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Biometric Variability of Arabia Goat in Laghouat (Algeria) Using the Mean of the Principal Component Analysis

Research Article

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ABSTRACT

Genetic erosion has a great risk for local goat genetic resources around the world and in Algeria. This study is aimed to verify the homogeneity of Arabia goat through multivariate analysis. A total of 111 females aged three years or more were involved. The Principal Component Analysis (PCA) and Hierarchical Classification Analysis (HCA) were conducted on 14 quantitative variables. Furthermore, 7 body indices were calculated. Through the PCA, the three first factorial components accounted for 60.50% of the total variability (31.02, 20.04 and 9.44%, respectively). HCA allowed classifying the Arabia population into three groups that differ significantly ($p<0.05$): the group 1 (n=30, 27.03% of the total) is constituted by the smallest goats, the group 2 (n=56, 50.45% of the total) is characterized by the highest values of body length, height at withers and chest circumference and finally the group 3 (n=25, 22.52% of the total) is characterized by the highest values of width measurements and canon circumference. Morphology indices calculated did not show a significant difference between the three groups for cephalic index, body index, body length index and thoracic development index. About body ratio, chest dactyl index, and canon thickness index, a significant difference was shown especially with group 3. This work highlighted the non-existent of morphometric similarity in Arabia breed of Laghouat region (Algeria).

KEY WORDS Algeria, Arabia, breed homogeneity, multivariate analysis.

INTRODUCTION

In recent years, local goat genetic resources in Algeria are suffering and this can lead to a real danger of genetic erosion due to the introduction of exotic breeds considered by breeders to be more productive. In otherwise, Arabia goat has been able to persist for decades, it is the most dominant in Algeria. It extends from the north to the southern limit of the steppe (Khemici *et al.* 1995) and has interesting characteristics in terms of resilience to climate and walking for long distances (Laouadi *et al.* 2018). However, one of the difficulties in conserving genetic resources is the lack of characterization and knowledge of the best production systems to breed it. Phenotypic characterization appears to be an important step in the breed conservation and identification program (Mwacharo *et al.* 2006; Dossa *et al.* 2007). According to Baccini (2010), multidimensional descriptive statistics (Principal Component Analysis, Factorial Correspondence Analysis, Multiple Correspondence Analysis) refer to all statistical methods that analyze several measurements in the same individual, and that are interdependent. They have been widely used in breed characterization and genetic diversity studies as it provides a descriptive analysis of differences between populations, considering all variables together and providing an overview of the data (Cazar, 2003; Dossa *et al.* 2007; Arandas *et al.* 2017). The principal components analysis (PCA) of body measurements in livestock were used to explain body conformation in many livestock such as goat (Okpeku *et al.* 2011; Boujenane *et al.* 2016), sheep (Yakubu, 2013; Birteeb *et al.* 2014; Khan *et al.* 2014), cattle (Boujenane, 2015), buffalo (Vohra *et al.* 2015), horse (Staiger *et al.* 2016), chicken (Udeh and Ogbu, 2011) and rabbit (Udeh, 2013). The results of the PCA have an impact not only on the management of animals but also help in the conservation and selection of multiple traits by breeders (Salako, 2006; Yunusa *et al.* 2013) because PCA serves as a way to extract the directions along which significant evolutionary changes are more likely to happen and visualize them directly (Gewers *et al.* 2018). Similarly, the use of morphological indices is an easier alternative for determining the type and function of animals (Mwacharo *et al.* 2006).

For these reasons, the present work was conducted to characterize morphologically the Arabia goat using the PCA and also showing existence of subpopulations within the same breed.

MATERIALS AND METHODS

Study area, animals and measured variables

This research was conducted at Laghouat province, located in southern Algeria, 400 km from Algiers (Figure 1). This area is situated at latitude 32˚ 47' 49" et 34˚ 42' 4" N and longitude 1˚ 21' 13" et 4˚ 29' 17" E about 400-1729 m above the sea level. The rainfall ranging from 300 to 400mm in the north, 150 mm in the center, and 50 mm in the south (ANDI, 2013). According to the Laouadi *et al.* (2020), the number of goats in Laghouat is estimated to 242000 representing 11% of the global ruminant livestock of the region.

The results of Laouadi *et al.* (2018) mentioned that the Arabia goat was the most dominant in the Laghouat region. To avoid the effect of sex and age, a total of 111 Arabia female goats aged three years or more were analyzed to investigate existence of subpopulations and phenotypic diversity within the same breed.

A correlation matrix was previously carried out to eliminate the variables highly correlated; it was variables of back height, pelvic width and chest depth. Therefore, only 14 quantitative variables were considered in this study and selected for the analysis (Table 1).

Statistical analysis and morphology indices

All data were analyzed with R software version 3.3.1 (R Development Core Team, 2005). The Shapiro-Wilk test was previously performed to verify the normality of the data. The variables that do not follow conditions of normality have undergone a logarithmic transformation. This is the data corresponding to HS, LarT, LB, LO, Lpoils, Lqueue, LrI, LT and TC variables. Principal component analysis (PCA) and hierarchical ascendant classification (HAC) were performed to establish a typology that consists of identifying similar individuals among themselves. The difference between classes was tested with ANOVA one factor.

To determine the type and function of the breed, seven morphological indices were calculated (Table 2) according to previous studies (Alderson, 1999; Salako, 2006; Chacon *et al.* 2011; Khargharia *et al.* 2015). To analyze indices between identified groups, the following model was used:

$$Y_{jk}= \mu + cluster_j + \varepsilon_{jk}$$

Y_{jk}: morphological indices (ICP, IC, ILC, DT, RC, IEC, IDT)
μ: global average.
$cluster_j$: fixed effect of cluster (three classes: cluster 1, cluster 2 and cluster 3).
ε_{jk}: residual random effect.

ANOVA one factor test is performed to determine significant differences between pairs of means.

RESULTS AND DISCUSSION

Principal component analysis was applied to 14 quantitative variables. According to Kaiser’s criterion, we only kept the axes whose inertia is greater than the average inertia, which is equal to 1; therefore, we will focus on three axes. However, in practice, we only retain the axes that we know interpret i.e. the first two axes.

The three first factorial components accounted for 60.50% of the total variability (31.02, 20.04 and 9.44%, respectively). The variables contributing the most to the first axis were: LrEp, TP, HS, LarT, Lqueue, LrI, LT, and TC. The main variables contributing to the second axis were: LC, Lcou, HG, TP, LB, LO, and LrI. The variables contributing the most to the third axis were: LrEp, HG, HS, LO, Lpoils, and LT (Table 3 and Figure 2).

The hierarchical classification led to classify the goat Arabia population in three subpopulations (Figure 3). The mean values as well as the difference between individuals in each cluster were revealed in Table 4.

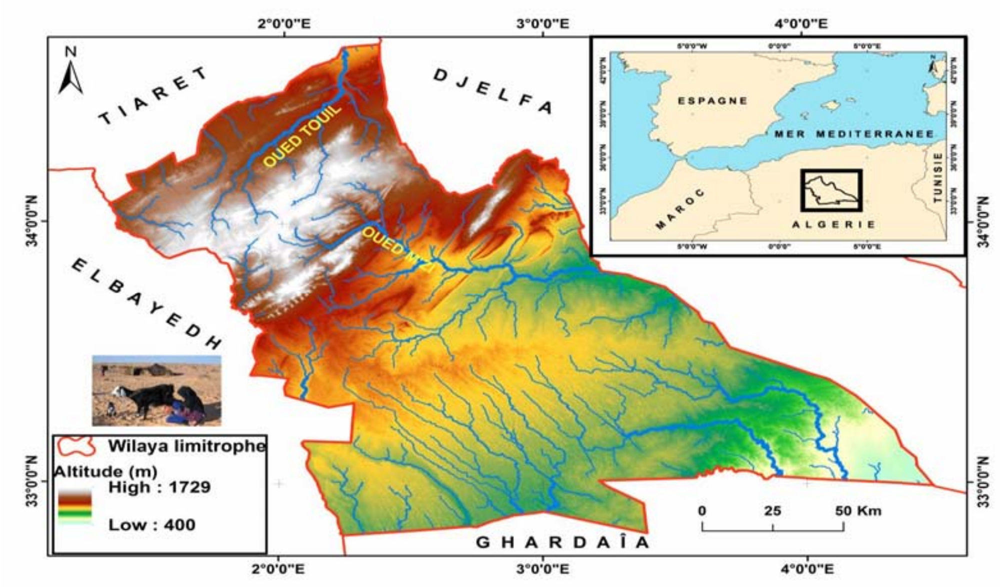

Figure 1 Map of Laghouat region

Table 1 Quantitative measures considered for principal component analysis

Variables	Abbreviations
Head length	LT
Body length	LC
Neck length	Lcou
Ear length	LO
Hair length	Lpoils
Rump length	LB
Tail length	Lqueue
Head width	LarT
Shoulder width	LrEp
Ischia width	LrI
Wither height	HG
Sacrum height	HS
Chest girth	TP
Canon circumference	TC

Table 2 Body indices calculated

Index	Calculus	Signification
Cephalic index (ICP)	LarT/LT	Dolichocephalous: head more longer than width Brachycephalic: head wider than long
Body index (IC)	LC/TP	IC > 0.90: longilineal animal IC between 0.85 and 0.89 : mediolineal animal IC < 0.85: brevilineal animal
Body length index (ILC)	LC/HG	90 > ILC < 1.10: square body shape ILC > 1.10: oblong body shape
Thoracic development index (DT)	TP/HG	DT > 1.2: animal with important thoracic development
Body ratio (RC)	HG/HS	RC > 1.05: animal descends towards the rump 0.95 > RC < 1.05: straight back line RC < 0.95: animal descends towards the withers
Canon thickness index (IEC)	(TC/HG) × 100	Animal robustness
Chest dactyl index (IDT)	(TC/TP) × 100	Not exceed 10.5 in light animals IDT > 10.8 in intermediate animals IDT > 11.00 in slightly meat animals IDT > 11.5 in heavy meat animals

After PCA and HAC, morphology indices were calculated for each cluster. The results obtained as well as the differences between groups are shown in Table 5. RC, IEC, and IDT showed a significant difference between groups especially with group 3. The cephalic index did not show a significant difference between the three groups. The values recorded were superior to 0.50. Body index (IC): the three groups did not show a significant difference and values recorded were superior to 0.90. Body length index (ILC) was between 0.90 and 1.10 for the three clusters with a non-significant difference. Thoracic development index (DT): the difference was not significant in the three groups recorded with values not exceeding 1.2. For body ratio (RC), the difference was significant with the third cluster, whereas, between the first and the second group, the difference was not significant. The first two groups have values higher than 1 while for the third group, the index was less than 1 but all they were between 0.95 and 1.05.

Canon thickness index (IEC) was significantly higher in cluster 3 (13.29 ± 0.25) compared to the other two groups. Finally, for chest dactyl index (IDT), the highest value was also recorded in the 3rd group (11.80±0.20). For the 1st group and the second group, the index was less than 10.5.

Evaluation of breed type by the use of body measurements is more objective than that obtained by visual examination although both are inferior to the notion of "function" as selection criteria of breeding animals (Salako, 2006). High phenotypic correlations between body weight and other linear measurements indicate that animal selection through the use of body measurements is more interesting than live weight (Khargharia *et al.* 2015; Khorshidi Jalali *et al.* 2019; Putra and Ilham, 2019).

In this study, the multivariate analysis conducted by PCA and HAC highlighted the heterogeneity of the local Arabia goat population and indicates the presence of various genetic types which is different to the results of the previous study of Ouchene-Khelifi *et al.* (2018). In fact, it is very difficult and even inexistent to talk about "local breed goats" as a homogeneous genetic group. The three groups showed significant differences (P<0.05); this difference could be attributed to several factors related to the environment or farming practices.

Table 3 Contributions and correlations of variables in the first three dimensions

Variables	Dim 1		Dim 2		Dim 3	
	Contri	Cor	Contri	Cor	Contri	Corr
Body length (LC)	4.21	0.43	**15.30**	**0.65**	1.12	/
Neck length (Lcou)	0.10	/	**19.58**	**0.74**	0.36	/
Shoulder width (LrEp)	**10.00**	**0.66**	0.66	/	**14.64**	**0.44**
Wither height (HG)	3.47	0.39	**11.11**	**0.56**	**26.12**	**-0.59**
Chest girth (TP)	**9.18**	**0.63**	**9.00**	**0.50**	5.38	-0.27
Sacrum height (HS)	**12.98**	**0.75**	0.62	/	**9.48**	**-0.35**
Head width (LarT)	**13.18**	**0.76**	1.35	-0.19	0.27	/
Rump length (LB)	0.02	/	**10.03**	**0.53**	0.08	/
Ear length (LO)	2.21	0.31	**7.86**	**0.47**	**13.61**	**0.42**
Hair length (Lpoils)	0.22	/	8.09	0.48	**12.70**	**0.41**
Tail length (Lqueue)	**9.04**	**0.63**	4.88	-0.37	0.00	/
Ischia width (LrI)	**9.63**	**0.65**	**9.36**	**-0.51**	0.22	/
Head length (LT)	**11.25**	**0.70**	0.23	/	**13.39**	**0.42**
Canon circumference (TC)	**14.49**	**0.79**	1.91	-0.23	2.61	/
Mean	7.14	/	7.14	/	7.14	/

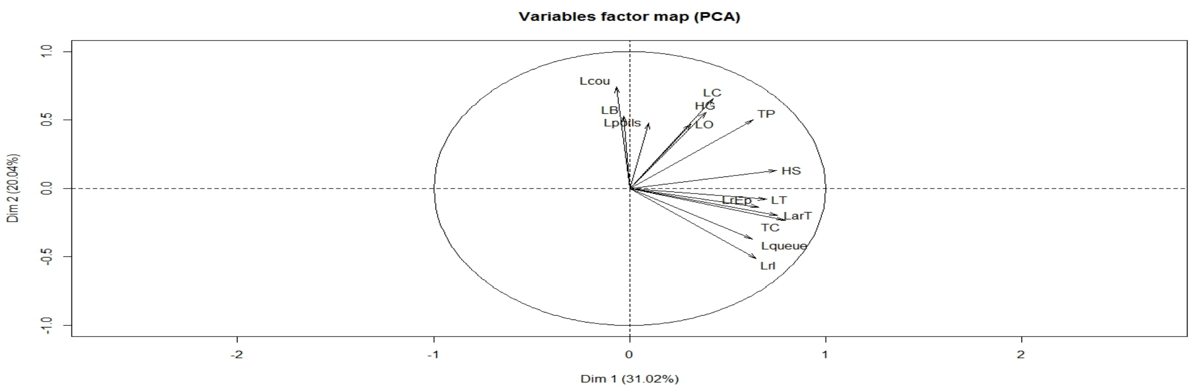

Figure 2 Distribution of variables on axes 1 and 2 (see Table 1 for code meanings)

It seems important to indicate the natural environment where these animals are raised; the 3rd group belongs to the area of the Saharan Atlas where the forest is dominant with altitudes ranging from 1000 to 1700 meters while the first two groups of goats were raised in the area of the Saharan highlands and plateaus where steppe was the most dominant with altitudes ranging from 700 to 1000 meters. This difference in the natural environment could influence the characteristics and function of animals. The animal performance especially those related to meat production can be evaluated by some body measurements such as shoulder width, pelvis width, and chest depth because they are less related to bone growth (Salako, 2006).

Shoulder and Ischia widths measured in this study showed that the 3rd group is the most renowned for meat production, then the 2nd group and finally the 1st group. Regarding hair length, statistical analysis revealed no significant difference proving that the Arabia breed is characterized by long hair type regardless of its location and environment in which it is raised.

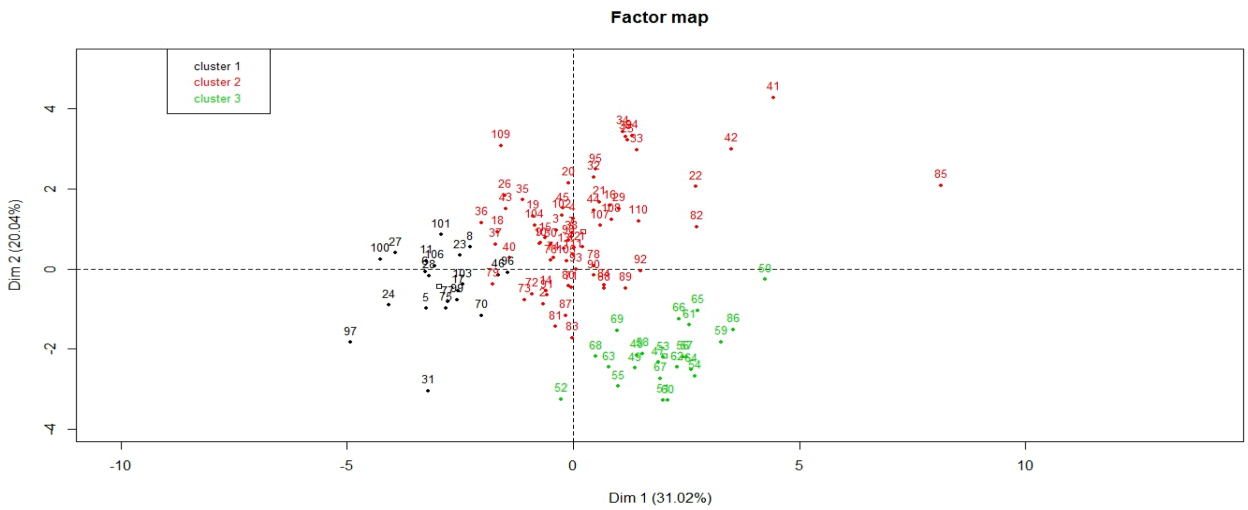

Figure 3 Projection of animals groups into the first two dimensions

Table 4 Characteristics of animals in the three clusters (Mean±Standard error)

Variables	Cluster 1 N=30	Cluster 2 N=56	Cluster 3 N=25	ANOVA one factor
Body length (LC)	69.30±0.92[a]	76.82±0.78[b]	71.68±1.09[a]	***
Neck length (Lcou)	32.07±0.73[b]	33.26±0.58[b]	27.84±0.52[a]	***
Shoulder width (LrEp)	12.97±0.25[a]	14.61±0.30[b]	18.40±0.39[c]	***
Wither height (HG)	69.55±0.61[a]	74.43±0.45[b]	70.16±0.81[a]	***
Chest girth (TP)	75.05±0.59[a]	82.64±0.65[c]	79.04±1.26[b]	***
Sacrum height (HS)	66.82±0.43[a]	72.76±0.47[b]	73.36±0.84[b]	***
Head width (LarT)	11.53±0,21[a]	12.91±0.14[b]	14.56±0.31[c]	***
Rump length (LB)	22.90±1.65[b]	22.94±0.24[b]	18.56±0.79[a]	**
Ear length (LO)	19.22±0.50[a]	21.28±0.52[b]	20.00±0.68[ab]	*
Hair length (Lpoils)	10.43±0.47	10.19±0.30	9.76±0.48	NS
Tail length (Lqueue)	11.07±0.49[a]	12.71±0.32[b]	16.68±0.39[c]	***
Ischia width (LrI)	5.18±0.23[a]	6.88±0.19[b]	9.96±0.39[c]	***
Head length (LT)	20.70±0.27[a]	22.13±0.23[b]	24.68±0.41[c]	***
Canon circumference (TC)	7.07±0.11[a]	8.16±0.10[b]	9.32±0.19[c]	***

Cluster 1 (n=30; 27.03% of the total): goats in this group appear to be the smallest. Measurements values of width (LrEp, LarT, and LrI), circumference (TC and TP), and some short bones (LT and Lqueue) differ significantly from the other groups.
Cluster 2 (n=56; 50.45% of the total): animals of this group constitute the majority of the population studied. They are characterized by the higher values of body length, height at wither, and chest girth ($P<0.05$).
Cluster 3 (n=25; 22.52% of the total): goats of this group were characterized by the higher width measurements (LrEp, LarT, and LrI) and canon circumference compared to the other groups ($P<0.05$).
The means within the same row with at least one common letter, do not have significant difference ($P>0.05$).
* ($P<0.05$); ** ($P<0.01$) and *** ($P<0.001$).
NS: non significant.

Table 5 Morphology indices calculated for goats in each cluster (Mean±Standard error)

Indices	Cluster 1 N=30	Cluster 2 N=56	Cluster 3 N=25	ANOVA one factor[2]
Cephalic index (ICP)	0.56±0.01	0.59±0.008	0.59±0.01	NS
Body index (IC)	0.92±0.01	0.93±0.009	0.91±0.01	NS
Body length index (ILC)	1.00±0.02	1.03±0.01	1.02±0.02	NS
Thoracic development index (DT)	1.06±0.007	1.08±0.009	1.07±0.01	NS
Body ratio (RC)	1.04±0.01[b]	1.02±0.006[b]	0.96±0.01[a]	***
Canon thickness index (IEC)	10.17±0.16[a]	10.98±0.14[b]	13.29±0.25[c]	***
Chest dactyl index (IDT)	9.41±0.12[a]	9.90±0.13[b]	11.80±0.20[c]	***

Cluster 1 (n=30; 27.03% of the total): goats in this group appear to be the smallest. Measurements values of width (LrEp, LarT, and LrI), circumference (TC and TP), and some short bones (LT and Lqueue) differ significantly from the other groups.
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The means within the same row with at least one common letter, do not have significant difference (P>0.05).
* (P<0.05); ** (P<0.01) and *** (P<0.001).
NS: non significant.

Some parameters such as head length and width are not useful in description of production function but can be used to characterize the breed of animal (Ramos *et al.* 2019). Our results revealed higher values than those recorded in goats of western Algeria (Saida) (Ouchene-Khelifi *et al.* 2018) and eastern Algeria (Setif) (Manallah and Dekhili, 2011).

Regarding morphological indices, ICP allowed classifying the Arabia goat as Dolichocephalic where the head is longer than width. This parameter is not useful in description of production function but can be used to characterize the breed of animal (Ramos *et al.* 2019).

Body index allowed to characterize Arabia goat as longilineal animal (IC>0.90); as also shown by other authors in the southeastern (Aissaoui *et al.* 2019) and the northeastern (Sahi *et al.* 2018) of Algeria.

Body length index was between 0.90 and 1.10 for all clusters which classify Arabia goat in the category of animals with a square body (Chacon *et al.* 2011; Khargharia *et al.* 2015). Otherwise, both measurements (HG and LC) are very close.

Thoracic development index is a good indicator of animal physical condition and its respiratory system. It gives information on skeletal fineness; it is more important in meat animals than dairy ones (Khargharia *et al.* 2015). Since Arabia goats are used mainly for meat production, the difference was not significant between the three clusters. This result is in agreement with that already found by Ouchene-Khelifi *et al.* (2018) in the same breed, and by Aissaoui *et al.* (2019) in goats of the semi-arid region of Biskra (Algeria). Thus, Arabia is more suited for meat production.

For RC, despite the difference which is significant between the first two groups and the third group, all are classified in the category of animals with a straight back line (0.95>RC<1.05) (Sahi *et al.* 2018).

However, for the 3rd group, the RC was less than 1 which means that the animals in this group have a sacrum height slightly greater than the height at withers.

Canon thickness index was the highest in the 3rd cluster, then the 2nd group and finally the 1st group. This index allows the detection of animal robustness. Those of the 3rd group show stronger legs than the other groups. This could be due to the hard natural environment in which they are reared (forest massif). The difference between the 1st and the 2nd group could be attributed to the breeding system. In fact, 73% of animals in the 2nd group are raised in the pastoral system which requires stronger legs and body characteristics because they graze in a harder environment than the 1st group where 50% are raised in an agro-pastoral system. Finally, for IDT, recorded values allow us to classify the two first groups in the category of light animals (IDT<10.5), while for the 3rd group (IDT>11.5), animals have a meat vocation. The survey conducted in the study of Laouadi *et al.* (2018) in the same region showed that the Arabia breed is used exclusively for meat. This observed result could be one of the reasons for the introduction of exotic breeds (which are characterized by faster growth) and the crossbreeding with goat Arabia in order to improve its production potential.

CONCLUSION

By the results of this study, we can confirm the presence of sub-populations within the same breed. In fact, we cannot talk about the homogeneity of the Arabia breed. The observed differences between the three subpopulations could be attributed to the environment and the farming system in which they are reared. Through the morphological indices, it seems that the 3rd group has more characteristics of meat production although they all are generally used for meat purposes.

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REFERENCES

Aissaoui M., Deghnouche K., Bedjaoui H. and Boukhalfa H.H. (2019). Caractérisation morphologique des caprins d'une région aride du Sud-Est de l'Algérie. *Rev. Méd. Vét.* **170(7),** 149-163.

Alderson G.L.H. (1999). The development of a system of linear measurements to provide an assessment of type and function of beef cattle. *Anim. Genet. Resour.* **25,** 45-55.

ANDI. (2013). Agence Nationale de Développement de l' Investissement. Wilaya de Laghouat, Algeria. Available at: http://www.andi.dz/PDF/monographies/Laghouat.

Arandas J.K.G., da Silva N.M.V., Nascimento R.D.B., Filho E.C.P., Lúcia Helena de Albuquerque Brasil L.H.dA. and Ribeiro M.N. (2017). Multivariate analysis as a tool for phenotypic characterization of an endangered breed. *J. Appl. Anim. Res.* **45(1),** 152-158.

Baccini A. (2010). Statistique descriptive multidimensionnelle. Publications de l'Institut de Mathématiques de Toulouse, Toulouse, France.

Birteeb P.T., Sunday O.P. and Michael O.O. (2014). Analysis of the body structure of Djallonke sheep using multideterminant approach. *Anim. Genet. Res.* **54,** 65-72.

Boujenane I. (2015). Multivariate characterisation of Oulmes–Zaer and Tidili cattle using the morphological traits. *Iranian J. Appl. Anim. Sci.* **5(2),** 293-299.

Boujenane I., Derqaoui L. and Nouamane G. (2016). Morphological differentiation between two Morrocan goat breeds. *J. Livest. Sci. Technol.* **4(2),** 31-38.

Cazar R.A. (2003). An exercise on chemometrics for a quantitative analysis course. *J. Chem. Educ.* **80(9),** 1026-1029.

Chacon E., Fernando M. and Francisco V. (2011). Morphological measurements and body indices for Cuban Creole goats and their crossbred. *R. Braz. Zootec.* **40,** 1671-1679.

Dossa L.H., Wollny C. and Gauly M. (2007). Spatial variation in goat populations from Benin as revealed by multivariate analysis of morphological traits. *Small Rumin. Res.* **73(1),** 150-159.

Gewers F.L., Ferreira G.R., de Arruda H.F., Silva F.N., Comin C.H., Amancio D.R. and Costa L. F. (2018). Principal component analysis: A natural approach to data exploration. Available at: https://arxiv.org/abs/1804.02502v1.

Khan M.A., Tariq M.M. and Eyduran E. (2014). Estimating body weight from several body measurements in Harnai sheep without multicollinearity problem. *J. Anim. Plant Sci.* **24(1),** 120-126.

Khargharia G., Kadirvel G., Kumar S., Doley S., Bharti P.K. and Das M. (2015). Principal component analysis of morphological traits of Assam Hill goat in eastern Himalayan India. *J. Anim. Plant Sci.* **25(5),** 1251-1258.

Khemici E., Lounis A., Mamou M., Sebâa-Abdelkader M. and Takoucht A. (1995). Indice de primarité et différenciation génétique des populations caprines de la steppe (Arabia) et du désert (Mekatia) d'Algérie. *Genet. Sel. Evol.* **27(6),** 503-517.

Khorshidi-Jalali M., Mohammadabadi M.R., Esmailizadeh A., Barazandeh A. and Babenko O.I. (2019). Comparison of artificial neural network and regression models for prediction of body weight in Raini Cashmere goat. *Iranian J. Anim. Sci.* **9(3),** 453-461.

Laouadi M., Tennah S., Kafidi N., Antoine-Moussiaux N. and Moula N. (2018). A basic characterization of small-holders' goat production systems in Laghouat area, Algeria. *Pastoral. Res. Policy Pract.* **8(1),** 24-32.

Laouadi M., Tennah S., Moula N., Antoine-Moussiaux N. and Kafidi N. (2020). Morphological characterization of indigenous goats in the region of Laghouat in Algeria. *Arch. Zootec.* **69(267),** 272-279.

Manallah I. and Dekhili M. (2011). Caractérisation morphologique des caprins dans la zone des hautes plaines de Sétif. *Agriculture*. **2,** 7-13.

Mwacharo J.M., Okeyo A.M., Kamande G.K. and Rege J.E.O. (2006). The small East African shorthorn zebu cows in Kenya. I: Linear body measurements. *Trop. Anim. Health Prod.* **38(1),** 65-74.

Okpeku M., Yakubu A., Peters S.O., Ozoje M.O., Ikeobil C.O.N., Adebambo O.A. and Imumorin I.G. (2011). Application of multivariate principal component analysis to morphological characterization of indigenous goats in Southern Nigeria. *Acta Agric. Slovenica.* **98(2),** 101-109.

Ouchene-Khelifi N.A., Ouchene N., Da Silva A. and Lafri M. (2018). Multivariate characterization of phenotypic traits of Arabia, the main Algerian goat breed. *Livest. Res. Rural Dev.* Available at: http://www.lrrd.org/lrrd30/7/nakh30116.html.

Putra W.P.B. and Ilham F. (2019). Principal component analysis of body measurements and body indices and their correlation with body weight in Katjang does of Indonesia. *J. Dairy Vet. Anim. Res.* **8(3),** 124-134.

Ramos I.O., De Rezende M.P.G., Carneiro P.L.S., De Souza J.C., Sereno J.R., Bozzi R. and Malhado C.H.M. (2019). Body conformation of Santa Inês, Texel and Suffolk ewes raised in the Brazilian Pantanal. *Small Rumin. Res.* **172,** 42-47.

R Development Core Team. (2005). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Sahi S., Afri-Bouzebda F., Bouzebda Z. and Djaout A. (2018). Étude des mensurations corporelles de caprins dans le Nord-Est algérien. *Livest. Res. Rural Dev.* Available at: http://www.lrrd.org/lrrd30/8/sameh30140.html.

Salako A.E. (2006). Application of morphological indices in the assessment of type and function in sheep. *Int. J. Morphol.* **24(1),** 13-18.

Staiger E.A., Rebecca R.B. and Nathan B.S. (2016). Morphological variation in Gaited horse breeds. *J. Equine Vet. Sci.* **43,** 55-65.

Udeh I. (2013). Prediction of body weight in rabbits using princepal component factor scores in multiple linear regression model. *Int. J. Bioflux Soc.* **3(1),** 1-6.

Udeh I. and Ogbu C.C. (2011). Principal component analysis of three strains of broiler chicken. *Sci. World J.* **6,** 11-14.

Vohra V., Niranjan S.K. and Mishra A.K. (2015). Phenotypic characterization and multivariate analysis to explain body conformation in lesser known buffalo (*Bubalus bubalis*) from north India. *Asian Australasian J. Anim. Sci.* **28(3),** 311-317.

Yakubu A. (2013). Principal component analysis of the conformation traits of Yankasa sheep. *Biotechnol. Anim. Husband.* **29(1),** 65-74.

Yunusa A.J., Salako A.E. and Oladejo O.A. (2013). Principal component analysis of the morphostructure of Uda and Balami sheep of Nigeria. *Int. Res. J. Agric. Sci.* **1(3),** 45-51.