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METRIC CHARACTERISTICS OF THE ZEBU (*Bos Indicus*) GUDALI VARIETY BANYO IN THE HIGH GUINEA SAVANNAH AREA OF CAMEROON

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Abstract: This work aims to assess the genetic diversity of local cattle breeds in Cameroon. For this purpose, biometric data were collected in six (6) localities of Mayo-Banyo, at random, on a sample of 321 adult Gudali variety Banyo zebus (234 cows and 87 bulls) aged 6 to 16 years old, with the body condition score varying from 2 to 4. Body measurements (cm) are presented as follows: Height at the withers (129.34 ± 0.50), height at the sacrum (134.56 ± 0.37), chest depth (67.37 ± 0.33), head length (47.62 ± 0.42), forehead length (20.33 ± 0.20), horn length (34.45 ± 1.56), ear length (22.66 ± 0.26), body length (187.74 ± 2.45), trunk length (130.5 ± 1.27), scapulo-ischial length (137.88 ± 1.33), pelvic length (42.87 ± 0.31), tail length (100.52 ± 0.88), pelvis width (38.31 ± 0.32), face width (17.61 ± 0.27), muzzle circumference (44.60 ± 0.44), chest circumference (167.81 ± 1.46), barrel circumference (18.60 ± 0.16), hock circumference (38.72 ± 0.35), hump circumference (73.37 ± 1.92) and live weight (350.24 ± 8.70). The main biometric indices are: The massivity index (2.69 ± 0.06 kg / cm), proportionality (94.42 ± 1.06), cephalic (37.13 ± 0.55), body profile (0.69 ± 0.01), surface (1.79 ± 0.02m2), format (1.44 ± 0.01), scapulo-ischial (1.06 ± 0.01), typist-thoracic (0.11 ± 0.00), thoracic development (0.77 ± 0.00), framing (0.14 ± 0.00). Bulls and other cattle reared in controlled systems presented a large format. The discriminant factor analysis made it possible to detect three morphometric types identifiable with two phenotypes.

Keywords: Gudali, Biometrics, Biometric index, Cameroon

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1. Introduction

In Cameroon, the cattle herd is estimated at just over 7.456.123 head and annually supplies 122,306 tons of meat, which represents an estimated contribution of 54% of all meat products (INS, 2017). This latter is mainly made up of zebus (99%), Taurus (1%) being very poorly represented. The zebus arrived in North Cameroon from Bornu (Nigeria today) almost 200 years ago (Paguem et al., 2020). Today they exist in two breeds: the Gudali zebu (34%) and the M'bororo zebu (66%) (Manjeli and Tchoumboué, 1990). The Gudali zebu exists in three varieties: the Ngaoundere, Tignere and Banyo (Lhoste, 1969).

They are found in Adamaoua where it is mainly reared by breeders of the Peul ethnic group. We estimate between 400.000 and 600.000 persons who derive most of their existence from cattle rearing (Hamadou, 2009). This breed represents for these breeders a very important animal genetic resource because of their immense capacity of adaptation in very varied climates and ecosystems (FAO, 2007) with a carcass yield oscillating between 46 and 52% (Lhoste, 1969), and an average milk yield of 483 liters in 168 days (Tebong, 1985). Despite the interest and importance of this breed, Gudali zebu has only been the subject of very few biometric studies (Lhoste, 1969; Tawah and Rege, 1994; Doba, 2016) compared to other breeds in the country. Metric characterization is most often used as a selection method (Sow et al., 1991). The Strategy Document for the Livestock, Fisheries and Animal Industries sub-sector prepared in 2011 by the Minister of Livestock, Fisheries and Animal Industries (MINEPIA), in line with strategic priority No.1 of the "Plan d'Action Mondial pour la gestion des resources zoogénétiques", recommends the inventory, characterization of animal genetic resources and monitoring of trends and associated risks. It is in this context that this study was initiated for a better evaluation of these animal genetic resources in Mayo-Banyo Division, Adamaoua region, which contains a little more than ¾ of the cattle population.

2. Materials and Methods

2.1. Study Period and Zone

This study was conducted between May and June 2020 in the Mayo-Banyo Division, Adamaoua region (Figure 1), and more precisely in the Banyo district. The prevailing climate is Sudano-Guinean, characterized by a long rainy season of seven months (from April to October) and a short dry season of five months (from November to March). Rainfall is abundant (1,500 to 1,800 mm) but unevenly distributed (MINEPAT, 2012). The relief is rugged with an altitude varying between 800m and 1800m.

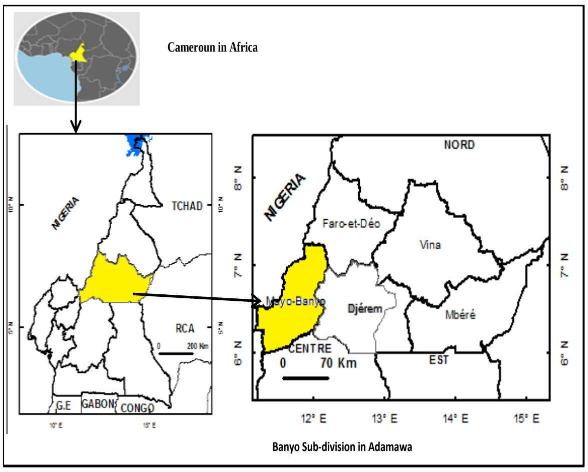

Figure 1. Study zone. Commune de Banyo (2015).

2.2. Sample Size

Data were collected in six (6) localities in Mayo-Banyo Division, in a random fashion, on a sample of 321 adult animals aged between 6 to 16 years with a body condition score ranging from 2 to 4 (Table 1). Pregnant cows, young bulls and sick animals were systematically eliminated from the collection. Age was estimated by dental chronometry and horn ring count, but also by interviewing the herdsman. Collection was done in the morning before the animals went out to pasture.

2.3. Data Collection

A total of 20 measurements were taken from the animal on level ground and in its normal stance (Figure 2), in accordance with the guidelines from AU-IBAR (2015) and FAO (2007). These are: chest perimeter (thoracic perimeter taken just behind the animal's front legs through the passage of the straps), body length (from the neck to the tail attachment), head length (from the bun to muzzle), scapulo-ischial length (measure from point of the shoulder to the ischium), trunk length (distance between the hump and the tail attachment), pelvis length (distance between the point of the hips and the point of the buttocks), tail length (length between the attachment of the tail and its end), length of the horns (longest distance from the root of the horn to its end), length of the forehead (length between the two horns and the two eyes), width of the face (distance between the two eyes), width of the pelvis (distance between the outer tips of the hips), height at withers (vertical distance from the ground to the point of the withers), ear length (measure the length behind the ear from root to tip), height at withers (vertical distance from the ground to the point of the withers), height to the sacrum (vertical distance from the ground to the sacrum), chest depth (vertical distance from the sternum straps to the spine), muzzle circumference (perimeter taken a little above the nostrils and around the point where the dewlap meets the chin), round of the barrel (perimeter taken at the level of the front barrel), round of the hump (perimeter taken at the level of the hump), round of the hock (perimeter taken at the level of the hock), live weight (estimated by the barymetry method described by Doba (2016), Live Weight = 0.00016 × Thorasic Perimeter$^{2.8467}$; r2 = 0.9701; probability threshold of 0.00001).

Table 1. Sample size according to different factors

Factors	Modalities	Sample size
Sex	Cow	234
	Bull	87
Reproduction system	Controlled	52
	Non controlled	269
Localities	Banyo Bunji	50
	Banyo Centre	116
	Banyo Leswouroun	9
	Banyo Tiqué	67
	Banyo-Tibati Border	34
	Mayo Djinga	45
Coat colour	White	25
	Black	23
	Pie	139
	Red	134

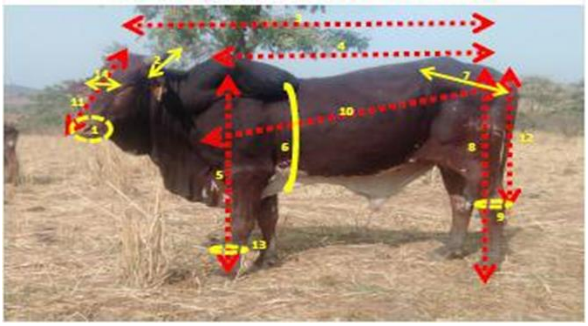

Figure 2. Biometric characteristics according to AU-IBAR (2015). 1: muzzle circumference, 2: length of the horn, 3: length of the body, 4: length of the trunk, 5: height at the withers, 6: chest circumference, 7: pelvis length, 8: height at the sacrum, 9: circumference hock, 10: scapulo-ischial length, 11: head length, 12: tail length, 13: barrel circumference, 14: face width.

In addition, to better appreciate the conformation of the animal, we used 10 biometric indices. These are: Scapulo-ischial index (ScI = scapulo-ischial length / Height at withers) Massiveness index (kg / cm) (MI = live weight / height at withers), Bones index (circumference of the anterior cannon / height at withers) ×100), Format index (FI = body length / height at withers), Cephalic index (CpI = (face width / face length × 100), Proportionality (Pr = height at withers / scapulo-ischial length) × 100), Thorasic development index (ThDeI = height at the withers / thoracic circumference), Surface index (cm^2) (SI = height at the withers × scapulo-ischial lengths), Dactylo Thoracic Index (DaThI = circumference of the anterior barrel / circumference of the thorax), Body Profile Index (PBI = height at withers / body length).

2.3. Statistical Analysis

The descriptive statistics (mean, standard deviation, coefficient of variation) as well as the General Linear Model were carried out using the SPSS.20 software while the XLSTAT-Pro version 2014.5.03 software was used to perform the principal component analysis (PCA). PCA reliability was established by the Kaiser-Meyer-Olkin Sampling Accuracy Test (KMO) and Bartlett's Sphericity Test. For a satisfactory factorial analysis, KMO > 0.50 is needed. 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).

3. Results

3.1. Measurements of the Head, Trunk, Peripherals and Live Weight According To Sex, Reproductive System, Location and Coat

The descriptive statistics of the measurements of the head, trunk and peripheral are summarized in Tables 2, 3, 4, 5 and 6.

Table 2. Lengths of the head, forehead, horns and ears according to sex, breeding system, locality and coat

Sources of variation	N	Face length	Face width	Front length	Horn length	Ear length
		μ ± se (cm) (CV)	μ ± se (cm) (CV)	μ ± se (cm) (CV)	μ ± se (cm) (CV)	μ ± se (cm) (CV)
Sex		***	***	***	ns	***
cows	234	46.76±0.37[a] (0.09)	16.62±0.24[a] (0.14)	19.90±0.26[a] (0.09)	36.01±1.39 (0.32)	21.98±0.23[a] (0.32)
Bulls	87	48.49±0.57[b] (0.08)	18.61±0.37[b] (0.14)	20.75±0.40[b] (0.17)	32.89±2.12 (0.36)	23.34±0.35[b] (0.32)
Breeding system		***	***	*	*	***
Controlled	52	48.82±0.70[a] (0.06)	18.52±0.44[a] (0.17)	20.84±0.49[a] (0.18)	31.48±2.57[a] (0.33)	23.41±0.42[a] (0.11)
Uncontrolled	269	46.42±0.29[b] (0.09)	16.71±0.19[b] (0.14)	19.82±0.21[b] (0.11)	37.42±1.09[b] (0.33)	21.91±0.18[b] (0.10)
Localities		***	ns	***	***	***
Banyo Bunji	50	46.26±0.61[c] (0.06)	17.12±0.39 (0.09)	19.84±0.43[bc] (0.06)	41.83±2.27[a] (0.29)	22.23±0.37[bc] (0.09)
Banyo Centre	116	50.20±0.32[a] (0.08)	17.99±0.20 (0.19)	21.90±0.22[a] (0.18)	44.21±1.18[a] (0.32)	23.30±0.19[a] (0.11)
Banyo Leswouroun	9	45.98±1.21[c] (0.04)	17.45±0.77 (0.05)	19.39±0.85[c] (0.04)	19.70±4.46[a] (0.30)	21.60±0.74[c] (0.09)
Banyo Tiqué	67	46.89±0.57[c] (0.07)	18.00±0.36 (0.10)	20.98±0.40[b] (0.04)	35.53±2.09[ab] (0.29)	22.46±0.34[bc] (0.08)
Banyo-Tibati Border	34	47.35±0.72[bc] (0.07)	17.57±0.46 (0.08)	20.45±0.50[bc] (0.04)	36.09±2.64[ab] (0.24)	23.01±0.43[b] (0.08)
Mayo Djinga	45	49.06±0.65[b] (0.07)	17.56±0.42 (0.11)	19.41±0.46[c] (0.04)	29.32±2.41[b] (0.34)	23.35±0.40[b] (0.09)
Coat color		***	***	ns	***	***
White	25	46.16±0.85[a] (0.02)	15.84±0.51[a] (0.03)	19.84±0.55 (0.03)	38.96±2.73[a] (0.07)	21.32±0.47[a] (0.02)
Black	23	48.652±0.88[b] (0.02)	17.217±0.53[b] (0.03)	20.74±0.58 (0.03)	40.35±2.84[ab] (0.07)	22.91±0.49[b] (0.02)
Pie	139	46.871±0.36[ab] (0.01)	16.849±0.22[ab] (0.01)	20.30±0.23 (0.01)	41.51±1.16[b](0.03)	22.14±0.20[ab] (0.01)
Red	134	47.269±0.37[ab] (0.01)	16.56±0.22[ab] (0.01)	20.25±0.24 (0.01)	41.25±1.18[ab] (0.03)	22.01±0.20[ab] (0.01)
Overall average	321	47.62±0.42 (0.09)	17.61±0.27 (0.16)	20.33±0.20 (0.15)	34.45±1.56 (0.34)	22.66±0.26 (0.11)

[a,b,c]Numbers assigned the same letter in the same column are statistically comparable. *P<0.05, ** P<0.01, *** P<0.001, ns= not significant, μ ± se= mean ± standard error, CV= coefficient of variation.

Table 3. Height at withers and Sacrum, chest depth, pelvis width and Thoracic circumference depending on sex, Breeding system, location and coat

Sources of variation	n	Height at withers	Sacral height	Chest depth	Pelvis width	Thoracic circumference
		μ ± se (cm) (CV)	μ ± se (cm) (CV)	μ ± se (cm) (CV)	μ± se (cm) (CV)	μ± se (cm) (CV)
Sex		*	**	***	**	***
Cows	234	128.48±0.95^{a} (0.07)	134.07±0.68^{a} (0.05)	66.76±0.57^{a} (0.07)	37.71±0.29^{a} (0.08)	162.10±1.30^{a} (0.07)
Bulls	87	130.99±1.45^{b} (0.05)	136.99±1.03^{b} (0.05)	71.07±0.87^{b} (0.10)	38.90±0.44^{b} (0.06)	173.51±1.98^{b} (0.10)
Breeding system		*	***	*	**	Ns
Controlled	52	131.63±1.75^{a} (0.10)	137.53±1.25^{a} (0.06)	70.02±1.06^{a} (0.07)	39.08±0.53^{a} (0.08)	169.06±2.40 (0.08)
Uncontrolled	269	127.83±0.74^{b} (0.06)	133.53±0.53b (0.05)	67.82±0.45^{b} (0.09)	37.53±0.22^{b} (0.07)	166.55±1.02 (0.08)
Localities		ns	*	**	**	***
Banyo Bunji	50	127.11±1.55 (0.05)	132.99±1.11^{c} (0.04)	67.65±0.93^{bc} (0.07)	37.93±0.47^{bc} (0.07)	160.75±2.12^{c} (0.06)
Banyo Centre	116	131.71±0.80 (0.09)	136.12±0.57^{a} (0.05)	70.48±0.48^{a} (0.09)	38.28±0.24^{ab} (0.08)	171.03±1.10^{a} (0.08)
Banyo Leswouroun	9	128.76±3.05 (0.04)	135.35±2.18^{bc} (0.03)	68.44±1.84^{bc} (0.06)	38.46±0.93^{abc} (0.05)	168.02±4.18^{bc} (0.04)
Banyo Tiqué	67	129.21±1.43 (0.05)	134.93±1.02^{bc} (0.05)	67.09±0.86^{c} (0.08)	38.07±0.43^{abc} (0.06)	167.46±1.96^{bc} (0.09)
Banyo-Tibati Border	34	130.10±1.81 (0.04)	136.31±1.29^{abc} (0.05)	70.96±1.09^{ab} (0.08)	37.50±0.55^{c} (0.05)	170.98±2.47^{ab} (0.07)
Mayo Djinga	45	131.50±1.65 (0.05)	137.48±1.18^{ab} (0.04)	68.87±0.99^{bc} (0.06)	39.60±0.50^{a} (0.04)	168.59±2.26^{bc} (0.06)
Coat color		ns	ns	***	***	***
White	25	126.56±1.82 (0.01)	132.24±1.33 (0.01)	65.56±1.19^{a} (0.02)	36.52±0.55^{a} (0.02)	161.16±2.73^{a} (0.02)
Black	23	127.52±1.8 (0.01)	134.00±1.39 (0.01)	68.65±1.24^{b} (0.02)	38.17±0.58^{b} (0.02)	164.78±2.84^{bc} (0.02)
Pie	139	128.73±0.77 (0.01)	133.22±0.56 (0.00)	67.48±0.51^{ab} (0.01)	37.72±0.24^{b} (0.01)	164.91±1.16^{bc} (0.01)
Red	134	128.40±0.79 (0.01)	134.08±0.58 (0.00)	67.38±0.52^{ab} (0.01)	37.33±0.24^{ab} (0.01)	165.36±1.18^{c} (0.01)
Overall average	321	129.34±0.50 (0.07)	134.56± 0.37 (0.05)	67.37± 0.33 (0.09)	38.31±0.32 (0.08)	167.81±1.46 (0.08)

^{a,b,c}Numbers assigned the same letter in the same column are statistically comparable. *P<0.05, ** P<0.01, *** P<0.001, ns= not significant, μ ± se= mean ± standard error, CV= coefficient of variation.

Table 4. Muzzle, barrel, shank and hump revolutions according to sex, breeding system, locality and coat

Sources of variation	n	Muzzle turn	barrel turn	shank turn	hump turn
		μ±es (cm) (CV)	μ±es (cm) (CV)	μ±es (cm) (CV)	μ±es (cm) (CV)
Sex		***	***	***	***
Cows	234	43.25±0.39^{a}(0.08)	17.85±0.14^{a}(0.08)	37.62±0.31^{a}(0.08)	63.63±1.71^{a}(0.21)
Bulls	87	45.96±0.60^{b}(0.09)	19.36±0.22^{b}(0.08)	39.81±0.47^{b}(0.09)	83.11±2.60^{b}(0.25)
Breeding System		ns	ns	ns	**
Controlled	52	44.75±0.73 (0.11)	18.57±0.27 (0.10)	38.39±0.57 (0.09)	69.47±3.15^{a}(0. 35)
Noncontrolled	269	44.46±0.31 (0.08)	18.64±0.11 (0.09)	39.04±0.24 (0.09)	77.27±1.34^{b}(0.24)
Localities		**	***	***	***
Banyo Bunji	50	43.22±0.64^{bc}(0.08)	18.11±0.23^{b}(0.07)	37.61±0.50^{b}(0.07)	66.32±2.78^{b} (0.26)
Banyo Centre	116	45.38±0.33^{a} (0.10)	19.76±0.12^{a}(0.10)	41.40±0.26^{a}(0.09)	73.03±1.44^{a} (0.31)
Banyo Leswouroun	9	42.86±1.27^{c} (0.09)	18.66±0.46^{b}(0.06)	38.42±0.99^{b}(0.07)	78.56±5.48^{a} (0.16)
Banyo Tiqué	67	45.19±0.59^{ab}(0.07)	18.37±0.22^{b}(0.06)	38.17±0.46^{b}(0.06)	77.61±2.57^{a} (0.16)
Banyo-Tibati Border	34	45.32±0.75^{ab}(0.08)	18.46±0.27^{b}(0.05)	38.64±0.59^{b}(0.05)	77.00±3.24^{a} (0.19)
Mayo Djinga	45	45.66±0.68^{a} (0.08)	18.2±0.25^{b} (0.06)	38.04±0.53^{b}(0.06)	67.68±2.96^{b}(0.21)
Coat color		ns	ns	ns	ns
White	25	44.28±0.78 (0.08)	17.92±0.35 (0.05)	37.92±0.69 (0.06)	72.24±3.66 (0.21)
Black	23	44.09±0.81 (0.09)	18.74±0.36 (0.06)	39.30±0.72 (0.06)	66.39±3.82 (0.21)
Pie	139	44.53±0.33 (0.10)	18.61±0.15 (0.06)	39.34±0.29 (0.07)	70.90±1.55 (0.21)
Red	134	43.99±0.34 (0.08)	18.49±0.15 (0.07)	38.82±0.30 (0.06)	71.54±1.58 (0.21)
Overall average	321	44.60±0.44 (0.09)	18.60±0.16(0.10)	38.72±0.35(0.09)	73.37±1.92(0.28)

^{a,b,c}Numbers assigned the same letter in the same column are statistically comparable. *P<0.05, ** P<0.01, *** P<0.001, ns= not significant, μ ± se= mean ± standard error, CV= coefficient of variation.

Table 5. Body, trunk, scapulo-ischial, pelvis and tail lengths as a function of sex, breeding system, locality and coat

Sources of variation		Body length	Trunk length	Scapulo-ischial length	Pelvis length	Tail length
	n	μ ± se (cm) (CV)	μ ± se (cm) (CV)	μ ± se (cm) (CV)	μ ± se (cm) (CV)	μ ± se (cm) (CV)
Sex		***	***	***	***	*
Cows	234	182.26±1.81[a] (0.09)	127.68±1.13[a] (0.08)	134.89±1.18[a] (0.08)	41.98±0.27[a] (0.07)	99.26±0.78[a] (0.07)
Bulls	87	193.21±2.76[b] (0.11)	133.46±1.72[b] (0.09)	140.87±1.81[b] (0.09)	43.76±0.42[b] (0.05)	101.78±1.19[b] (0.08)
Breeding Systèm		***	***	ns	***	***
Controlled	52	195.62±3.35[a] (0.11)	134.84±2.08[a] (0.09)	139.86±2.19 (0.07)	43.70±0.51[a] (0.06)	103.15±1.44[a] (0.11)
Uncontrolled	269	179.86±1.42[b] (0.09)	126.30±0.89[b] (0.08)	135.90±0.93 (0.09)	42.04±0.21[b] (0.06)	97.89±0.61 [b] (0.06)
Localities		**	**	***	***	*
Banyo Bunji	50	185.86±2.96[ab] (0.08)	129.58±1.84[ab] (0.07)	131.93±1.93[b] (0.07)	42.04±0.45[b] (0.06)	102.76±1.27a (0.07)
Banyo Centre	116	180.88±1.53[ab] (0.13)	127.77±0.95[b] (0.10)	139.82±1.00[a] (0.09)	42.80±0.23[a] (0.08)	100.24±0.66a (0.09)
Banyo Leswouroun	9	185.69±5.82[b] (0.05)	129.96±3.63[a] (0.04)	137.97±3.81[ab] (0.07)	42.63±0.89[b] (0.04)	95.49±2.51b (0.09)
Banyo Tiqué	67	187.46±2.73[ab] (0.09)	128.19±1.70[a] (0.09)	139.63±1.79[a] (0.08)	42.98±0.41[ab] (0.05)	102.25±1.17a (0.06)
Banyo-Tibati Border	34	196.09±3.44[a] (0.07)	134.03±2.14[a] (0.05)	138.03±2.25[ab] (0.08)	42.48±0.52[b] (0.05)	102.89±1.48a (0.08)
Mayo Djinga	45	190.44±3.15[ab] (0.06)	133.91±1.96[a] (0.06)	139.92±2.06[a] (0.07)	44.27±0.48[a] (0.04)	99.50±1.35ab (0.05)
Coat color		ns	ns	ns	ns	ns
White	25	180.12±3.50 (0.07)	126.52±2.17 (0.07)	131.84±2.31 (0.09)	41.20±0.55 (0.06)	97.56±1.49 (0.05)
Black	23	184.26±3.65 (0.07)	127.74±2.27 (0.07)	134.35±2.41 (0.07)	42.65±0.57 (0.05)	100.65±1.55 (0.05)
Pie	139	178.58±1.49 (0.08)	126.08±0.92 (0.07)	137.22±0.98 (0.07)	42.07±0.23 (0.07)	98.59±0.63 (0.05)
Red	134	176.62±1.51 (0.08)	124.37±0.94 (0.09)	134.88±1.00 (0.09)	41.78±0.24 (0.06)	98.81±0.64 (0.05)
Overall average	321	187.74±2 .45 (0.10)	130.5±1.27 (0.09)	137.88±1.33 (0.09)	42.87±0.31 (0.07)	100.52±0.88 (0.08)

[a,b,c]Numbers assigned the same letter in the same column are statistically comparable. *P<0.05, ** P<0.01, *** P<0.001, ns= not significant, μ ± se= mean ± standard error, CV= coefficient of variation.

Table 6. Live weight according to sex, breeding system, locality and coat

Sources of variation	Live weight		
	n	μ ± se (kg)	(CV)
Sex		***	
Cows	234	315.74±7.73[a]	(0.21)
Bulls	87	384.75±11.78[b]	(0.23)
Breeding system		ns	
Controlled	52	356.93±14.27	(0.22)
Uncontrolled	269	343.56±6.08	(0.24)
Localities		***	
Banyo Bunji	50	310.46±12.60[c]	(0.18)
Banyo Centre	116	370.59±6.55[a]	(0.24)
Banyo Leswouroun	9	348.80±24.80[bc]	(0.12)
Banyo Tiqué	67	350.03±11.65[bc]	(0.25)
Banyo-Tibati Border	34	368.08±14.68[b]	(0.21)
Mayo Djinga	45	353.49±13.42[bc]	(0.17)
Coat color		ns	
White	25	335.64±6.99	(0.19)
Black	23	335.24±6.86	(0.18)
Pie	139	332.73±16.87	(0.22)
Red	134	311.04±16.18	(0.18)
Overall average	321	350.24±8.70	(0.24)

[a,b,c]Numbers assigned the same letter in the same column are statistically comparable. *P<0.05, ** P<0.01, *** P<0.001, ns= not significant, μ ± se= mean ± standard error, CV= coefficient of variation.

The results show that this is a heterogeneous population (CV>15%) for the peripheral measurements (circumference of the hump, length of the horns) but also the live weight. With the exception of horn length, measurements were more pronounced in bulls than in cows, as were animals from controlled breeding systems. The sexual dimorphism being in favor of the males as well as the selection of the males would explain this observed variability. These measurements were significantly higher in animals from Banyo Center, the area teeming with breeders and dealers. The white coat color presented the smallest measurements, those of the other coat color (magpie, red and black) being statistically comparable. The tail goes completely through the hock, making the latter animals with long tails (wig under the hock).

3.2. Correlations between Measurements

Table 6 shows the correlation coefficients between the different metric characteristics as main variables but also those of sex and the reproductive system as additional variables. This table reveals three types of correlations: strong positive correlations (correlation coefficients between 0.8 and 1) recorded between the circumference of the shank and that of the barrel; the average positive correlations (correlation coefficients between 0.5 and 0.7) observed between the circumference of the muzzle, the live weight, scapulo-ischial length, the thoracic circumference, length of the forehead, the circumference of the hock, the circumference of the barrel, the length of the horn, the length of the face and the width of the face; but also the weak positive correlations (correlation coefficient less than 0.5) appearing mainly between the main variables, sex and the reproductive system. Figures 3 and 4 show the distribution of the main variables (in red) and additional variables (in blue) in the factorial plan (F1-F2).

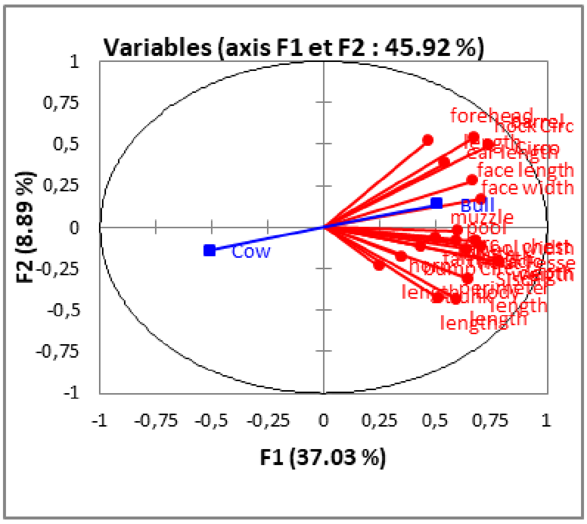

Figure 3. Correlation circle between body measurements.

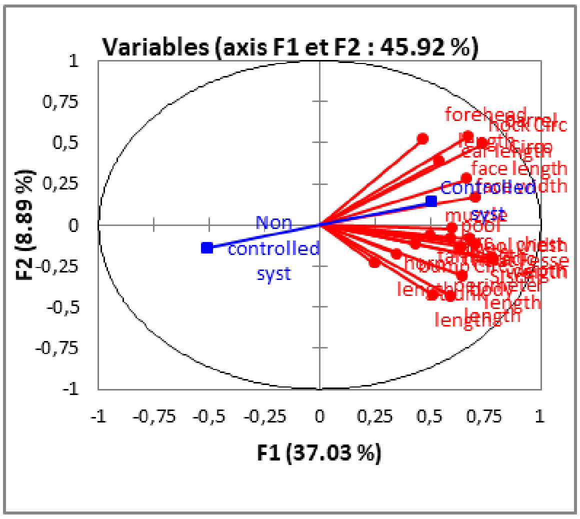

Figure 4. Correlation circle between body measurements.

Figures 3 and 4 show that the factors, sex and reproductive system, are well discriminated on the factorial axis F1 while the factors live weight, 6 measurements are better discriminated on the F2 axis. These figures show overall that the highest body measurements are observed in bulls and cattle from controlled breeding systems. These are therefore animals having a relatively larger format.

3.3. Biometric Index

A total of ten biometric indices were used to assess the general conformation of the animal as well as the development of the different regions. The latter are summarized in Table 7. The latter were globally significantly higher in males than in females.

3.4. Metric Variability

Principal component analysis was carried out in order to assess the individual contribution of the 20 quantitative characteristics in the morphometric variability observed within the population. The measurement of precision of the Kaiser-Meyer-Olkin sampling (0.84) as well as the Bartlett sphericity test (Khi^2 = 4451.08, ddl = 190, p-value <0.0001) were found to be very satisfactory (Table 9). Table 8 shows that the factorial axes F1 (37.03%), F2 (8.89%) and F3 (7.12%) contribute to 53.03% of the total phenotypic variability observed within the population. The KMO as well as the individual contribution (%) of the 20 variables to the F1 and F2 factorial axes are presented in Table 9.

Table 9 shows that the F1 axis, explaining at 37.03% the total phenotypic variability observed within the population, the strong contributions are those of the body weight (8.20%) and the thoracic circumference (8.30 %). Given the strong positive correlation that there is between body weight and chest circumference, this axis can be considered as that of growth performance. In addition, the F2 axis, explaining at 8.89% the total phenotypic variability observed in the 7 within the population, the strong contributions are those of the circumferences of the hock (16.58) and the barrel

(13.75%), the width of the forehead (15.39%) and the lengths of the body (10.70%) and trunk (10.41%). This axis can be considered as that of peripheral and body measurements.

3.5. Population Structure

The discriminant factor analysis (DFA) made it possible to detect 3 sub-populations below the base of the maximum likelihood.

3.5.1. Animals in subpopulation 1

The animals of this population (morphotype 1) are characterized by the predominance of magpie (47.5%) and monochrome (37.5%) coats. Drooping (30%) and erect (70%) bumps. More red coat and its derivatives (78.75) than black coat and its derivatives (20%). Clear muzzles, eyelids and hooves (56%). White-black horns (60%) in crescent (73.75%) and raised (72%). The limits of variation (at 95%) of the mean values of thoracic perimeter and height at the withers are between 181.86 and 185.36cm; 131.00 and 133.92cm respectively. Their live weight varies between 434.98 and 460.06kg. The circumference of the hock and the hump vary respectively between 40.39 and 41.91cm and between 75.59 and 85.53cm respectively. The length of the pelvis varies between 42.11 and 43.23 cm (Figure 5).

Table 7. Main biometric indices of the Gudali zebu

		Biometric index									
	n	MI μ±se (CV)	Pr μ±se (CV)	CpI μ±se (CV)	CPI μ±se (CV)	SI μ±se (CV)	FI μ±se (CV)	SI μ±se (CV)	BI μ±se (CV)	ThDeI μ±se (CV)	ThDaI μ±se (CV)
Sex		***	ns	***	**	***	**	ns	***	***	ns
Cows	234	2.46±0.05[a] (0.07)	95.53±0.94 (0.12)	35.65±0.49[a] (0.09)	0.70±0.00[a] (0.10)	1.73±0.02[a] (0.19)	1.42±0.01[a] (0.11)	1.05±0.01 (0.12)	0.14±0.00[a] (0.09)	0.79±0.00[a] (0.09)	0.11±0.00 (0.08)
Bulls	87	2.92±0.08[b] (0.09)	93.31±1.44 (0.12)	38.61±0.75[b] (0.07)	0.67±0.01[b] (0.10)	1.84±0.03[b] (0.22)	1.47±0.02[b] (0.11)	1.07±0.01 (0.14)	0.15±0.00[b] (0.08)	0.75±0.01[b] (0.10)	0.11±0.00 (0.09)
Total	321	2.69±0.06 (0.22)	94.42±1.06 (0.09)	37.13±0.55 (0.13)	0.69±0.01 (0.11)	1.79±0.02 (0.13)	1.44±0.01 (0.10)	1.06±0.01 (0.09)	0.14±0.00 (0.10)	0.77±0.00 (0.09)	0.11±0.00 (0.09)

Pr= proportionality, MI= massiveness index, CpI= cephalic index, PBI= body profile index, ScI=scapulo-ischial index, DaThI= dactylo-thoracic index, ThDaI= dactylo-thoracic index, BI= bones index

Table 8. Eigenvalue and phenotypic variance of the principal components in the analysis of the variability observed within the population

Principal components (F)	Value	Variance (%)	Cumulative variance
F 1	7.41	37.03	37.03
F 2	1.78	8.89	45.92
F 3	1.42	7.12	53.03
F 4	1.17	5.83	58.87
F 5	1.08	5.41	64.28
F 6	0.99	4.97	69.26
F 7	0.85	4.26	73.52
F 8	0.77	3.85	77.36
F 9	0.69	3.43	80.79
F 10	0.59	2.93	83.72
F 11	0.57	2.83	86.55
F 12	0.56	2.81	89.36
F 13	0.48	2.42	91.79
F 14	0.45	2.23	94.02
F 15	0.41	2.04	96.06
F 16	0.35	1.73	97.79
F 17	0.20	1.02	98.81
F 18	0.16	0.78	99.60
F 19	0.08	0.38	99.98
F 20	0.00	0.02	100.00

Table 9. KMO and contributions of the 20 variables (%) to the F1 and F2 factorial axes

Variables	KMO	F1	F2
Body weight	0.77	8.20	2.42
Circumference of muffle	0.96	4.86	0.02
Lorn length	0.77	0.84	3.15
Face length	0.94	6.01	4.45
Face width	0.93	6.66	1.61
Body length	0.76	4.71	10.70
Scapulo-Ischial length	0.93	5.59	5.45
Thoracic circumference	0.77	8.30	2.47
Trunk length	0.72	3.61	10.41
Height at withers	0.93	3.37	0.22
Sacral height	0.91	5.55	1.00
Barrel circumference	0.79	7.36	13.75
Hock circumference	0.79	6.11	16.58
Pelvis length	0.81	6.20	0.38
Pelvis width	0.78	4.72	0.39
Thoracic depth	0.92	6.77	0.79
Tail length	0.89	2.53	0.72
Forehead width	0.86	2.99	15.39
Hump circumference	0.78	1.62	1.74
Ear length	0.90	3.98	8.35

KMO= Kaiser-Meyer-Olkin sampling accuracy test

Figure 5. Cow of subpopulation 1

Figure 6. Cow of subpopulation 2

3.5.2. Animals in subpopulation 2

Animals of this population are characterized by their erect hump (97.45%), the magpie coat (35.66%) and simple (50.31%). The dominance of the red coat and its derivatives (65.60%) followed by speckling and stoat (12.10%). Predominantly black muzzles, eyelids and hooves (70%). Crescent horns (77.07%), low lyre (15.92%) and stump (3.18%) raised. The limits of variation (at 95%) of the mean values of thoracic perimeter and height at the withers are respectively between 152.83cm and 154.74cm; and between 124.35 and 127.69cm respectively. Their live weight varies between 265.40 and 274.55kg. The circumference of the hock and the hump vary respectively between 37.37 and 38.37cm and between 62.84 and 66.88cm. The pelvis length varying between 40.33 and 41.14 cm (Figure 6).

3.5.3. Animals of subpopulation 3

The animals of this population (morphotype 3) are generally identified by the red coat and its derivatives (67.85%) with a white list, but also animals with a matt white coat. a monochrome (46.43%) and pie (14.29%) pattern with erect bumps (82%). These animals have raised horns (86.90%) in a crescent (66.66%) or lyre (21.43%), black hooves (64.28%) but also black eyelids and muzzles (58.33%). The variation limits (at 95%) mean values of thoracic perimeter and height at the withers are respectively between 166.85 and 168.08; and between 127.4 and 130.08cm. Their average live weight varies between 339.4 and 346.58kg. The circumference of the hock and the hump vary between 38.44 and 39.78cm and between 69.18 and 77.16cm respectively. The length of the pelvis varies 42.11 and 43.23 cm (Figure 7).

Figure 7. Cow of subpopulation 3

3.6. Phylomorphometric Analysis

Discriminant factor analysis (DFA) made it possible to divide the 321 adult animals into the three (3) sub-populations (I, II and III) identifiable with two (2) phenotypes, suggesting an evolving population. In favor of this hypothesis, Paguem et al. (2020) reported, following the work of complete genomic characterization of five breeds from Cameroon (Gudali, White Fulani, Red Fulani, Namchi and Kapsiki), a similarity between the Gudali, White and Red Fulani, namely 163784 single nucleotide polymorphisms (SNPs) in common. In addition, phylogenetic analysis revealed that the Gudali breed was closer to the White Fulani breed than the other breeds (Red Fulani, Namchi and Kapsiki). The latter also report several genetic mutations. Figures 8 and 9 establish the relationship and the comparison between the different sub-populations.

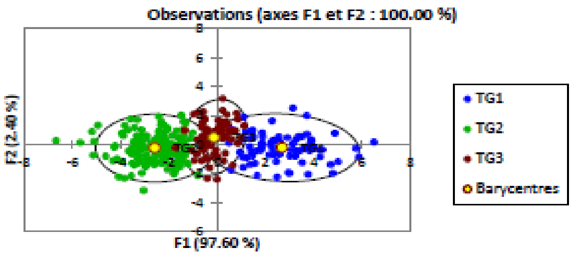

Figure 8. Population structure

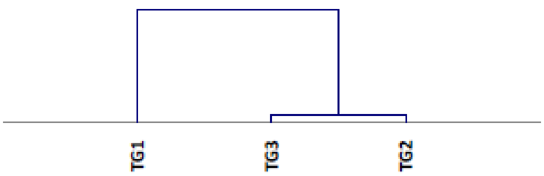

Figure 9. Dendrogram of sub-populations

4. Discussion

Overall measurements were higher in bulls. This result joins those of Pagot (1943) on the Azaouak zebus in Sudan, Coulomb (1976) on the N'Dama breed in Ivory Coast, Thys and Wandi (1970) on the Namchi breed in Cameroon, Ebangi and al. (2011) on the Namchi, Akouango et al. (2014) on the N'Dama, Yahaya breed et al. (2019) on the zebu Djelli, Kanh et al. (2019) on the N'Dama breed, Lhoste (1969) on the Gudali variety Ngaoundere and Ngono et al. (2019). The locality significantly influenced the different measurements. This result is in accordance with that found by Boma et al. (2018). Lhoste (1969) found in Gudali variety Ngaoundere cows a width of the head greater than that of the present study (18.61cm). It is probably due to the small size (13 bulls and 25 cows) used by this author. The height at the withers was 128.48cm and 130.99cm respectively in cows and bulls. This result is sufficiently close to that reported by Doba (2016), but however slightly higher than that found by Lhoste (1969), namely 123.2cm and 131.8cm respectively in Gudali variety Ngaoundere. The pelvis width was 38.90cm in the cows of the present study, against 50.06cm in the Gudali variety Ngaoundere cows selected at the Wakwa Research Center (Lhoste, 1969). The lengths of the pelvis and scapulo-Ischial were respectively 41.98cm and 134.89cm in cows, against 48.3cm and 145.2cm in Gudali variety Ngaoundere cows (Lhoste, 1969). It is likely that the observed differences are due to the variety and size effects of the population. The sex effect on the average adult weight was reported by Lhoste (1969) on the Gudali variety Ngaoundere zebu in station. He obtained 563kg in males against 335.4kg in females. The difference in weight observed between these two results would be justified by the fact that these are two varieties of Gudali: that of Ngaoundere in the station and that of Banyo in a peasant environment. In addition, the weight was estimated using the barymetric method while Lhoste (1969) carried out weighings on a weighbridge. The work on barymetry, carried out by Doba (2016) on the Gudali variety Ngaoundere and crosses zebu has shown weight superiority in favor of males. Either on average 416.12 ± 95.64 and 341.46 ± 51.97kg respectively in the Gudali bulls variety Ngaoundere and the cross, against 351.92 ± 52.85 and 358.85 ± 53.34kg respectively in Gudali variety Ngaoundere and crosses cows. These values, on the other hand, are well above those obtained in the present study.

Several other authors have reported the sex effect on adult weight in favor of males. These are Pagot (1943), Lhoste (1969), Coulomb (1976), Ebangi et al. (2011), Akouango (2014). The proportionality index was statistically comparable between the two sexes while the massiveness index was significantly influenced by sex, in favor of males. This conclusion is in harmony with that reported by Ngono and However, Ngono et al. (2019) found no significant effect of gender on surface area index and cephalic index as was the case in the present study. The factor axes F1 (37.03%), F2 (8.89%) and F3 (7.12%) contributed to 53.03% of the total phenotypic variability observed within the population. A percentage much lower than that reported by Ngono et al. (2019) on the White Fulani of North Cameroon, namely 73.45% for the first three main components. It is probable that the observed differences are due to the size of the population and to the breed effect (88White Fulani / 321Gudali variety Banyo). In Ivory Coast, N'goran's work et al. (2008) led to the conclusion according to which there is genetic diversity within this population. They also believe that this genetic diversity is due to the various uncontrolled crosses with other breeds. The measurements of animals in subpopulations 1, 2 and 3 are comparable to those of subpopulations 1, 2 and 3 found in Côte d'Ivoire by N'goran et al. (2008) for body length, thoracic perimeter, head length and live weight. However, these measurements were much higher than those found in Congo Brazzaville by Akouango et al. (2014) on the N'dama breed. The breed effect would explain the observed differences. Boma et al. (2018) also detected three subpopulations in local humpless cattle from Togo and attribute this diversity to interbreeding.

5. Conclusion

At the end of this study of which the main objective was the metric characterization of the Gudali zebu variety Banyo in the high Guinean savannah zone of Cameroon, the main results show that the different measurements were significantly influenced at varying degrees by sex, reproductive system and locality. Both males and animals from controlled reproduction systems have presented a significantly larger size. The results of the discriminant factor analyzes revealed the existence of three (03) subpopulations or morphotypes, grouped together on the basis of maximum likelihood. In perspective, it is desirable that this study extend to the other two varieties (Ngaoundere and Tignere) of Gudali by taking into account the zootechnical implication (reproduction, growth, production and carcass) of these different measurements.

Author Contributions

All authors have equal contribution and the authors reviewed and approved the manuscript.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethical permission was taken from Cameroon Agricultural Research Institute for Development, Polyvalente Research Station of Bangangté (date; January 2020, numbered: 2020-1)

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