Body Length; RL: Rump Length; RW: Rump Width; TL: Tail Length; BC: Barrel Circumference; TesL: Testicle Length; TesC: Testicle Circumference; BW: Body Weight.

Table 4: Influence of biometric index of Fulani sheep according to sex, Genetic typeand zone

Variable	Sex	Genetic type	Zone	Total
	Mean ± SE (CV)	Mean ± SE (CV)	Mean ± SE (CV)	Mean ± SE (CV)

DOI: 10.46325/gabj.v7i1.282

	Female [n = 229]	Male [n = 80]	Oudah [n = 237]	Waïla [n = 72]	Sahelian [n = 146]	Sudanian [n = 163]	[n = 309]
IGS	1.03±0.22[a] (21.35)	1.02±0.18[b] (17.64)	1.03±0.21[a] (20.38)	1.02±0.20[b] (19.60)	1.16±0.21[a] (18.10)	0.91±0.11[b] (12.08)	1.03±0.21 (20.38)
ATI	0.53±0.07[a] (13.20)	0.50±0.07[a] (14.00)	0.52±0.07[a] (13.46)	0.51±0.08[b] (15.68)	0.56±0.06[a] (10.71)	0.48±0.05[a] (10.41)	0.52±0.07 (13.46)
FI	1.25±0.10[a] (8.00)	1.25±0.10[b] (8.00)	1.25±0.10[a] (8.00)	1.28±0.09[a] (7.03)	1.32±0.07[a](5.30)	1.20±0.09[a] (7.50)	1.26±0.10(7.93)
CI	0.83±0.09[a] (10.84)	0.85±0.07[b] (8.23)	0.84±0.09[a] (10.71)	0.82±0.09[a] (10.97)	0.79±0.10[a] (12.65)	0.87±0.06[a] (6.89)	0.83±0.09 (10.84)
MI	1.04±0.11[a] (8.00)	1.07±0.12[b] (11.21)	1.04±0.11[a] (10.57)	1.06±0.11[b] (10.37)	1.05±0.15[a](14.28)	1.05±0.06[b] (5.71)	1.05±0.11 (10.47)
SI	0.50±0.04[a] (8.00)	0.50±0.04[b] (8.00)	0.50±0.04[a] (8.00)	0.50±0.05[b] (10.00)	0.53±0.04[a] (7.54)	0.47±0.03[a] (6.38)	0.50±0.04 (8.00)
FrI	0.11±0.02[a] (18.18)	0.11±0.01[b] (9.09)	0.11±0.02[a] (18.18)	0.11±0.01[a] (9.09)	0.11±0.02[a] (9.09)	0.11±0.02[b] (9.09)	0.11±0.02 (9.09)
BI	0.87±0.14[a] (16.09)	0.83±0.10[a] (12.05)	0.86±0.14[a] (16.27)	0.87±0.12[a] (13.79)	0.87±0.18[a] (20.68)	0.85±0.06[a] (7.06)	0.86±0.13 (15.11)
FTI	0.11±0.02[a] (18.18)	0.10±0.01[b] (10.00)	0.11±0.02[a] (9.09)	0.11±0.01[b] (9.09)	0.10±0.03[a] (10.00)	0.11±0.02[b] (9.09)	0.10±0.02 (10.00)
CaI	0.59±0.08[a] (13.55)	0.58±0.07[b] (12.07)	0.59±0.08[a] (13.55)	0.60±0.06[b] (16.66)	0.59±0.08[a] (13.55)	0.59±0.08[b] (13.55)	0.59±0.08 (13.55)
EI	0.26±0.03[a] (11.55)	0.25±0.02[b] (8.00)	0.25±0.03[a] (12.00)	0.26±0.03[a] (11.54)	0.26±0.03[a] (11.54)	0.25±0.03[b] (12.00)	0.26±0.03 (11.54)

[a,b]the means with the same letter on the line differ significantly (P<0.05), N: Number; ES: Standard Error; CV: Variation coefficient

SGI: Sternal Gracility Index, ATI: Auriculo-thoracic Index, FI: Format Index, CI: Compactness Index, MI: Massivity Index, SI: Slenderness index, FrI: Frame Index, BI: Body Index, FTI: Finger-Thoracic Index, CaI: Caudal Index and EI: Ear Index

DOI: 10.46325/gabj.v7i1.282

Table 5: Correlation of body measurement of Fulani sheep in sahelian and sudanian zones of Chad

	HW	RH	CC	CD	NL	HL	HWh	BL	TBL	RL	RW	BC	TL	NL	TesL	TesC	BW
HW	1																
RH	0.897**	1															
CC	0.402**	0.350**	1														
CD	0.692**	0.677**	0.442**	1													
NL	0.399**	0.397**	0.204**	0.492**	1												
HL	0.497**	0.498**	0.354**	0.696**	0.406**	1											
HWh	0.256**	0.212**	0.165**	0.229**	0.144**	0.263**	1										
BL	0.441**	0.400**	0.377**	0.495**	0.305**	0.292**	0.330**	1									
TBL	0.401**	0.399**	0.295**	0.217**	0.301**	0.250**	0.253**	0.402**	1								
RL	0.485**	0.512**	0.236**	0.593**	0.558**	0.447**	0.363**	0.394**	0.466**	1							
RW	0.185**	0.134**	0.424**	0.135**	-0.029	0.177**	0.048	0.102*	0.145**	0.003	1						
BC	0.236**	0.113*	0.309**	0.286**	0.255**	0.268**	0.126*	0.287**	0.269**	0.143**	0.065	1					
TL	0.388**	0.368**	0.164**	0.439**	0.417**	0.325**	0.276**	0.316**	0.268**	0.422**	0.166**	0.054	1				
NL	0.011	0.095*	0.112*	0.015	-0.035	-0.052	-0.011	-0.058	-0.016	0.123*	0.056	-0.125*	0.163**	1			
TesL	0.368**	0.363**	0.552**	0.304**	0.246*	0.200	0.055	0.103	0.382**	0.496**	0.299**	0.320**	0.395**	0.195	1		
TesC	0.379**	0.449**	0.373**	0.036	0.247*	-0.247*	-0.279*	0.026	0.252*	0.311**	0.147	0.278*	0.040	0.062	0.638**	1	
BW	0.950**	0.897**	0.402**	0.692**	0.399**	0.497**	0.256**	0.441**	0.401**	0.485**	0.185**	0.236**	0.388**	0.011	0.368**	0.379**	1

** : *Coefficient of correlation is significant at level 0.01*

*: *Coefficient of correlation is significant at level 0.05*

HW: Height at Withers, RH: Rump Height, CC: Chest Circumference, CD: Chest Depth, EL: Ear Length, HL: Head Length, HWh: Head Width, LB: Length Body, NL: Neck length, TBL: Total Body Length; RL: Rump Length; RW: Rump Width; TL: Tail Length; BC: Barrel Circumference; TesL: Testicle Length; TesC: Testicle Circumference; BW: Body Weight.

Table 6: Correlation matrix between variables and factors of Fulani sheep in Sahelian and Sudanian zones of Chad

Factor (F)					
Variables	F1	F2	F3	F4	F5
HW	0.874	0.034	0.202	-0.318	-0.217
RH	0.836	-0.055	0.300	-0.287	-0.197
CC	0.544	0.609	-0.006	0.155	0.137
CD	0.837	-0.042	0.041	-0.165	0.272
EL	0.602	-0.356	-0.188	0.048	0.406
HL	0.686	0.020	-0.073	-0.115	0.350
HWh	0.404	-0.133	-0.231	0.442	-0.381
BL	0.620	0.068	-0.294	0.177	-0.210
TBL	0.549	0.041	-0.250	0.285	-0.362
RL	0.710	-0.371	-0.034	0.253	0.063
RW	0.237	0.736	0.217	0.225	0.058
BC	0.361	0.285	-0.606	-0.040	0.242
TL	0.558	-0.236	0.186	0.382	0.157
NL	0.044	-0.022	0.644	0.485	0.164
BW	0.874	0.034	0.202	-0.318	-0.217

WH: Height at Withers,RH: Rump Height, CC: Chest Circumference, CD: Chest Depth, EL: Ear Length, HL: Head Length, HWh: Head Width, LB: Length Body, NL: Neck length, TBL: Total Body Length; RL: Rump Length; RW: Rump Width; TL: Tail Length; BC: Barrel Circumference; TesL: Testicle Length; TesC: Testicle Circumference; BW: Body Weight

Table 7: Characteristics of morphotypes based on measurements of Fulani sheep in Sahelian and Sudanian zones of Chad

Variables	T1	T2	T3	T4
HW	78.00	88.28	94.00	81.00
RH	79.97	87.21	95.00	91.00
CC	84.38	97.50	101.00	61.00
CD	39.90	46.25	50.50	40.00
NL	20.87	22.07	23.00	18.00
HL	25.01	31.14	30.00	26.00
HWh	10.61	12.43	10.00	10.00
BL	72.15	77.35	75.00	70.00
TBL	100.89	111.07	116.00	102.00
RL	21.39	24.93	26.00	24.00
RW	16.61	19.14	18.00	13.00
BC	9.14	10.07	10.00	9.00
TL	47.36	56.78	55.00	51.00
NL	25.55	24.71	31.00	32.00
TesL	21.91	26.43	20.00	22.11
TesC	30.39	31.50	38.00	30.47
BW	38.18	43.08	46.62	38.56

T1 = Oudahmorphotype; T2 = Waïla morphotype ; T3 = Oudah morphotype ; T4 = Oudah morphotype.
HW: Height atWithers, RH: Rump Height, CC: Chest Circumference, CD: Chest Depth, EL: Ear Length, HL: Head Length, HWh: Head Width, LB: Length Body, NL: Neck length, TBL: Total Body Length; RL: Rump Length; RW: Rump Width; TL: Tail Length; BC: Barrel Circumference; TesL: Testicle Length; TesC: Testicle Circumference; BW: Body Weight.

Phylogenetic relationship between morphotype according to measurements Fulani sheep in Sahelian and Sudanian zones of Chad

The analysis of the structure of the population was carried out thanks to the Discrimant Factoriel Analysis (DFA), which made it possible to distinguish 2 groups. The 1st group consists of types 1 and 2 and the 2nd group consists of types 3 and 4. The same applies to the biometric characteristics of the morphotype observed (Table 7). It turns out that types 3 and 2 have higher characteristics than types 1 and 4.

According to Figure 6, the HWh is negatively correlated with the F2 axis. The TBL, HWh, RW, BC, BL, and RL are strongly correlated with the F1 axis. The TBL, RH, BW, and CC seem to be the most discriminating.

The dendrogram (Figure 7) illustrates the relationships between morphotypes based on their dissimilarity. Thus while confirming the phylogenetic tree, morphotypes 1 and 3 are closer, on the other hand, morphotypes 3 and 4 are distant

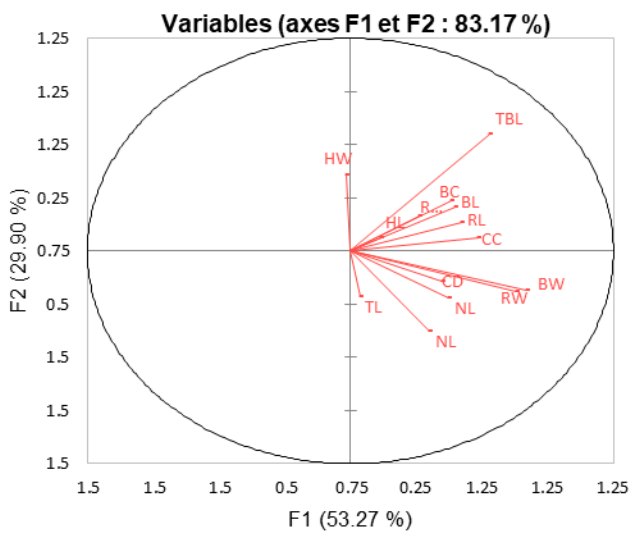

Figure 6: Correlation of Fulani sheep class factor variables in Sahelian and Sudanian zones of Chad
HW: Height at Withers, RH: Rump Height, CC: Chest Circumference, CD: Chest Depth, EL: Ear Length, HL: Head Length, HWh: Head Width, LB: Length Body, NL: Neck length, TBL: Total Body Length; RL: Rump Length; RW: Rump Width; TL: Tail Length; BC: Barrel Circumference; TesL: Testicle Length; TesC: Testicle Circumference; BW: Body Weight

The Table 8 indicates that the intra-class variance greater than the inter-class variance.

Table 8: Variance decomposition for optimal classification of Fulani sheep in sahelian and sudanian zones of Chad.

Categories de variance	Absolute	%
Intra-class	124257.42	90.59
Inter-class	12909.01	9.41
Over all inertia	137166.43	100.00

DOI: 10.46325/gabj.v7i1.282

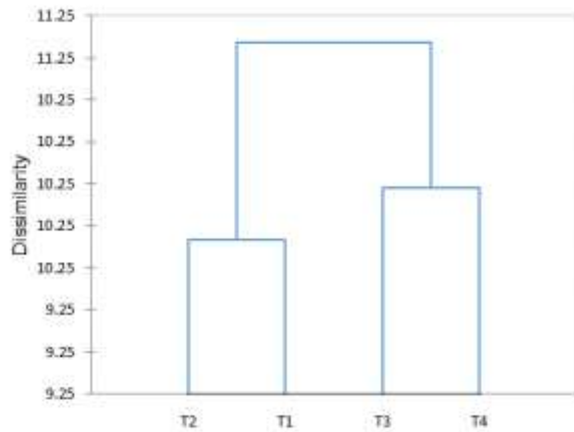

Figure 7: Dendrogram of Fulani sheep morphotype in sahelian and sudanian zones of Chad *T1, T3, T4: Oudah morphotype; T2: Waïla morphotypeVérifier le séparateur des décimales sur l'axe des ordonnées*

Discussion

The results of the analysis of biometric data obtained in the Fulani sheep population show a phenotypic variability (P<0.05). The average WH obtained in Oudah and Waïla sheep (81.37±5.32 cm and 78.90±6.56 cm) is comparable to those reported by Yakubu*et al*. (2011) in Uda (83.9±0.21 cm) and Yankassa (75.8±0.48 cm) sheep in Nigeria. Yunusa (2013) obtained (77.41±0.42 cm) in Uda sheep in Nigeria. Zeuh*et al*. (2013) reported an average of 83.85 cm in male and 80.01 cm in female Fulani sheep in Chad. On the other hand, lower averages were reported among the Uda (61.20 cm) and Balami (71.13 cm) by Fayeye and Adewale (2017) in Nigeria. In general, the HL of 25.28±3.24 cm in the Oudah and (25.40±3.22 cm) in the Waïla was obtained. Tadakeng (2015) obtained a lower value in sheep from West Cameroon (20.04±3.34 cm). The average HW obtained in Oudah and Waïla sheep was 10.61±1.48 cm and 10.96±1.60 cm. These results corroborate those of Meka et al. (202) in Blackbelly sheep (10.88 ± 1.42 cm). The EL obtained is significant among the Oudah (21.09±2.87 cm) and the Waïla (20.31±2.98cm). Dumas (1980) in Chad and Dayo (2015) in Togo reported similar values in Fulani sheep (20.5±0.8 cm) and Sahel sheep (21.63±2.48 cm) respectively. In general, the mean BL obtained in the two provinces among the Oudah and Waïla was 72.57±6.70 cm and 71.75±7.76 cm respectively. These results are comparable to those obtained by Zeuh (2013) in Fulani sheep (70.90 cm). On the other hand, Meka (2021) obtained a higher average (79.196±8.98 cm) in Blackbelly sheep in Central Africa. Yakuba (2011) obtained (76.6±0.27cm) among the Uda and (70.9±0.37cm) among the Yankassa in Nigeria. Yunusa (2013) obtained similar values (69.97±0.42 cm) in Uda sheep in Nigeria. The mean length and width of the rump of 21.67±2.70 cm and 16.71±2.93 cm were obtained respectively. A similar value was reported by Denis (1975) in Fulani sheep from Senegal (14.4±0.5 cm). Meka (2021) reported a rump length in black belly sheep in Cameroon of 19.93 ± 6.22 cm.

The general mean of the RH obtained was 81.14±5.36 cm and 78.50±6.56 cm in the Oudah and Waïla sheep respectively. Osaiyuwu (2010) reported a similar average of 83.96±5.99 cm in Balami sheep in Nigeria. The mean TesL obtained was 22.94±3.07 cm among the Oudah and 19.63±3.51 among the Waïla. On the other hand, Fayeye and Adewale (2017) reported the highest values in the Uda (32.09 cm) and Balami (39.19 cm) in Nigeria.

The average BW obtained was higher in the Sudanian zone (39.28±3.03 Kg) whatever the type of sheep. This result could be explained by the availability of food resources for a good part of the year, unlike the Sahelian part. Dumas (1980) reported a high BW in Fulani sheep in Chad of 47.7±1.6 Kg. Meka *et al.* (2021) in Cameroon, reported low weight in Blackbelly (27.45±6.08 kg). Wagari *et al.* (2020) reported a weight (29.2±0.15Kg) in indigenous sheep of Ethiopia.

A positive and significant correlation (P<0.05) between the different measurements of Fulani sheep was obtained. The correlation coefficient varies from -0.011 (between HL and NL) to 1.00 (between BW and

DOI: 10.46325/gabj.v7i1.282

WH). A higher correlation is obtained between BW and WH (r=0.95). A strong and significant correlation (P<0.01) is observed between WH and RH (r=0.89). A significantly negative correlation (-0.058) is obtained between the BL and NL.

Analysis of biometric indices showed significant variability (P<0.05) in the Fulani sheep population. The average of the SGI observed in Oudah and Waïla sheep are 1.03±0.21 and 1.02±0.20 with a coefficient of variation of 19.20. Meka et al. (2021) and Gueye (1997) reported a similar result in Blackbelly sheep in Central Africa and Fulani in Senegal of (1.29±0.56) and (1.51). The highest CI is obtained in the Sudanian zone for Oudah (0.87±0.05) and Waïla (0.86± 0.08) sheep. The overall mean of the MI obtained was 1.04 ± 0.11. Similar means are reported by Meka et al. (2021) and Tadakeng (2015) of 1.20±0.11 and 1.13 respectively in Blackbelly sheep and in West Cameroon sheep. The BI was higher by 0.87±0.19 and more dispersed with a coefficient of variation of 21.83 in Oudah sheep.

The principal component analysis revealed that 5 components contribute to 70.94% of the phenotypic variability observed within the Fulani sheep population. Components 1 and 2 explain 39.39 and 8.97 of the variability observed according to body measurements respectively. On the other hand, Yakubu (2013) and Osaiyuwu (2010) obtained 3 components after the PCA of the measurements collected from Blackbelly, Yankassa and Balami sheep from Cameroon and Nigeria respectively. These results are almost similar to those of Meka *et al.* (2021) and Rodrigo (2015) who reported that 6 components explained the phenotypic variability in the sheep population of Cameroon and Chile respectively. However, we can observe in all these results that the 1st component mainly explains the major phenotypic variability and could be used for a selection program. PCA showed that the 7 variables (WH, RH, CC, RL, BL, HL and BW) explain the variation at CP1 to the maximum. The CC had a strong contribution to CP1 in Yankassa sheep in Nigeria (Yakubu, 2013). Our results corroborate those of Meka*et al*. (2021), who reported that WH has a strong contribution to CP1. Thus WH could well be a selection criterion because it is strongly and significantly correlated with BW.

Discriminant Factor Analysis (DFA) made it possible to obtain 4 classes in the Fulani sheep population. Class 1 is characterized by low body measurements (HW=78cm; CC= 84 cm; TBL= 100 cm and BW= 38 kg), class 4 recorded low characteristics (HW=81cm; CC= 61 cm; TBL= 102 cm and BW= 38.56 kg); class 2 has medium characteristics (HW = 88.28 cm; CC= 97.72 cm; TBL= 111.07 cm and BW=43.07 kg) and class 3 has high characteristics (HW=94 cm; CC=101 cm; TBL=111 cm and BW=46.6 kg) compared to the previous ones. The Ascending Hierarchical Classification (HAC) has made it possible to distinguish two subgroups based on the body measurement of Fulani sheep. The 1st subgroup is made up of types 2 and 1 and the 2nd subgroup is made up of types 3 and 4. AFD confirms these results; however, types 1, 3, and 4 are closer from the morphotype point of view than type 2, which is distant from type 4. Meka*et al.* (2021) reported 3 types of Blackbelly sheep from Central Africa.

Conclusion

A relatively wide phenotypic variability was observed in the Fulani sheep population. A high correlation is obtained between BW and HW (r=0.95). The HW could be used to estimate the BW and do the selection. The Discriminant Factor Analysis (DFA) made it possible to obtain 4 classes in the Fulani sheep population. AFD confirms these results, types 1, 3, and 4 are closer from the morphotype point of view while type 2 is distant from type 4. Biometric assessment coupled with genomics would increase the efficiency of the selection, improvement, and conservation of Fulani sheep.

Acknowledgement

Authors are grateful to ACCEPT project for providing financial support. Thank are also addressed to the decentralized livestock services, the guide and the pastors for their welcome and their frank collaboration during the surveys.

Authors' contribution

Djomtchaigue designed, collected, made analyzed the data and wrote manuscript,
Koussou, Awah-Ndukum and Meutchieye, supervised the work, revised and improved the paper contents.
Zeuh, Oumarand Tadakeng revised and improved the paper content.

Ethics

Authors declare that there are no ethical issues that may arise after the publication of this manuscript.

References

AU-IBAR. 2015. Pictorial field guide for linear measurements of animal genetic resources, Nairobi, Kenya. 65p.

Amadou H. Dossa LH. Lompo DJ. Abdulkadir A and Schlecht E 2012. A Comparison between Urban Livestock Production Strategies in Burkina-Faso, Mali and Nigeria in West-Africa. Tropical Animal Health and Production. Available at: DOI; 10.1007/s11250-012- 0118-0.

BarkerT. MooreM. Matheson and Selvaraj 2001. Genetic variation and relationships among populations of Asian goats *(Capra hircus).Journal of Animal Breeding and Genetics*, 118: 213233. doi:10.1046/j.14390388.2001. 00296.x.

Dayo GK. Alfa EE. Talaki K. Soedji S and 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.

Dumas R. 1980. Contribution à l'étude des petits ruminants du Tchad. *Revue Elev. Méd. Vét. Pays trop.*, 33(2): 215- 233.

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.

Faria FDE. Dias AN. Veloso ALC. Bueno CFD. Couto FAP. Matos JJB. Barreto KZO. Rodrigues PA. Carneiro WA. 2010. Classification of coefficients of variation in experiments with commercial layers. Braz J PoultSci, 12(4): 255 – 257

Faye B. Alharary FZ and Alrwaily SH. 2012. Gestion et évaluation du statut énergétique du dromadaire en Arabie Saoudite. Revue des BioRessources, 2 (2).

Fayeye TR and Adewale IF. 2017. Morphometric characterization of Uda, Balami and West African dwarf sheep. *Wayamba Journal of Animal Science* – ISSN: 2012-578X; P1553 - P1560, 2017 First Submitted May 21, 2017; Number 1495655400.

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

Groeneveld LF. Lenstra J.A. Eding H. Toro MA. Scherf B. Pilling D. Negrini R. Finlay E.K. Jianlin H. Groeneveld E and Weigend S 2010. Genetic diversity in farm animals a review. *Animal Genetics, 41: 6-31. Doi :10.1111/j.1365-2052.2010.02038.x.*

Meka ZII. Martin A. Tadakeng Y. Meutchieye F and Fonteh F. 2021. Biometric Assessment of Blackbelly Sheep in Central Africa. *Genet. Biodiv. J* , 5(2) : 139-153.

Mopate LY.TellahM. AdoumYI.SouleymanMS. 2020. Rendement carcasse des ovins sahéliens dans la Province du Guera au Centre-Est du Tchad. www.m.elewa.org/journals/on 29thFebruary 2020. https://doi.org/10.35759/JABs.

Muigai A and Hanotte O. 2013. The Origin of African Sheep: Archaeological and Genetic Perspectives. *African Archaeological Review.* 30. 10.1007/s10437-013-9129-0.

Ndiaye B. Diouf MN. Ciss M. Wane M. Diop M and Sembène M 2013. Morphologie et pratiques d'élevage du mouton Fulani-Fulani du Sénégal. Journal Homepage: -www.journalijar.com Article DOI:10.21474/IJAR01/7089 DOI URL: http://dx.doi.org/10.21474/IJAR01/7089.

Ngono EPJ. Meutchieye F and 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.

Njoya A. Awah ND and Bouchel D 1997. Influence de la complémentation et de la prophylaxie sur la variabilité des ovins Foulbé au Nord-Cameroun. *Revue Elev. Méd. vét. Pays trop.*, 50(2): 227-233.

Osaiyuwu OH. Akinyemi MO and Salako AE. 2010. Factor analysis of the morphostructure of mature Balami sheep. *Res J Anim Sci*. 2010;4(2):63–65.

Otchere EO. Ahmed HU. Adenowo TK. Kallah MS. Bawa ELK. Olorunju SA and Voh J 1987. Production ovine et caprine dans le secteur agropastoral traditionnel Fulani, au Nigeria septentrional. *Revue Mondiale de Zootechnie*. 64: 50-55.

Peter F. 2020. Mesures de dispersion et de forme. Statistiques (les stats en bulles) / Pearson Education, 22p.

RodrigoB.AndrésC. Cecilia C. FernandoS.2015. Body arquitecture of main sheep breeds in chile: Journal of Animal Ethnology (2015) 1: 1-9.

Roux M. 2006. Algorithmes de classification. Université Paul Cézanne Marseille, France.

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

Sougnabé P 2013. La sédentarisation comme moyen d'adaptation aux baisses de la pluviométrie chez les éleveurs Peuls en Savane tchadienne. VertigO, 13(1).

Tadakeng DY 2015. Biodiversité des ovins *(Ovisaries)* des hautes terres de l'ouest-Cameroun. Département des science Animales, Université de Dschang.

Traoré A. Tamboura HH. Kaboré A. Yaméogo N. Bayala B. Zaré I 2006. Caractérisation morphologique des petits ruminants (ovins et caprins) de race locale ''Mossi'' au Burkina Faso. Agri., 39 : 39-50. DOI: 10.1017/S101423390000212.

Traore A. Tamboura HH. Kabore A. Royo LJ. Fernandez I. Álvarez I. Sangare M. Bouchel D. Poivey JP. Francois D. Toguyeni A. Sawadogo L and Goyache F 2008. Multivariate Characterization of Morphological Traits in Burkina Faso Sheep. Small Ruminant Res. 80:62-67.

Wagari G, Getachew T, Bayou E 2020. Multivariate analysis of phenotypic traits of indigenous sheep revealed new population in western part of Ethiopia. Int J Agric Sc Food Technol 6(1): 050-057. DOI: https://dx.doi.org/10.17352/2455-815X.000055

Yakubu A. Raj AO and meje JN 2010. Genetic and phenotypic differentiation of qualitative traits in Nigerian indigenous goat and sheep populations. *ARPN J. Agric. Bio. Sci.*, 5(2): 58-66.

Yunusa AJ. Salako AE and Oladejo OA 2013. Morphometric characterization of Nigeria indigenous sheep using multifactorial discriminant analysis. Vol. 5(10), pp. 661-665, October2013.DOI:10.5897/IJBC2013.0592.ISSN2141243X©2013.AcademicJournalshttp://www.academicjournals.org/IJBC.

Zaitoun IS. Tabbaa MJ and Bdour S 2005. Differentiation of native goat breeds of Jordan on the basis of morphostructural characteristics. Small Ruminant Res. 56 :173-182.

Zeuh V 2000. Caractérisation génétique des ruminants domestiques et inventaire des ressources végétales. ME/LRVZ/SCAC, Projet ASETO-2, Rapport Final, Laboratoire de Farcha, Tchad., 27 p.

Zeuh V. Mopaté LY and Issa Y 2013. Characterization of the Mayo-Kebbi Sheep: a Previously Unrecognised Ovine Breed of the Agro-Pastoral Zone of SouthWest Chad. *J Anim Prod Adv* 2013, 3(12): 331-341. DOI: 10.5455/japa.20140105080311.