Chapter

Goat Breeding in the Katanga Copper Belt (KCB): Constraints, Opportunities and Prospects

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Abstract

DR Congo's copper belt is south of the dismembered former province of Katanga. The population has grown over the past twenty years due to the resumption of industrial and artisanal mining. This situation has led to an increase in demand for agricultural products including meat. The majority of these products are imported due to insufficient local production. Goat meat is the most consumed of the ruminants and most of these animals are imported from Zambia. Thousands of the goats are slaughtered daily and its meat sold in all markets and especially next to thousands of drinking establishments as appetizers. Unfortunately, this opportunity does not benefit local breeders because of several factors including the low productivity of the local goat, a stray breeding system, insufficiency and lack of space for breeding, contamination of pastures by heavy metals, insecurity, supremacy of the mining code over agricultural law, the dispossession of agricultural land belonging to peasants for the benefit of private farmers ... In perspective, the establishment of a collaborative structure between breeders, development agents and technicians, researchers and policy makers in sectors related to goat farming and its environment will provide access to information and improve goat production.

Keywords: Katanga, goats, indigenous, breeding, mining, Miombo

1. Introduction

For the CFSVA [1], despite the country's enormous agricultural potential, the majority of the population of the DRC remains largely exposed to poverty, food insecurity, malnutrition and hunger. According to the UNDP_RDC report, more than 71% of Congolese live on less than one US dollar / person / day. In terms of the Human Development Index, the UNDP ranked the country 41st out of 53 in Africa and 176th out of 189 countries in 2018 [2]. For the country as a whole, only one percent of arable land is used, and the country resorts to massive imports of almost all food products such as maize, rice, wheat, sugar, poultry, fish, meat, dairy products and other foodstuffs [3–6]. The majority of the population of the DRC lives on agricultural activities, often associated with animal husbandry [7]. According to Brunneau [8], in Katanga, Kasai, Kivu provinces many villagers have lost their farmland to mining companies. Southern Katanga is one of the populated regions of the DRC. Mining, urbanization, insecurity in some parts of the country

and the fluidity of the roads have allowed a rural exodus and an attraction of several populations from other towns and villages of the country. This massive presence of populations constitutes a potential market for agricultural products including milk, meat and vegetables. The same CFSVA report [1] mentions that in the DRC, poultry, goats, pigs, sheep and cattle are common livestock species and are thus among the important sources of income and meat production; they can be used as active savings assets for small farmers. Goat and pork meat is consumed in the HMK region. Goat meat is mainly sold cut in markets or around bars and drinking flow. The majority of goats sold and slaughtered in the Katanga Copper Belt (KCB) are imported from Zambia through the borders of Kasumbalesa, Kipushi, Kasenga, and others. According to the President of the Zambia Cross-Border Traders Association (CBTA), there is a high demand for animals and a huge market for goat meat in DRC. In only Kasumbalesa border on average, more than 4,500 goats are traded monthly [6], not counting sellers not officially registered and other points of entry into the DRC from Zambia. The optimal management of goat breeding and agricultural perimeters: soils, livestock resources, including the production, use, conservation, complementarity of species and the sharing of the resulting benefits, is therefore a necessity for an improvement of living conditions and income for the peasants of the Katanga Mining Hinterland.

Listing the constraints and opportunities of the goat sector in the KCB would serve as support for responsible decision-making at the level of decision-makers and actors involved.

2. Presentation of the environment

The Katanga copper belt area is included in the Hinterland-Minier of the former province of Katanga, which is currently dismembered. This mining area is currently located in the provinces of Lualaba and Haut-Katanga. It was from Kolwezi (Lualaba) to Sakania (Haut-Katanga) (**Figure 1**). These two new provinces are

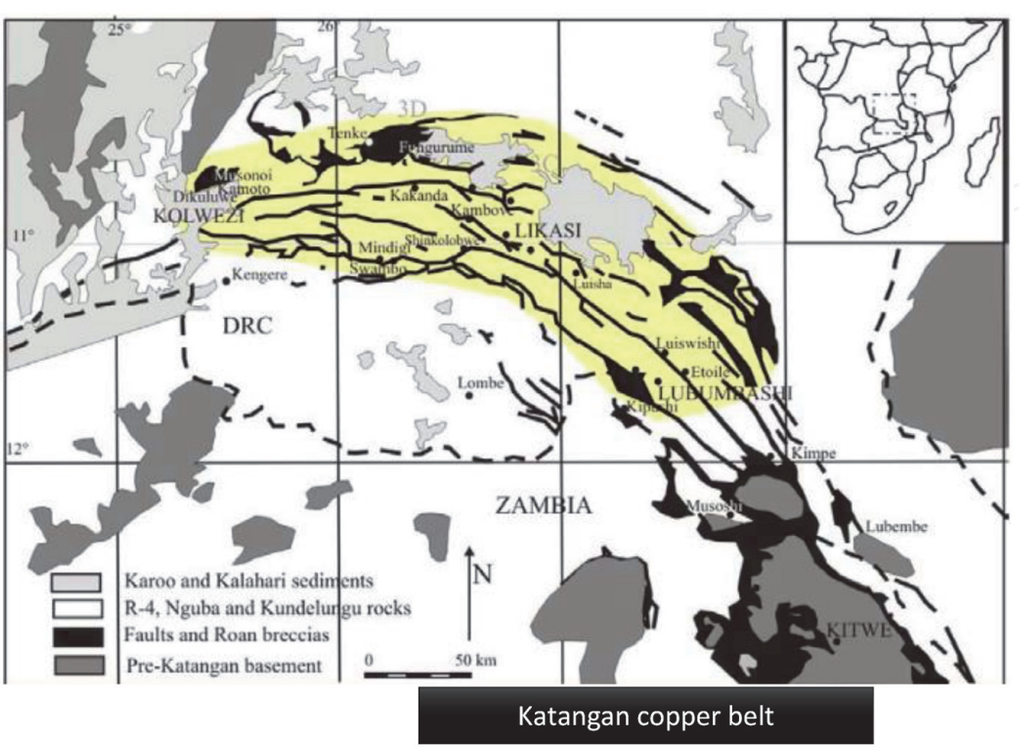

Figure 1.
Katangan copper belt region of Democratic Republic of Congo. (Source: Ref. [9]).

subdivided into five territories for Lualaba, three of which are mining (Lubudi, Mutshasha and Dilolo) and six territories for Haut-Katanga, five of which are mining (Kambove, Kipushi, Sakania, Pweto and Mitwaba). The main minerals mined in this area are copper, cobalt, zinc, manganese, uranium, germanium, gold, cassiterite and silver.

Beyond the mining sector, the copper belt is also an agricultural and livestock area. The main agricultural products are maize, cassava, sweet potatoes, vegetable crops, rice, soya and other.

Animal husbandry is a secondary activity practiced by the majority of farmers and non-farmers. The main livestock species are in order of importance the chickens, the goat, the pig, the rabbits, the ducks ...

The vegetation of the mining hinterland of Katanga (**Figure 1**) is characterized by an open forest (Miombo), wooded savannas, swampy meadows and grassy savannas. There is a specific cupricola vegetation installed on soils highly contaminated with copper and other metals characteristic of the region [10].

The different types of soils encountered are ferrisols, arreno-ferrals, hydro-kaolisols, recent tropical soils, the tropical black earths on alluvium.

The climate is classified as warm and temperate. Precipitation is heavier in summer than in winter. The Köppen-Geiger classification is of the Cwa type. The annual average temperature is 20.5°C. The average annual precipitation is 1240 mm. The climatological characteristics of the region are presented in **Figure 2**.

The economic activities of the population bordering on mining are based on a subsistence economy, which is an economy chosen or suffered, relatively or totally separate from economic flows, where there is essentially self-consumption. The production of food, movable or immovable goods necessary for existence depends on the family or a small group without there being any trade or in a very limited way. They are mainly based on subsistence farming, the production of embers, small trade, fishing, hunting, breeding, crafts, education and in some urban planning sites, some households live off the property rights of the Earth. Several studies show that 61% of people earn their income from farming. This shows that agriculture remains the main income-generating activity in areas around mines and in general in rural areas [11].

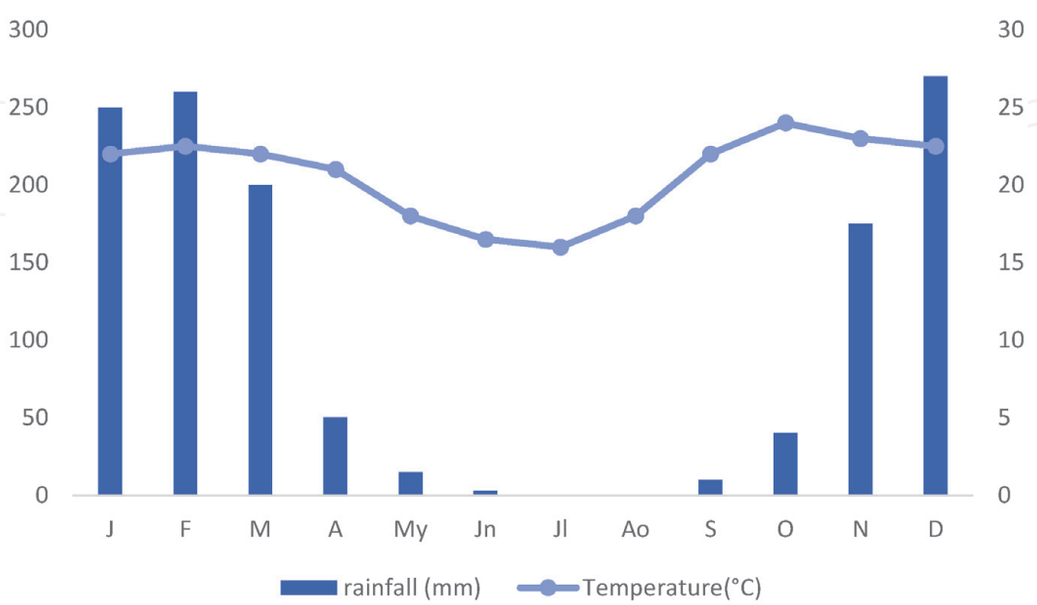

Figure 2.
Ombrothermal diagram of the hinterland-Minier of Katanga region. (source: Climate-data.org, 2021. Climat Lubumbashi (Congo-Kinshasa): https://fr.climate-data.org/afrique/congo-kinshasa/katanga/lubumbashi-503/)

3. Material and methods

This study on goat breeding in KCB was made possible by a compilation of official documents, in particular: reports from state institutions such as national and provincial ministries, provincial inspections of agriculture, fishing and breeding; the national statistics institute. Reports from international organizations. Reports from state institutions and development NGOs, scientific articles, theses and dissertations from higher studies, the laws of the country and archives of the territorial administration, testimonies from village chiefs, reports from cadastral services and mining cadastre, as well as data from our own investigations and professional experience and our discussions with goat breeders.

The protein content was determined by the Digesdahl method (CP = Nx6.25). Contents of parietal fiber (ADF and NDF) were determined by the FibreBag Gerhardt procedure as described by Van Soest et al. [12]. The ether extracts (EE) were determined by the Soxtec System using the method described by Matsler and Siebenmorgen [13]. The organic material was determined by placing the samples in a muffle furnace at 560°C overnight. Crude ash levels were deduced by the difference of dry matter and organic matter. Dry matter concentration was determined after drying leaves and root in an oven at 105°C for 24 h. Soil total concentrations of copper, cobalt, zinc and lead were measured in duplicate, and results reported in mg/kg dry soil. The pH was determined using a pH-meter glass electrode in a soil to distilled water ratio of 1: 2.5. The mineral content of the soil was determined according to the method described by Alsac [14]. Digestion was carried out on 0.5 g soil with 6 ml of hydrochloric acid and 2 ml of nitric acid (aqua regia) at 95°C for 75 min on a heating block. The digest was then adjusted to 50 ml. Mineral content were done using atomic absorption spectrometry, according to the NF EN ISO 17294-1 and 17294–2 French standard method [15]. The minimum detection limit for each of these metals in leaves and roots samples were Cu: 3 ppb, Co: 5 ppb, Pb: 10 ppb and Zn: 1 ppb. For Influence of Washing, Samples of the plant, were collected from the shallows, slopes and trays on each of the sites. Whole plants of were harvested at the same places where soil profiles were dug for soil sampling. Roots were separated directly from the aerial parts of plants, washed and tops sampled into two parts. Fractions were packaged and labeled. In the laboratory, one of two aliquot of each aerial part was washed with deionized water containing Alconox [16].

4. Constraints

4.1 Mining and decline in peasant farming activities

The presence of the mining industry in the KCB has had an impact on agricultural activities in general and goat breeding in particular. Mining companies and artisanal mining activities have resorted to an active local workforce. This practice has had the following consequences [11]: - Food insecurity due to the drop in agricultural production per capita: exodus of young people to the mines and adults and old people who remain in the rural environment must feed everyone who is in the quarries and in the city, – Diversion of agricultural labor: the villages are depopulated by young people who prefer quarries than the village because of the high income provided by mining activity, – Rise in food prices so much both plant and animal origin, – Ecological imbalance which paralyzes certain crops and other rural activities, – Disappearance of certain villages and centers.

The granting of mining squares resulted in the expropriation of agricultural land and even the relocation of local peasant farmers. The acquisition of land by some

mining companies to the detriment of communities is a form of land grabbing. The precedence of the mining code over the agricultural law [17] has a lot to do with the dispossession of agricultural land. Land, the precious capital that provided the bare minimum of subsistence to small producers, through agriculture is in alteration. At the provincial level, the study carried out by in 2015 by [11], revealed that out of a total of 496,865 km^2 of land, 356,220 km^2 are occupied by mining companies, or 71.69%. Another study estimates that 85% of the territory of former Katanga is divided into mining squares ceded to third parties, Yan Gorus (2009) cited by [11]. The part of the land that remains unassigned to mining companies is approximately 140.645 km^2, or 28% of the land. It is also necessary to subtract from it all the space occupied by the national parks (17.870 km^2) as well as the water surfaces (lakes: approximately 26.899 km^2) and the 95.932 km^2 remain free for agriculture without considering to what degree they lend themselves to this in terms of fertility without subtracting urban space. According to the same study 87% of farmers have reduced the area of their fields as a result of the pressure exerted by the occupation of land for mining activities. Areas that were once used for agricultural activities are closed to indigenous populations. However, the agricultural activity practiced in rural areas is nothing other than shifting slash-and-burn agriculture with the practice of fallow. For the communities, this leads to the reduction of areas or cultivable land, and as a result, a drastic reduction in subsistence income.

Mining has opened a door to easy but very precarious and unsecured gain for the young people who engage in it. For most of the peasants in this region, mining is a quick and easy way to earn income, to the detriment of farming and goat farming. The breeding time to obtain an adult animal that can be cheap being "long", the peasants, men, women and even children, prefer to practice artisanal mining and other activities related to it including washing. Minerals, prostitution, petty trade and transport. These activities are not without negative consequences on the health and social life of the population: precarious income, sexually transmitted diseases, debauchery, drugs, banditry, unemployment and teenage delinquency and especially contamination with characteristic metallic trace elements from the cupro-cobalt-bearing region. Exposure and contamination to heavy metals in KCB has been well described by [18, 19].

4.2 Small business

The rush for mining centers and quarries fostered intense commercial activity. As with the artisanal mining mentioned above, the petty trade, especially in foodstuffs from the countries of southern Africa, mainly from neighboring Zambia, has taken a toll on agricultural and livestock activities. This activity also has consequences on the social life of households, including household instability, monetary instability, the advent of COVI-19 which, at certain periods, has forced the confinement of populations, the instability of prices of manufactured products, debts, the eviction of artisanal miners unexpectedly by the politico-administrative authorities ... All these acts have repercussions on the life of the peasants: their social and monetary stability which could be guaranteed by an activity agricultural and/or goat breeding.

4.3 Seasonality and nutritional value of forages

The south-eastern region of the former dismembered province of Katanga is characterized by a CWa type climate according to the Koppen classification. Pastures are mainly made up of seasonal grasses and rarely legumes. The rainy season is spread out from November in the first half of April and the dry season is from April

to October. During the long dry season, with cold periods (**Figure 2**), the grassy vegetation dries up completely and leaves in place highly lignified straw of poor nutritional quality for ruminants. Likewise, the crop residues of the main food crops are very lignified and do not provide an acceptable quality fodder, especially since the method of rearing straying, without supplementation leaves ruminants no choice but to be satisfied with these quality poor foods.

This situation is to the detriment of the animals with the consequence of a decrease in performance and an economic loss for local breeders.

4.4 Exploitation of the clear forest "Miombo"

Following the flourishing mining activities in the region, the residents exploit natural resources of the clear forest: the Miombo. Among the available resources exploited we find caterpillars, edible mushrooms, game, honey ... and especially wood.

Of all these non-timber and wood resources, the exploitation of wood, firewood and charcoal production is one of the intense activities of farmers. Due to the insufficient supply of electrical energy for domestic needs, charcoal is the primary resource for cooking for all households in the region (**Figure 3**). This activity is preferred by peasants (**Figure 4**) after agriculture. Logging is one of the activities of environmental degradation and imbalance of Miombo ecosystems.

4.5 Other agricultural activities

Some agricultural and livestock activities are adopted by agro-pastoralists because of the short time frame and simplicity. Market gardening activities are preferred by many farmers because of their short duration and market demand. Chicken breeding, mainly broilers, is also preferable to goats rearing, among other things, to the short raising time, the demand and preference of more and more

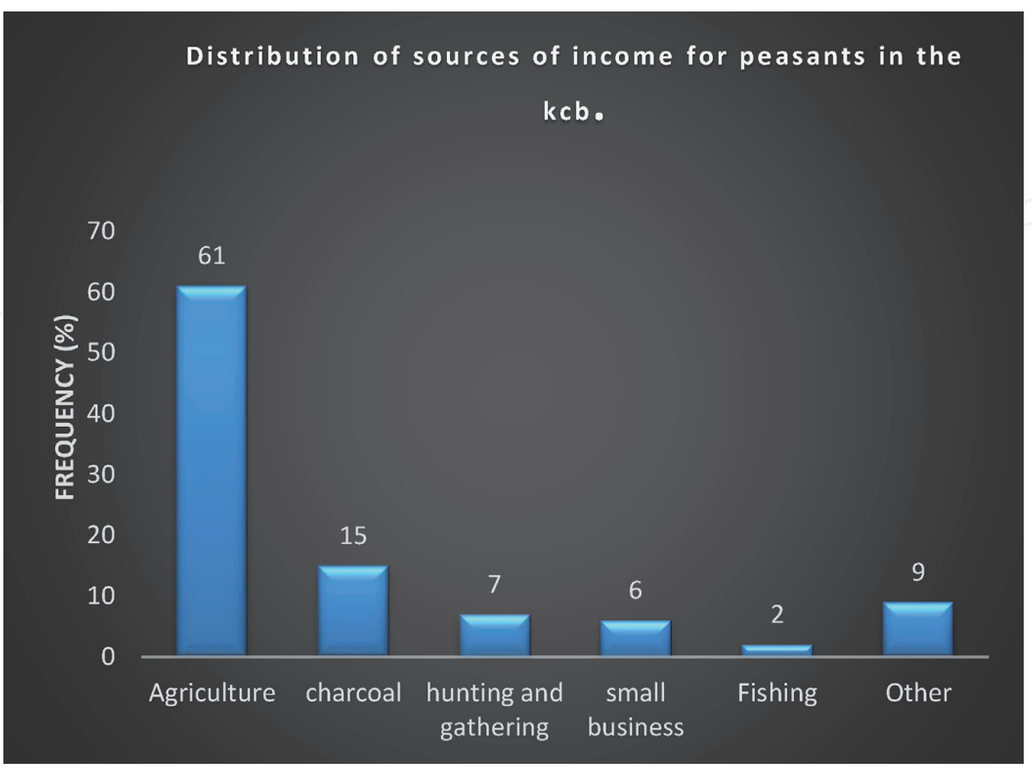

Figure 3.
Distribution of sources of income for peasants in the KCB [9].

Figure 4.
Peasants selling charcoal in KCB. (source: Alexis Huguet, 2019. En RDC, le charbon de bois vital pour les foyers, mortel pour les forêts. Agence France-Presse.)

consumers and the availability of chicks and feed imported completely without difficulty from neighboring Zambia. All these activities are without consequences because market gardening crops face competition with that from Zambia and also they are exposed to rapid degradation in the event of unsold, for lack of techniques and means of conservation and/or processing. The cost of local production of broilers is so far higher than the selling price of imported chicken. This constitutes a huge difficulty for local semi-intensive poultry farmers.

4.6 Insecurity and theft

The insecurity experienced by the DRC following the various wars that have taken place for more than twenty years; have caused negative effects on animal husbandry as a whole. Armed groups have had to constantly resort to farm animals for food in various war zones including the Hinterland-mining region of Katanga. Several villages have been victims of this practice and some agro-pastoralists have abandoned the practice of goat breeding. An example is the incursion of militiamen and the looting in the city of Diambala and Kakokonya, in the territory of Kipushi (Haut-Katanga). During the night of Thursday, January 16, 2014, these attackers took goats, agricultural products and other goods from the population of these localities.

Another constraint linked to insecurity is theft. The wandering breeding system and the precarious housing conditions of the animals are factors that contribute to the loss of animals by theft. The high selling price of goats in urban centers and large towns in the region is the determining factor in this practice. Stray animals are stolen either by some inhabitants of the village or by strangers in the village. This practice is often organized at night during which thieves, coming from urban centers, bring in vehicles and spray insecticides in goat houses to steal animals without agitation or noise. Several villages, some of which have benefited from NGDOs aid, nowadays find themselves without goats because of this practice.

4.7 Poverty and urgent household needs

Several NGOs have contributed to the rebuilding of goat herds in the dismembered province of Katanga after the unfortunate events of the repetitive wars that have raged in the country. Unfortunately, some breeders, having benefited from these donations, have preferred to sell their herd for emergency medical care or children's schooling. Some preferred other activities, mainly petty trading and the sale of charcoal or market gardening which allows them to have permanent access to cash.

4.8 Heavy metal contaminations

Several studies have shown that soils and fodder are contaminated with trace metal elements characteristic of the region (**Tables 1–3**) [16, 20–22]. This situation does not encourage fodder vegetation to spread in certain potentially grazing areas. Goats reared on vegetation in Lubumbashi in its southwest and northwest part had debris and tissues including meat, liver and kidneys containing high levels of Cd and Pb exceeding the recommended standards [18]. And that the feces of these goats had high levels of Cu, Cd, Pb and Zn [18]. This is explained by the presence of the former foundry plant of the state mining company, "Générale des Carrières et des Mines: ***Gécamines***" and of a new plant of the Lubumbashi slag processing company (STL). High concentrations of heavy metal are in soils and vegetation found in the direction of the prevailing wind as found by others authors in the Penga Penga site [20]

Soils	pH_{h2O}	pH_{kci}	COT	Cu	Co	Cd	Pb	Zn
Garden	6.2	5.8	2.2	142	6.7	0.67	15.3	24.9
Penga penga	5.4	5.3	1.1	3524	109	8.59	249	290.4

Source [20].

Table 1.
Physicochemical characteristics of the two soils studied: Contents of pH, TOC (%) and ETM extractable by ammonium acetate-EDTA (mg,kg^{-1}).

Culture	ETM ($mg.kg^1$)	SN	TO	C15	M105	CM1
Amaranth	*Cu*	31	—	118	—	121
	Co	—	—	8.8	—	6.5
	Cd	4.1	—	8.6	—	6.1
	Pb	1.2	—	6.5	—	7.1
	Zn	100	—	80	—	113
Swiss chard	*Cu*	49	2601	62	156	121
	Co	1.5	91.2	3.2	84	6.5
	Cd	5	0.9	2.9	6.1	2.3
	Pd	1.7	11.5	2	7.1	3.1
	Zn	192	348	94	113	58

Contaminated soil without amendment (T0), with 15 g of limestone (C15), 105 g of compost (M105) per kg of soil, 15 g of limestone +105 g of compost (CM1) per kg of soil and reference soil of experimental garden (SN). Source [20].

Table 2.
Contents of ETM extractable by ammonium acetate-EDTA in the harvested plants ($mg.Kg^{-1}$ MS).

		Sites			Topography				Effect (p > F)		
Parameters	**WS**	**KAS**	**KINS**	**LUI**	**S**	**T**	**SI**	**SEM**	**Site**	**top**	**site*top**
Cu	Unwashed	63^{Aa}	42^{Ab}	$I68^{Aa}$	85^{Aa}	98^{Aa}	90^{Aa}	27,8	**	NS	NS
	Washed	20^{Ba}	12^{Aa}	$45^{B'}$	$I8^{BA}$	30^{Ba}	29^{Ba}	9,5	NS	NS	NS
Co	Unwashed	14^{Aa}	10^{Aa}	60^{Ab}	29^{Aa}	25^{Aa}	30^{Aa}	2,7	*	NS	NS
	Washed	10^{Aa}	3^{Ab}	$I3^{Ba}$	8*	11^{Ba}	7^{Ba}	1,3	NS	NS	NS
Zn	Unwashed	185^{Aa}	24^{Ab}	87^{Ab}	38^{Ab}	107^{Aab}	151^{Aa}	33	*	*	NS
	Washed	103^{Aa}	26^{Ab}	39^{Aab}	37^{Aa}	58^{Ab}	$\mathbf{73^{Aa}}$	12,3	*	NS	NS
Pb	Unwashed	107^{Aa}	8^{Ab}	$l36^{Aa}$	78^{Aa}	65^{Aa}	78^{Aa}	21,7	**	NS	NS
	Washed	7^{Ba}	3^{Aa}	7^{Ba}	4^{Ba}	9^{Ba}	4^{Ba}	1,4	NS	NS	NS

*1: **KAS** - Kasombo; **KINS** -Kinsevere; **LUI** - Luiswishi,*
*2: **S** — shallows; **T** — Trays; **SI** — Slopes;*
Values with different uppercase letters in a row arc significantly different at $p < 0,05$,
Values with different uppercase capital letters in one column arc significantly different at $p < 0,05$,
**: $p < 0,05$; **: $p < 0,01$;* p < *0,001; NS: not significant.*
SEM: standard error of the mean.
Source [16].

Table 3.
Heavy metal concentration in Adenodolichos rhomboideus leaves according to site, topography and washing at Lubumbashi.

(**Table 1**). In the same area hi gh levels were found in the fodder of *Setaria pallidefusca*, in the leaves of amaranths and chard perry [20] (**Table 2**).

High levels of heavy metals were found in different soils and fodder in a few sites near certain mining quarries in Kasombo (Kipushi), MMG (Kinsevere) and Luisuishi (Lubumbashi) [16]. For these authors, the Cu contents were high in all the sites, the Pb contents were read high at Kasombo and Luiswishi; Co levels were high at the Luiswishi sites and moderately at Kasombo, while Zn was higher at Kasombo and Luiswishi (**Table 3**).

As the region is a mining area, there is no policy of choosing pasture with uncontaminated vegetation to practice goat breeding. The consumption of forages containing high levels of heavy metals can have several consequences in animals and in consumers of goat meat. The consumer can, through the food chain, become intoxicated by regularly consuming meat from these farms.

More than 40% of samples of kidneys, livers and muscles from goats reared in the prevailing wind area levels of cadmium, lead, copper and zinc above the recommended standards (**Table 4**). While samples collected from farms indicate values below recommended limits in feces. Samples of offal and meat from goats collected from contaminated sites showed high levels of Pb and Cd in kidneys and liver (**Table 5**) [18].

Samples taken from edible offal in some markets show that only the Pb contents are above the recommended limits in the kidneys and liver (**Table 6**). In view of these results, the regular consumption of goat offal may be the basis of lead poisoning in humans.

4.9 Rearing practices, pathologies and genetic type of goats

4.9.1 Rearing practice

Another constraint is linked to the practice of traditional and rudimentary rearing [25]. The majority of goat keepers resort to straying and tethering [26] (**Figure 5**) without supplementation, prophylaxis or breeding stock selection. The

	Contaminated urban areas		Peri-urban farms	
	Dry season	**Rainy season**	**Dry season**	**Rainy season**
Cd	3.02 ± 1.41	4.39 ± 2.55	2.49 ± 2.28	2.27 ± 1.41
Cu	277.80 ± 304.07	236.83 ± 272.16	87.05 ± 66.71	71.57 ± 28.92
Pb	24.24 ± 24.93	23.99 ± 20.25	4.92 ± 4.94	6.01 ± 3.07
Zn	221.63 ± 124.81	259.59 ± 98.21	106.19 ± 30.02	145.20 ± 33.88

Source [18].

Table 4.
Average concentrations of Cd, Pb, Cu and Zn in the feces of goats reared in Lubumbashi (mg/kg).

	Kedney	Liver	Muscles	Standard
Cd	1.91 ± 0.69	1.39 ± 0.62	0.36 ± 0.12	0.5[22] (FAO/WHO)
Cu	36.09 ± 12.17	47.84 ± 22.59	24.48 ± 11.87	200[23] (ANZFA)
Pb	4.7 ± 2.55	1.8 ± 0.5	0.96 ± 0.46	1[23] (ANZFA)
Zn	66.06 ± 30.1	106.94 ± 50.21	12.98 ± 5.38	150[23] (ANZFA)
T				

Source: [18].

Table 5.
Heavy metal concentrations (Cd, Cu, Pb, Zn) found in certain tissues of goats reared in the contaminated zone.

	Kidney	Liver	Muscles	Standard
Cd	0.084 ± 0.037	0.061 ± 0028	0.015 ± 0.006	0.5 [23]
Cu	36.09 ± 12.17	47.84 ± 22.59	24.48 ± 11.87	200 [24]
Pb	4.7 ± 2.55	1.8 ± 0.5	0.96 ± 0.46	1 [24]
Zn	66.06 ± 30.1	106.94 ± 50.21	12.98 ± 5.38	150 [24]

Source [18].

Table 6.
Heavy metal concentrations (Cd, Cu, Pb, Zn) found in the meat and certain offal of goats sold at the market (ppm).

practice of stake tying is often done during the maize growing period, at the start of the rainy season, to prevent goats from grazing the young plants of this food crop. Animals are satisfied with natural vegetation regardless of its composition. A few rare breeders sporadically bring in crop residues.

Prophylaxis is almost non-existent and goats hardly ever receive veterinary services. These are often limited to inspecting meat and collecting state taxes. The practice of straying, which is the general breeding method for almost all breeders, promotes uncontrolled mating. This practice has harmful consequences such as consanguinity, the transmission of venereal diseases, the increase in genetic defects and abnormalities. This does not promote good animal yields for growth and reproduction.

4.9.2 Genetic type

The average sub-sternal gracefulness index (IGs) of adult animals in this region, all sexes combined, is close to 1, indicating that these goats are mostly brevipedes,

Figure 5.
Grouping of farms based on farming method. SystemeE: Breeding system; divagation: Rambling goats system; piquet: Stakes attachment system. Source [26].

and that considering the average weight and other body measurements, in particular the average height at the withers greater than 50 cm, they belong, like small ruminants of the "Mossi" breed, to the small-format genetic type[7]. However, these authors have found that these goats are very heterogeneous, this does not allow them to be classified into a homogeneous genetic type. This gives rise to a great possibility of selection.

The small size and low weight of these animals may be due to the fact that the grazing in the study area is generally poor. Indeed, soils have a high metal content, acid rain makes phosphorus virtually unavailable, and uncontrolled bushfires destroy huge amounts of organic matter every year and deplete the soil of nitrogen [27].

The poor performance of these goats does not allow them to be marketed within a reasonable time (**Table 7**). The live weight of adult goats ranging from 12.8 to 26.3 kg [29] and some authors found weights of 13.28 and 14.41 kg respectively for females and males at the age of 9 months [28]. The male: female ratio is on average 1: 3. However, 11.4% of herds have a zero ratio with absence of males [29]. And this zero ratio can reach more than 60% for some goat herds in the region [30].

4.9.3 Pathology

Several symptoms related to pathologies have been documented by some authors [26, 29, 31].

In the event of pathologies, breeders resort to pharmacopeia, using some local substances and plants, and the main symptoms encountered in goats are: diarrhea, cough, mange, cachexia [26] (**Figure 6**). An extrapolation of the etiological causes of some of the symptoms of the diseases was carried out on the basis of the diagnoses carried out in the field: - weight loss, usually associated with bloating of the abdomen, poor general condition and a "pricked hair »Is a sign of significant gastrointestinal verminosis; –the causes of abortion are undoubtedly diverse: their etiology has not been specifically studied; –diarrheas are frequently cited, but their

Variable	N	Average	Standard deviation	Minimum	Maximum
P0days: Weight at Birth					
Average herd	245	1.75	0.46	0.5	2.8
Females	119	1.74	0.36	0.6	2.5
Males	126	1.75	0.54	0.5	2.8
P10days					
Average herd	111	2.69	0.59	1.4	5
Females	54	2.62	0.47	1.6	3.9
Males	57	2.77	0.69	1.4	5
P30days					
Average herd	235	4.28	1.04	1.8	8.9
Females	113	4.2	0.96	2	6.1
Males	122	4.34	1.12	1.8	8.9
P90days					
Average herd	228	7.14	2.04	3.2	12.3
Females	111	6.82	2.05	3.2	10.6
Males	117	7.46	1.99	3.7	12.3
P180days					
Average herd	218	10.22	2.15	4.2	14.4
Females	105	9.9	2.13	4.2	14.4
Males	113	10.52	2.09	5.3	13.4
P270days					
Average herd	216	13.37	3.47	5.5	19.4
Females	104	13.28	2.9	5.5	17.1
Males	112	14.41	3.87	6.6	19.4

N: effective, P: Weight.
Source [28].

Table 7.
Weight (kg) of local kids from birth to 270 days.

intensity and frequency vary from one farm to another. This variability could be linked to farming conditions and more specifically to hygienic conditions; - the diarrhea described as "red" by the breeders are in fact bloody diarrhea; – the udder problems, which the breeders clearly dissociate from agalactia, are probably mastitis in the majority of cases: they describe swollen udders, red and painful; –the skin problems revealed by breeders most often result in the presence of scabs and scratching lesions, probably due to the presence of ectoparasites (scabies, lice, ticks, even myiasis); –Cough a sign of an upper and/or lower respiratory disorder. It is more frequent, according to pastoralists, during the rainy season which lasts from October to April [31].

A few cases of reproductive pathologies including physiological (muco-sanguinolent or bloody discharge) and pathological (mucopurulent or purulent discharge) vaginal and/or uterine secretions in 13% and 5% of the 739 non-pregnant goats examined, respectively in farms. And that a number of cases (n = 59) of more specific pathological situations were also observed including eleven cases of

hydrosalpinx, eleven cases of paraovarian cysts, two cases of hydrometer and one case of paracervical cyst. Six cases of genital tract abnormalities were observed out of 346 males examined. They mainly concerned the testes (atrophy, cryptorchidism, hydrocele, orchitis) [29].

In addition to reproductive pathologies, a few cases of contagious ecthyma, scabies and estrosis have also been detected [30]. A few cases of caprine brucellosis have also been reported in the killings of goats in the city of Lubumbashi, around 9.8% of cases recorded [30].

Other pathologies are linked to gastrointestinal parasitosis. **Table 8** provides information on the symptoms linked to infestations of these parasitosis.

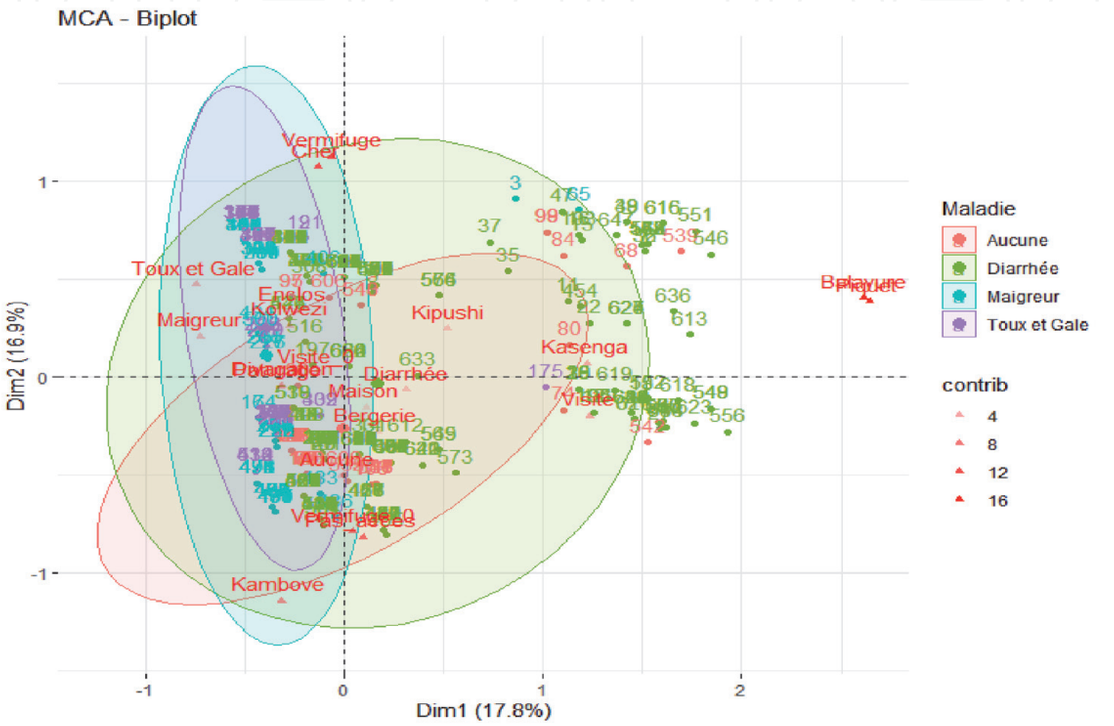

Figure 6.
Grouping of farms in relation to the pathological symptoms encountered. Aucccune: None, Diarhée: Diarrhea, Maigreur: Weight loss, Toux et gale: Cough and scabies. Source [26].

Symptoms and causes of gastrointestinal parasitosis		Frequency
Symptoms:	Weight loss	28/44
	Lack of appetite	28/44
	Hairless hairs	39/44
	Belly bloating	32/44
	Presence of worms in stool	32/44
	Diarrhea	19/44
Causes:	Water	44/44
	Pasture	37/44
	Night kraal	2/44
	Humidity	3/44

Source [32].

Table 8.
Symptoms and causes related to gastrointestinal parasitic infections.

5. Opportunities for goat breeding in the Katanga copper belt

5.1 Market opportunity

The DR Congo is the world's leading producer of cobalt (the leading strategic mineral in the electric automobile industry with a third of world reserves[31], the leading African producer of copper and the fourth in the world. The mining code [17] of 2002, inspired by the World Bank and designed to attract foreign investment, encouraged the rise of the mining sector. DR Congo's mining industry has been one of the most dynamic in sub-Saharan Africa over the past two decades. There are currently several industrial companies that exploit deposits mainly of copper and cobalt and nearly sixty cooperatives including those working in artisanal mining [11]. There are also several other independents not officially recognized who sell directly to expatriate intermediaries, mainly Chinese and Indo-Pakistani. This situation has encouraged a massive exodus of the Congolese populations to the mining centers and agglomerations of this region. Added to this is the insecurity due to the wars and armed groups that have taken place in certain regions of the Northeast favoring the influx of displaced people from internal wars to the more secure Southeast. The presence of all these populations has constituted a labor force for mining companies and also for artisanal mining which represents about 20% of the mining production of the DRC. Currently more than ten million people depend directly or indirectly on this mining activity [33]. This has fostered a strong demand for primary foodstuffs including meat products.

Goat meat is among the meat products most consumed by the population of Katanga. This meat is the most preferred of ruminant meats, because it is sold in all public markets and especially near the thousands of bars and drinking establishments scattered throughout the KCB, in the form of CABRI commonly called "MITSHOPO", appetizers (pieces of goat meat cooked on a hearth of wood fires). Every day vendors slaughter thousands of goats in large towns, villages and in artisanal mining quarries. Raising domestic animals is generally a savings opportunity for marginalized farming households in the Democratic Republic of Congo. Goats are the second farmed species in this region [26, 27, 29] and in DRC after chicken [25]. It is rustic, easy to breed and easy to handle, with the ability to adapt to harsh and poor grazing areas. Goat droppings are also used as organic manure which serves to amend the acidic soils (ferrisols) which characterize the region. They can also be used to produce biogas in combination with other crop residues. The vegetation of the HMK lends itself well to the rearing of goats.

5.2 Feeding

Some studies on forages have shown interesting results. The studies carried out the supplementation of goats fed on hay of *Imperata cylindrica* and *Setaria palidefusca* supplemented by hay of the legumes *Stylosanthes guianensis, Leucaena leucocephala* and *Adenodolichos rhomboideus* have shown a good opportunity in the rearing of goats in terms of growth performance (**Table 9**), especially in the dry season, if grass and legume hay are used [34]. These legumes showed good nutritional values and were very palatable for indigenous goat [34–36] (**Tables 10** and **11**). They improved the consumption of hay and nutrients (**Figure 7**).

Tests carried out on ten forage species (**Table 12**) have shown the good productive and nutritive capacities of these forage [21]. Some of these species have adapted well despite their first attempts at cultivation in the region. Their use in fodder crops or in association with spontaneous vegetation would be an asset for the

Treatments	WI (kg)	WF (kg)	GWF(g)	ADG(g)
HA	16.85a	17.9a	1050a	17.5a
HAR	16.35a	20ab	3970bc	66bc
HAL	16.7a	21.5b	4820c	80c
HAS	16.6a	19.9ab	3300b	55b
ESM	0.37	0.49	0.42	6.9
P	0.97	0.012	0.000	0.000

Means followed by different letters in the column are different.
SEM: standard error of the mean; *WI:* initial live weighr; WF: final live weight; GWF: liveweight gain; *ADG: average daily gain, HA = hay; HAR = hay and A, rhomboideus; HAL = hay and L, leucocephala; and HAS = hay and S, guianensis,*
Source [34].

Table 9.
Effect on the growth performance of the consumption of hay consisting of a mixture of Setaria palidefusca and Imperata cylindrica*, complemented with the forage from Adenodolichos rhomboideus,* Stylosanthes guianensis *or* Leucaena leucocephala *in local goats at Lubumbashi.*

Fodder	QC (g,DM,Head^{1} day^{1})	Index
Hay	187.5 ± 46.6b	1c
Adenodolichos	83.7 ± 16.9a	1.44 ± 0.5a
Leucaena	268.7 ± 119d	1.7 ± 0.8
Stylosanthes	230 ± 23.7	1.56 ± 0.64ab
Periods		
A	164.4 ± 68.6a	1.6 ± 1.1b
B	208.4 ± 105b	1.3 ± 0.3a
C	208.2 ± 101b	1.4 ± 0.4 ab
D	164.4 ± 68.6a	
P		
Feed	0.00000	0.000000
Periods	0.001	0.016571
Animal	0.272471	0.871944
forage x periods	0	0.778595
periods x animal	0.997815	0.000042
forage x animal	0.919552	0.884571
periods x animal x forage	1	0.996648

*The means followed by different letters in the same column, for each variable, are significantly different from each other ($p < 0,05$), NS: not significant, **: highly significant, ***: very highly significant, QC: Quantities consumed; A: period 1; B: period 2; C: period 3 and D: period 4.*
Source [36].

Table 10.
Average quantities consumed and palatability index of fodder consumed by goats.

improvement of goats and to solve the problems linked to nutritional deficiencies, especially in the dry season. Another opportunity is that some of these forage species have shown good adaptability on soils contaminated with heavy metals characteristic of the HMK region [16, 20, 36].

5.3 Selection and crossbreeding

Studies of indigenous goat crossbreeds have taken place and have shown encouraging results for improved growth and average daily gain. These studies show that crossbreeding has improved the growth rate and average daily gain of hybrids between the indigenous goat and the South African Boer breed [37] (**Tables 13** and **14**).

Forage	*DV-*	OM	CP	ADF	NDF	EE	Asli	UFL	PDLX	PDLE
Hay	977a	959a	30a	503a	709a	11a	40a	0.59a	18a	47a
A rhomboideus	892b	960a	153b	480a	600a	33b	40a	0.71b	96c	76c
L. leucocephala	896b	897b	305.6c	264b	345b	51.5c	100b	1.5c	192d	130d
S. guianesis	910b	947a	104d	492a	560a	17ab	53a	0.68b	65b	66b
Corn	—	—	—	—	—	—	—	1	74	97
SEM	17	24	6.8	10.6	43.8	4.25	24	0.01	1.6	1.1
p	0.002	0.01	0.000	0.001	0.004	0.002	0.01	0.000	0.000	0.000

Means followed by different letters in the row are different ai level p < 0.05.
DM: dry matter, OM: organic matter, CP: crude protein, ÁDF: insoluble fiber in acid detergent, NDF: insoluble fiber in neutral detergent, E: ether extract, UFL: net energy for lactation, PDIN: protein digested in the small intestine when rumen-fermentable nitrogen is limiting, PDIE: protein digested in the small intestine when rumen-fermentable energy is limiting S&M: standard error of the mean.
Source: [36].

Table 11.
Chemical composition (g/kg) of legume forage.

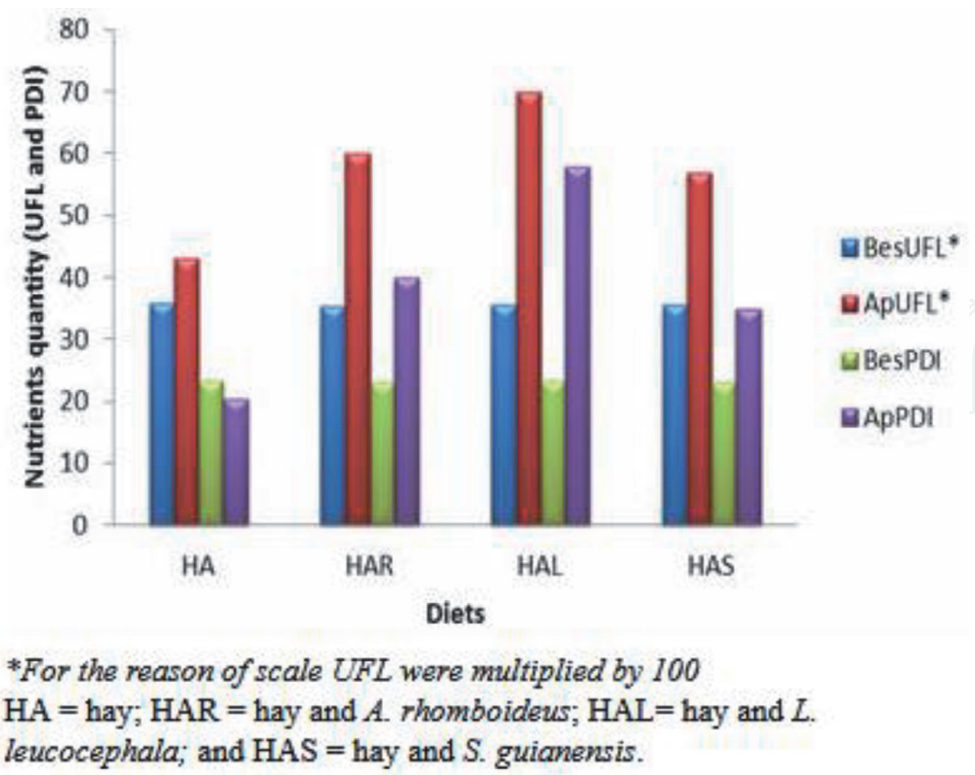

Figure 7.
Comparison between energy and nitrogen, requirement and intake of experimental diets consumed by local goats in Lubumbashi. BesUFL: Requirement net energy for lactatio, ApUFL: Intake net energy for lactation, BesPDI: Requirement protein digested in the small intestine when rumen-fermentable nitrogen is limiting, ApPDI: Intake protein digested in the small intestine when rumen-fermentable nitrogen is limiting. (Source: Ref. [34]).

Species	Production (TDM/ha/year)	CP (%MS)	NDF (%MS)	ADF	CPt/Ha/year	CE
Leucaena leucocephala	7.9	21.38–29.31	48.15–42.41	42.45–29.77	1.8	3340.69–3152.82
Cajanus cajan	10.6	24.51–25.67	50.16–55.89	41.62–50.66	2.7	3444.05–3650.52
Albizia lebbeck	3.8	22.76–24.21	42.13–37.23	24.99–24.45	0.9	3112.35–3053.35
Moringa oleifera	6.3	20.71–26.02	24.68–24.55	16.75–14.07	0.5	3111.54–3251.58
Cynodon dactylon	4.3	7.38	72.94	40.32	0.3	11137,5
Trypsacum laxum	13.9	7.6–9.01	67.40–64.06	39.30–36.28	1.2	2834.27–2661.95
Setaria palidefusca	5.9	3.95	74.47	54.19	0.2	2648.25
Echinochloa pyramidalis	6.5	3.56	65.66	37.50	0.2	2679.64
Panicum maximum	8.7	5.37–6.53	73.13–61.55	48.41–37.36	0.5	2777.22–2485.73
Paspalum dilatatum	13.1	5.66–7.79	71.00–69.77	34.48–44.66	0.8	2631.83–2449.69

TDM: ton dry matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ADL: acid detergent lignin, CE: crude energy.
Source [21].

Table 12.
Productivity and chemical composition of forage species cultivated in Lubumbashi.

Genetic group	Birth	30 days	90 days	180 days	270 days
Boer (n = 62)	2.41 ± 0,38a	6.87 ± 0.38a	14.3 ± 0.38a	17.9 ± 0.38a	24.7 ± 0.38a
F1 (n = 167)	2.18 ± 0,15a	6.87 ± 0.38a	9.53 ± 0.15b	14.4 ± 0.15c	21.4 ± 0.15c
Local (n = 116)	1.75 ± 0,12a	4.27 ± 0.12b	7.11 ± 0.12c	10.2 ± 0.13b	13.8 ± 0.13b
Genetic group * sex					
Boer F	2.29 ± 0.49[a]	6.59 ± 0.49a	13.9 ± 0.49a	17.6 ± 0.49a	24.4 ± 0.49a
F1 F	2.06 ± 0.22a	4.89 ± 0.22b	8.68 ± 0.22b	13.8 ± 0.22c	21.9 ± 0.22b
Local F	1.75 ± 0.17a	4.19 ± 0.18c	6.79 ± 0.18c	9.87 ± 0.18[b]	13.2 ± 0.18d
Boer M	2.52 ± 0.57a	7.14 ± 0.57a	14.5 ± 0.57a	18.3 ± 0.57a	25.1 ± 0.57a
F1 M	2.29 ± 0.20a	5.45 ± 0.20[b]	10.4 ± 0.20d	14.9 ± 0.20d	20.8 ± 0.20c
Local M	1.75 ± 0.17a	4.34 ± 0.17b.c	7.43 ± 0.17e	10.5 ± 0.18e	14.4 ± 0.18e

F1: Hybrid; F: femelle, M: male.
Source [37].

Table 13.
Average weights (kg) of kids in the pre-weaning and post-weaning period of the genetic groups and the genetic group-sex interaction. Means followed by different letters; a, b, c, d and e; in the column are different at level $p < 0.05$.

5.4 Veterinary care and prophylaxis

Studies of the remedies used for the care of goats in this region show that the majority of goat breeders use local plants to care for their animals (**Table 15**). And that for the majority of breeders, this knowledge of herbal remedies is acquired by family transmission; only one of these breeders has enriched his knowledge by

Sources of variation	Days 0–30 (g.d-^{1})	Days 30–90 (g.d^{-1})	Days 90–180 (g.d^{-1})	Days 180–270 (g.d^{-1})
Groupe génétique*sexe				
Boer F	143 ± 9.10 ^{a}	122 ± 5.91^{a}	41.2 ± 4.44^{a}	75.7 ± 5.53^{a}
F1 F	94.3 ± 4.07^{b}	62.2 ± 2.64^{b}	56.5 ± 1.98^{b}	88.7 ± 2.47^{a}
Local F	81.0 ± 3.30^{c}	43.0 ± 2.16^{d}	33.4 ± 1.68^{a}	37.4 ± 2.10^{b}
Boer M	154 ± 10.6^{a}	124 ± 6.90^{a}	41.1 ± 5.18$^{a.c}$	75.3 ± 6.45^{a}
F1 M	106 ± 3.74^{b}	82.1 ± 2.43^{c}	50.8 ± 1.85c	65.6 ± 2.31^{a}
Local M	85.7 ± 3.19^{c}	51.0 ± 2.16^{e}	34.4 ± 1.62^{a}	43.0 ± 2.02^{b}

F1 = Hybrid; F = femelles; M = males.
Source [37].

Table 14.
Averages of daily gain (ADG) of different genetic groups. Means followed by different letters; a, b, c and d; in the column are different at level p<0.05.

studying botany. Almost a quarter of breeders report having acquired this knowledge esoterically by dreaming, or by communicating with a deceased relative, or even by inspiration. Only one breeder reports acquisition by trial and error [31].

5.5 Reproduction

Like all other ruminants in the tropics, the goat reproduces at any time in the DRC, which makes it economically profitable to have births during all periods of the year. More births are observed in the dry season than in the rainy season [38]. This situation would be due to the fact that the births which arrive in the dry season result from the gestations of the rainy season which is characterized by an abundance of fodder and that the dry season where there is a lack of fodder is characterized by fewer gestations and therefore, fewer births in the rainy season. The mean age of farrowing is 15 months and therefore corresponds to an average age of pregnant matings of around 10 months [30]. While the age of pregnant females ranged from 7 to 108 months [38].

6. Perspectives and recommendations

In view of the constraints and opportunities related to goat breeding in the Katanga Mining Hinterland, it is necessary to list the perspectives and recommendations to overcome the difficulties of breeding and the goat sector in the area.

6.1 Role of politico-administrative authorities and the state

In view of the foregoing, goat breeders are abandoned by the authorities and decision-makers of the Congolese State at all levels. Political leaders should get involved in the organization and supervision of breeders in general, and those in the goat sector in particular, by prohibiting the straying of animals. They should help agro-pastoralists by granting breeding areas chosen according to the quality of pastures and according to safety to help them do their best work in serenity. These pastures must be community-based taking into account the remoteness of the mining and mineral processing areas and also far from urban areas. The breeders should be organized in cooperatives or associations. Each organization must be

Plant used	Vernacular name (in Swahili)	Symptoms treated	Parts of the plant used	Method of preparation of administration remedies	Dosage	Solvent	Number of breeders using this remedy (n = 50)
Allium sativum L. Alliacea	Hayi	Cough	Pods	Pounded and given in syrup (with honey)	1 glass for 2 to 3 days	Honey	27
Carica papaya L. Caricaceae	Kipayi payi	Skin problems (scabs and itching)	Leaves	Fiction on lesions of previously looted leaves	Depending on the surface to be treated	No solvent	42
Carica papaya L. Caricaceae	Kipayi payi	Skin problems (scabs and itching)	latex from unripe fruit	Fiction about lesions	Depending on the surface to be treated	No solvent	43
Carica papaya L. Caricaceae	Kipayi payi	Skin problems (scabs and itching)	Seeds	Maceration	1 to 3 glasses for 2 to 3 days	Water	50
Cucurbitamoschata Duchesne cucurbitaceae	Kibwabwa	Stung belly bloating	Seeds	Maceration	1 to 2 glasses / day for 2 to 3 days	Water	34
Elaeis guineensis arecaceae	Mafuta ya ngaji	Wounds	Paml oil	Local application			21
Euphorbia hirta L. Euphorbiaceae	Kavudji	Belly bloating and prickly hair	whole plant	Maceration	1 to 2 glasses / day for 2 to 4 days	Water	41
Mangifera indica L. Anacardiaceae	Manga	Diarrhea	Trunk bark	Maceration	1 to 2 glasses / day for 3 to 4 days	Water	26
Psidium guajava L. Myrtaceae	Mapela	Diarrhea	Leaves	Decoction	1 to 2 glasses / day for 3 to 4 days	Water	21
Tephrosia vogelii Hook. F. Fabaceae	Buba	Skin problem (scabs and itching)	Leaves	Fiction on lesions	1 to 2 glasses / day for 3 to 4 days	No solvent	23
Tithonia diversifolia (Hemsl.) A. Gray Myrtaceae	Kilulu nkundja	Skin problem (scabs and itching)	Leaves	Fiction on lesions	Depending on the surface to be treated.	No solvent	39
Tithonia diversifolia (Hemsl.) A. Gray Myrtaceae	Kilulu nkundja	Belly bloating and prickly hair	Leaves	Maceration	1 to 2 glasses / day for 3 to 4 days	Water	41

Source [31].

Table 15.
Latin name, vernacular in Swahili and parts of plants identified as constituents of remedies administered to goats, symptoms treated, methods of preparation of herbal remedies, method of administration and dosage. Frequency of use of the remedy is also specified by the number of families out of the 50 questioned.

organized so as to have its own pastures, its own technicians and its organization of the market. This would serve to conduct the feeding well, the improvement and management grazing, prophylaxis, veterinary care, reproduction, selection, other zootechnical operations and the marketing of animals.

6.2 Breeding practice and selection of goats

Poor husbandry practice contributes negatively to the economic profitability of goat rearing in the KCB. Straying like breeding exposes animals to loss, theft, disease, nutritional deficiency and increased rate of inbreeding. It also results in an irrecoverable loss of dejection following straying. In order to compensate for the nutritional deficiency linked to the scarcity of fodder, especially in the dry season, and the low nutritional value of fodder, it is important to resort to the enrichment of pastures with grasses and fodder legumes which have made proof of good growth, good productivity, good palatability and good nutritional value. It should also be noted the valuation of excessive vegetation during the active period as hay for use in cold and dry season where there is a lack of vegetation. Providing decision-makers and breeders with a map of uncontaminated pastures would help guide a good use of the available fodder resources in the region,

The use of a lick block and/or multi-nutritional block, especially in the dry season, could make it possible to compensate for the deficiency in minerals, energy and protein.

The quantification, the study of the nutritional value and the methanogenic potential in combination of the goat droppings of the crop residues of the main crops in the region could also make it possible to increase the productivity per unit of agricultural area and the well-being of households agricultural.

To avoid losses, theft, straying, nutritional deficiencies and allow the welfare of animals, agro-pastoralists must be obliged to build goat barns that meet standards. Good housing for animals would also protect them against diseases and bad weather linked to climatic hazards such as showers, winds, dust and ectoparasites. This practice would also allow the collection of droppings, to be used as organic manure or for methanogenesis, wasted when the animals are straying.

6.3 Promotion of local herbal medicine

The promotion of local medicinal plants is a major asset in the prophylaxis and the fight against common diseases such as parasitoses, bacterial infections and others. This would allow breeders to save the costs associated with the purchase of conventional veterinary drug. A systematic inventory and studies on chemical compounds, biology, cultivation attempts and then the popularization of medicinal plants would be an asset for their conservation and their use for veterinary care and prophylaxis in the region.

6.4 Diversification of goat breeding speculations

The introduction of the goat milk sector which is a stable activity, not depending on the season, providing daily milk, would allow the diversification of sustainable activities and permanent family recipes. This activity would be made possible after studies on livestock purebred goats or crosses of specialized exotic breeds with the indigenous goat. Among these breeds there are some that have proven themselves in sub-Saharan Africa such as Saanen, Nubian, Alpine, Topinambour and others.

7. Conclusion

The goat is the second highest species in the DRC and it is its meat that is consumed the most by ruminants. Too little attention is paid to its breeding; which remains a secondary activity for several peasant families. The goat industry is characterized here by a very low level of inputs in subsistence farms which are made up exclusively of small family farms. The lack of support for its breeding is an obstacle to the development of this sector, which provides meat and financial resources for peasant households. For the Katanga copper belt region, the majority of goats are imported from Zambia, which constitutes a big shortfall for the country and for the local farmers.

The goat sector receives almost no sustainable financial support from the government, unlike the crop production sector. A synergy between researchers, breeders and the political-administrative authorities on improving the goat sector would be a breath of fresh air for the poor farmers and this will save a few masses of currency which are exported for the purchase of meat abroad.

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