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Phenotypic traits, reproductive and milk production performances of indigenous goats in south Kivu, democratic republic of Congo

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ABSTRACT

Objectives: Quantification of the phenotypic variations of indigenous goats in South Kivu and its relationship with economically important farm traits could open the way for both the conservation and breeding options for goat improvement.

Methodology and Results: This study quantified the phenotypic variation and its association with questionnaire-based reproductive and lactation parameters in indigenous female goats of South Kivu. Six reproductive traits, three lactation parameters, and fourteen morpho biometric traits were analysed following a general linear model. The shape of the horn, the shape of the tail and the eye colour explained the variability among goat populations. The length and the thickness of the tail positively correlated ($p < 0.01$) with the number of kidding per year, with the age of doe at the first service, and with the number of kidding. The lactation length was correlated ($r= 0.33$) ($p < 0.05$) with the estimated age of kids at weaning.

Conclusions and application of findings: The results suggest that these traits can act as phenotypic markers for goat selection. However, further research based on genome-wide association studies is required to confirm and verify these findings and to elucidate either they are genetically based or are from environmental influence.

Keywords: DR Congo, a female goat, milking potential, phenotypic traits, prolific

INTRODUCTION

Goat farming is practised worldwide, with goat products having a favourable image (Gooki *et al*., 2019; Khorshidi-Jalali *et al*., 2019). The number of goats has increased globally, both in countries with high and low-income resources (Robinson et al., 2011). In developing countries, goats play an important socio-economic, nutritional, and cultural role in rural households (Bettencourt *et a*l., 2015; Onzima *et al*., 2017). To remain more important and to contribute more to farmers' household economy, goats should present more productive traits in terms of economically farm traits including prolificacy, milk production, disease resistance, drought tolerance, adaptability and other traits in association with their productivity. However, the productivity improvement requires the integration of technologies, good farming practices and adapted breeds, and good management of the production environment (Thornton *et al*., 2010). In the Democratic Republic of Congo, goat breeding is favourable for the development of the livestock sector (Lafleur *et al*., 2018). In the region of South Kivu, livestock is an integral part of the region's mixed farming systems. Farmers focus on small livestock kept accumulating household reserves that are strongly invested in children's education (Maass *et al*., 2012). Additionally, goats (estimated at 4111789) and chickens are the most accessible by farmers in the different environments of the region (FAOSTAT, 2018 accessed on 28May 2020). Due to its adaptation to the production system, breeding of goats contributes to 40% of rural household income (Baenyi *et al*., 2020; Wasso *et al*., 2018). Therefore, livestock numbers per household that remain low could affect goat's productivity and reflect the poverty because of violent conflict in the region (Maass *et al*., 2012). To alleviate the problem and increase the size of goat herds in South Kivu, goats' breeding stocks were distributed to 150 households under a food security project led and funded by OCHA in 2014. Production system based on free-range grazing, the introduction of exotic breeds as well as the proximity of South Kivu with neighbour countries to DR Congo could affect the genetic diversity of goat populations influencing their productive and reproductive performances (Wasso *et al*., 2018; Gasigwa *et al*., 2017). The assessment of goat variability, the estimation of the relationship between phenotypic variability, productive parameters including milk production and reproductive performances would be necessary for increasing goat's productivity and developing efficient selection programs (Montaldo *et al*., 2002; Weppert *et al*., 2004; Torres-Vázquez *et al*., 2009; Montaldo *et al*., 2010). This study, focused on an understanding of phenotypic variability and its possible association with reproduction and lactation statement in indigenous goat breeds in South Kivu in the Democratic Republic of Congo.

MATERIALS AND METHODS

Study area: This study was conducted in the South Kivu region located in the eastern part of the Democratic Republic of Congo. South Kivu is characterized by a tropical rainforest along the Congo River and its tributaries characterized by two rainy seasons, occurring from March to May and from September to December, followed by two short dry seasons stated by June to August and from January to February. The average temperatures vary between 24 and 25° C with limited variability throughout the year. South Kivu shares limits on the north with North Kivu, with the Kivu Lake on the northeast, Maniema on the west, Katanga on the South and Burundi, Rwanda and Tanzania countries on the east. South Kivu is located at 3.0167°S, 28.2667°E with 1531 m of altitude above sea level. The average rainfall is about 1500 mm with more than 50% of the total land used for animal grazing. According to the Koppen Geiger Climate classification, South Kivu's climate is classified as tropical wet and dries (AW). Livestock and agriculture are one of the major pillars contributing to the economy of rural households in the region. Goat populations are distributed in all agro-ecological zones of the region (Table 1).

Table 1: Geographical description of the study area

Region	zone	Latitude (South)	Longitude (East)	Average annual tº C	Average Altitude (meter)	Ecology of the area
South Kivu	Mwenga	3 º03'	28 º26'	26	1650	Highland and forest area
	Kabare	2 º30'	28 º30'	22.6	2225	Cold mountain climate
	Walungu	2 º38'	28 º40'	18.6	1765	Cold mountain climate
	Uvira	4°20'	29 º30'	26	833	Humid and semi-arid tropical type

Statement of animal rights: The study reported here was carried out in strict accordance with the ethical approval for the permission for interview of farmers and collection of samples provided by:
(1) the Université Evangélique en Afrique, Bukavu, South Kivu, DR Congo, under the research certificate Nº FACAGRO/UEA/KK/308/18; and
(2) the South Kivu provincial inspection, Ministry of Agriculture, Fishery and Livestock, Bukavu, DR Congo, under the authorization Nº 55.00/004/IPAPEL/SK/2019.
A consent form that described the aim of the study was signed by farmers willing to participate in the study after translation into local languages. The manuscript does not contain clinical studies and patient data**.**

Data collection: Data were collected during a survey in 148 goat farms from January to June 2020. All the selected farms were characterized by the same production system, which is the free-grazing system. Farm's structure, farmers' experience in goats breeding (more than 10 years), phenotypic variability mostly observed by body hair coat colour were considered as the inclusion criteria for the selection of farms. Morphological traits, reproductive traits and some lactation parameters were recorded on one adult doe (with more than one kidding) that was randomly selected in each farm to avoid the effect of consanguinity due to the small flock size varying between 5 to 13 animals. The selected farms were distributed in 4 of 8 territories of the region including Uvira (n = 49), Walungu (n = 31), Kabare (n = 28) and Mwenga (n = 40). The concerned animals were not pregnant to avoid any effect of pregnancy on the accuracy of data.

Information on 6 reproductive parameters including age at the first service (AFS), number of kidding (NK), number of kids born at the last kidding (NKBLK), number of kidding per year (NKY) and number of kids weaned at the last kidding (NKWLK) were recorded on the doe, whereas the age of kids at weaning (AKW) was recorded on the kids for the analysis. The estimation of milk production performance was based on the length of lactation, the milking practice and the use of milk produced parameters (Lôbo *et al*., 2017). Milk yield was not quantified and considered as a studied parameter since goats were not milked in South Kivu.

Live body weight, total body length, height at withers, head profile, presence or absence of the shape and horn, presence or absence of beard, orientation of ear, presence or absence of tassels, body hair coat colour type, body hair coat colour pattern, hair shape and light, the shape of the tail and body conformation were recorded for the phenotypic traits. The shape of the tail and the body conformation was appreciated by palpation according to the body condition scores evaluating method (McKenzie-Jakes *et al*., 2007). The shape of the tail was considered thin when the tail bone was quite pronounced; moderate or medium when it was less prominent and little fat covering the tail head area or when the tail born area felled spongy to the touch. The tail was considered as fat when fat was observable and palpable over its head area. The length of the tail was measured from the base of the tail to the pinpoint of the tail without hair. It varied between 9 and 16 cm. accordingly, between 9 and 12 cm, it was considered as short, and over 12 cm as long. The body conformation of the goat was considered as normal confirmation when the spine and the ribs were individually identified by palpation, but feel rounded rather than sharp (some fat is over the ribs) or when the goat had a good overall appearance (fat is over the ribs, hips, and tail bone areas and feels spongy to the touch). The body conformation was considered as vigorous when the fat was observable and palpable over the ribs and tail head area or when the animal appeared fleshy and carriers a considerable amount of fat (very spongy fat covers ribs and tail head areas). All measurements for the morpho biometric characterization were taken in the morning between 6 to 8 am before the animals were released for grazing according to Lauvergne's approach and the recommendations of FAO for the phenotypic characterization of animal genetic resources (Lauvergne *et al.* 1993; FAO, 2012). Bodyweight measurements were done using suspending balance having 50 kg capacity with 0.2 kg precision, metric tape and measuring sticks were used for the measurements on all animals. These morphological traits were considered according to their possible association with litter size and milk production performances (Lefebvre *et al*., 1976; Shongjia *et al*., 1992; Odubote *et al*., 1994)

Data analysis: Data collected were subjected to descriptive statistical analysis using the Xlstat 2019.1.2 software (Atoui *et al*., 2018). General linear model was used for analysing data. The fixed effects in the model included location or territories, phenotypic traits like the shape of the tail, ear orientation, the shape of the horn and eye colour. Mean percentages and Chi2 simulated p-values were calculated for qualitative parameters, while the mean and the standard deviation were determined for quantitative variables. Analysis of variance was performed to estimate the reproductive performances based on morphometric traits (Atoui *et al*., 2018). Pearson correlation coefficient (r) values were calculated to assess the relationship between body measurement traits, reproductive and milk production performances.

RESULTS

Descriptive analysis for the qualitative traits: Based on the phenotypic appearance, it was found that the most variable ($P < 0.01$) phenotypic traits were the horn shape, ear orientation and the shape of the tail. However, the body hair coat colour; mostly grew (33.78%), the eye colour mostly represented by the umber colour (83.11%) varied with the goat's geographic location or territory (Table 2). The observed variations were based on the geographic location since the production system was the same and characterized by the free-grazing system in all the regions.

Table 2: Qualitative traits of indigenous female goat in different territories in South Kivu

Parameters	Kabare	Mwenga	Uvira	Walungu	Overall, Mean (%)	(Chi²)
Coat colour type						
white	3.57	7.50	4.08	6.45	5.41	0.004*
black	21.43	22.50	24.49	16.13	21.62	
grey	28.57	22.50	40.82	41.94	33.78	
Grey with black spots	17.86	5.00	14.29	25.81	14.86	
Black with white spots	28.57	32.50	8.16	6.45	18.24	
Grey with white spots	0.00	10.00	8.16	3.23	6.08	
Eye colour						
umber	82.14	70.00	83.67	100.00	83.11	< 0.001
blue	17.86	15.00	16.33	0.00	12.84	
brown	0.00	15.00	0.00	0.00	4.05	
Beard presence						
no	85.71	87.50	87.76	87.10	87.16	0.184
yes	14.29	12.50	12.24	12.90	12.84	
Tassels						
no	7.14	2.50	14.29	0.00	6.76	0.038*
yes	92.86	97.50	85.71	100.00	93.24	
Horn shape						
absent	3.57	15.00	4.08	0.00	6.08	< 0.001
shot	0.00	7.50	0.00	0.00	2.03	
curved	82.14	72.50	89.80	100.00	85.81	
spiral	7.14	5.00	6.12	0.00	4.73	
cut	7.14	0.00	0.00	0.00	1.35	
Ear orientation						
erect	67.86	47.50	61.22	93.55	65.54	< 0.001
pendulous	0.00	47.50	0.00	0.00	12.84	
horizontal	32.14	5.00	38.78	6.45	21.62	
Body hair coat colour pattern						
plain	92.86	77.50	87.76	100.00	88.44	0.004**
patchy	7.14	22.50	12.24	0.00	11.56	
Shining of body hair						
yes	10.71	37.50	38.78	41.94	33.78	0.041*
no	89.29	62.50	61.22	58.06	66.22	
Shape of the tail						
Short and thin	28.57	22.50	10.20	6.67	16.33	< 0.001
Short and medium	28.57	30.00	0.00	93.33	32.65	
Short and fat	42.86	25.00	83.67	0.00	42.86	
Long and thin	0.00	2.50	2.04	0.00	1.36	
Long and medium	0.00	7.50	0.00	0.00	2.04	
Long and fat	0.00	12.50	4.08	0.00	4.76	
Body conformation						
normal	10.71	7.50	16.33	0.00	9.46	0.041*
vigorous	89.29	92.50	83.67	100.00	90.54	

**Significant at 0.05 level, **significant at 0.01 level*

Analysis of variance for the morphometric and the reproductive traits: The highest body length and height at withers were recorded on goats from Uvira 60.78 ± 3.49 cm and 54.84 ± 3.09 cm, respectively while goats from Kabare have shown the highest body weight 36.86 ± 5.54 kg. The studied morphometric traits including live body weight, total body length, height at withers were statistically different ($p < 0.01$) among goats from different locations or territories (Table 3). The variation ($p < 0.01$) in the age for the first service, the age of kids at weaning and the number of kidding per year were observed in goat populations with the geographic location. The highest (10.82 ± 2.79 months) age at the first service was observed in goats from Mwenga and the lowest in goats from Kabare (6.75 ± 0.61months). Particularly, goats were used for the first service with the age below ten months, specifically between 7 to 8 months. Goats have registered a high number of kidding (3.86± 1.99) in Uvira and Walungu (3.9± 1.76). In Walungu, goats have registered the high number of kids born at the last kidding and the high number of kidding per year (Table 3).

Descriptive analysis for the lactation traits: The lactation length of does varied ($p < 0.01$) with the location of animals (Table 4). The average lactation length of does was 4.12 ± 1.34 months. Does from Kabare have presented the highest lactation length (4.94 ± 2.21 months), whereas the lowest lactation length was observed in does from Walungu (3.12 ± 0.28 months). Goats were not milked (90%); the produced milk has never been quantified (97.69%) but was mostly used for kids breastfeed (85.38%).

Table 3: Mean (± SD) of body weight, body measurements and reproductive traits of female indigenous goats in different territories/geographic locations in South Kivu

	Kabare	Mwenga	Uvira	Walungu	Overall mean	p. value
Morphometric parameters	**Body length (cm)**					
	59.29 ± 6.13^{ab}	59.15 ± 3.27^{ab}	60.78 ± 3.49^{b}	58.00 ± 3.92^{a}	59.32 ± 4.23	0.032*
	Height at withers (cm)					
	54.32 ± 4.51^{ab}	53.60 ± 2.7^{ab}	54.84 ± 3.09^{b}	52.61 ± 3.54^{a}	53.93± 3.47	0.035*
	Body weight (kg)					
	36.86 ± 5.54^{b}	28.10 ± 3.36^{a}	29.77 ± 3.51^{a}	29.99 ± 6.52^{a}	30.70 ± 5.55	< 0.0001
Reproduction parameters	**Age of doe at the first service; AFS (months)**					
	6.75 ± 0.61	10.82±2.79	8.10±0.98	7.87±0.61	8.54±2.17	< 0.0001
	Number of kidding; NK					
	3.48± 1.64	3.25± 1.97	3.86± 1.99	3.9 ± 1.76	3.66 ± 1.87	0.437
	Number of kids born at the last kidding; NKBLK					
	2.32 ± 0.62	2.10 ± 0.62	2.33 ± 0.47	2.4 ± 0.49	2.29 ± 0.55	0.183
	Number of kids weaned at the last kidding; NKWLK					
	2.04 ± 0.73	1.92 ± 0.60	2.31 ± 0.46	2.40 ± 0.49	2.19 ± 0.58	0.03*
	Age of kids at weaning; AKW (months)					
	5.36 ± 1.27	4.28 ± 0.71	4.00 ± 0.76	3.11 ± 0.28	4.12 ± 1.09	<0.0001
	Number of kidding per year; NKY					
	1.38 ± 0.48	1.26 ± 0.25	1.22 ± 0.38	1.75 ± 0.41	1.39 ± 0.43	<0.0001

**significant at 0.05 level; a, b = letters showing the statistically significant differences among variables. With a < b < c; SD = standard deviation*

Table 4: Mean (± SD) of lactation length and descriptive analysis for milking possibility, quantification on milk produced possibility and use of milk produced (%)

	Kabare	Mwenga	Uvira	Walungu	Mean	p-values (Chi2)
Lactation length Mean (± SD)					**p-values**	
	4.94 ± 2.21^{c}	4.60 ± 0.87^{b}	4.0 ± 0.77^{b}	3.12 ± 0.28^{a}	4.12 ± 1.34	< 0.001
Milking possibility (%) (Chi2)						
no	96.29	100.00	77.78	93.33	90.00	0.006
yes	3.70	0.00	22.22	6.67	10.00	
Quantification of milk produced (%)						
no	96.3	100.00	100.00	93.33	97.7	0.268
yes	3.7	0.00	0.00	6.67	2.3	
Use of milk produced (%)						
any	11.11	0.00	0.00	0.000	2.31	0.003
kid's breastfeeding	85.18	92.86	75.56	93.33	85.38	
Domestic consumption	3.70	7.14	24.44	6.67	12.31	

a, b and c= letters showing the statistically significant differences among variables. With a < b < c; SD = standard deviation

Correlation between the reproductive and the lactation traits : It was observed (Table 5) that the estimated age of the does (r = - 0.038), the estimated age of the doe at the first kidding (r = - 0.05), the number of kidding (r = - 0.10), and the number of kidding per year (r = - 0.17) were not significant and were negatively correlated with the lactation length, whereas the age of kids at weaning was positively and significantly correlated (r = 0.33; $p < 0.01$) with the lactation length. The age of does was positively and significantly correlated (r = 0.24, 0.80 and 0.39; $p < 0.05$) with the age of doe at the first kidding, the number of kidding, and the number of kids born at the last kidding, respectively.

Estimation of reproductive performances based on morphological traits: It was shown in Table 6 that the age at the first service, the number of kidding and the number of kidding per year varied with the shape of the tail. The number of kidding positively varied with the short and fat tail ($p < 0.05$) (Figure 1a). The age at the first service positively varied ($p < 0.01$) with the long and thin tail (Figure 1b). Additionally, the age at the first service positively varied with the long and medium tail ($p < 0.01$) (Figure 1c). The long and fat tail (Figure 1d) did not affect the variation of the considered reproductive traits. The number of kidding per year varied ($p < 0.05$) with a short and fat tail. Positive variation was also observed for the age of kids at weaning ($p < 0.01$) with the erect horn.

Table 5: Coefficient of correlation between reproduction and lactation parameters

Variables	AD	AFK	NK	NKBLK	NKWLK	AKW	NKY	LL	KB	QMP
AD	1	0.24**	0.80 **	0.39 *	0.24 ns	-0.02 ns	0,01 **	-0.04 ns	-0.16 *	-0.09 ns
AFK		1	0.034**	-0.26 *	-0.24 ns	-0.03 ns	-0.08 ns	0.05 ns	-0.05 ns	-0.11 ns
NK			1	0.43 ns	0.3 ns	-0.07 **	0.22 **	-0.10 ns	-0.007 ns	-0.004 ns
NKBLK				1	0.79 **	-0.25 ns	0.09 ns	-0.04 ns	- 0.05 ns	-0.08 ns
NKWLK					1	-0.35 **	-0.008 *	-0.09 ns	0.04 ns	-0.052 ns
AKW						1	-0.28 **	0.33 **	-0.19 ns	-0.02 ns
NKY							1	-0.17 ns	0.12 ns	0.099 ns
LL								1	-0.07 ns	-0.090ns
KB									1	0.20*
QMP										1

ns, non-significant (P > 0.05); ** significant at 0.05 level; *significant at 0.01 level

AD = age of Doe, AFK = Age of Doe at the First Kidding, NK = Number of Kidding, NKBLK = Number of Kids Born at the Last Kidding, NKWLK = Number of Kids Weaned at the Last Kidding, AKW= Age of Kids at Weaning, NKY = Number of Kids per Year, LL = Length of Lactation, KB = Kids Breastfed, QMP = Quantity of Milk Produced

Table 6 Analysis of variance for the estimation of reproductive performances of female indigenous goats based on the morphological traits

Morphological traits		**Reproductive performances**														
		AFS			**NK**			**NKWLK**			**AKW**			**NKY**		
Shape of tail	**Variables**	**value**	**SE**	**Pr**	**value**	**SE**	**Pr**	**value**	**SE**	**Pr**	**value**	**SE**	**Pr**	**value**	**SE**	**Pr**
	1	-1.16	0.79	0.14	0.38	0.82	0.65	0.22	0.27	0.41	-0.82	0.47	0.084	-0.023	0.18	0.90
	2	-1.23	0.74	0.10	0.91	0.77	0.24	0.22	0.26	0.32	-1.33	0.44	0.003	0.38	0.17	0.03
	3	-1.50	0.75	0.05	1.55	0.77	0.05	0.2	0.26	0.45	-0.55	0.44	0.25	-0.033	0.17	0.85
	4	14.33	1.85	< 0.0001	0.33	1.93	0.86	-1.00	0.64	0.12	1.00	1.10	0.37	0.25	0.42	0.56
	5	-0.67	1.22	0.58	3.667	1.26	0.004	0.000	0.42	1.000	-1.33	0.72	0.07	0.42	0.28	0.14
	6	0.000	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Ear orientation	1	0.307	0.48	< 0.0001	-0.49	0.42	0.24	0.17	0.13	0.21	-0.58	0.24	0.02	0.042	0.1	0.67
	2	2.01	0.64	0.52	0.014	0.56	0.98	0.08	0.18	0.65	-0.42	0.32	0.2	-0.05	0.13	0.71
	3	0.000	0.00	0.002	0.00	0.00	0.08	0.000	0.00	0.000	0.00	0.00	0.000	0.00	0.00	
Shape of horn	1	6.29	1.56	< 0.0001	-0.43	1.50	-0.77	-0.14	0.47	0.76	-3.21	0.82	0.000	-0.071	0.35	0.84
	2	5.67	1.77	0.002	-1.67	1.71	0.33	0.33	0.54	0.54	-3.50	0.93	0.000	-0.17	0.40	0.68
	3	2.29	1.38	0.10	-0.26	1.34	0.84	0.23	0.42	0.58	-3.43	0.73	< 0.0001	-0.11	0.31	0.72
	4	1.83	1.59	0.25	0.17	1.53	0.91	0.000	0.48	1.00	-3.33	0.83	0.000	-0.25	0.36	0.49
	5	0.000	0.00	0.001	0.000	0.00	0.002	0.000	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Eye colour	1	-4.8	0.82	< 0.0001	-0.34	0.78	0.66	0.40	0.25	0.10	-0.42	0.46	0.36	0.06	0.18	0.74
	2	-3.97	0.95	< 0.0001	0.07	0.90	0.94	0.23	0.28	0.41	-0.07	0.53	0.90	0.000	0.21	1.00
	3	0.000	0.000	< 0.0001	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000

(Significant at 0.05 level). Legend: AFS = Age of Doe at the First Kidding, NK = Number of Observed Kidding, NKWLK = Number of Kids Weaned at the Last Kidding, AKW = Age of Kids at Weaning, NKY = Number of Kids per Year,

Shape of the tail: 1: shot and thin; 2: shot and moderate; 3: shot and fat; 4: long and thin; 5: long and moderate; 6: long and fat. Ear orientation: 1: erect; 2: pendulous; 3: horizontal. Shape of horn: 1: absent; 2: scurs; 3: curved; 4: spiral; 5: cut. Eye colour 1: umber; 2: blue; 3: Brown

Figure 1: Length and thickness of the tail: (a): Shot and fat tail, (b): long and thin tail, (c): long and medium tail, (d): the long and fat tail

DISCUSSION

Characterization of indigenous goats will provide large knowledge and give a clear perspective on the population structure that will assist in the decision making of future breeding programmes. In this study, it was found that the dominant hair coat colour type for the local goat breeds in South Kivu was grey (33.78%) followed by black (21.62%). A different observation was made by Hansen *et al*. (2012) who have shown that the most frequent coat colour for Ethiopian indigenous goats was white with spots (20.7%) and that black coats with or without spots or patches were less frequent than brown or white ones. However, it is believed that black coloured animals including goats have superior adaptation to seasonal cold weather or cold nights as the dark pigment allows them to warm up earlier than goats with other coat colours (Robertshaw *et al*., 2006). The white colouration could be an advantage in an intense radiant environment due to its reflectance property as reported by Hansen *et al*. (1990). As reported by Odubote *et al.* (1994), coat colour influences radiant heat loss affecting on its turn the body weight and other productive adaptability factors in livestock species in the tropical environment. Light coat colours such as white, grey and fawn have an impact on radiant heat loss (Baenyi *et al*., 2020). The relative proportion of light colour observed in the goat populations in South Kivu is an indication that local goats breed of the region was not thermal stressed and their productivity could not be affected (Baenyi *et al*., 2020). In this study, the majority of goats were not bearded (87.16%); this result lines with the findings of Odubote *et al.* (1994) and Adedeji *et al.* (2006) who have shown that majority of indigenous goat populations in Nigeria were not bearded (82.6%) despite the numerous benefits associated with the presence of beard in goats reared under hot and humid environments. Generally, among the most important benefits of the beard are the thermoregulatory functions and its association with reproductive traits such as higher prolificacy, higher milk yield, higher litter size, fertility index and conception rate (Osinowo *et al*., 1988; Yakubu *et al*., 2010). Being characterized by the mountain climate, temperature variation in South Kivu could not affect the adaptability of goats. Thus, the reproductive performances could be explained by other phenotypic traits than the presence of the beard. The body length and height at withers of local goat breeds in this study were higher than previous findings for indigenous breeds in southern Nigeria as reported by Fajemilelin *et al.* (2008) and by Hagan *et al.* (2012) in Ghana. The observed difference can be explained by the difference of the geographic location, the climate characteristics and the phenotypic traits of indigenous goats in the western part of Africa mostly closed to dwarf goats characterized by their short body size. As reported by Cam *et al.* (2010), morphometric measurements and how they relate to each other can describe roughly animal's production status and breed characteristics. According to Devendra *et al.* (1982), goats are classified as large when they weigh between 20-60 kg and with a height at withers above 65 cm. On this basis, the local goat breed observed in this present study could be classified as small-sized breeds. As reported by Hagan *et al.* (2012), linear body measurements reflect breed characteristics and the management conditions under which the animals are kept. Thus, the observed homogeneity based on the considered linear body measurement on South Kivu local goat could be attributable to similarities in feed resource availability base (in terms of quantity and quality), grazing field and management conditions to which the animals were subjected (Cam *et al.*, 2010). On the other hand, the observed homogeneity in local goats in South Kivu could mean that there is no effect of gene interaction from the crossbreed between local goats and exotic breeds or goat breeds exchange and gene flow from neighbouring countries. Results of this study showed that the age of the doe was positively correlated with the age at the first service ($r = 0.24$; $p < 0.01$), number of kidding per year (0.80; $p < 0.01$), and number of kids born at the last kidding ($r = 0.39$; $p < 0.01$). At the same time, it has been observed that most of these reproductive performances (number of kidding per year, age of doe at the first service and number of kidding at the third kidding) were in positive association with both shapes of tail and horn (little literature for further discussion). It has been reported that higher age, heavier body weight at breeding, higher parity order was associated with the chance of triplet and quadruplet births on prolific Black Bengal goats and meat-type goats (Pan *et al.*, 2015; Haldar *et al.*, 2014). In this study, the high number of kidding in a lifetime, the high number of kids per year, and the high number of kids born at the last kidding were observed in goats used earlier for reproduction, as it was the case for goats from Uvira and Walungu. Results of this study have shown that the lactation length significantly varied ($p < 0.01$) with the locations (territories) and was correlated ($r = 0.033$) with the age of kids at weaning. This result is different from results obtained by Gökdal *et al.* (2017) who have shown that the lactation milk yield, daily milk yield, and lactation length of the does were not significantly different between the different groups of age at weaning. Additionally, it has been reported by Zumbo *et al.* (2007) that the higher daily milk yield was high for terziparous goats compare to uniparous goats. This finding does not corroborate with the finding for this study from where most goats were approximately at the fourth (3.66 ± 1.87) kidding with approximate three kids per parity but with less production of milk. The lactation length of local goats in South Kivu was averaged 4.12 ± 1.34 months (Table 4). This is higher than the findings of other researchers for other indigenous goats under different management systems (Mestawet *et al.*, 2012; Mohammed *et al.*, 2012; Abraham *et al.*, 2017). Diet, environmental conditions, breed, litter size, parity, and season of kidding might affect the significant variation observed between the average lactation length of different breeds (Mourad *et al.*, 2001; Güler *et al.*, 2007). Findings for this study revealed significant effects of the geographic location, the age of kids at weaning on the lactation length variation. The highest age of kids at weaning observed in Kabare corresponded with the longest lactation length, whereas the lowest age of kids at weaning, which was observed in Walungu, corresponded with the shortest lactation length. Further researchers should be considered to investigate and to more explain the correlation between the shape and the length of the tail with some reproductive traits.

CONCLUSION AND APPLICATION OF RESULTS

The shape of the horn and tail, the body coat colour, the ear orientation and the eye colour explained the phenotypic variability (heterogeneity) among goat populations in South Kivu. The length and the thickness of the tail were associated with three reproductive traits (the number of kidding per year, the age of kids at weaning and the age of doe at the first service) and with the lactation length. These findings suggest that these traits can act as phenotypic markers used in the selection for reproductive traits particularly the number of kidding per year and the lactation length. Further research based on molecular characterization through genome-wide association studies is required to confirm the association between the shape of the tail and horn, the ear orientation with the number of kidding per year and the lactation length. This could be useful and considered as a phenotypic marker for the selection and improvement of goats in South Kivu.

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REFERENCES

Abraham, H., Gizaw, S., & Urge, M. (2017). Milk production performance of Begait goat under semi-intensive and extensive management in Western Tigray, North Ethiopia. *Livest. Res. Rural Dev*, *29*, 12

Adedeji, T. A., Ojedapo, L. O., Adedeji, O. S., Aderogba, T. A., & Abdullah, A. R. (2006). Characterization of traditionally reared West African Dwarf goats (WAD) in the derived savannah zone of Nigeria. *Journal of Animal and Veterinary Advances*.

Atoui, A., Luengo, M. J. C., & Najari, S. (2018). Evaluation of a local goat population for fertility traits aiming at the improvement of its economic sustainability through genetic selection. *Spanish journal of agricultural research*, *16*(2), 11.

Baenyi, S. P., Birindwa, A. B., Mutwedu, V. B., Mugumaarhahama, Y., Munga, A., Mitima, B., ... & Ayagirwe, R. B. B. (2020). Effects of coat colour pattern and sex on physiological traits and heat tolerance of indigenous goats exposed to solar radiation. https://doi.org/10.31893/jab.2017

Bettencourt, E. M. V., Tilman, M., Narciso, V., Carvalho, M. L. D. S., & Henriques, P. D. D. S. (2015). The livestock roles in the wellbeing of rural communities of Timor-Leste. *Revista de Economia e Sociologia Rural*, *53*, 63-80. https://doi.org/10.1590/1234-567818060-94790053s01005

Cam, M. A., Olfaz, M., & Soydan, E. (2010). Possibilities of using morphometrics characteristics as a tool for body weight prediction in Turkish Hair Goats (Kilkeci). *Asian Journal of Animal and Veterinary Advances*, *5*(1), 52-59. 2010;5 (1):52-59. https://doi.org/10.3923/ajav.2010.52.59

Devendra, C., & McLeroy, G. B. (1982). Goat and sheep production in the tropics. *Longman, Malaysian Agric. Res. & Development Inst*., Serdang, Selangor, Malaysia. 271 pp

Fajemilehin, O. S., & Salako, A. E. (2008). Body measurement characteristics of the West African Dwarf (WAD) Goat in deciduous forest zone of Southwestern Nigeria. *African Journal of Biotechnology*, *7*(14).

FAO (2012). Phenotypic characterization of animal genetic resources. FAO Animal Production and Health Guidelines Rome, No. 11. http://www.fao.org/3/a-i2686e.pdf

FAOSTAT (2018). Agriculture Organization of the United Nations. Available online: http://www. fao. org/faostat/en/? data. *QC (accessed on 28 May 2020).*

Gasigwa SR, Baenyi SP, Kizungu VR (2017). Reproductive and population dynamics parameters of indigenous goats in Mbanza-Ngungu, Democratic Republic of Congo. *Rev. Elev. Med. Vet. Pays Trop*.70 (3):93-97. https://doi.org/10.19182/remvt.31522

Gökdal, Ö., ÖZUĞUR, A. K., Atay, O., & Eren, V. (2017). The effects of individual weaning based on birth weight on growth performance and milk yield in dairy goats. *Turkish Journal of Veterinary and Animal Sciences*, *41*(5), 672-678. https://doi.org/10.3906/vet-1611-71

Gooki, F. G., Mohammadabadi, M., Fozi, M. A., & Soflaei, M. (2019). Association of biometric traits with growth hormone gene diversity in Raini Cashmere Goats. *Walailak Journal of Science and Technology (WJST)*, *16*(7), 499-508.

Güler, Z., Keskin, M., Masatçioğlu, T., Gül, S., & Biçer, O. (2007). Effects of breed and lactation period on some characteristics and free fatty acid composition of raw milk from Damascus goats and German fawn x Hair goat b_1 crossbred. *Turkish Journal of Veterinary and Animal Sciences*, *31*(5), 347-354.

Hagan, J. K., Apori, S. O., 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.* 2(10):813-821.

Haldar, A., Pal, P., Datta, M., Paul, R., Pal, S. K., Majumdar, D., ... & Pan, S. (2014). Prolificacy and its relationship with age, body weight, parity, previous litter size and body linear type traits in meat-type goats. *Asian-Australasian journal of animal sciences*, *27*(5), 628. https://doi.org/10.5713/ajas.2013.13658

Hansen, P. J. (1990). Effects of coat colour on physiological responses to solar radiation in Holsteins. *Veterinary record*, *127*(13), 333-334.

Hassen, H., Baum, M., Rischkowsky, B., & Tibbo, M. (2012). Phenotypic characterization of Ethiopian indigenous goat populations. *African Journal of Biotechnology*, *11*(73), 13838-13846. https://doi.org/10.5897/ajb12.2092

Khorshidi-Jalali, M., Mohammadabadi, M., Koshkooieh, A. E., Barazandeh, A., & Babenko, O. (2019). Comparison of artificial neural network and regression models for prediction of body weight in Raini Cashmere goat.

Lafleur, M. M. R., Litalema, L., Utshudienyema, N., Dino, L., Kapiteni, M., Justin, M., ... & Alio, A. (2018). Brief Theoretical Overview of the Goat (Capra hircus L. 1758) Indigenous of Ituri in the Democratic Republic of Congo and of Africa. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, *44*(1), 209-230.

Lauvergne, J. J., Souvenir Zafindrajaona, P., Minvielle, F., Bourzat, D., & Zeuh, V.

(1993). A gene for reducing horn length of goats in North Cameroon and Chad. *Revue d'Elevage et de Medecine Veterinaire des Pays Tropicaux (France).*

Lefebvre J, & Ricordeau G. (1976). Canonical correlations between milk performance and conformation in the Montbeliarde and Normande breeds. IX International Zootechnics Congress. Edinburgh Annals of Zootechnics,

Lôbo, A. M. B. O., Lôbo, R. N. B., Facó, O., Souza, V., Alves, A. A. C., Costa, A. C., & Albuquerque, M. A. M. (2017). Characterization of milk production and composition of four exotic goat breeds in Brazil. *Small Ruminant Research*, *153*, 9-16.

Maass, B. L., Musale, D. K., Chiuri, W. L., Gassner, A., & Peters, M. (2012). Challenges and opportunities for smallholder livestock production in post-conflict South Kivu, eastern DR Congo. *Tropical animal health and production*, *44*(6), 1221-1232. https://doi.org/10.1007/s11250-011-0061-5

Mestawet, T. A., Girma, A., Ådnøy, T., Devold, T. G., Narvhus, J. A., & Vegarud, G. E. (2012). Milk production, composition and variation at different lactation stages of four goat breeds in Ethiopia. *Small Ruminant Research*, *105*(1-3), 176 181. https://*doi*.org/10.1016/j.smallrumres.2011.11.014

McKenzie-Jakes, A. (2007). Getting Started in the Meat Goat Business: Selecting and Evaluation Goats for Meat Production. *Bulletin I*, *7*.

Mohammed B, Aynalem H, Hailu D. & Alemu, T. (2012). (2012) Estimates of genetic and phenotypic parameters for milk traits in Arsi-Bale goat in Ethiopia. *Livestock Research for Rural Development.* 24(6)

Montaldo, H. H., & Manfredi, E. (2002). Organisation of selection programmes for dairy goats. *Proc. 7 th Wrld. Congr. Genet. Appl. Livest. Prod*, *29*, 187-194.

Montaldo, H. H., Castillo-Juárez, H., Valencia-Posadas, M., Cienfuegos-Rivas, E. G., & Ruiz-López, F. J. (2010). Genetic and environmental parameters for milk production, udder health, and fertility traits in Mexican Holstein cows. *Journal of dairy science*, *93*(5), 2168-2175. https://doi.org/10.3168/jds.2009-2050

Mourad, M. (2001). Estimation of repeatability of milk yield and reproductive traits of Alpine goats under an intensive system of production in Egypt. *Small Ruminant Research*, *42*(1), 1-4.

Odubote, I. K. (1994). Influence of qualitative traits on the performance of West African Dwarf goats. *Nigerian Journal of Animal Production*, *21*, 25-28. https://doi.org/10.4236/as.2015.68079

Onzima, R., Upadhyay, M. R., Mukiibi, R., Kanis, E., & Crooijmans, R. P. M. A. (2017). Genetic Admixture in Indigenous Ugandan goat breeds using genome-wide SNP data. In *36th conference of the International Society of Animal Genetics (ISAG)* (pp. 193-194). ISAG..

Osinowo, O. A., Buvanendram, V., & Koning, N. L. (1988, March). A study of coat type, pigmentation and wattle incidence in Yankasa sheep and their effects on fertility and weaning weight. In *13th Annual Conference of the Nigerian Society of Animal Production Held at the University of Calabar, Nigeria* (pp. 20-24).

Pan, S., Biswas, C. K., Majumdar, D., Sengupta, D., Patra, A., Ghosh, S., & Haldar, A. (2015). Influence of age, body weight, parity and morphometric traits on litter size in prolific Black Bengal goats. *Journal of applied* *animal research*, *43*(1), 104-111. https://doi.org/10.1080/09712119.2014.928623

Robertshaw, D. (2006). Mechanisms for the control of respiratory evaporative heat loss in panting animals. *Journal of Applied Physiology*, *101*(2), 664-668. https://doi.org/10.1152/japplphysiol.01380.2005

Robinson, T. P., Thornton, P. K., Francesconi, G. N., Kruska, R. L., Chiozza, F., Notenbaert, A. M. O., ... & See, L. (2011). *Global livestock production systems*. FAO and ILRI.

Shongjia, L., Xinagmo, L., Gangy, X., & Shenov, C. (1992, March). Relationship between physical traits, litter size and milk yield in Saanen, Guanzhong and crossbred goats. In *Proceedings of the international Conference on Goats* (Vol. 1, p. 83). Book of Abstracts New Delhi, India.

Thornton, P. K. (2010). Livestock production: recent trends, future prospects. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1554), 2853-2867. https://doi.org/10.1098/rstb.2010.0134

Torres-Vázquez, J. A., Valencia-Posadas, M., Castillo-Juárez, H., & Montaldo, H. H. (2009). Genetic and phenotypic parameters of milk yield, milk composition and age at first kidding in Saanen goats from Mexico. *Livestock Science*, *126*(1-3),147-153. https://doi.org/10.1016/jivsci.2009.06.008

Vidal, N. P., Manful, C. F., Pham, T. H., Stewart, P., Keough, D., & Thomas, R. (2020). The use of XLSTAT in conducting principal component analysis (PCA) when evaluating the relationships between sensory and quality attributes in grilled foods. *MethodsX*, *7*, 100835.

Wasso DS, Akilimali JI, Baenyi P, Bajope B (2018). Goat farming: Current situation, challenges and socioeconomic impact on the population of the territory of Walungu, Democratic Republic of Congo. *Journal of Applied Biosciences*. 129 (1):13050-13060. https://doi.org/10.4314 / jab. v129j1.8

Weppert, M., & Hayes, J. F. (2004). Direct genetic and maternal genetic influences on first lactation production in four breeds of dairy goats. *Small ruminant research*, *52*(1-2), 173-178.

Yakubu, A., Salako, A. E., Imumorin, I. G., Ige, A. O., & kinyemi, M. O. A. (2010). Discriminant analysis of morphometric differentiation in the West African Dwarf and Red Sokoto goats. *South African Journal of Animal Science*, *40*(4), 381-387. https://doi.org/10.4314/sajas.v40j4.65261

Zumbo, A., & Di Rosa, A. R. (2007). Effects of parity and type of kidding on the quantitative and qualitative milk characteristics of “Rossa Mediterranea” goats. *Italian Journal of Animal Science*, *6*(sup1), 636-636. https://doi.org/10.4081/ijas.2007.1s.636