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The Koundoum sheep breed in Niger: morpho-biometric study and description of the production system

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Abstract

The diffusion of highly productive breeds across developing countries goes along with a neglect of indigenous breeds, which are well suited to their environment but often show low yields. Thus, in Niger, the flock of Koundoum sheep are rapidly decreasing. The Koundoum is one of the few wool sheep breeds of Africa and shows important adaptive feature to its native environment, i.e. the humid pastures on the banks of the Niger River. To characterise the breed and to understand its production context, a survey has been conducted in 104 herds in four communes along the Niger River (Kollo, Tillabery, Say and Tera). Nine body measurements, including live weight, were taken on 180 adult sheep (101 females and 79 males). The herds varied from 2 to 60 heads, with a median size of eight animals and two thirds of the herds having less than 10 animals. Mainly fed on natural pastures, 85.6 % of the herds received crop residues. Only natural mating was practiced. Veterinary care was restricted to anti-helminthic and some indigenous treatments. The frequent affiliation of breeders to professional unions appeared as favourable to the implementation of a collective conservation program. The Koundoum sheep were white or black coated, with the black colour being most frequent (75.6 %). Wattles were present in both sexes at similar frequencies of around 14 %. All biometric variables were significantly and positively correlated between them. The thoracic perimeter showed the best correlation with live weight in both males and females. Three variables were selected for live weight prediction: thoracic perimeter, height at withers and rump length. From the present study, it is expected that the *in situ* conservation of the Koundoum sheep will be highly problematic, due to lack of market opportunities for wool and the willingness of smallholders to get involved in pure Koundoum rearing.

Keywords: biodiversity, description, conservation, Koundoum sheep, morpho-biometry, Niger

1 Introduction

With the main part of its land being under arid and semi-arid climate, Niger is home to a wide and diversified livestock population: 13.2 million goats, 10 million sheep, 9.5 million cattle and 1.7 million camels (INS, 2013). Mainly in sheep and cattle, the diffusion of breeds show high production abilities and the homogenisation of the production systems go along with a neglect of more resilient indigenous breeds. This substitution between breeds and the uncoordinated use of crossbreeding lead to an erosion of animal genetic resources, in Niger and West Africa as in the rest of the world (Rege, 1999; Rege & Gibson, 2003). Animal losses due to epizootics and droughts contribute to the

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difficulties met in the conservation of some local breeds; however, the main cause for genetic erosion lies in the choices made by breeders themselves. Regarding the genetic diversity of sheep in Niger, seven breeds are listed but have been poorly characterised. Among these breeds, the Koundoum sheep, which is the main wool sheep in West Africa, shows a dramatic decline in the cradle of the breed, i.e. the inundation zone of the Niger River (Ibrahim, 1998; Meyer *et al.*, 2004).

The Koundoum breed is described as a medium-sized animal with slightly convex profile. The horns are highly developed in the male, prismatic and directed backwards. In the female, the horns are smaller and often absent (Meyer *et al.*, 2004). The ears are long, wide, thick and drooping (Charray *et al.*, 1980). The body is covered with wool; the head, the belly and the limbs are naked. The fleece is black and white with black spots on the head (Richard *et al.*, 1985). Its meat production performances are low, with a mean adult weight of 30 and 25 kg in males and females, respectively (Charray *et al.*, 1980), and a carcass percentage of 40 % (Wilson, 1991). Despite this low yield, meat of Koundoum sheep is reported to be lean (Wilson, 1991) and renowned for its taste and tenderness (Richard *et al.*, 1985).

In the frame of a national conservation plan of animal genetic resources, the University of Niamey initiated a conservation program for the Koundoum sheep. The set-up of an optimal conservation strategy requires the full characterisation of the breed and its own diversity, as well as of the diversity of its production contexts (Chikhi & Boujenane, 2003; FAO, 2007). Therefore, this survey aimed at the characterisation of the production systems harbouring the Koundoum sheep and the morpho-biometric characterisation of the breed in four communes on the banks of the Niger River. Due to the importance of live weight as a selection criterion and in the daily management of herds (Mahieu *et al.*, 2011; Birteeb & Ozoje, 2012), live weight prediction formula have been established on the basis of body measurements. Such prediction formula are, indeed, a cheap and easy tool available to smallholders, who are the main users of indigenous animal genetic resources and thus important actors for their conservation (Porhiel *et al.*, 2005).

2 Materials and methods

2.1 Study area

The survey was conducted in four communes of the administrative region of Tillabery: Kollo, Say, Tera and Tillabery. This region is located in the Niger valley, at the extreme west of the country. Its main city, Tillabery, is situated at14°13’ North latitude and 1°27’ East longitude.

Economic activities in the Tillabery region are agriculture, livestock, fishing and forestry. Rain-fed agriculture is practiced from June to September and mainly consist of pearl millet cultivation (monoculture or in association). During the dry season, from October to March, market gardening is practiced. The majority of households also keep animals. Three animal breeding systems are described: extensive sylvo-pastoral, semi-intensive agro-pastoral and intensive agro-pastoral systems. The latter is found in the vicinity of the river.

2.2 Household survey

The survey was conducted from October to December 2011 among 104 sheep keepers. The surveyed households were selected on the basis of a list delivered by the village chiefs. The only selection criterion was the ownership of sheep, regardless of the breeds kept. The questionnaire consisted of both open-ended and close-ended questions, asked during face-to-face individual interviews. The questions covered the characteristics of the breeder (ethnic group, age, activities, membership of associations, motivations for the practice of breeding), those of the animals (species, numbers, sheep breeds) and the production system (movements and pasture management, reproduction, health care, feeding, housing).

2.3 Morpho-biometric characterisation of the Koundoum sheep

The studied sheep were the wool sheep called Koundoum by breeders. From October to December 2011, 180 sheep were characterised, among which 101 female and 79 male animals. The age of the animals was estimated by teeth inspection (Gatenby, 1991) and classified in three age groups. The first group included sheep still showing deciduous teeth and one pair of permanent teeth (0 and 1 year). The second group included sheep with two or three pairs of permanent teeth (2 and 3 years). The third group included sheep with four and five pairs of permanent teeth (4 and older).

For each Koundoum sheep, the colour of the wool and the presence/absence of wattles and horns were noted. The following body measurements were then recorded according to FAO recommendations (FAO, 2011): the height at withers, the thoracic perimeter, the length of the back, the scapulo-ischial length, the length of the

rump, the ear length, the length of the tail, the length of the head, and live weight. The latter was measured using an electronic dynamometer (KERN Germany), with a maximal allowance of 100 kg and an accuracy of 200 g.

2.4 Statistical analysis

All statistical analyses were performed with the Statistical Analysis Software SAS® (SAS Institute, 2001). The Chi-square test was used to compare the differences in the frequency of wattles and of the coat colours according to sex. The effect of sex and age group on the different body measurements was studied through an analysis of variance (generalised linear model, *proc glm*). Pearson's correlation coefficients between the different body measurements have been calculated. The determination of an equation for the prediction of live weight from linear body measurements was achieved through a linear regression model, the variables included in the model being chosen through a stepwise elimination process (linear regression, *proc reg, option stepwise*).

3 Results

3.1 Characteristics of the sampled herds

The characteristics of the sampled breeders and their practices are presented in Table 1 and Table 2, respectively.

Table 1: *Socio-economic characteristics of sheep breeders surveyed.*

Variables	*Modalities*	*Freq. (%)*
Location	Left riverbank	76.9
	Right riverbank	23.1
Ethnic group	Djerma	79.8
	Fulani	8.7
	Tuareg	7.7
	Hausa	3.8
Main activity	Crops	94.2
	Livestock	5.8
Age	≤ 30 years	4.8
	30–50 years	39.4
	≥ 50 years	57.8
Membership in local association	None	51.0
	At least one	49.0

Table 2: *Characteristics of herds surveyed and sheep breeding practices.*

Variables	*Modalities*	*Freq. (%)*
Species	Mixed species	92.0
	Specialised in sheep	8.0
Sheep number	≤ 10	67.3
	10 to 20	19.2
	≥ 20	13.5
Mobility	Sedentary	80.8
	Transhumant	19.2
Supplementation	Yes	85.6
	No	14.4
Ethno-veterinary practices	Yes	28.8
	No	71.2
Frequency of anthelminthic treatments	None	24.1
	1 per year	11.5
	At least 2 per year	64.4
Housing	Local materials	50
	None	43.3
	Wire net	6.7

3.1.1 Breeders

Most of the interviewed breeders were located in the communes of Kollo and Tillabery on the left bank of the Niger River (76.9 %). The majority of the interviewees belong to the Djerma ethno-linguistic group (79.8 %), the rest include Fulani (8.6 %), Tuareg (7.7 %) and Hausa (3.8 %). The age of the respondents varied from 27 to 90 years, with a median at 53. The breeders keeping exclusively Koundoum sheep were between 42 and 89 years old (median at 65).

All interviewees practiced agriculture in association with livestock keeping. Livestock was a secondary activity for 94.2 % of interviewees, only 5.8 % considered livestock as their main activity.

The principal motivation for keeping sheep was savings for 93.2 % of the respondents. To keep sheep out of tradition was the first motivation for only 2.0 % of the livestock keepers. 3.8 % justified their activity by both motives and 1.0 % presented the generation of revenue by selling animals as primary motive. Half of the sampled livestock keepers were member of an organisation active at village level. 11.5 % declared having benefitted at least once from technical advices provided by extension services.

3.1.2 Animals

The majority of herds (92.3 %) included mixed species: sheep, goat and cattle. Only 7.7 % kept exclusively sheep. The number of sheep per flock varied from 2 to 60 heads, with a median of 8 and more than two-thirds of the herds consisted of less than 10 animals. 26.0 % of the respondents kept only one sheep breed and 74.0 % kept different breeds. The most frequent breed was called Kassawa sheep, kept by 58.6 % of surveyed households. Koundoum sheep were kept by 30.7 % of the respondents. In 10.6 % of all cases Koundoum was the only sheep breed.

3.1.3 Breeding practices

92.3 % of the breeders were sedentary and 7.7 % practiced a particular type of transhumance, between the riverbanks and the islands in the Niger River that emerge during dry season. There were shelters for sheep in 56.7 % of the households. The materials used for building shelters were wood, mud bricks and millet straw for 50.0 % of the herds and wire nets for 6.7 %.

Feeding was based on natural pastures, with complementary feeding composed of conserved fodder and crop residues that were harvested and distributed. Interviewees reported the progressive infestation of pastures with *Sida cordifolia* (flannel weed) on the plateaus and *Eichhornia crassipes* (water hyacinth) on the riverbanks. None of the livestock keepers in our study cultivated fodder for their animals. Nevertheless, 76.0 % of them collected natural fodder to make hay that was fed during the end of dry season. The chopping of straw (crop residues) before feeding was seldom practiced (2.5 %). A few livestock keepers used tree fodder for their sheep, harvesting and feeding it directly: 23.1 % used *Faidherbia albida*, 2.0 % used *Piliostigma reticulatum* and 2.0 % used *Balanites aegyptiaca* and *Vachellia tortilis*. Watering occurred in the river or at wells during the dry season, while water holes could also be used in the rainy season.

Natural mating was the only mode of sheep breeding. The choice of the breeding rams was based on their overall conformation and their colour, with a preference for white. Only 6.7 % of interviewees practiced castration of the males that were not retained for breeding.

The health follow-up of sheep was limited in most cases to anthelminthic treatments, which were practiced by 76.0 % of the respondents: 64.4 % dewormed their flock at least twice a year, 11.5 % once a year. Indigenous treatments were used by 28.8 % of interviewees. Three categories of indigenous treatment could be described: physical treatment (like branding and ear incision), treatments using plants (*Khaya senegalensis*, *Striga hermonthica*), and treatments using chemicals (potassium hydroxide, cooking oil).

The fattening of sheep was practiced by 44.2 % of interviewees, mainly for slaughtering at the Islamic feast called Tabaski. Koundoum wool and ewes' milk were not exploited. Manure was most often used as organic fertiliser for their own crops (89.4 % of cases). Other uses of manure were sale, gift or barter (2.9 %).

Table 3: *Morphological traits of the Koundoum sheep (n=180).*

Trait	*Sex*	*Phenotype*	*N*	*Freq. (%)*	χ^2
Colour	Females	Black	77	76.24	***
		White	24	23.76	
	Males	Black	59	74.68	***
		White	20	25.32	
Wattles	Females	Presence	26	25.74	***
		Absence	75	74.26	
	Males	Presence	25	31.65	***
		Absence	54	68.35	
Neck ruff	Females	Presence	1	0.99	***
		Absence	100	99.01	
	Males	Presence	14	31.11	**
		Absence	31	68.89	
Horns	Females	Presence	4	3.96	***
		Absence	97	96.04	
	Males	Presence	77	97.47	***
		Absence	2	2.53	

N: number; Freq.: frequency; χ^2: statistical significance of Chi-square test, ***: $p < 0.001$

Table 4: *Body measurements in the Koundoum sheep (Least Square Mean ±SE).*

	Age group 1			*Age group 2*			*Age group 3*		
	Females	*Males*	*t*	*Females*	*Males*	*t*	*Females*	*Males*	*t*
Number	42	61		29	13		30	5	
Body weight (kg)	24.4 ± 0.8	22.5 ± 0.6	ns	28.2 ± 0.9	36.2 ± 1.4	*	31.1 ± 0.9	48.3 ± 2.2	*
Thoracic perimeter	70.0 ± 0.8	66.0 ± 0.7	*	73.7 ± 1.0	76.00 ± 1.5	ns	76.8 ± 1.0	81.2 ± 2.4	ns
Height at withers	65.6 ± 0.7	63.6 ± 0.6	*	67.4 ± 0.8	72.3 ± 1.2	*	69.9 ± 0.8	78.4 ± 1.9	*
Rump length	19.0 ± 0.2	18.2 ± 0.2	*	19.6 ± 0.3	21.0 ± 0.4	*	20.2 ± 0.3	23.2 ± 0.7	*
Scapuloischial length	51.2 ± 3.0	50.8 ± 3.5	ns	51.6 ± 3.2	53.7 ± 2.1	ns	53.0 ± 3.5	(58.00)	–
Length of ears	13.3 ± 0.9	13.1 ± 1.5	ns	13.1 ± 0.9	11.7 ± 1.0	ns	13.5 ± 1.2	(14.00)	–
Tail length	36.1 ± 2.3	35.2 ± 3.3	ns	36.2 ± 2.8	37.2 ± 2.6	ns	36.5 ± 2.1	(36.00)	–
Head length	17.7 ± 1.6	18.6 ± 1.7	ns	18.6 ± 1.6	20.8 ± 0.8	ns	19.2 ± 1.3	(21.00)	–
Length of the back	41.4 ± 3.1	39.9 ± 2.9	ns	43.0 ± 3.3	43.7 ± 2.9	ns	43.9 ± 2.3	(50.00)	–

t : statistical significance of difference between sexes for each variable and age group (* : $p < 0.05$; ns : not significant; – : not calculated). Values between brackets have been measured on one individual.

3.2 Morpho-biometric characterisation of Koundoum sheep

3.2.1 Qualitative variables

Morphologic characteristics of Koundoum sheep and their frequencies are shown in Table 3. Two colours were present: black (brownish to black) and white. The black colour was most frequent (75.6 %) ($p < 0.0001$). Wattles were present in both sexes at similar frequencies: 14.4 % in females and 13.9 % in males ($p > 0.05$). Horns are rarely absent in males (4.4 %) and sometimes present in females (3.9 %). Two male Koundoum sheep presented three horns, thus being specifically named *Djomoddi* in the local language. Around a third of the males had a neck ruff.

3.2.2 Body measurements

The first age group included 77.2 % of all observed male sheep and 41.6 % of the female sheep. The average weight tended to be higher in females ($p = 0.06$) (Table 4). In age groups 2 and 3, males were heavier than females ($p < 0.0001$). All body measurements were significantly and positively gender correlated ($p < 0.001$) (Table 5). However, higher Pearson correlation coefficients were obtained for males. The measure that displayed the highest correlation to live weight was the thoracic perimeter in males and females (0.92 and 0.79, respectively). The variable with the second highest correlation to live weight was the length of the rump in males (0.90) and the height at withers in females (0.66).

Table 5: *Pearson correlation coefficient matrix for selected body measurements according to sex.*

	Age	*TP*	*LW*	*HW*	*LR*
Age	–	0.62 ***	0.82 ***	0.66 ***	0.64 ***
TP	0.53 ***	–	0.92 ***	0.88 ***	0.85 ***
LW	0.52 ***	0.79 ***	–	0.89 ***	0.90 ***
HW	0.46 ***	0.60 ***	0.66 ***	–	0.88 ***
LR	0.41 ***	0.69 ***	0.65 ***	0.63 ***	–

Upper right part of the table shows correlations in males (grey), Lower left part of the table shows correlations in females (white); *TP*: thoracic perimeter; *LW*: live weight; *HW*: height at withers; *LR*: length of the rump; *** $p < 0.001$

3.2.3 Live weight prediction equations

Three variables, i.e. the thoracic perimeter, the height at withers and the length of the rump, proved useful for the prediction of live weight. Equations are given in Table 6. All three variables were needed for females from the first age group. In all other cases, two variables proved satisfactory for live weight prediction. No equation could be estimated for age group 3 due to a lack of data for males and due to low correlation coefficients for females of this age group.

Table 6: *Live weight prediction formulae in Koundoum sheep by age group and sex.*

Age	*Sex*	*Equation*	R^2
Group 1	Females	$LW = -38.26 + 0.37\,TP + 0.30\,HW + 0.91\,LR$	0.65
	Males	$LW = -31.54 + 0.58\,TP + 0.83\,LR$	0.94
Group 2	Females	$LW = -46.23 + 0.62\,TP + 0.42\,HW$	0.63
	Males	$LW = -77.07 + 0.88\,TP + 2.19\,LR$	0.88

LW: live weight; *TP*: thoracic perimeter; *HW*: height at withers; *LR*: length of the rump; R^2: determination coefficient of the model

4 Discussion

4.1 Status and breeding context of the Koundoum sheep

The lack of outlets for wool, which is the main asset of the Koundoum breed, as already reported in 1975 by Toubo, led most breeders to shift their flocks towards meat breeds. This shift is practiced through simple substitution or through crossbreeding with e.g. Fulani, Kassawa and Tuareg sheep. In 1975, the number of Koundoum sheep was estimated in Niger at 30,000 heads (Toubo, 1975). Although the present study does not allow for such estimation, the Koundoum breed seems to have undergone a sharp decline since then, as illustrated by the high frequency of surveyed households that keep crossbreed and mixed-breed flocks. Indeed, the sheep called Kassawa by breeders in the present study is the result of the crossbreeding between the Bali-Bali and the Koundoum sheep. These crossbreds are appreciated for their intermediary characteristics regarding meat production and adaptation to humid pastures (which includes resistance to fluke infestation). Nevertheless, there is a lack of management of the pure-bred Koundoum sheep. Also, the systematic preference of breeders for animals showing a better conformation leads to a progressive erosion of the original genetic make-up of the breed, despite the acknowledgement by breeders of the value of its adaptation to the riverbank environment.

In the present sample, flocks were relatively small with a maximum of 60 heads. This clearly indicates that the Koundoum sheep is currently kept by smallholders and that any policy aiming at its conservation should support these actors. Also, the lack of involvement of the younger interviewees (between 20 and 45 years old) in the exclusive breeding of Koundoum sheep may be a worrying sign of the progressive neglect of the breed. Although the means to get younger people involved in livestock in general and in native breeds in particular are far from self-evident, a strong public support to family farming may be part of the solution. The present situation, however, is far from fulfilling this need. Indeed, the availability for breeders of technical extension services and veterinary health care appear as very limited in this survey. A low technical support also entails a weak access to information about the importance and the means of breed management. Nevertheless, the high rate of membership of breeders in local associations tends to constitute an institutional environment favourable to collective action, as needed for an *in situ* conservation scheme of the Koundoum sheep. The effectiveness and ownership of projects are, indeed, best achieved when they can fit into pre-existing social organisations and do not imply newly developed, theoretically framed and uniform organisations (Gonneville & Sarniguet, 1986).

The main motivation for sheep keeping was savings. This general motive thus leaves space for the reintroduction of wool production in the livelihood strategy of households, provided that outlets for the Koundoum wool can be organised. The better resistance of the Koundoum breed to local humid conditions of the Niger riverbanks reported by Richard *et al.* (1985) could, moreover, be proposed as an advantage by securing this asset. While at some period of the year local people indeed wear warmer clothes, this market is completely taken by cotton and synthetic fibres or more generally by imported clothes. Furthermore, from informal accounts not shown in the results, the meat of the Koundoum sheep also appeared to be better appreciated than that of more productive breeds, as already mentioned in the literature (Richard *et al.*, 1985). This aspect should be better investigated and possibly linked to a potential willingness-to-pay for quality in some niche markets. Therefore, the identification of niche markets (textile

and meat) could contribute significantly to the promotion of the Koundoum breed and its *in situ* conservation (LPP, LIFE Network, IUCN–WISP and FAO, 2010). In addition, this type of niche production might have positive outcomes in terms of employment and poverty alleviation for people involved in wool transformation. Such a handicraft would present a cultural and possibly touristic value, which could underpin its development.

4.2 Pastures and decline in the distribution area of Koundoum sheep

Formerly, Koundoum sheep were found on the river islands and on the banks of the Niger River from the city of Kollo to the border with Mali (a strip of approximately 250 km). They now appear to be mainly concentrated in the commune of Tillabery. A parallel with this drastic decline in area of distribution is the well documented case of the Xisqueta sheep, in the mountainous regions of Spain (Avellanet *et al.*, 2005). The neglect of the latter breed is also motivated by a preference for more productive breeds, as well as the loss of relative importance of livestock keeping in the local economy with a rise in that of tourism, without any touristic valorisation of those traditional pastoral systems.

However, besides the economic dynamic, an ecological one is also at play, leading to the neglect of the Koundoum breed. Indeed, *Sida cordifolia* (flannel weed) and *Eichhornia crassipes* (water hyacinth) are highly invasive plants that constitute a threat to the quality of pastures. Being an aquatic plant, water hyacinth especially threatens the quality of pastures in the vicinity of the river and therefore affects preferentially Koundoum flocks, which find their economic relevance in the exploitation of these ecological zones. One might add that the decrease in pasture quality first affects smallholders that rely almost exclusively on these common resources and therefore, threatens the native breeds of which they are the main guardians.

This decrease in the number of breeders specialised in Koundoum sheep causes a decrease in the practice of the transhumance between islands and the riverbanks. The very peculiar adaptation of the Koundoum breed to this environment and herding practice means that the conservation of the cultural value attached to this lifestyle is tied to that of the Koundoum sheep. The loss of the tradition and know-how of wool transformation pertains to that same dynamic, linking the persistence of livestock breeds to the evolution of cultural environment (Gandini & Villa, 2003). As in other parts of the world, the erosion of the genetic diversity of farm animals may be understood in the context of an erosion of the cultural diversity.

4.3 Morpho-biometry

The greater frequency of the black colour among Koundoum sheep is in accordance with older descriptions (Toubo, 1975). The wattles were commonly observed in the breed. Some authors associated the presence of wattles to good ability for milk production and prolificacy (Casu *et al.*, 1970). If confirmed, such abilities may be good incentives for the *in situ* conservation of this breed, besides its adaptation to humid environment. While prolificacy is directly in line with the objective of savings of breeders, milk is, however, not considered of high enough value. Like in the case of wool, the creation of a specific market should thus be supported. As a matter of fact, the production abilities of Koundoum regarding milk and prolificacy remain to be assessed.

Observations in this survey could confirm the rare occurrence of male Koundoum sheep showing three horns. These sheep are highly valued by buyers interested in its use for traditional ceremonies. Such practices are considered confidential by users and therefore are difficult to investigate.

The present sample is marked by a low number of adult males. Indeed, in Niger, as in almost all countries with a predominantly Islamic population, rams are preferentially slaughtered for ceremonies or religious occasions. The lack of difference in live weight between young males and females (age group 1) is also found in the literature regarding other native breeds (Sowande & Sobola, 2008; Kunene *et al.*, 2009; Cam *et al.*, 2010).

4.4 Live weight prediction equation

In traditional herding, the livestock keepers or livestock services do not have scales available (Kunene *et al.*, 2009; Younas *et al.*, 2013). Moreover, the owners are reluctant to weigh their animals, fearing accidents while handling them (Sow *et al.*, 1991). Therefore, breeders and livestock services often need to estimate the weight. As guessing weight at sight does not show sufficient precision (Salako, 2006; Otoikhian *et al.*, 2008), live weight estimation from body measurements are useful under field conditions (Trillaud Geyl & Baudoin, 2006).

The strong correlation between live weight and thoracic perimeter is often reported in the literature and exploited in the prediction of live weight (Atta & El Khidir, 2004; Salako, 2006; Samuel Fajemilehin & Salako, 2008; Bello & Adama, 2012; Birteeb & Ozoje, 2012). The greater correlation between body measurements in males compared to females is also reported by

Alade *et al.* (2008) for sheep in Nigeria. A strong correlation between the length of the rump and live weight is less frequently reported but is in accordance with Alderson (1999) for cattle in the United Kingdom. Finally, the same three body measurements were shown to have a strong correlation with live weight in the West African dwarf sheep in Nigeria (Sowande & Sobola, 2008).

The present results highlight the importance of taking account of sex and age in the use of predictive equations of live weight, as recommended by Poivey *et al.* (1980). As also pointed out by Ravimurugan *et al.* (2013) for the Kilakarsal sheep in India, the thoracic perimeter appears here as an important estimator, being selected in all categories of animals in the present study. Nevertheless, the addition of other variables in the estimation significantly improves its accuracy. The principle of parsimony led us to retain two or three variables according to the animal category, similarly to Birteeb & Ozoje (2012) for live weight prediction in young West African dwarf sheep in northern Ghana, who retained three variables, namely body length, thoracic perimeter and height at withers. Other similar examples are available in the literature (Thiruvenkadan, 2005; Yakubu, 2010). Importantly, such equations can be used only for this peculiar breed.

5 Conclusion

The Koundoum sheep appears to be a declining domestic breed. Its original characteristics, i.e. its production of wool, its adaptation to humid environments and its insertion in a unique transhumant system, justify a national conservation plan. However, to better highlight the ways of its conservation, a full assessment of its productive abilities should be carried out, including production of wool and milk, its growth and meat quality as well as its reproduction performances. From the present results, it is also expected that the *in situ* conservation of the Koundoum sheep will be highly problematic, due to the lack of market for wool and milk and the willingness of smallholders to get involved in pure Koundoum rearing. Hence, while a strong support on the field is advisable in this regard, any national conservation scheme should also include *ex situ* solutions, both *in vivo* and *ex vivo*.

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