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Morphological and serum biochemical characterizations of local pig populations from three different agro-ecological areas of Cameroon

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A study was carried out to investigate the morphological and biochemical characteristics of local pig populations in three agro-ecological areas of Cameroon from June to September 2018. Morphological and morphometric parameters were measured in 300 pigs (147 males and 153 females) aged 6 to 8 months old. Phenotype characterization of local pigs showed diversity as follows: concave head profile, black coat colour type, plain coat colour pattern, prick ear type, projecting upwards, a long and thin snout type and straight tail. Analysis of variance showed that all quantitative parameters measured in the pigs of the three agro-ecological zones were considered. Comparisons between sexes also revealed differences in some features in some regions. The growth-related parameters were strongly correlated, case of Heart Girth and Head Length, Body Length, Height Withers, Wither Hock, Tail Length, Live Weight; Body Length and Wither Hock, Live Weight; Live Weight and Wither Hock. Local pigs from the bimodal rainfall, Sudano-Sahelian and highland areas of Cameroon showed a great morphological and biochemical diversity; those from the highland are better discriminated from those of the Sudano-Sahelian and bimodal rainfall areas. The cluster analysis of biochemical and morphological features could be congruent, confirming the differentiation of highland pigs from the pigs of the other two agro-ecological zones.

Keywords: Cameroon, Genetic resource, morphological characteristics, blood biochemical characteristics, swine.

INTRODUCTION

Indigenous livestock genetic resources, including breeds and populations, play a major role in the development of

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different production systems in sub-Saharan Africa where climatic and environmental conditions are unfavorable to the survival and optimal production performances of imported exotic breeds (Ayizanga, 2016; Djimenou et al., 2018). This is also true for pigs, considering the increasing demand for their meat in several countries of this region (Kouam et al., 2020).

Cameroon has a population of about 25.2 million inhabitants and pork is consumed by nearly 70% of them (Kouamo et al., 2015). This percentage represents 12% of total meat production after that of poultry (40%) and beef (34%) (FAOSTAT, 2018). The number of pigs bred in Cameroon is estimated to be ~3.11 million heads. Pork production reached about 40,000 tons in 2016, and projection s for 2020 indicate an increase of about 10% (Mfewou and Lendzele, 2018). Recent developments in pig production technologies in Cameroon have contributed to boosting this livestock sector although there is still room for large improvements that could be also derived from the proper use and management of autochthonous genetic resources (Adeola et al., 2013; Karnuah et al., 2018; Youssao et al., 2018).

Cameroonian pigs are represented by exotic (Large White, Landrace, Duroc, and Berkshire) and indigenous (Bakossi, Bakweri, Bamileke, Makon long nose, and Kousseri) breeds and populations. Indigenous pigs are, in general, known for their good quality and tasty meat and are considered adapted to the local breeding systems. However, due to the lack of planned breeding programs, their populations are gradually decreasing (Motsa'a et al., 2017). Despite their general usefulness, the exploitation of the potential of indigenous pig genetic resources remains unsatisfactory in Cameroon and all over Africa (Mbaga et al., 2005; Motsa'a et al., 2017).

Morphometric features have been used to describe and distinguish various animal breeds and phenotypic characterization studies are important to manage animal genetic resources for conservation and food security (Adeola et al., 2013; Karnuah et al., 2018).

In Cameroon, indigenous pigs have been described only for a few populations in the Humid forest with monomodal rainfall agro-ecological region in which three main genetic types have been observed, whereas data available for the other agro-ecological regions are very limited (Motsa'a et al., 2017). However, the description of these genetic resources is poor and the quality of the available information for most populations is usually low. It is therefore needed to re-evaluate the main characteristics of the local pig populations in this country, taking also into account that they could be well adapted to the local harsh husbandry conditions and that they might be resistant to local diseases and/or pests (Halimani et al., 2012). The genetic potential of Cameroonian pig breeds and their contribution to the establishment of sustainable management strategies require prior knowledge of their phenotypic, morphometric diversity, and health status. Also, the assessment of serum biochemical parameters is useful for determining the health status of the herd; likewise, early identification of a disease or poor growth performance helps clinicians and researchers in the interpretation of the results of blood samples analysis (Abonyi et al., 2018). However, the normal physiological values of serum biochemical parameters of Cameroonian local pigs are not available.

The objective of this study was to carry out a phenotypic and serum biochemical characterization of Cameroonian local pig populations that might present suitable morphotypes for their genetic adaptation in different Cameroonian agro-ecological (climatic and altimetric) environments and production systems.

MATERIALS AND METHODS

Description of the study zones

This study was carried out in three extreme Cameroonian agro-ecological zones, defined based on the climatic conditions, geographical positions, and altimetric features (Figure 1). The Sudano-Sahelian Area (SSA) is located between 8°36" and 12°54" North latitude and 12°30" and 15°42" east longitude. This area is characterized by a monomodal rainfall type with variable intensity (400 to1200 mm per year). Its surface is 100,353 km^2. The average temperature is 28°C, with maximum of 40 to 45°C in April. The SSA is represented, in the Far North Region, by three divisions: Diamaré, Mayo Kani, and Mayo Danay (Cheo, 2016).

The Humid forest with bimodal rainfall Area (HBA) is located from 2°6" à 4°54"/5°48" North latitude to 10°30" and 16°12" east longitude. It is characterized by an average annual temperature of 25°C, a bimodal rainfall varying between 1500 to 2500 mm/year, and relative humidity of 70 to 90%. This agro-ecological zone is represented by three divisions: Upper Sanaga, Mfoundi, and Lekie. Its surface area is 165,770 km^2 (Djoufack, 2011). The Western highlands Area (WHA) is localized between 4°54" to 6°36 "North latitude and 9°18" to 11°24 "east longitude. Average temperatures are low (19°C), and heavy rains (1500-2000 mm) fall in a monomodal pattern. The WHA is constituted by the Bamboutous, Menoua, and Noun divisions. Its surface area is 31,192 km^2 and the rainfall varies from 1500 to 2000 mm/year (Djoufack, 2011). These agroecological zones are known for their high densities of production and marketing of pigs, with about 0.6 million heads in both the SSA and HBA and about 1.7 million individuals in the WHA (INS, 2015).

Investigated populations

A total of 300 household pig owners, from the aforementioned three regions, were selected randomly and interviewed to obtain information on their pig populations in order to identify the herds that could be considered useful for the study. The selected herds included animals that originated only from local genetic resources that is, all generations of the boars and sows were not derived by crossbreeding with exotic breeds, therefore, could be reconstructed from historical information obtained from the interview responses from the owners. The production system was mainly based on subsistence that used backyard scavenging and/or local feeds. Up to two animals randomly selected in the same herd were used for body measurement to maximize the possibility to obtain a comprehensive characterization of the represented pig populations in the three regions. A total of 300 native pigs (6 to 8 months old)

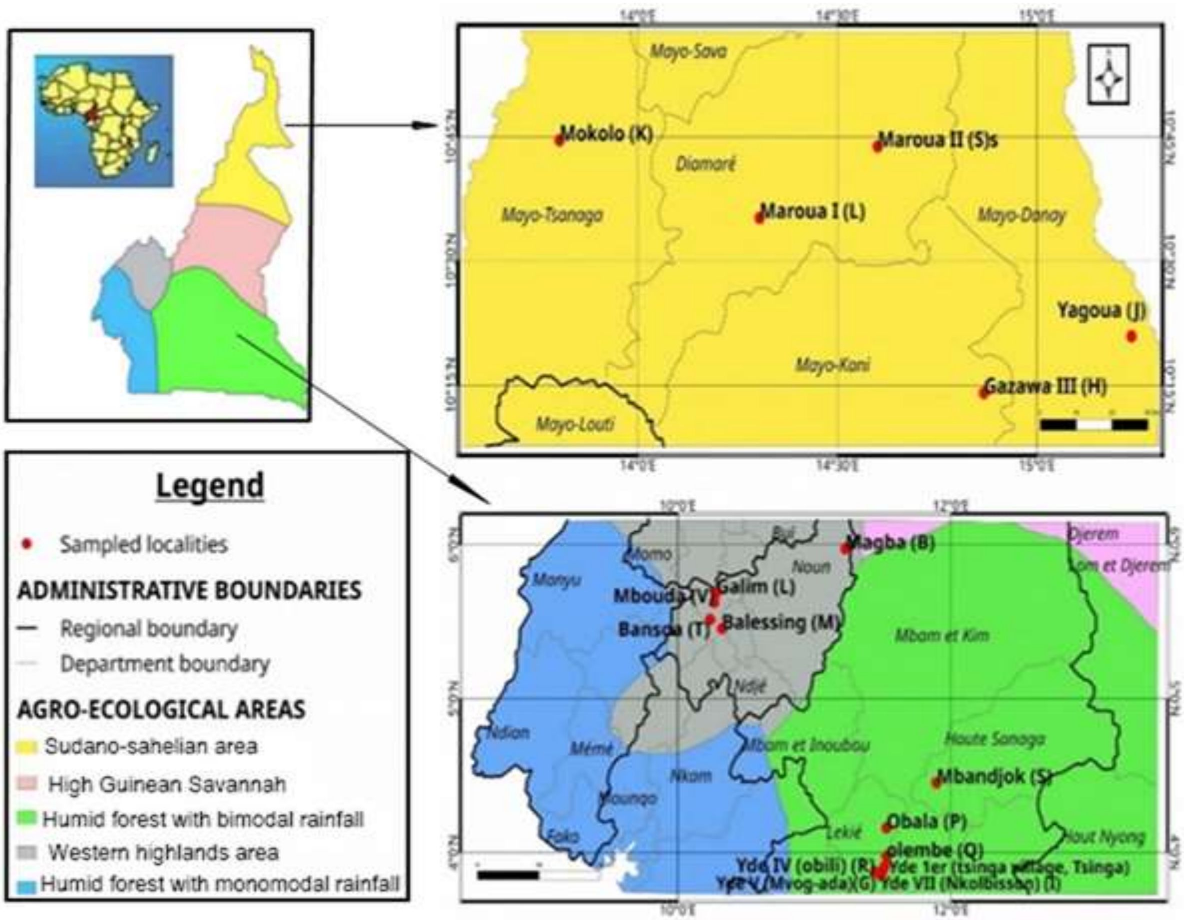

Figure 1. Map of the three Cameroonian agro-ecological zones considered and the sampled localities. Source: QGIS Development Team (2009).

were finally selected for morphological characterization (147 males and 153 females). The distribution of pigs from the three different regions was 128, 109, and 63 from the Sudano-Sahelian, the Western highlands, and the Humid forest with bimodal rainfall zones, respectively.

Information on the animals and morphological parameters

Phenotypic characterization of the pigs was based on several descriptors (Adeola et al., 2013). These included sex (male or female); coat color (white, black, brown, white with black spots, greyish with black spots, black with a white belly, brown with black spots); coat model (plain, patchy, spotted); nature of hair (curly, straight, short, long); skin nature (smooth, wrinkled); head profile (concave, convex or straight); snout type (long and thin, short and cylindrical); ear type (prick, droopy, lopped); ear orientation (projected forward, backward, upward); nature of backline (straight, sloping towards rump); tail type (straight, curly); and the number of teats (NT) counted on the sows.

The morphometric characterization of the pigs was also based on several measures defined below (expressed in cm) and taken using textile tape. These body measures were those in Figure 2: snout circumference (SC); snout length (SL): distance between the frontal nasal suture and the upper part of the muzzle; head length (HL): distance between the snout and the occipital point of the animal; inter-orbit length (IL): the shortest distance between the two orbits; ear length (EL): distance between the end of the ear and the base; neck circumference (NC); body length (BL): distance from the tip of the shoulder to the bone of the spit or spindle; heart girth (HG): length of the circumference immediately behind the forelimbs; shoulder width (SW): distance between the points of the shoulders; the height of withers (HW): distance of the height of the animal; width of the hock (WH): the distance between the points of the hock (hindquarters); tail length (TL): distance between the tip and the base of the tail; live weight (LW): body weight of live animals (Adeola et al., 2013). The body weight (in kg) was recorded using a referenced Animeter animal weighing tape. All body measurements were taken in the early hours of the day. Animals were in a calm disposition in their pen (for those enclosed) and were taken in open doors for those in divagation (Scherf et al., 2015).

Pictures of the various morphological features of animals were taken with a numeric camera Panasonic Lumix DE-A92.

Blood sampling and biochemical analyses

One hundred and fifty (150) pig blood samples were collected from three different agro-ecological zones, fifty in each zone. For this purpose, 5 ml were collected with a 5 ml hypodermal syringe in a vacutainer without anticoagulant, from the jugular vein of each pig with help of a veterinary technician. Blood serum was obtained by

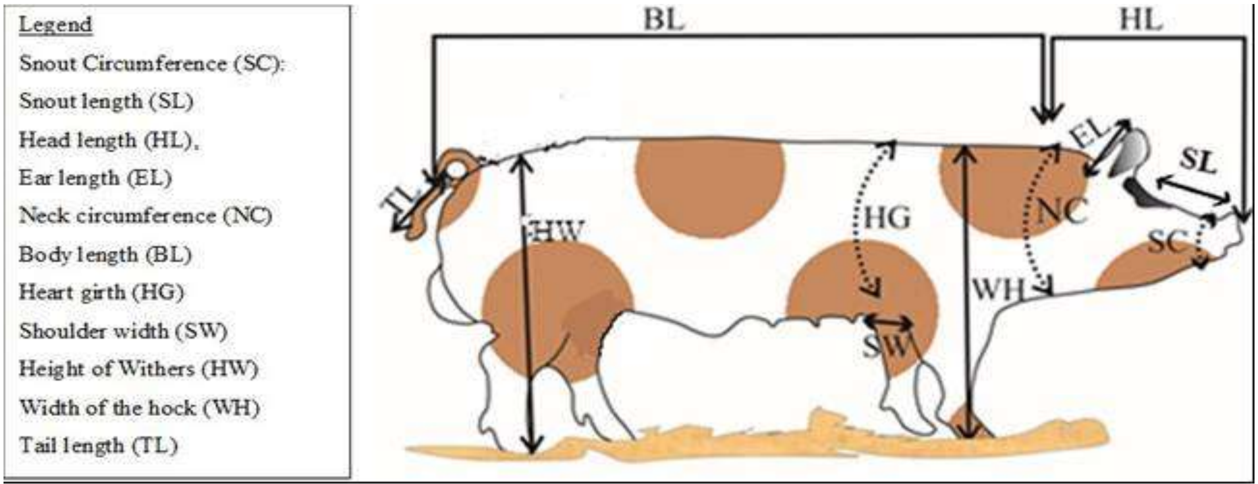

Figure 2. Illustration of morphometric measurements.

centrifugation at 3000 rpm for 5 min at 4°C, then stored at -80°C until biochemical analysis. Serum total protein was determined by the Biuret method (Gornal et al., 1949), Albumin by the Bromocresol Green (BCG) method and total cholesterol (TC) by the CHOP-PAP method (Gindler and Westgard, 1973). The globulin content was determined by subtracting albumin from the total protein.

The other parameters measured were: high density (HDLC) cholesterol, triglycerides, glucose, and transaminases Triglycerides were determined using a colorimetric enzymatic method (Trinder, 1969). Alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activities were determined by the method of Reitman and Frankel (1957) using the spectrophotometric method via SGM Italia diagnostic kits (SGM Italia-Via Pindaro 28C-Roma).

Statistical analyses

Basic statistics (frequency, mean and standard error) were calculated for each categorical or quantitative parameter. Quantitative and biochemical data were submitted to the analysis of variance (ANOVA) using the SAS application version 9.4, based on the GML procedure (Clark and SAS Institute, 2004). Differences between means were tested using the Student Newman Keuls test of Duncan's. The discrimination of pigs based on of their morphometric characteristics and serum biochemical were done using software R version 3.4.1 for principal components analysis (PCA) and confirmed by the cluster analysis respectively. The mathematic model used was as follows: where: Y_{ij} is the Performance of the individual; μ the sample population mean number; αi the random effect of the "I" repetition (i= 1 or 2); βj the fixed effect of the animal (j= 1, 2, …100); $(\alpha\beta)ij$ the random effect of the repetition interaction x animal or error Pearson correlation coefficient values between two dependent variables were calculated (R Core Team, 2019).

RESULTS

All pig populations investigated in the three agro-ecological areas considered were quite heterogeneous for all categorical descriptors and were not fixed for any specific features (Table 1). Completely black pigs were most frequent in the SSA (62.5%) but were also observed in the other two regions. Animals having black with white belly coat color were observed with high frequency (36.7%) only in the WHA, whereas in the HBA brown was the most frequent color of the pigs (34.9%), followed by the white color. Pigs with white and black spots were not recorded in the HBA. The plain coat pattern was prevalent with an overall percentage of 82.3%. A few examples of coat colors and coat patterns observed are reported in Figure 3.

Most of the pigs in all three areas had straight hairs (84.7%) and a few had curly short or long hairs. The skin was smooth in most (78%) animals: 45.2% in the bimodal rainfall zone, 79.7% in the SSA, 94.5% in the WHA The head profile was concave in most of the local pigs (60.7%) and convex or straight (39.3%) for the remaining animals. A total of 92% of the pigs had a long and thin snout versus 8% with a short and cylindrical snout.

The ears were prick (82.3%), droopy (17.0%), or looped (0.7%) and their orientation was upward in most animals (53.7%), otherwise projected forward (38.7%) or backward (7.7%) in the other pigs.

The backline was mostly straight (85.3%) otherwise sloping towards the rump in the rest of the animals (14.7%). A straight tail was observed in 68.0% of pigs, whereas a curly tail was reported only in 32% of animals.

All the quantitative parameters measured in the pigs (Figure 2) differed significantly between the three agro-ecological regions. In general, pigs in the HBA were bigger while those of the WHA were smaller. Comparisons between sexes also revealed differences. Males were bigger than females, in the case of IL, HG and TL (SSA) and EL (HBA); on the contrary, females appeared bigger than males in the case of IL, NC, TL, SC, HG, HW, BL and LW in the highlands; SC, NC, and BL in the SSA; IL, HW, and BL in the HBA (Table 2). The

Table 1. Numbers of pigs and corresponding frequency distribution of the different morphological traits recorded in local pigs from the three agro-ecological areas (Sudano-Sahelian Area (SSA), Humid forest with bimodal rainfall Area (HBA), Western highlands Area (WHA)).

Trait	Type/category	Agro-ecological area			Total no. (%)
		HBA	SSA	WHA	
Coat colours	Black	18	80	20	118 (40)
	White	18	20	10	48 (16)
	White with black Spots	0	11	25	36 (12)
	Greyish with black spots	4	8	1	13 (4)
	Brown	22	7	4	33 (11)
	Black with white belly	0	0	40	40 (13)
	Brown with black spots	1	2	9	12 (4)
Coat patterns	Patchy	3	16	9	28 (9.3)
	Plain	45	104	98	247 (82.3)
	Spotted	14	8	3	25 (8.3)
Hair types	Curly	0	14	5	19 (6.3)
	Short	9	2	2	13 (4.3)
	Straight	48	107	99	254 (84.7)
	Long	5	5	4	14 (4.7)
Skin types	Smooth	28	102	104	234 (78)
	Wrinkled	34	26	6	66 (22)
Head profiles	Concave	58	100	24	182 (60.7)
	Convexe or straigth	4	28	86	118 (39.3)
Snout types	Short and cylindrical	3	7	14	24 (8)
	Long and thin	59	121	96	276 (92)
Ear types	Prick	46	93	108	247 (82.3)
	Droopy	16	33	2	51 (17)
	Lopped	0	2	0	2 (0.7)
Ear orientation	Projected forward	13	57	46	116 (38.7)
	Projected backward	2	15	6	23 (7.7)
	Projected upward	47	56	58	161 (53.7)
Backline types	Straigth	60	90	105	256 (85.3)
	Sloping toward rump	2	38	5	44 (14.7)
Tail type	Curly	5	23	68	96 (32)
	Straight	57	105	42	204 (68)
Teat mean number (females)		10.63	9.9	12.62	

growth-related parameters were strongly correlated (r>0.7) as defined in the case between HG and HL, BL, HW, WH, TL, LW; BL and WH, LW; (Table 3). Most features were positively correlated, except NT and SL, EL (r 0.07 and -0.04 respectively).

The morphometric parameters measured in the pigs of the three regions tended to distinguish one morphological group (morphotype) made up of animals from the WHA;

Figure 3. Pigs with different coat colours and patterns were observed: **a)** black; (**b)** white; **(c)** greyish with black spots; (**d)** brown with black spots; **e)** black with a white belly; **f)** brown with black spots; with different head profile: (**g)** concave; (**h)**convex head profile; with different ear types: **i)** droopy ear; **j)** prick ear; with different tail type: (**k)**Straight;**l)** curly.
Source:

for the pigs of the HBA and those of the SSA, their features overlap with the HBA and animals of the SSA (Figures 4 and 5; Table 2).

Agro-ecological areas did not influence Albumin, Total Cholesterol, HDL Cholesterol, Urea, Creatinine, and AST levels. Total protein, globulin, triglycerides, glucose, ALAT contents were lower in pigs of WHA. In general, serum biochemical parameters also tend to more distinguish animals of the WHA (Table 4). Results of the cluster analysis-based structure of local pigs in Cameroon are reported in Figure 5, which shows that local pigs in the three Cameroonian agro-ecological zones are biochemically structured into three separate clusters.

DISCUSSION

This study reported, for the first time, an extensive phenotypic characterization of pig populations in three different agro-ecological regions of Cameroon. All populations were phenotypically very heterogeneous, probably reflecting an ancestral origin from many different genetic pools coupled with subsequent introgression from different genetic lines. A similarly high level of morphological heterogeneity has been described elsewhere in African pig populations (Mbaga et al., 2005; Halimani et al., 2012; Adeola et al., 2013; Ayizanga, 2016; Djimenou et al., 2018; Karnuah et al., 2018). Local African pig populations are rich resources of genetic is deduced from their morphological heterogeneity. These populations could represent interesting starting points to design breeding programs aimed to boost sustainable pork production chains in these countries. Most animals in all agro-ecological zones presented a concave head profile, long and thin snout, black color coat, prick ear projected upward, and straight hair with smooth skin. Similar results were obtained in SSA. Our results showed that the black color coat, which generally characterized the local pigs in Cameroon (Motsa'a et al., 2017), decreases considerably in favour of the white coat and other colors, including a dilated phenotype. The latter could be probably represented in the whole population with very low frequencies and masked by a recessive allele against the dominant white allele which is also epistatic over several other coat color loci (Fontanesi et al., 2010). It is assumed that the mixture of colors observed is a consequence of the interbreeding of local pigs (usually black) with exotic ones notably with the Large-White (Djimenou et al., 2018). The specificity of the coat color may also be related to an aptitude for production or environmental adaptation (Fontanesi and Russo, 2013).

Table 2. Body measurements of the local pigs from the three considered agro-ecological areas of Cameroon (mean±SEM).

Trait	Agro-ecological Areas						*p* value
	HBA		SSA		WHA		
	Female	Male	Female	Male	Female	Male	
SC	19.17±0.30[b]	18.88±0.33[b]	19.13±0.68[b]	18.47±0.26[c]	20.34±0.50[a]	19.78±0.50[b]	0.0472
SL	15.02±0.27[a]	14.93±0.37[a]	14.54±0.23[a]	14.26±0.26[a]	9.03±0.36[b]	9.63±1.10[b]	<.0001
HL	28.48±0.46[a]	26.91±0.72[a]	23.23±0.61[b]	20.55±0.55[b]	20.55±0.53[c]	19.44±0.60[c]	<.0001
IL	9.35±0.12[a]	9.25±0.17[b]	8.59±0.08[c]	8.88±0.10[b]	7.60±0.19[c]	7.2±0.20[d]	<.0001
EL	13.59±0.41[c]	14.19±0.82[b]	14.89±0.14[a]	14.94±0.24[a]	12.54±0.33[d]	11.68±0.30[d]	<.0001
NC	55.46±1.08[a]	54.89±1.59[a]	49.77±0.78[b]	49.98±0.97[b]	48.07±1.90[c]	43.71±20[d]	<.0001
HG	71.17±1.55[a]	68.53±1.76[a]	66.91±1.01[b]	68.28±1.17[a]	63.14±1.90[c]	57.41±1.90[d]	<.0001
SW	21.95±1.11[a]	21.42±0.65[a]	16.19±0.37[b]	16.91±1.08[b]	11.68±1.20[c]	10.34±0.70[c]	<.0001
HW	47.51±1.33[a]	44.49±1.19[b]	45.03±0.47[b]	44.79±0.61[b]	42.48±1.40[c]	37.71±1.20[d]	<.0001
WH	15.44±0.25[a]	15.10±0.35[a]	14.88±0.15[a]	15.16±0.20[a]	13.34±0.40[b]	12.79±1.60[b]	<.0001
BL	63.27±1.60[a]	57.05±2.09[b]	61.62±0.68[a]	61.02±0.70[b]	55.09±1.70[c]	51.29±1.80[d]	<.0001
TL	20.40±0.44[a]	19.15±0.70[a]	19.04±0.30[b]	19.44±0.36[a]	19.45±0.70[a]	17.54±0.60[c]	0.0082
LW	38.78±0.37[a]	37.17±1.32[a]	35.91±0.59[b]	35.91±0.44[b]	32.71±1.20[b]	31.44±0.40[c]	<.0001

[1]SC, snout circumference; SL, snout length; HL, head length; IL, inter-orbit length; EL, ear length; NC, neck circumference; BL, body length; HG, heart girth; SW, shoulder-width; HW, the height of withers; WH, the width of the hock; TL., tail length LW, live weight.
Values with the same letter in the same line are not significantly different.

Table 3. Pearson correlation coefficient values between body measurements of local pigs irrespective of agro-ecological areas.

SL	0												
HL	0.08	0.44											
IL	0.02	0.53	0.7										
EL	0.11	0.43	0.44	0.56									
NC	0.3	0.27	0.48	0.47	0.38								
BL	0.25	0.43	0.59	0.65	0.62	0.62							
HG	0.28	0.4	0.73	0.66	0.55	0.68	0.81						
SW	0.02	0.46	0.65	0.59	0.4	0.38	0.47	0.54					
HW	0.19	0.39	0.64	0.63	0.58	0.59	0.8	0.78	0.47				
WH	0.3	0.39	0.62	0.63	0.51	0.64	0.78	0.78	0.52	0.64			
TL	0.3	0.32	0.61	0.53	0.52	0.55	0.69	0.74	0.37	0.7	0.64		
NT	0.09	-0.07	0.07	0	-0.04	0.1	0.1	0.08	0.03	0.14	0.02	0.12	
LW	0.3	0.34	0.66	0.59	0.46	0.63	0.73	0.87	0.52	0.69	0.79	0.67	0.03
	SC[1]	SL	HL	IL	EL	NC	BL	HG	SW	HW	WH	TL	NT

SC, snout circumference; SL, snout length; HL, head length; IL, inter-orbit length; EL, ear length; NC, neck circumference; BL, body length; HG, heart girth; SW, shoulder width; HW the height of withers; WH the width of the hock; TL., tail length LW, live weight

The longer snout, wider head, and long erect ears morphotypes indicate that local pigs represent large unselected genetic groups (Ritchil et al., 2014). In this study, 68% of animals had a straight tail; this value is close to 72% were found by Subalini et al. (2010) and in the same direction of prevalence (98.5%) reported by Ritchil et al. (2014). The strait tail might represent a feature of unselected pigs or that also are adapted to extensive production systems where tail biting is not a problem, considering that pigs with strait tails might more frequently be affected by this problem that is quite frequent in intensive production systems where animals are raised inside, with high density (Bertolini et al., 2018).

A few parameters that were recorded in this study could be compared to the results reported in other local populations raised in several other developing countries. The best averages HG and LW were in pigs from HBA, while that of the SC was in highlands. Ritchil et al. (2014) found out that the average HG for the adult male and female pigs in Bangladesh was 82.8 ± 1.7 and 81.3 ±1.1 cm. The average number of teats varied from 9 to 13 for all agro-ecological areas, while in Ghana Ayizanga (2016)

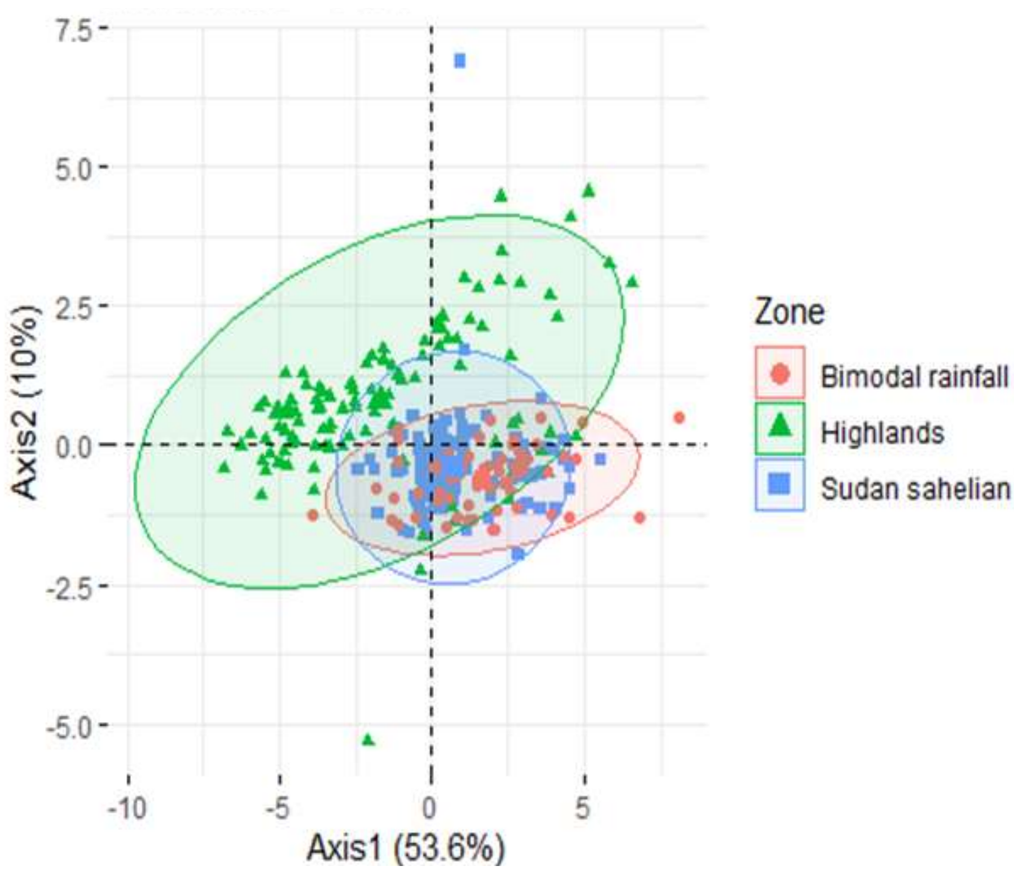

Figure 4. Distribution of the pigs based on the measured morphological phenotypes as function of the three agro-ecological areas.

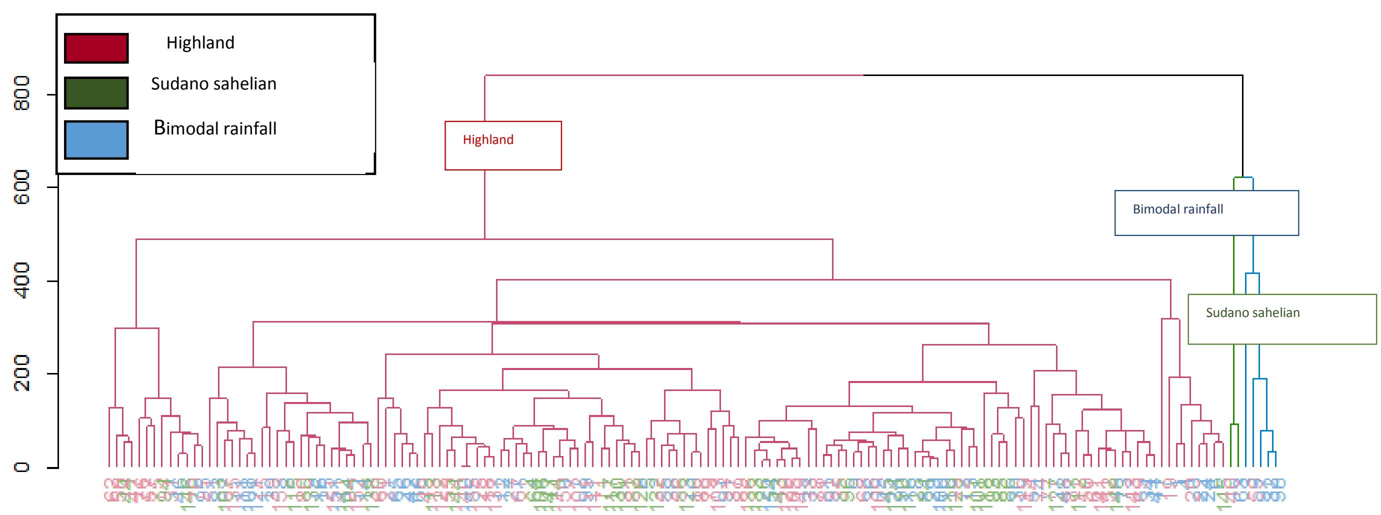

Figure 5. Cluster analysis of the pigs based on biochemical data as function of the agro-ecological

found 10 to14 numbers of teats in females. All variables differed significantly amongst localities and sometimes amongst sexes (Table 2). In related studies, McManus et al. (2010) found that measurements of morphometric traits were significantly different (p<0.05) between sexes. These differences may be driven by environmental influences

Table 4. Serum biochemical parameters of the local pigs from the three agro-ecological areas considered in Cameroon irrespective of the sex.

Parameter	Agro-ecological zone			*p* value
	HBA, n=50	SSA, n=50	WHA,n=50	
Total Protein (g/dL)	5.15± 0.72 [a]	5.02±0.97 [ab]	4.79± 1.14 [b]	0.0443
Albumin (g/dL)	3.29± 0.9[a]	3.39±0.83[a]	3.19± 0.8[a]	0.2343
Globulin (g/dL)	1.86± 0.18 [a]	1.64 ± 0.14 [ab]	1.60± 0.34 [b]	0.0190
Albumin/Globulin ratio	1.763±0.20 [b]	2.07± 0.17 [a]	2.00± 0.12 [ab]	0.0123
Total Cholesterol (mmol/L)	2.80± 0.17[a]	2.80± 0.12[a]	2.90± 0.14[a]	0.8646
HDL Cholesterol (mmol/L)	22.38± 2.32[a]	25.33± 3.52[a]	22.95± 3.05[a]	0.7893
Triglyceride (mmol/L)	0.95± 0.11[b]	1.29± 0.11 [a]	0.91± 0.08[b]	0.0130
Glucose (g/L)	3.20± 0.23[a]	3.01± 0.14[a]	2.50± 0.11[b]	0.0087
Urea (µmol/L)	156.64± 14.24[a]	163.30± 7.38[a]	182.80± 13.19[a]	0.2666
Creatinine (µmol/L)	50.00± 35.43[a]	50.00± 22.50[a]	19.00± 8.77[a]	0.4160
ALAT (UI/L)	16.60± 30[a]	16.60± 1.45[a]	7.53 ±2.68[b]	0.0086
ASAT (UI/L)	12.08± 2.71[a]	8.14± 1.78[a]	15.3± 2.77[a]	0.1007

Values are mean ± SEM of pig of the same agro-ecological areas with the same letter in the same line are not significantly different.

such as climate, nutrition, and management. The smaller size may yield a greater ability to survive under harsh conditions than the larger size as an evolutionary adaptation to conditions of low-input production systems (Halimani et al., 2012; Mbaga et al., 2005).

The HG was highly correlated to the live weight of animals and could be used to estimate this trait that is relevant for breeding purposes. This structure reflected the population of pigs generally kept by subsistence peasant farmers in rural areas (Adeola et al*.,* (2013). The greater live weight of females to males shows the existence of a great phenotypic variability presumably favorable to a well-organized selection that could produce heavy animals. The significant differences observed amongst males and females also express the sexual dimorphism which increases with age and that might be an indicator of how animal populations are managed, considering the preference/persistence of multiparous sows that could be more frequently found in the rural areas and that was more frequently sampled in our study (Ayizanga, 2016; Motsa'a et al., 2017).

Despite selection pressure on morphological traits was probably not relevant, each pig population was adapted to its agro-ecological conditions (Djimenou et al., 2018). The morphometric parameters discriminated one morphological group (morphotype) made up of animals from the WHA; batches constituted by pigs from the bimodal rainfall region and those from individuals of the SSA are not well distinguished possibly as a consequence of interbreeding and more frequent past introgression from exotic breeds that tended to reduce their genetic differentiation. These two populations could also have a similar origin or genetic history; illustrated by principal component analysis.

Biochemical tests, which refer to the analysis of blood plasma or serum, represent the functioning of organs or systems and these data could be used to determine health status (Abonyi et al., 2018). Although all biochemical values were obtained in normal reference intervals (Pawlowsky et al., 2017), agro-ecological areas did not influence Albumin, Total Cholesterol, HDL Cholesterol, Urea, Creatinine, and ASAT levels. Total protein, globulin, triglycerides, glucose and ALAT contents were lower in pigs of highlands as were morphometric parameters, suggesting that biochemical and morphological features could be congruent, confirming the differentiation of highland pigs from the pigs of the other two agro-ecological zones.

Conclusion

The large morphological diversity of the described populations represents a common general feature of many other African pig populations. These populations also have a large genetic potential exploitable with organized approaches considering the structure of the pork production systems in Cameroon and in other African regions. Characterization of these populations at the genome level is also needed to evaluate if they have acquired genetic elements conferring adaptation to harsh environments.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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