Morphological characterization of indigenous goats in the region of Laghouat in Algeria

Laouadi, M.[1,2@]; Tennah, S.[2]; Moula, N.[2,3]; Antoine-Moussiaux, N.[2,3] and Kafidi, N.[4]

[1]Department of Agronomy. University Amar Telidji. Laghouat. Algeria.
[2]Research Laboratory Management of Local Animal Resources. Higher National Veterinary School. Algiers. Algeria.
[3]Fundamental and Applied Research for Animals & Health (FARAH). Sustainable Animal Production. Faculty of Veterinary Medicine. University of Liege. Liege. Belgium.
[4]Canadian Food Inspection Agency. Ottawa. Ontario. Canada.

SUMMARY

This study aims to characterize phenotypically two indigenous goat breeds in Laghouat area (Algeria) and to evaluate effect of age and sex on morph-biometrics characteristics. A total of 312 animals were investigated : 58 females of Mekatia breed and 254 of Arabia breed (44 males and 210 females). The results show that Mekatia breed is characterized by short hair type (96.55%) whereas Arabia breed by long hair type (100% for males, 92.38% for females). The majority of both breeds were multi-coloured (≥3 colors). The semi-pendulous ears were the most represented in Mekatia (48.28%) while in Arabia, the pendulous ears were the dominant (79.55% and 75.72% for males and females respectively). About quantitative traits, both breeds are classified as large. The age effect is shown for more half of measurements with an overall increase of animal size with age (p<0.05). A significant sexual dimorphism (p<0.05) is shown for all measurements except two characters (ear length and ischia width). The results of this study can be a basis for the description and standardization of goat breeds, Mekatia and Arabia, in the region of Laghouat in Algeria.

Caracterización morfológica de cabras indígenas en el área de Laghouat en Argelia.

SUMMARY

El objetivo de este estudio es caracterizar fenotípicamente dos razas de cabras indígenas en el área de Laghouat (Argelia), y evaluar el efecto de la edad y el sexo sobre las características biométricas morfológicas. Se analizarón un total de 312 animales: 58 hembras de raza Mekatia y 254 de raza Arabia (44 machos y 210 hembras). Los resultados muestran que la raza Mekatia se caracteriza por el pelo corto (96.55%) mientras que Arabia muestra un pelo largo (100% para los machos, 92.38% para las hembras). La mayor parte de los animales de ambas razas eran multicolores (≥3 colores). Las orejas semi-pendulares fueron las más representadas en Mekatia (48.28%) mientras que en Arabia, las orejas pendulares fueron las dominantes (79.55% y 75.72% en machos y en hembras, respectivamente). Sobre los rasgos cuantitativos, ambas razas se clasifican como grandes. El efecto de la edad se muestra para más de la mitad de las mediciones con un aumento general del tamaño del animal con la edad (p <0.05). Se muestra un dimorfismo sexual (p<0.05) para todas las mediciones, excepto para dos caracteres (longitud de la oreja y ancho del isquion). Los resultados de este estudio pueden ser la base para la descripción y estandarización de las razas de cabras, Mekatia y Arabia, en la región de Laghouat en Argelia..

INTRODUCTION

Worldwide, goats play an important socioeconomic role particularly for the poor population living in harsh environments of arid regions (Ogola & Kosgey 2012). The continuous and rapid increase in goat population and their products in developing countries: 888 million heads in 2008 against more than one billion heads in 2017 (FAOSTAT 2019) indicate that this animal resource might constitute an important source of protein required to supply food needs chiefly with the rapid growth of human population (Boyazoglu, Hatziminaoglou & Morand-Fehr 2005). This is reinforced by the formidable resilience and adaptation of local breeds to low fertility of lands and extreme climates (Iñiguez 2004). However, more than half of the world's indigenous breeds are threatened by uncontrolled crossbreeding. Moreover, they are not completely characterized (Arandas et al. 2017). The first step of the characterization of local genetic resources is based on the knowledge of variation in the morphological traits

(Delgado et al. 2001). Phenotypic characterization is an accessible and easy tool for programs of conservation and selection of breeds (Pires et al. 2019). In Algeria, four native goat breeds are recorded: Arabia, Mekatia, M'zabite and dwarf of Kabylia (FAO 2014). However, insufficient information is available on the genetic and phenotypic variability of these resources although some studies have given information about morpho-biometric characteristics of some breeds in some regions of Algeria (Khemici et al. 1995; Manallah & Dekhili 2011; Ouchene-Khelifi et al. 2015). Moreover, with the lack of selection scheme in Algeria, the practice of uncontrolled crossbreeding between native and exotic breeds (mainly Saanen and Alpine) and between local breeds has increased, resulting in the loss of traits expressed by local breeds particulary for Mekatia and M'zabite (Ouchene-Khelifi et al. 2015). In the study area (Laghouat), goats are very important in livelihoods of local population, being a source of cash income, milk and meat (Laouadi et al. 2018). Two breeds dominate in the region, namely the Arabia and the Mekatia, however lacked of characterization. The present study aims to characterize phenotypically these two breeds according sex and age in order to establish a conservation strategy in the context of a program for genetic improvement of goats in Algeria.

MATERIAL AND METHODS

DESCRIPTION OF THE STUDY AREA

The study was conducted in Laghouat, southern region of Algeria (**Figure 1**). It is located at 400 km from Algiers, covers a total land area of 25,052 km². Its climate is continental in the northwest, Saharan and arid in the center and the south (ANDI 2013). According to the Direction of Agricultural Services DSA (2017), the number of goats in Laghouat is estimated to 250 thousand representing 11% of the global ruminant livestock of the region.

DATA COLLECTION

In a subsequent inquiry conducted in the province of Laghouat to identify the principal genetic diversity of goat, three population of goat were recorded: local breeds (Arabia and Mekatia), exotic breeds (Saanen, Alpine and Damascus) and crossbreds (between local breeds or local*exotic). For this study carried out from January to May 2015, a random sample of 312 goats from 84 herds of Mekatia and Arabia breeds, aged at least one year, were used:

58 females Mekatia (**Figure 2**),

254 Arabia: 44 males (Figu**re 3**) and 210 females (**Figure 4**).

In the study area, we could not find male of Mekatia breed. Usually, females Mekatia are crossed with other populations mainly Saanen and therefore the study was made only on females.

The age of animals was estimated based on dentition as described by Wilson and Durkin (1984). Three groups of animals were formed according to age: the first group included goats aged one year, the second group two years and the third group included goats aged three years or more.

Data on 14 qualitative morphological variables and 19 quantitative body measurements were collected according to the guidelines provided by the FAO (2012) for the

Figure 1. Map of the study area (Mapa del área de estudio).

Figure 2. Female of Mekatia breed, personal photograph 2015 (Hembra de la raza Mekatia, foto personal 2015).

phenotypic characterization of animal genetic resources. The detailed lists of descriptors used, are available in **Tables I** and **II**, respectively.

In order to eliminate the biases introduced by the errors in taking measurements, we proceeded as follows: to avoid the effects of feeding and watering on the fattening state and conformation of the animal, measurements were made early in the morning using a metric tape. All measurements were done by the same person to avoid variations between operators and only healthy and non-pregnant animals were included in the study.

DATA ANALYSIS

Figure 3. Male of Arabia breed, personal photograph 2015 (Macho de la raza Arabia, foto personal 2015).

Table I. Frequencies, in %, of qualitative traits for Mekatia and Arabia breeds (Frecuencias, en %, de características cualitativas para las razas Mekatia y Arabia).

Variables	Modalities	Frequencies(%)		
		Females of Mekatia breed (N=58)	Males of Arabia breed (N=44)	Females of Arabia breed (N=210)
Body hair coat colour-pattern	Plain	22.41	13.64	7.62
	Patchy	77.59	86.36	92.38
Body hair coat colour	1color	22.41	13.64	6.67
	2colors	22.41	45.45	37.62
	≥3colors	55.18	40.91	55.71
Head colour	1color	25.86	20.45	10.48
	2colors	34.48	65.91	61.43
	≥3colors	39.66	13.64	28.09
Leg colour	1colors	34.48	25.00	19.05
	2colors	41.38	50.00	47.62
	≥3colors	24.14	25.00	33.33
Hair type	Short	96.55	0.00	0.00
	Semi-long	3.45	0.00	7.62
	Long	0.00	100.00	92.38
Horn presence	Absent	32.76	31.82	20.00
	Present	67.24	68.18	80.00
Horn shape	Straight	2.63	3.33	3.57
	Curved	97.37	6.67	92.26
	Spiral	0.00	90.00	4.17
Horn orientation	Lateral	0.00	90.00	1.19
	Upward	7.89	0.00	1.79
	Backward	92.11	10.00	97.02
Ear orientation	Erect	3.45	0.00	0.00
	Horizontally	17.24	2.27	0.95
	Semi-pendulous	48.28	18.18	23.33
	Pendulous	31.03	79.55	75.72
Facial profile	Straight	98.28	52.25	96.67
	Convex	1.72	47.75	3.33
Back profile	Straight	51.72	43.18	66.70
	Concave	48.28	56.82	33.30
Mane presence	Absent	96.55	90.91	99.42
	Present	3.45	9.09	0.58
Beardpresence	Absent	50.00	0.00	16.19
	Present	50.00	100.00	83.81
Wattlespresence	Absent	93.10	93.18	86.67
	Present	6.90	6.82	13.33

All statistical analyses were carried out using the SAS (version 9, 2002). Frequencies were used to describe qualitative traits. The General Linear Model (GLM) procedure is employed to analyze quantitative data where sex and age were considered fixed effects. Least square means and their corresponding errors were obtained for each body trait. The general model employed was the following:

For Arabia breed: $Y_{ijk} = \mu + sex_i + age_j + \varepsilon_{ijk}$

For Mekatia breed: $Y_{jk} = \mu + age_j + \varepsilon_{jk}$

Where:

Y_{ijk}, Y_{jk}: quantitative variables (body length, head length, neck length, horn length, ear length, hair length, rump length, tail length, head width, shoulder width, rump width, ischia width, wither height, back height, sacrum height, chest depth, muzzle circumference, chest girth, canon circumference).

μ: global average.

Sex_i: fixed effect of the sex i (two classes: male and female).

Age_j: fixed effect of the age j (three classes: one year, two years and ≥ three years).

ε_{jk}, ε_{ijk}: residual random effect.

The Tukey test is performed to determine significant differences between pairs of means.

RESULTS

Qualitative traits

Morphological characteristics of females Mekatia and their frequencies are shown in **Table I**. More than half of animals presented three colors or more (55.18%) with predominance of black, white and brown. Hair was short in 96.55%; horns were present (67.24%), curved (97.37%) and backward (92.11%). Mane, wattles were sometimes

Figure 4. Female of Arabia breed, personal photograph 2015 (Hembra de la raza Arabia, foto personal 2015).

Table II. Least squares means (LSM) ± standard error (SE) of body measurements by age group for the Mekatia breed (Mínimos cuadrados significa ± error estándar de las mediciones corporales por grupo de edad para la raza Mekatia).

BM	Age effect			
	1 year	2 years	≥3 years	P value
BL	72.36±2.67	73.97±1.71	76.87±1.21	ns
HL	20.43±0.65[a]	22.47±0.42[b]	23.06±0.29[b]	**
NL	29.86±2.10	32.94±1.35	32.41±0.97	ns
HorL	16.80±2.90[a]	21.59±1.96[ab]	24.81±1.42[b]	*
EL	16.43±0.89	17.18±0.57	17.87±0.40	ns
HrL	4.28±0.82	5.94±0.53	5.65±0.37	ns
RL	21.57±0.88[a]	22.71±0.57[ab]	23.83±0.41[b]	*
TL	12.36±0.97	11.75±0.64	11.97±0.44	ns
HW	12.57±1.32	13.41±0.85	15.39±0.61	ns
SW	14.28±2.34	16.73±1.50	18.32±1.08	ns
RW	14.14±0.68[a]	15.09±0.43[ab]	15.91±0.31[b]	*
IW	6.78±0.77	7.53±0.51	7.67±0.36	ns
WH	66.71±1.51[a]	68.68±0.97[a]	71.79±0.68[b]	**
BH	69.50±1.28[a]	71.00±0.82[a]	73.85±0.59[b]	**
SH	64.78±1.39[a]	68.06±0.89[a]	70.91±0.64[b]	***
CD	30.57±1.26[a]	33.47±0.81[ab]	34.53±0.58[b]	*
MC	24.75±1.55[a]	28.10±1.38[ab]	29.26±0.75[b]	*
CG	74.50±2.22[a]	78.79±1.42[ab]	80.87±1.01[b]	*
CC	7.71±0.34	7.91±0.22	7.88±0.16	ns

BM: Body measurements, BL: body length (n=58), HL: head length (n=58), NL: neck length (n=57), HorL: horn length (n=37), EL: ear length (n=58), HrL: hair length (n=58), RL: rump length (n=57), TL: tail length (n=57), HW: head width (n=57), SW: shoulder width (n=57), RW: rump width (n=57), IW: ischia width (56), WH: wither height (n=58), BH: back height (n=57), SH: sacrum height (n=57), CD: chest depth (n=57), MC: muzzle circumference (n=26), CG: chest girth (n=58), CC: canon circumference (n=57). ns: not significant (p>0.05), *: p<0.05, **: p<0.01, ***: p<0.001. a,b : the difference between the groups with different letters is significant (p<0.05).

present (3.45%, 6.90% respectively) and beard is presented in 50% of goats. The semi-pendulous ears were the most represented (48.28%). Straight profile of face was the dominant (98.28%), but back profile may be straight (51.72%) or concave (48.28%).

About Arabia breed, the phenotypic frequencies according the sex are presented in **Table I**. More than half of variables show the same trends between sex. However, the spiral horn shape with lateral orientation was the most present in males (90%) while the curved (92.26%) with backward orientation (97.02%) was the most present in females. All males have a beard, while the proportion of females with beard was 83.81%. The facial profile was straight (52.25%) or convex (47.75%) in males but almost all of females have a straight profile (96.67%), same for the back where straight profile was the dominant in females (66.7%), but for males, concave profile was the most represented (56.82%). Mane and wattles were mostly absent in both males (90.91%, 93.18%) and females (99.42%, 86.67%).

QUANTITATIVE TRAITS

The morphometric traits of Mekatia females by age group are presented in **Table II**. A significant effect of age was shown for head, horn and rump lengths, rump width, wither, back and sacrum heights, chest depth,

muzzle circumference and chest girth. Overall, there are increases in values with ages. Horn length, rump length and width, chest depth, muzzle circumference and chest girth increased significantly between age group 1 and 3 but between groups 1 and 2 or 2 and 3, differences were not significant for these measurements (**Table II**). About height measurements, the difference is showed between age group 1 and 3 or 2 and 3 but between the first and the second group differences were not significant.

For Arabia breed, least-squared means for the body measurement traits by sex and age are given in **Table III**. About sex influence, except ear length and ischia width where the sex effect was not significant, all body measurements were significantly higher in males than females.

A significant effect of age is shown for the majority of variables except neck, ear and rump lengths, with tendency to increase for the most. The body, head and horn lengths, head, shoulder and rump widths, wither and sacrum heights, chest depth and girth, muzzle and canon circumferences, showed a significant difference from the beginning of the second age group compared to the first age group. However, about hair, tail lengths and ischia width, differences are showed only between the second and the third age group. For some measure-

Table III. Least squares means (LSM) ± standard error (SE) of body measurements by age and sex groups for the Arabia breed (Mínimos cuadrados significa ± error estándar de las mediciones corporales por grupo de edad y sexo para la raza Arabia).

BM	Sex effect			Age effect			
	Female	Male	P	1 year	2 years	≥3 years	P
BL	68.43±0.70	83.08±1.24	***	71.21±1.54[a]	77.19±1.12[b]	78.86±0.77[b]	***
HL	20.71±0.22	23.83±0.38	***	21.08±0.48[a]	22.54±0.35[b]	23.19±0.24[b]	***
NL	31.31±0.45	36.88±0.72	***	33.39±0.98	34.21±0.68	34.68±0.47	ns
HorL	19.17±0.71	36.53±1.19	***	20.89±1.52[a]	29.79±1.10[b]	32.88±0.76[c]	***
EL	20.23±0.32	21.47±0.62	ns	20.41±0.74	21.46±0.52	20.69±0.37	ns
HrL	10.88±0.27	14.15±0.48	***	12.53±0.59[ab]	13.10±0.44[a]	11.91±0.29[b]	*
RL	21.18±0.26	25.56±0.42	***	22.51±0.57	23.81±0.40	23.79±0.27	ns
TL	12.26±0.24	13.35±0.42	*	12.64±0.52[a]	12.02±0.38[a]	13.74±0.26[b]	***
HW	12.32±0.15	14.31±0.24	***	12.52±0.32[a]	13.50±0.22[b]	13.93±0.15[b]	***
SW	13.58±0.28	17.12±0.44	***	13.49±0.59[a]	15.69±0.41[b]	16.86±0.29[c]	***
RW	13.16±0.18	14.17±0.29	**	12.20±0.40[a]	14.22±0.27[b]	14.57±0.19[b]	***
IW	5.88±0.22	5.38±0.37	ns	4.73±0.49[a]	5.35±0.34[a]	6.80±0.24[b]	***
WH	69.28±0.46	81.72±0.81	***	72.50±1.00[a]	75.63±0.74[b]	78.36±0.51[c]	***
BH	73.04±0.45	80.84±0.72	***	74.51±0.97[a]	77.93±0.67[b]	78.38±0.46[b]	**
SH	69.83±0.46	77.40±0.74	***	71.48±1.00[a]	74.29±0.69[b]	75.08±0.48[b]	**
CD	32.22±0.38	38.96±0.61	***	32.63±0.82[a]	36.27±0.57[b]	37.86±0.39[c]	***
MC	26.62±0.39	30.29±0.57	***	26.18±0.85[a]	29.18±0.59[b]	30.00±0.36[b]	***
CG	75.29±0.52	88.43±0.92	***	76.92±1.14[a]	82.57±0.83[b]	86.10±0.58[c]	***
CC	7.69±0.10	9.48±0.16	***	8.12±0.21[a]	8.63±0.15[b]	9.00±0.10[c]	***

BM: Body measurements, BL: body length (n=254), HL: head length (n=254), NL: neck length (n=217), HorL: horn length (n=167), EL: ear length (n=246), HrL: hair length (n=248), RL: rump length (n=217), TL: tail length (n=254), HW: head width (n=21), SW: shoulder width (n=213), RW: rump width (n=217), IW: ischia width (n=212), WH: wither height (n=253), BH: back height (n=253), SH: sacrum height (n=217), CD: chest depth (n=217), MC: muzzle circumference (n=163), CG: chest girth (n=254), CC: canon circumference (n=217). ns: not significant (p>0.05), *: p<0.05, **: p<0.01, ***: p<0.001. a,b : the difference between the groups with different letters is significant (p<0.05).

ments (HorL, SW, WH, CD, CG, CC), the difference is showed between the three age groups.

DISCUSSION

Qualitative traits

Results of qualitative traits from both breeds demonstrated that Mekatia breed is characterized by short hair type and Arabia breed by long hair. This agrees with earlier results reported by Khemici et al. (1995) in the same region, Ouchene-Khelifi et al. (2015) in Algeria and Fantazi et al. (2017) for Mekatia breed. According to Acharya et al. (1995), goats with short hair are less resistant to solar radiation than those with long hair. This is why, according to breeders of the region, the Mekatia breed is not resistant to heat stress compared to the Arabia breed. About horns, they were present in the majority of both breeds as reported by Ouchene-Khelifi et al. (2015) and Fantazi et al. (2017). It is an indication of their abilities to defend themselves and survive in the harsh environments in which they are reared. Likewise, the presence of horns in males is a sign of better reproductive performance (Al-Ghalban, Tabbaa & Kridli 2004).

The large variation in coat color in this study is an indication of a traditional population and might be resulting from uncontrolled movement of animals through various public markets. A high percentage of white coat color offers a better resistance to heat stress in environments characterized by high solar radiation (Hansen 1990). Robertshaw (2006) reported that animals with black coat color have a better adaptation to the cold seasonal climate. The predominance of these two colors in the present study is a kind of adaptation to the climate of Laghouat region which is characterized by very cold winter and very hot summer.

This study reports also that semi-pendulous ears were the dominant orientation for Mekatia which is different with results of Ouchene-Khelifi et al. (2015) where erect ears were mainly reported (68.73%). This difference can be partially explained by limited knowledge of breeders about characteristics of the Mekatia breed (many of them confuse with Saanen) and the effect study area (other provinces in Algeria in the case of Ouchene-khelifi et al. 2015). About Arabia breed, the same tendency was recorded with the same author about the pendulous ears (75.72% in our study vs 74.37% in the study of Ouchene-khelifi et al. 2015). The advantage of long and pendulous ear is to offer a better defense against heat stress by facilitating exportation of calories outcome from metabolism by heat contact exchange (Robertshaw 1982). This result reflects the adaptation of Arabia breed to environmental conditions of steppe and desert.

Osinowo, Buvanendram and Koning (1988), Yakubu et al. (2010) reported that beard and wattles presences were associated with high prolificity and milk yield. In the current study, wattles were mostly absent and beard was mainly present in Arabian males (100%) and females (83.81%). As well, the presence of beard in all males is that the coding gene for beard exists in a dominant state in males (Yakubu et al. 2010).

Quantitative traits

According to Cam, Olfaz and Soydan (2010), morphometric measurements and how they relate to one another can define roughly the animal's production status and breed characteristics.

Using the classification of Devendra and Burns (1983) on the basis of height at wither (>65 cm for large breeds, 51-65 cm for small and 50 cm for dwarf), we can describe Mekatia and Arabia breeds in our study as large (table II and III). A similar tendency is recorded in the study of Manallah and Dekhili (2011) for the goat population in the semi-arid region of Setif Algeria (66.89±8.48 cm) and the study of Ouchene-Khelifi et al. (2015) for the Mekatia (65.11±6.49 cm) and the Arabia (71.07±4.34 cm) breeds. Martini et al. (2010) reported that goats reared under an intensive system appear lower at wither than those in extensive system.

The significant effect of age on more than half of the measurements with increases values confirms earlier observations of Fajemilehin and Salako (2008), Hagan et al. (2012) and Sánchez Gutiérrez, Gutiérrez Luna and Flores Nájera (2018) that reported the shape and the size of animal increase with animal ages. Our results indicate that the attainment of mature age in both breeds is around the two years and three years or more which is in agreement with findings of Jeffery and Berg (1972), Fajemilehin and Salako (2008), who observed that goats attain their full matured body characteristics at three years and above.

The influence of sex on the morphometric traits are likely connected to the difference in the physiology of males and females related to the sex hormonal action which leads to differential growth rates (Carneiro et al. 2010; Frandson & Elmer 1981). This is in agreement with earlier reports on goats (Vargas, Larbi & Sanchez 2007), sheep (Yakubu & Akinyemi 2010) and cattle (Polák & Frynta 2010), respectively. The results confirm also previous works (Akpa, Duru & Amos 1998; Devendra & Burns 1983; Ifut, Essien & Udo 1991) that sex significantly influenced linear body measurements. It was reported in sheep that females has a slower rate of growth than males, and reaches lower mature size due to the effect of estrogen in restricting the growth of the long bones of the body (Sowande & Sobola 2008).

CONCLUSIONS

This study provides a working basis on the morphology of local goats in Laghouat region by the way of phenotypic characterization. It describes morpho-biometric characteristics of two indigenous breeds in the region namely Mekatia and Arabia. The Mekatia and the Arabia breeds are described as large and the mature age is around two or three years' worth, with for Arabia larger size for males compared to females. Some morphological traits (ear and hair types) reflect the adaptation of these breeds to the environmental context of the region. The authors recommend the characterization of the same breeds in other provinces of Algeria to fully describe the diversity existing.

BIBLIOGRAPHY

Acharya, RM, Gupta, UD, Sehgal, JP & Singh, M 1995, 'Coat characteristics of goats in relation to heat tolerance in the hot tropics', *Small Ruminant Research*, vol. 18, no. 3, pp. 245-248.

Akpa, GN, Duru, S & Amos, TT 1998, 'Influence of strain and sex on estimation of within-age-group body weight of Nigerian Maradi goats from their linear body measurements', *Tropical Agriculture (Trinidad)*, vol. 75, no. 4, pp. 462-467.

Al-Ghalban, AM, Tabbaa, MJ & Kridli, RT 2004, 'Factors affecting semen characteristics and scrotal circumference of Damascus bucks', *Small Ruminant Research,* vol. 53, no. 1-2, pp. 141-149.

Andi 2013, *Wilaya de Laghouat*, Agence Nationale de Développement de l'Investissement, pp. 1-20.

Arandas, JKG.; da Silva, NMV, Nascimento, RB, Pimenta Filho, EC, Brasil, LHA & Ribeiro, MN 2017, 'Multivariate analysis as a tool for phenotypic characterization of an endangered breed', *Journal of Applied Animal Research*, vol. 45, no. 1, pp. 152-158.

Boyazoglu, J, Hatziminaoglou, I & Morand-Fehr, P 2005, 'The role of the goat in society: Past, present and perspectives for the future', *Small Ruminant Research*, vol. 60, no. 1, pp. 13-23.

Cam, MA, Olfaz, M & Soydan, E 2010, 'Possibilities of using morphometric characteristics as a tool for body weight prediction in Turkish hair goats (Kilkeci)', *Asian Journal of Animal Veterinary Advances*, vol. 5, no. 1, pp. 52-59.

Carneiro, H, Louvandini, H, Paiva, SR, Macedo, F, Mernies, B & McManus, C 2010, 'Morphological characterization of sheep breeds in Brazil, Uruguay and Colombia', *Small Ruminant Research*, vol. 94, no. 1, pp. 58-65.

Delgado, JV, Barba, C, Camacho, ME, Sereno, FTPS, Martinez, A & Vega-Pla, JL 2001, 'Livestock characterization in Spain', *Animal Genetic Resources*, vol. 29, pp.7-18.

Devendra, C & Burns, M 1983, *Goat Production in the Tropics.* 2nd edn, Farnham Royal, Commonwealth Agricultural Bureau, UK.

DSA 2017, *Statistiques wilaya de Laghouat*, Ministère de l'Agriculture, du Développement Rural et de la Pêche, Algérie.

Fajemilehin, OKS. & Salako, AE 2008, 'Body measurement characteristics of the West African Dwarf (WAD) Goat in deciduous forest zone of South Western Nigeria', *African Journal of Biotechnology*, vol. 7, no. 14, pp. 2521-2526.

Fantazi, K, Tolone, M, Amato, B, Sahraoui, H, di Marco, LPV, La Giglia, M, Gouar, SBS & Vitale, M 2017, 'Characterization of morphological traits in Algerian indigenous goats by multivariate analysis', *Genetics and Biodiversity Journal*, vol. 1, no. 2, pp. 20-30.

FAO 2012, *Phenotypic characterization of animal genetic resources*, FAO Animal Production and Health Guidelines, no. 11, Rome, pp. 1-142.

FAO 2014, 'Characterization and value addition to local breeds and their products in the Near East and North Africa', paper presented to the Regional Workshop, Rabat, Morocco, Animal Production and Health Report, no. 3, Rome, 16-21 November 2012, pp. 1-39.

FAOSTAT 2019, *Statistics of Food and Agriculture Organization of the United Nations*, viewed 20 December 2019, http://www.fao.org/faostat/fr/#data/QA QA.

Frandson, RD & Elmer, HW 1981, 'Anatomy of male reproductive system', in Frandson RD (ed), *Anatomy and physiology of farm Animals*, 3rd edn, pp. 430-442.

Hagan, JK, Apori, SO, Bosompem, M, Ankobea, G & Mawuli, A 2012, 'Morphological Characteristics of Indigenous Goats in the Coastal Savannah and Forest Eco-Zones of Ghana', *Journal of Animal Science* Advances, vol. 2, no. 10, pp. 813-821.

Hansen, PJ 1990, 'Effect of coat colour on physiological responses to solar radiation in Holsteins', *Veterinary record*, vol. 127, no. 13, pp. 333-334.

Ifut, OJ, Essien, AI & Udo, DE 1991, 'The conformation characteristics of indigenous goat reared in South Western tropical humid Nigeria', *Beiträge zur tropischen Landwirtschaft und Veterinärmedizin*, vol. 29, pp. 215-222.

Iñiguez, L 2004, 'Goats in resource-poor systems in the dry environments of West-Asia, Central Asia and the Inter-Andean Valleys', *Small Ruminant Research*, vol. 51, no. 2, pp. 137-144.

Jeffery, HB & Berg, RT 1972, 'An evaluation of several measurements of Beef cow size as related to progeny performance', *Canadian Journal of Animal science*, vol. 52, pp. 23-37.

Khemici, E, Lounis, A, Mamou, M, Sebâa-Abdelkader, M & Takoucht, A 1995, 'Indice de primarité et différenciation génétique des populations caprines de la steppe (Arabia) et du désert (Mekatia) d'Algérie', *Genetics Selection Evolution*, vol. 27, no. 6, pp. 503-517.

Laouadi, M, Tennah, S, Kafidi, N, Antoine-Moussiaux, N & Moula, N 2018. 'A basic characterization of small-holders' goat production systems in Laghouat area, Algeria', *Pastoralism: Research, Policy and Practice*, vol. 8, no. 24, pp. 1-8.

Manallah, I & Dekhili, M 2011, 'Caractérisation morphologique des caprins dans la zone des hautes plaines de Sétif', *Agriculture*, vol. 2, pp. 7-13.

Martini, M, Salari, F, Altomonte, I, Rignanese, D, Chessa, S, Gigliotti, C & Caroli, A 2010, 'The Garfagnina goat: a zootechnical overview of a local dairy population', *Journal of Dairy Science*, vol. 93, no. 10, pp. 4659-4667.

Odubote, IK 1994, 'Influence of qualitative traits on the performance of West African Dwarf goats', *Nigerian Journal of Animal Production*, vol. 21, pp. 25-28.

Ogola, TDO & Kosgey IS 2012', Breeding and development of dairy goats: eastern Africa experience', *Livestock Research for Rural Development*, vol. 24, no. 1, viewed 30 November 2017, <http://www.lrrd.org/lrrd24/1/ogol24021.htm>.

Osinowo, OA, Buvanendram, V & Koning, NL 1988, 'A study of coat type, pigmentation and wattle incidence in Yankasa sheep and their effects on fertility and weaning weight', paper presented to the 13th Annual Conference of the Nigerian Society of Animal Production Held at the University of Calabar, Nigeria, 20-24 Marsh, pp. 1-10.

Ouchene-Khelifi, NA, Ouchene, N, Maftah, A, Da Silva, AB & Lafri, M 2015, 'Assessing admixture by multivariate analyses of phenotypic differentiation in the Algerian goat livestock', *Tropical Animal Health and Production*, vol. 47, no. 7, pp. 1343-1350.

Pires, LC, Machado, TM, Fonseca, J de D, Fonseca, JF, Pile, E & Brandão, FZ 2019, 'Caracterização Biométrica dos Caprinos da República de Cabo Verde', *Archivos de Zootecnia*, vol. 68, no. 263, pp. 384-394.

Polák, J & Frynta, D 2010, 'Patterns of sexual size dimorphism in cattle breeds support Rensch's rule', *Evolutionary Ecology*, vol. 24, no. 5, pp. 1255-1266.

Robertshaw, D 1982, 'Concepts in animal adaptation: Thermoregulation of the goat', *Proceedings of the third International Conference on Goat Production and Disease*, Dairy Goat Publishing Company, Scottsdale, Arizona, pp. 395-397.

Robertshaw, D 2006, 'Mechanisms for the control of respiratory evaporative heat loss in panting animals', *Journal of Applied Physiology*, vol. 101, pp. 664-668.

Sánchez Gutiérrez, RA; Gutiérrez Luna, R & Flores Nájera, M de J 2018, 'Caracterización morfológica de un rebaño de conservación de cabras criollas en Zacatecas, México', *Archivos de Zootecnia*, vol. 67, no. 257, pp. 73-79.

Sowande, OS & Sobola, OS 2008, 'Body measurements of west African dwarf sheep as parameters for estimation of live weight', *Tropical Animal Health and* Production, vol. 40, no. 6, pp. 433-439.

Yakubu, A & Akinyemi, MO 2010, 'An evaluation of sexual size dimorphism in Uda sheep using multifactorial discriminant analysis', *Acta Agriculturae Scandinavica A- Animal Science*, vol. 60, no. 2, pp. 74-78.

Yakubu, A, Salako, AE, Imumorin, IG, Ige, AO & Akinyemi, MO 2010, 'Discriminant analysis of morphometric differentiation in the West African Dwarf and Red Sokoto goats', *South African Journal of Animal Science*, vol. 40, no. 4, pp. 381-387.

Vargas, S, Larbi, A & Sanchez, M 2007, 'Analysis of size and conformation of native Creole goat breeds and crossbreds used in smallholder agrosilvopastoral systems in Puebla, Mexico', *Tropical Animal Health and Production*, vol. 39, no. 4, pp. 279-286.

Wilson, RT & Durkin, JW 1984, 'Age at permanent incisor eruption in indigenous goats and sheep in semi-arid Africa', *Livestock Production Science*, vol. 11, no. 4, pp. 451-455.