Research Article

Phenotypic and allele frequencies of visible polymorphic traits in Fulani sheep breed in Sudano-Sahelian zone of Chad

Djomtchaigue BH[1,2*], Meutchieye F[2*], Koussou MO[1], Tadakeng DY[2], Zeuh V[3], Awah-Ndukum J[2]

[1]Livestock Research Institute for Development, PO Box. 433. N'Djamena, Chad.

[2] Biotechnology and Bioinformatics Research Unit, Department of Animal Science, Faculty of Agronomy and Agricultural Sciences, University of Dschang PO Box. 188. Dschang-Cameroon.

[3]University of N'Djamena, Department of Biology. Chad.

*Corresponding authors: dbamare@gmail.com and fmeutchieye@gmail.com

Abstract

A study was carried out in the Sudano-sahelian zone of Chad, with the aim of evaluating the polymorphism of qualitative traits in Fulani sheep. A total of 309 adult Fulani sheep (229 ewes and 80 rams) were randomly sampled. The qualitative traits observed were the shape and orientation of the horns, toggles presence, beard presence and the color pattern of the coat (white, black, white black, white brown). The main results show that Fulani sheep in majority did not have mane (98%), toggles (99%) and no beard at all (100%). The frequency of horns was 54% for presence. The hooked facial profile was more represented (87.05%), the shape of the spiral horns was 25%. The ears were droopy (99%). Coat color varied significantly (P<0.05) according to genetic type. The unclassified color pattern group was more represented (77.07%) followed by the white colored pattern (21%). Presence of alteration and great belt were 70% and 69% respectively. Dominant allele frequencies were Ho^p (0.54), Wa^w (0.01) and Br^b (0.00) in the study population. However, all of these dominant allele values were significantly lower ($P \leq 0.05$) than the expected Mendelian value of 0.75 at Hardy-Weinberg equilibrium. The observation of differences between the allele frequencies of this sheep population and the values established by the Hardy-Weinberg model suggests then the intervention of evolutionary factors such as genetic drift, natural selection or mutations. Further investigations are ongoing to link these traits with production and adaptation traits for this native sheep breed.

Key words: Phenotypic, qualitative traits, alleles, Fulani sheep, Chad.

Received: 10/09/2024

Accepted: 27/10/2024

DOI: https://dx.doi.org/10.4314/jcas.v21i1.4

Résumé

Une étude a été conduite dans les zones soudano-sahélienne du Tchad, dans le but d'évaluer le polymorphisme des traits qualitatifs chez le mouton Fulani. Un total de 309 moutons Fulani (229 brebis et 80 béliers) a été échantillonné au hasard. Les traits qualitatifs observés étaient la forme et l'orientation des cornes, la présence des pendeloques, la présence de la barbe et les motifs colorés de la robe (blanc, noir, blanc noir, blanc brun). Les principaux résultats montrent que les moutons Fulani en majorité n'avaient pas de crinière (98%), ni de pendeloques (99%) et la totalité n'avait pas de barbe (100 %). La fréquence des cornes était de 54% pour ce qui est de la présence. Le profil facial busqué était plus représenté (87%), la forme des cornes spiralées était de 25%. Les oreilles étaient tombantes (99%). La couleur de la robe variait significativement (P < 0,05) selon le type génétique. Le patron coloré illisible était le plus représenté (77%) suivi du patron coloré blanc (21%). La présence de l'altération et de la grande ceinture était 70% et 69% respectivement. Les fréquences des allèles dominants étaient Ho^{p} (0,54), Wa^{w} (0,01) et Br^{b} (0,00) au sein de la population étudiée. Cependant toutes ces valeurs des allèles dominants étaient significativement inférieures (P ≤ 0,05) à la valeur Mendélienne attendue de 0,75 à l'équilibre de Hardy-Weinberg. L'observation d'écarts entre les fréquences alléliques de cette population animale et les valeurs établies par le modèle de Hardy-Weinberg, suggère l'intervention de facteurs d'évolution comme la dérive génétique, la sélection naturelle ou des mutations. Des travaux subséquents sont envisagés pour établir les relations entre les caractères qualitatifs et les performances de production de cette race ovine locale.

Mots clés : Phénotype, traits qualitatifs, allèles, mouton Peul, Tchad.

Introduction

The African Union's Agenda 2063 has identified agriculture as a driver of economic transformation. Indeed, livestock sector in Africa contributes to poverty alleviation and also significantly to food and nutrition security. Native African animal breeds have unique features (AU-IBAR, 2019) from which could be mined innovative solutions to some core issues. In Chad for instance, the sheep population is estimated at 41,771,900 heads. About 80% of the Chadian livestock is led by highly diversified mobile pastoral systems and largely dependent on renewable natural resources (REG, 2021). The local sheep populations are made up of 5 breeds: Arab, Fulani with 2 genetic types (Oudah and Waila), Mayo Kebbi, Kirdimi and Kababish. They play a very important role in food security and strongly contribute to the household economy and poverty reduction in rural areas (Alary et al., 2015). These breed varieties are transboundary to Cameroon and Chad where they play interesting roles as means of subsistence (Ebangi et al., 1996). According to Hall (1999), the diversity of genetic background, climatic conditions, random mating and natural selection could give rise to different local populations of sheep and therefore to the development of differential adaptive behaviors which could be evident through morphotype diversification. Along the same line, the findings of Oseni et al. (2006) showed that, diversity, expression of qualitative traits may have certain mechanisms related to adaptation and survival in different ecological zones. This theory was earlier supported by Odubote's (1994) report on the influence of some qualitative traits on the genetic potential and adaptability of Nigerian goats. These observations are obvious in typical low-input management smallholder production systems (Rege and Gibson, 2003). Given that the characterization of a given breed is the first step in the genetic improvement strategy, the aim of the present study was to provide information on the distribution and alleles' frequencies of certain qualitative traits of Fulani sheep populations in Chad.

Materials and methods

Study zone

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

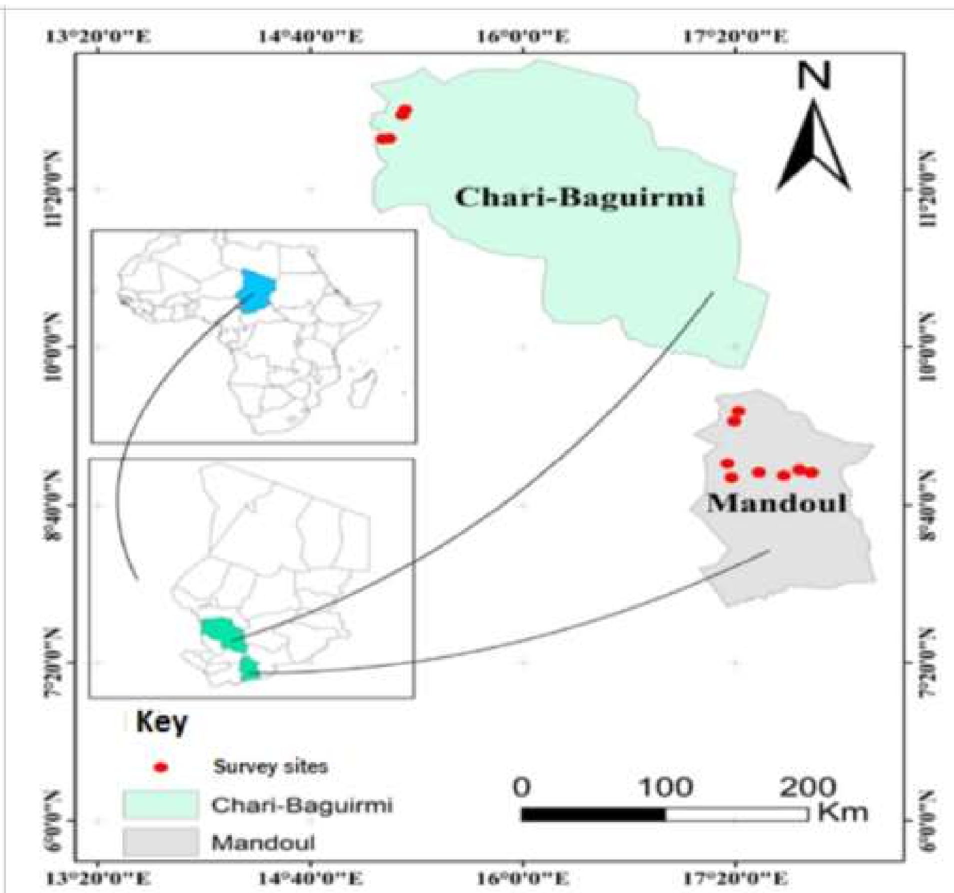


Figure 1: Study areas location

Data Collection

Three hundred and nine (309) adult Fulani sheep made up of 2 genetic types (Oudah and Waila), 80 ewes and 229 rams were randomly sampled in the Sahelian and Sudanian area. The animal was chosen randomly, 3 animals per household. Four qualitative traits (horns, toggles, beard and coat color) were observed for the classification of this sheep population. The presence or absence of horns, toggles and beard observed in the sample was as follows:

- ? Ho^p for [absence of corns];
- ? Ho^+ for [presence of horns] (variation of horns and orientations);

1. Wa^+ for [absence of toggles];
2. Wa^w for [presence of toggles];

1. Br^+ for [absence of beard];
2. Br^- for [presence of the beard].

The observed color patterns were classified as white (Wh^+), black, black white and brown white. The absence and presence of spotting, belt, white spot on the flank, black spot on the forehead, shape and orientation of the horns were considered.

The qualitative traits were studied according to the approach used by Zafindrajoana and Lauvergne (1993), Yakubu et al. (2010) and Djoufack et al. (2020), for the analysis of morphological and genetic differentiation in small ruminants. Coat color and color patterns were studied using the approach of Lauvergne (1993) and Machado et al. (2000).

Data analysis

Descriptive statistics approach was used to describe the distribution of qualitative traits. The distribution of qualitative traits was presented in the form of frequency and percentage according to area and sex. The chi-2 test was used to assess relationships between variables, provinces and owner gender.

The frequencies of recessive alleles (Ho^+, Wa^+, Br^+ and not mane) were estimated using the Hardy-Weinberg equilibrium according to Facolner and Mackay (1996) and as used by Yakubu et al. (2010) and as indicated below:

$$q^2 = \frac{m}{M} \quad => \quad q = \sqrt[2]{m/M}$$

m: number of animals observed presenting the morphological characters;

M: total number of animals sampled.

From q below, the frequencies of the dominant alleles (Ho^p, Wa^w, Br^b and presence of mane) were calculated as follows: **p = 1 – q**, with p frequency of the particular dominant allele.

The observed frequencies were tested against the Mendelian ratio of 3:1 corresponding to the values 0.75 for the dominant alleles and 0.25 for the recessive alleles using the Pearson chi-square test. The null hypothesis (Ho) is that the population studied has Mendelian proportions, while the alternative hypothesis (H1) is that the population does not have Mendelian proportions.

The Pearson Chi-Square Test for Goodness of Fit states that:

$$\chi 2 = \sum_{n=1}^{\infty} \left(\frac{(Expected - Observed)2}{Expected} \right)$$

The significance level was set at pÂ0.05. These different statistical analyzes were carried out using SPSS 21.0 and XLSTAT 2022 software.

Results

Visible features and phenotypic frequencies

The results show that Fulani sheep have no mane (98.38 %), not toggles (99.09 %) and not beard at all (100 %). The frequency of horns was 54.04 % for presence. The hooked facial profile was more represented (87.05 %), the shape of the spiral horns was 25.88%. The frequency of drooping ear orientation was more represented (99.02 %) (Table 1).

Depending on the sex (Table 2), a significant difference was observed related to the heredity of the horns, this demonstrates a sexual dimorphism marked by an absence of horn in the ewe (54.04%) and a presence of horn in the ram (45.97 %). The absence of mane, toggles are respectively 98.13% and 99.02 %. The facial profile and the orientation of the ears are 87.04 % and 99.02 %. The shapes of the horns are curved and lumpy in ewe (17.47 %) and 22.33 % in ram.

Table 1: Distribution of visible characteristics in Fulani sheep according to type

Traits	Allele	Expression	Genetic type				All type		χ2
			Oudah		Waila				
			%	n	%	n	%	n	
Mane	-	Absence	100	237	93.05	67	98.38	304	0.23ns
	-	Presence	0	0	6.94	5	1.62	5	
Toggles	Wa^+	Absence	100	237	95.83	69	99.09	306	0.18ns
	Wa^w	Presence	0	0	4.16	3	0.91	3	
Horns	Ho^p	Absence	52.74	125	58.23	42	54.04	167	0.04s
	Ho^+	Presence	47.26	112	41.67	30	45.95	142	
Beard	Br^+	Absence	100	237	100	72	100	309	0.00s
	Br^b	Presence	0	0	0	0	0	0	
Face Profile	-	Busked	95.78	227	58.33	42	87.05	269	0.48ns
	-	Mean busqued	2.95	7	38.88	28	11.32	35	
	-	Straight	1.26	3	2.78	2	1.62	5	
Horn shape	-	Curved	44.46	50	60.00	12	20.06	62	0.11ns
	-	Spiral	55.36	62	0	18	25.88	80	
Orientation of the ears	-	Peduncle	1.26	3	0	0	0.97	3	0.05*
	-	Drooping	98.74	234	100	72	99.02	306	

*: significant (P<0.05); **: significant (P<0.01); ns: not significant (P>0.05); -: non determined ; %: Percentage; n: Number; χ2: Chi-2.

Table 2: Distribution of visible characteristics in Fulani sheep according to sex

Traits	Allele	Expression	Sex				All sex		χ2
			Ewe		Ram				
			%	n	%	n	%	n	
Mane	-	Absence	100	229	93.75	75	98.14	304	0.21ns
	-	Presence	0	0	6.25	5	1.65	5	
Toggles	Wa^+	Absence	99.56	228	97.50	78	99.02	306	0.09ns
	Wa^w	Presence	0.44	1	2.50	2	0.97	3	
Horns	Ho^p	Absence	71.62	164	3.75	3	54.04	167	0.59ns
	Ho^+	Presence	28.38	65	96.25	77	45.94	142	
Beard	Br^+	Absence	100	229	100	80	100	309	0.00**
	Br^b	Presence	0	0	0	0	0	0	
Face Profile	-	Busked	85.59	196	91.25	73	87.04	269	0.07ns
	-	Mean busqued	12.66	29	7.50	6	11.32	35	
	-	Straight	1.74	4	1.25	1	1.62	5	
Horn shapes	-	Curved	83.08	54	10.39	8	20.04	62	0.82ns
	-	Spiral	16.92	11	89.61	69	25.88	80	
Orientation of the ears	-	Peduncle	1.31	3	0	0	0.97	3	0.05*
	-	Drooping	98.69	229	100	80	99.02	306	

*: significant (P<0.05); **: significant (P<0.01); ns: not significant (P>0.05); -: non determine; %: Percentage; n: Number; χ2: Chi-2.

The mane (98.13 %) and toggles (99.02 %) are almost absent in the study zones. The facial profile was hooked respectively 63.64 % in Sahelian zone and 23.62% in Sudanian zone. The shape of the spiral horns is 25.89 % against 20.06 % of the curved horns (Figure 3). The frequency of ear orientation is 47.25 % in Sahelian zone and 52.75 % in Sudanian zone (Table 3).

Table 3: Distribution of visible characteristics in Fulani sheep according to zone

Trait	Allele	Expression	Zone % (n)				All zone		χ2
			Sahelian		Sudanian				
			%	n	%	n	%	n	
Mane	-	Absence	100	146	96.93	158	98.38	304	0.15^{ns}
	-	Presence	0	0	3.07	5	1.65	5	
Toggles	Wa+	Absence	100	146	98.16	160	99.03	306	0.12^{ns}
	Wa^{w}	Presence	0	0	1.84	3	0.97	3	
Horns	Ho^{p}	Absence	47.94	70	59.51	97	54.04	167	0.13^{ns}
	Ho^{+}	Presence	52.05	76	21.36	66	45.95	142	
Beard	Br^{+}	Absence	100	146	100	163	100	309	0.00**
	Br^{b}	Presence	0	0	0	0	0	0	
Face Profile	-	Busked	82.19	120	91.41	149	84.14	269	0.25^{ns}
	-	Mean busqued	17.81	26	5.42	9	11.32	35	
	-	Straight	0	0	3.07	5	1.62	5	
Horn shapes	-	Curved	53.94	41	31.82	21	43.66	62	0.24^{ns}
	-	Spiral	46.06	35	68.18	45	56.34	80	
Orientation of the ears	-	Peduncle	0	0	0	0	0	0	0.10^{ns}
	-	Drooping	100	146	100	163	100	309	

*: significant (P<0.05); **: significant (P<0.01); ^{ns}: not significant (P>0.05); -: non determined; %: Percentage; n: Number; χ2: Chi-2.

Coat color pattern frequency in Fulani sheep

Coat color frequency varies significantly (P < 0.05) according to genetic type. White and black group was more represented (58.89 %), followed by white (26.86 %) and white and brown (14.59 %) animals. The unclassified color pattern group is more represented (77.07 %) followed by the white colored pattern (21.68 %). The observed frequencies of the presence of weathering and the great belt are respectively 70.55 % and 69.90 % (Table 4).

Table 4: Distribution of color patterns in Fulani sheep according to genetic type

Trait	Allele	Expression	Genetic type				All type		χ2
			Oudah		Waila				
			%	n	%	n	%	n	
Coat	-	White black	79.13	182	0	0	58.89	182	0.91^{ns}
	-	White brown	19.56	45	0	0	14.59	45	
	Aw^{h}	White	0	0	100	83	26.86	83	
	$S^{+}S+$; $S^{+}S^{b}$	Black	1.30	3	0	0	0.97	3	
Color pattern	-	Absence	0	0	1.39	1	0.32	1	0.96^{ns}
	-	Eumelanic	1.26	3	0	0	0.97	3	
	-	Illisible	98.73	234	5.55	4	77.07	238	
	Aw^{h}	All white	0	0	93.05	67	21.68	67	
Alteration	-	Absence	10.13	24	93.06	67	29.44	91	0.76^{ns}
		Presence	89.87	213	6.94	5	70.55	218	
Streak	-	Absence	10.55	25	94.36	67	29.77	92	0.77^{ns}
		big belt	89,45	212	5,63	4	69,90	216	

*: significant (P<0.05); **: significant (P<0.01); ^{ns}: not significant (P>0.05); -: non determine; %: Percentage; n: Number; χ2: Chi-2.

Gender significantly influenced (P < 0.05) the coat color of Fulani sheep. The black and white bichromic pattern is more represented 59.84 % followed by the white monochromic pattern 24.27 % (Figure 2). The frequency of the unclassified color pattern is more represented 77.02 % followed by white 22.00 %. The presence of alteration and streak is represented at 70.55 % (Table 5).

Table 5: Distribution of color pattern in Fulani sheep according to sex

Trait	Allele	Expression	Sex				All sex		χ2
			Ewe		Ram				
			%	n	%	n	%	n	
Coat	-	White black	58.33	133	65.00	52	59.84	185	0.25^{ns}
	-	White brown	14.42	42	3.75	3	14.56	45	
	Aw^h	White	23.25	53	27.50	22	24.27	75	
	S+S+;S+S b	Black	0	0	3.75	3	0.97	3	
Color pattern		Eumelanic	0	0	3.75	3	0.97	3	0.24^{ns}
	-	Unclassified	79.91	183	68.75	55	77.02	238	
	-	All white	20.09	46	27.50	22	22.00	68	
Alteration	-	Absence	26.64	61	37.50	30	29.45	91	0.14^{ns}
	-	Presence	73.36	168	62.50	50	70.55	218	
Streak	-	Absence	20.64	61	38.75	31	29.97	92	0.12^{ns}
	-	Big belt	73.36	168	62.25	49	70.22	217	

*: significant (P<0.05); **: significant (P<0.01); ns: not significant (P>0.05); -: non determine; %: Percentage; n: Number; χ2: Chi-2.

A significant difference (P < 0.05) of coat color was observed by province. The bichromic pattern is more represented (59.84 %) followed by the white coat 24.27 %). The unclassified color pattern is more represented (77.07 %). The presence of alteration and streak are respectively 70.55 % and 70.22 %.

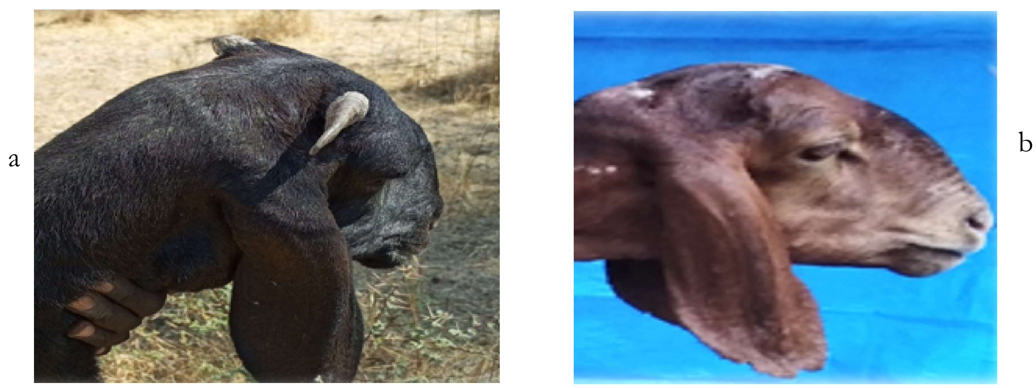
Table 6: Distribution of color pattern in Fulani sheep according to the zone

Trait	Allele	Expression	Zone				All zone		χ2
			Sahelian		Sudanian				
			%	n	%	n	%	n	
Coat	-	White black	58.33	133	65.00	52	59.84	185	0.35^{ns}
	-	White brown	18.42	42	3.75	3	14.56	45	
	A^{wh}	White	23.25	53	27.50	22	24.27	75	
	S^+S^+; S^+S^b	Black	0	0	3.75	3	0.97	3	
Color pattern	-	Eumelanic	2.05	3	0	0	0.97	3	0.26^{ns}
	-	Unclassified	92.97	108	79.75	130	77.02	238	
	-	All white	23.65	35	20.25	33	22.00	68	
Alteration	-	Absence	39.19	58	20.25	33	29.45	91	0.28^{ns}
	-	Presence	60.27	88	79.75	130	70.55	218	
Streak	-	Absence	37.67	55	22.70	37	29.97	92	0.26^{ns}
	-	Big belt	62.33	91	77.30	126	70.22	217	

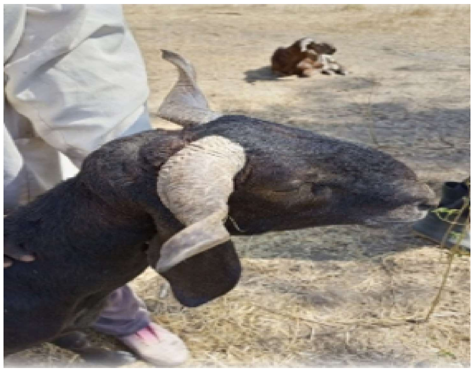
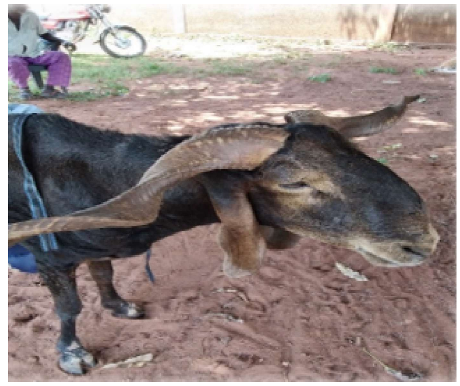
*: significant (P<0.05); **: significant (P<0.01); ns: not significant (P>0.05); -: non determine; %: Percentage; n: Number; χ2: Chi-2.

a,b) Monochromic Waila Sheep; c,d) Bichromic Oudah Sheep

Figure 2: Color patterns in Fulani sheep



a) Root balled horn in ewe **b)** Absence of horn in ewe

c) Lateral curved horns in ram **d)** Forward-facing curved horns in ram e   f

(e,f) Laterally oriented spiral horns in ram

Figure 3: Horn shapes and orientations

Phenotypic frequency of qualitative traits in the Fulani sheep

The frequencies of the dominant alleles were Ho^p, Wa^w, and presence of mane and Br^b within the studied population. However, all these dominant allele values were significantly lower ($P \leq 0.05$) than the expected value of 0.75 at Hardy-Weinberg equilibrium (Table 7). Nevertheless, very high values of recessive alleles have been recorded. The absence of Hardy-Weinberg equilibrium in the Fulani sheep population can be justified by the occurrence of influencing factors such as migration and time sections. High values of recessive alleles were generally recorded. We observe a Wa^w phenotypic frequency and the presence of the mane (0.00 %). In addition, we also noted a higher allelic frequency according to the provinces (0.99 %), while the Wa^w frequency of 0.01 in the zone (Table 8). These values are lower than expected (3; 1), it can be said that the Fulani population is not in Hardy-Weinberg equilibrium for these traits.

Table 7: Phenotypic frequencies of qualitative traits in Fulani sheep according to genetic types

Trait	Allele	Expression	Genetic type									
			Oudah			Waila			Total			
			Observed	Expected	Phenotypic frequency	Observed	Expected	Phenotypic frequency	Observed	Expected	Phenotypic frequency	p-value
Mane	-	Absence	237	233	1.00	67	71	0.93	304	304	0.98	0.000**
	-	Presence	0	4	0.00	5	1	0.07	5	5	0.14	
Toggles	Wa^+	Absence	237	235	1.00	69	71	0.97	306	306	0.99	
	Wa^w	Presence	0	2	0.00	3	1	0.03	3	3	0.01	
Horns	Ho^P	Absence	125	128	0.53	42	39	0.59	167	167	0.54	
	Ho^+	Presence	112	109	0.47	30	33	0.42	142	142	0.46	
Beard	Br^+	Absence	237	237	1.00	72	72	1.00	309	309	1.00	
	Br^b	Presence	0	0	0.00	0	0	0.00	0	0	0.00	

*: significant ($P<0.05$); **: significant ($P<0.01$); ns: not significant ($P>0.05$); -: non determine; $\chi 2$: Chi-2.

Table 8: Phenotypic frequencies of qualitative traits in Fulani sheep according to the zone.

Trait	Allele	Expression	Zone									
			Sahelian			Sudanian			Total			
			Observed	Expected	Phenotypic frequency	Observed	Expected	Phenotypic frequency	Observed	Expected	Phenotypic frequency	p-value
Mane	-	Absence	146	144	1.00	158	160	0.96	304	304	0.98	0.076ns
	-	Presence	0	2	0.00	5	3	0.03	5	5	0.02	
Toggles	Wa^+	Absence	146	145	1.00	160	161	0.98	306	306	0.99	
	Wa^w	Presence	0	1	0.00	3	2	0.02	3	3	0.01	
Horns	Ho^P	Absence	70	79	0.48	97	88	0.59	167	167	0.54	
	Ho^+	Presence	76	67	0.52	66	75	0.40	142	142	0.46	
Beard	Br^+	Absence	146	146	1.00	163	163	1.00	309	309	1.00	
	Br^b	Presence	0	0	0.00	0	0	0.00	0	0	0.00	

*: significant ($P<0.05$); **: significant ($P<0.01$); ns: not significant ($P>0.05$); -: non determine; $\chi 2$: Chi-2.

Discussion

Gender significantly influenced ($P < 0.05$) the coat color of Fulani sheep. In this study, the frequency of the unclassified color pattern was more represented (77.02 %) followed by white (22.00 %). These results are similar to those of Ndiaye et al. (2018) in native Fulani sheep in Senegal. The presence of alteration and variegation was represented in 70.55 % of sheep. Yakubu et al. (2010) observed the predominance of white coat color in rams and ewes in Balami sheep in Nigeria. According to Ozoje and Kadri (2001), in addition to the relationship between white color and environmental stress, there is also morphostructural importance, as it affects shoulder width in sheep. Additionally, Dyrmundsson and Adalsteinsson (1980) reported that the Aw^{h} allele responsible for white coat plays a role in suppressing off-season breeding, which is an advantage in harsh environmental conditions where off-season breeding with lambing in the cold season would lead to high mortality of young. The phenotypic frequencies of qualitative traits observed in Fulani sheep indicate phenotypic polymorphism. There was an observation of Wa^{w} phenotypic frequency and the presence of the mane (0.00%). These values were lower than those expected (3; 1), indicating the Fulani population is not in Hardy-Weinberg equilibrium for these characters. The observation of differences in the allele frequencies of this animal population and the values established by the Hardy-Weinberg model, then suggests the intervention of evolutionary factors such as genetic drift, natural selection or mutations are operating in the population of sheep.

Yakubu et al. (2010) showed higher tipping frequencies in females (36.63 %) compared to males (11.45 %) for the Yankassa sheep breed in Nigeria. However, in Uda and Balami sheep, the same researchers found higher frequencies in ram (10.26 % and 19.59 %) than in ewe (1.59 % and 13.59 %). The total frequency of 98.38 % is consistent with the 48 % and 98.28 % reported respectively by Ozoje and Kadri (2001) on West African dwarf sheep and Rodero et al. (1996) on the Lebrijan Churro sheep in Andalusia. Salako (2012) obtained tipping frequencies of 4.59 % and 82.14 % respectively in the Djallonké sheep and in the Yankassa sheep in Nigeria, which is therefore not comparable with our observations. The frequency of 0 % observed in our study corroborates the observations of Yakubu et al. (2010) in Balami, Yankassa and Uda sheep in Nigeria.

Salako (2012) reported that the presence of horns in rams and ewes in Djallonké and Yankassa sheep in Nigeria with sexual dimorphism in favor of Ram. According to Yakubu et al. (2010), having the horns could be advantageous in the tropics where the temperature can easily reach extremes due to the fact that they are the only specific areas with significant blood drainage through the cavernous sinus, which according to Robertshaw (2006), is involved in the control of thermal homeostasis mechanisms.

Yakubu et al. (2010) found Wa^{w} allele frequencies ranging from 0.08%; 0.02% and 0.09% respectively in Yankassa, Uda and Balami sheep in Nigeria. On the other hand, Ozoje and Kadri (2001) report a frequency of 0.39% for the Wa^{w} allele which is in contradiction with the observations on these sheep populations. According to Yakubu et al. (2010), such a low frequency of the gene responsible for the presence of flip-flops is a sign that it is subject to disappearance. Such observations should lead to appropriate decision-making to improve understanding of the decline mechanisms and potential impact on current and future breeding programs.

Conclusion

The visible polymorphism in Fulani sheep displays significant variability which demonstrates a rich and exploitable genetic heritage. The present study showed that the distribution of these qualitative traits in Fulani sheep is influenced by the genetic type. There was an absence or a fairly low frequency of some characters common in african sheep breeds (toggles, horn and mane) in the agro-ecological zones which would be due to rehabilitation and natural or commercial selections. The main sexual dimorphism characters identified are the horns in favor of the ram This character seem to have an influence on the mechanisms of natural selection in empirical local breeding practices. Some characters like Wa^w seem to be disappearing more in this population. But, its sexual dominance in ewe should lead to the conservation and exploitation of ewes' fertility. However, genetic molecular studies are necessary to confirm this variation to allow better conservation and exploitation of the characters with production targeted traits.

Conflicts of interest

The authors declare that there is no conflict of interest related to this study.

Author's contributions

DBH and MF ensured the development of the research protocol, the collection, the data processing and the writing of the manuscript under the direction and the supervision of MF, ANJ and KM; ZV and TDY contributed to the proof reading of the different versions to improve the scientific quality of the manuscript.

Acknowledgments

Our sincere thanks to the Coordination of ACCEPT project for the support in organizing the data collection. We also thank the decentralized livestock services, the traditional authorities and the breeders for their frank collaboration during the investigation.

References

Alary, V., Aboul-Naga, A., El Shafie, M., Abdelkrim, N., Hamdon, H., Metawi, H. (2015). Roles of small ruminants in rural livelihood improvement – Comparative analysis in Egypt. Rev. Elev. Med. Vet. Pays Trop., 68 (2-3): 79-85

AU-IBAR. (2019). The state of Farm Animal Genetic Resources in Africa, AU-IBAR publication.

Djoufack, Y.T., Meutchieye, F., and Manjeli, Y. (2020). Phenotypic and genetic differentiation of qualitative traits in sheep ecotype from Cameroon Western Highlands. Gen. Biodiv. J: 4 (1):23-29

Dyrmundsson, O.R., and Adalsteinsson, S. (1980). Coat-color gene suppresses sexual activity in Icelandic sheep. J. Heredity. 71: 363-364. DOI: 10.1093/oxfordjournals.jhered.a109389.

Ebangi, A.L., Nwakalor, L.N., Mbah, D.A., Abba, D. (1996). Factors affecting the birth weight and neonatal mortality of Massa and Fulbe sheep breeds in a hot and dry environment, Cameroon. Revue Élev. Méd. vét. Pays trop., 49 (4):349-353.

FAO. (2013). Caractérisation phénotypique des ressources génétiques animales. FAO sur la production et la santé animale. N° 11. Rome,152p.

Falconer, D.S., and Mackay, T.F.C. (1996). Introduction to quantitative genetics. 4th ed. Longman, London. 464p.

Hall, S.J.G. (1991). Body dimensions of Nigerian cattle, sheep and goats. Anim. Prod. (UK). 53 : 61-69. DOI : https://doi.org/10.1017 S0003356100005985.

Lauvergne, J.J. (1983). Utilisation du principe de l'homologie interspécifique pour l'étude du déterminisme de couleur de pelage des ruminants domestiques, à l'exemple du locus Agouti. Bulletin de la société Zoologique de France. 108 : 201-243.

Lauvergne, J.J., Souvenir, Z.P., Minvielle, F., Bourzat, D., et Zeuh, V. (1993). Un gène de réduction de la corne au Nord Cameroun et au Tchad. Revue Élev. Méd. vét. Pays trop., 4. : 651-665.

Machado, T.M.M., Igarashi M.L.S.P., Contel E.P.B., Ferro J.A. (2000). Diversité génétique entre populations caprines brésiliennes. In proceedings of the 7th International conference on Goats pp: 958-960

Ndiaye, B., Diouf, M.N., Ciss M., Wane, M., Diop, M., and Sembène, M. (2018). Morphologie et pratiques d'élevage du mouton peul-peul du Sénégal. Int. J. of Adv. Res. 6: 727 738.http://dx.doi.org/10.21474/IJAR01/7089.

Odubote, I.K. (1994). Characterization of West African Dwarf goats for certain qualitative traits. Nig. J. Anim. Prod. 21: 37-41. http://doi.org/10.1155/2015/728210

Oseni, S., Sonaiya, B., Omitogun, G., Ajayi, A., Muritala, I. (2006). West African Dwarf goat production under village conditions: I. Characterization and the establishment of breed standards. Conference on International Agricultural Research for Development, University of Bonn, Tropentag. 11-13 October.

Ozoje, M.O., Kadri, O.A. (2001). Effects of coat color and wattle genes on body measurement traits in the West African Dwarf sheep. Trop. Agric. 78: 118- 122. DOI: JSAER2018-05-10-155-161.

Rege, J.E.O. And Gibson, J.P. (2003). Animal genetic resources and economic development: Issues in relation to economic valuation. Ecological Economics 45: 319-330. DOI: https://dx.doi.org/10.1016/S0921-8009(03)00087-9.

Robertshaw, D. (2006). Mechanisms for the control of respiratory evaporative heat loss in panting animals. Journal of Applied Physiology 101: 664-668. DOI : japplphysiol.01380.2005.

Rodero, E., Haba, M.R., Rodero, A.Y., Herrera, M. (1996). Genetic and phenotypic profile ofendangered Andalusian sheep and goat breeds. FAO Health Paper. 88: 77-97.

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

SPSS.21: Statistic and social package. Version 21.

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

XLSTAT: Statistical Software for Excel. https://www.xlstat.com/en/

Yakubu, A. (2013). Principal component analysis of the conformation traits of Yankassa sheep. Biotechnology Animal Husbandry, 29(1):65 74.

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

Yaye, B.H., Dayo, G.K., Issa, M., Mani, M., Idi, I., et Marichatou, H. (2019). Etude des pratiques d'élevage des moutons Peulh du Niger : le Peulh blanc et le Peulh bicolore. Int. J . Biol. Chem. Sci. 13(1): 83-98. DOI: 10.4314/ ijbcs.v13i1.8

Yunusa, A.J., Salako, A.E., and Oladejo, O.A. (2013). Morphometric characterization of Nigerian indigenous sheep using multifactorial discriminant analysis. Journal of Biodiversity and Conservation, 5(10):661-665. DOI: 10.5897 IJBC2013.0592

Zeuh, V., Lauvergne, J.J., Bourzat, D., et Minvielle, F. (1997). Cartographie des ressources génétiques caprines du Tchad du Sud-Ouest I, Hauteur au garrot (HG), profondeur de thorax (PT) et indice de gracilité sous-sternale (IGs). Revue Élev. Méd. vét. Pays trop., 50 (3) : 250 260.

Zeuh, V. (2000). Caractérisation génétique des ruminants domestiques et inventaire des ressourcesvégétales. ME/LRVZ/SCAC. Projet ASETO – 2. Rapport Final, juillet 2000. 27p.

Zeuh, V., Mopate, L.Y., et Issa, Y. (2013). Characterization of the Mayo-Kebbi Sheep: a previously unrecognised ovine breed of the agro-pastoral zone of South-West Chad. Journal of Animal Production Advances. 3(12): 331-341.

Zeuh, V. (2013). Etat des lieux des ressources zoogénétiques au Tchad. 80p.