Heliyon 7 (2021) e07656

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Ethnoveterinary knowledge of sheep and goat farmers in Benin (West Africa): effect of socioeconomic and environmental factors

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ARTICLE INFO

Keywords:
Ethnoveterinary
Diseases
Sheep
Goats
Benin

ABSTRACT

Sheep and goats are two of the main animal species raised in Benin and one of the main sources of income for people living in rural areas. Faced with the inaccessibility of synthetic veterinary products and their low purchasing power, the majority of breeders use ethnoveterinary practices to treat small ruminants diseases. The specific objectives of the current study were (1) to document the traditional knowledge regarding the disorder groups treated and the medicinal plants used in the health and zootechnical management of small ruminants in Benin and (2) to assess the effect of gender, ethnicity, agro-ecological zone and herd size associated with them. To achieve these objectives, an ethnoveterinary survey was conducted in different agro-ecological zones from September 2018 to February 2019. A questionnaire was administered to 506 breeders. The data were analyzed through calculation of the Fidelity Level (FL), Cultural Importance Index (CI) and Informant Consensus Factor (ICF). Ten disorder groups were treated by the people surveyed. These were mainly digestive disorders (D) and reproductive disorders (W), both presenting a ICF value of 0.8. A total of 101 medicinal plants belonging to 42 families and 90 genera were recorded. *Spondias mombin*, *Zanthoxylum zanthoxyloides* and *Khaya senegalensis* were the most important plants with CI values of 0.208, 0.125 and 0.121, respectively. Gender, ethnicity, agro-ecological zone and flocks size were the socioeconomic and environmental factors that significantly influenced the level of ethnoveterinary knowledge. Chemical and biological analysis are needed on less studied plants such as, *Striga hermonthica*, *Crossopteryx febrifuga*, *Elaeis guineensis* and *Momordica charantia*.

1. Introduction

Small ruminants are one of the main sources of income for poor families. In Benin, their number in 2018 was estimated at 2,875,000 (1,921,000 goats and 954,000 sheep), ranking second after poultry (Faostat, 2018, http://www.fao.org/faostat/fr/#data/QA). Sheep and goats were contributed to 13% of total meat production in Benin in 2013 (Mensah et al., 2018). For the breeders, small ruminants play an economic role but also have social, cultural and religious functions (Dossa et al., 2007, 2015; Lakew et al., 2017). Sheep and goats are kept by breeders mainly for economic function and the income are used to buy foods, clothes, to pay school fees for children and solve people health

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https://doi.org/10.1016/j.heliyon.2021.e07656
Received 25 January 2021; Received in revised form 21 April 2021; Accepted 20 July 2021

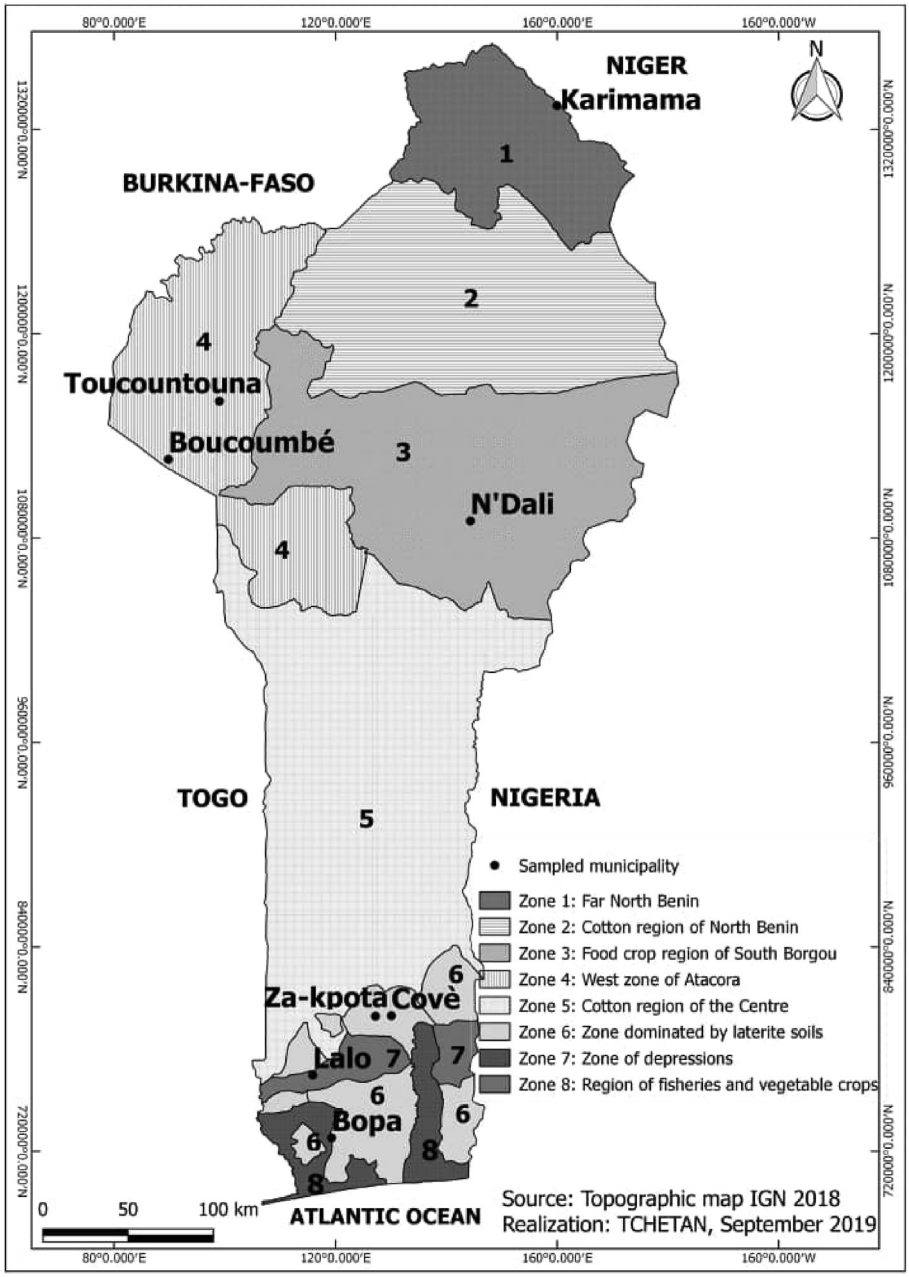

Figure 1. Map showing the distribution of the surveyed municipalities in the agro-ecological zones of Benin.

problems (Dossa et al., 2007). In addition, small ruminants are used in certain sociocultural practices such as marriage, traditional ceremonies and their excrements serve to organic fertiliser (Mensah et al., 2018).

Small ruminants farming in Benin encounter certain constraints namely, diseases that lower their performance (Hounzangbé-Adoté, 2001; Dossa et al., 2007). According to Attindéhou et al. (2012), gastrointestinal parasitosis remain the main disease encountered in sheep and goats farms. In addition to this, diarrhoea, scab, respiratory problems and reproductive disorders are the most symptoms identified in small ruminants farms in South of Benin (Hounzangbé-Adoté, 2001; Dossa et al., 2007), that lead to high mortality. Similary, in Nigeria, diarrhoea and pneumonia are encountered, respectively, in 12.4% and 20.3% of small ruminants farming (Omoike, 2006).

Faced with the inaccessibility of synthetic veterinary products and their low purchasing power, the majority of breeders use ethnoveterinary practices to treat animals (Dassou et al., 2015a; Houndje et al., 2016). Thus, several studies conduct in Benin have addressed ethnoveterinary practices by listing the medicinal plants used to treat livestock diseases (Hounzangbé-Adoté, 2001; Ogni et al., 2014; Dassou et al., 2015a; Houndje et al., 2016). However, most of these studies inventoried medicinal plants used to treat diseases of all domestic animals (Ogni et al., 2014; Dassou et al., 2014, 2015a), while medicinal plants as well as the traditional recipes used by breeders depend on the animal species targeted. For example, Ouachinou et al. (2019) analysed medicinal plants used to treat gastrointestinal disorders in cattle in Benin. The few studies analysing ethnoveterinary practices in sheep and goats farming in Benin have been limited to the South (Hounzangbé-Adoté, 2001; Attindéhou et al., 2012), while small ruminants are distributed across the entire country. The northern part of the country is home to a number of sociocultural groups not found in the South, which practice sheep and goats farming. This area is not easily accessible to veterinary agents and products. Breeders are therefore obliged to develop ethnoveterinary practices to ensure the well-being of their animals. Ethnoveterinary medicine practices depend

on the ethnic groups and resources available in the area (Wanzala et al., 2005). Moreover, studies conducted in the South analysing plants used to treat parasitic diseases (Attindéhou et al., 2012), while ethno-vinarinary practices in sheep and goats farming cannot be limited to parasitic diseases only.

In this study, we present the results of an ethnoveterinary survey to document traditional knowledge and practices related to the zoo-sanitary management of sheep and goats farms in Benin. Specifically, the study aims to:

- Document the traditional knowledge regarding the disease groups treated and the medicinal plants used for the health and zootechnical management of small ruminants in Benin.
- Assess the effect of gender, ethnicity, agro-ecological zone and herd size associated on this traditional knowledge.

2. Material and methods

2.1. Study area

The study was conducted in Benin (West Africa), in 6 of the 8 agro-ecological zones defined (Figure 1). SICC/Benin (2016) (https://www.changementsclimatiques.bj/zones-agro-ecologiques-de-la-republique-du-benin/.) defines these areas as follows:

- Zone 1 (Far North Benin) hosts the largest part of the forest reserves with the W National Park of Niger. Its climate is of Sudano-Sahelian type, with temperature reaching 40 °C in the shade in the dry season. The zone includes 2 municipalities, one being Karimama.
- Zone 3 (Food crop region of South Borgou) is essentially characterized by a very high availability of agricultural land. It covers 8 municipalities including N'Dali. It is part of Sudanian zone and the climate is characterized by a rainy season from April to September and a dry season that lasts almost 5 months.
- Zone 4 (West zone of Atacora) benefits for the presence of Atacora chain which leads to a particular climate where the temperatures are cooler and thunderstorms more frequent than in the other zones. Precipitation varies from 800 to 1350 mm anually. The main river is the Pendjari with its tributaries. The zone hosts 8 municipalities including Toucoutouna and Boukoumbé.
- Zone 6 (Zone dominated by laterite soils) is located in the southern part of Benin and counts 22 municipalities including Covè and Za-Kpota. The climate is marked by two rainy seasons (March–July; October–November) and two dry seasons (December–February; August). Annual precipitation varies between 1000 to 1400 mm.
- Zone 7 (Zone of depressions) is the smallest of the 8 agro-ecological zones in terms of area and hosts the municipality of Lalo. On the climatic level, it is quite comparable to zone 6 with, however, a high relative humidity (around 85%).
- Zone 8 (Region of fisheries and vegetable crops): a main characteristics of this zone is the presence of inland and maritime fishing in addition to plant and animal production. Geographically, it is the most southerly zone and occupies the fluvio-lacustrine zone of the Atlantic, Mono, Oueme and Zou departments. It covers 13 municipalities including Bopa.

The population of Benin was estimated at 12,118,842 in 2019. Fon, Adja, Yoruba, Bariba, Dendi, Peulh, Otammari, Yoa and Lokpa are the main sociocultural groups encountered (INSAE, 2016). Christianity, Islam and Vodoun are the main religions practiced. Agriculture, livestock and handicraft are the main activities. Eight more poor municipalities where small ruminants breeding is predominant were selected to host the study. Then, we used the 8 agro-ecological zones defined to identify those covert by the respective municipalities. In each municipality, 4 villages were chosen based on their accessibility and the ethnoveterinary practice to treat small ruminants diseases.

2.2. Sampling

A baseline survey was conducted beforehand and this allowed to identify 4 villages per municipality to conduct the survey. The baseline was carried out with the support of Non Governmental Organisations (NGOs) and governmental institutions that intervene in the target municipalities and made it possible to choose villages with easy accessibility and predominance of ethnoveterinary practices. The sample size (n) per municipality was determined according to Dagnelie (1998) formula (Equation 1).

$$n = \frac{U^2_{1-\frac{\alpha}{2}} \times p(1-p)}{d^2} \quad (1)$$

Where n is the sample size of the population to be surveyed per municipality, $U^2_{1-\frac{\alpha}{2}} = 1.96$ is obtained from the standard distribution table of normal distribution with $\alpha = 0.05$, p ($p = 80\%$) being the proportion of the population using medicinal plants to treat small ruminants diseases, and d ($d = 0.075$) being the margin of error we fixed. Based on the formula, a minimum of 56 persons were interviewed per municipality. Therefore, a minimum of 14 persons were selected per village to participate in the study.

2.3. Data collection

The ethnobotanical survey was conducted from September 2018 to February 2019 and surveyed 506 people identified by purposive selection. The choice of respondents was based on their availability and willingness to participate in the study. Approval from the ethics committee of the University of Abomey-Calavi was granted. A questionnaire was developed and took into account, among other things the characteristics of the respondents (gender, age, ethnicity ...), the main plants

Table 1. Socioeconomic characteristics of respondents.

Variables	Description	Frequency
Sex	Male	366 (72.4%)
	Female	140 (27.6%)
Sociocultural groups	Fon	126 (24.9%)
	Otammari	78 (15.4%)
	Peulh	63 (12.4%)
	Sahoue	62 (12.2%)
	Adja	61 (12.1%)
	Dendi	48 (9.5%)
	Natimba	23 (4.6%)
	Wama	25 (4.9%)
	Bariba	25 (3.1%)
Age	[20 40]	141 (27.9%)
	[40 60]	220 (43.5%)
	[60 80]	108 (21.3%)
	[80 100]	37 (7.3%)
Religion	Animist	241 (47.6%)
	Christian	144 (28.5%)
	Muslim	121 (23.9%)
Level of education	Illiterate	340 (67.2%)
	Alphabet in local language	34 (6.7%)
	Primary level	80 (15.8%)
	Secondary level	40 (7.9%)
	University level	12 (2.4%)
Main activity	Agriculture	369 (72.9%)
	Breeding	54 (10.7%)
	Handicraft	43 (8.3%)
	Phytotherapy	41 (8.1%)

Table 2. Quantitative analysis of medicinal plants used to treat small ruminants diseases in Benin.

Family	Specie	Vernacular name	Origin	FC	CI
Anacardiaceae	*Mangifera indica* L.	Amanga (f)	From the garden	15	0.03
	Pupalia lappacea (L.) Juss.	Trèdoagboko(f)	From the wild	5	0.01
	Spondias mombin L.	Akikontin (f)	From the garden	105	0.208
Annonaceae	*Annona senegalensis* Pers.	Yariti (b)	From the wild	3	0.006
Apocynaceae	*Saba senegalensis* (A. DC.) Pichon	Agbankan (f)	From the wild	1	0.002
	Thevetia peruviana (Pers.) K.Sehum.	Tenia (w)	From the wild	2	0.004
Arecaceae	*Elaeis guineensis* Jacq.	Detin (f)	From the farm	24	0.047
Asclepiadaceae	*Calotropis procera* (Ait.) Ait. f	Sagayi (d)	From the garden	2	0.004
	Leptadenia hastata (Pers.) Decne	Sokpotoroï (p)	From the wild	1	0.002
	Pergularia daemia (Forssk.) Chiov.	Kpanyanwé (f)	From the wild	3	0.006
Asteraceae	*Acanthospermum hispidum* De.	Véglè (f)	From the wild	1	0.002
	Chromolaena odorata (L.) R.M.King	Agatoutin (f)	From the wild	4	0.008
	Tridax procumbens (L.) L.	Azouiman (f)	From the farm	2	0.004
	Vernonia amygdalina Delile	Kakawaabou (w)	From the garden	17	0.034
Bignoniaceae	*Newbouldia laevis* (P. Beauv.) Seem	Désrégué (f)	From the garden	20	0.04
	Stereospermum kunthianum Cham	Bewebe (b)	From the wild	1	0.002
Boraginaceae	*Rhodognaphalon brevicuspe* (Sprague) Roberty	Kpatin dèhoun (f)	From the wild	15	0.03
Caricaceae	*Carica papaya* L.	Kpèntin (f)	From the garden	10	0.02
Chrysobalanaceae	*Maranthes polyandra* (Benth.) Prance	Kpakpiru (b)	From the wild	2	0.004
Combretaceae	*Anogeissus leiocarpa* (DC.) Guill. & Perr.	Aligbangangni (p)	From the wild	8	0.016
	Combretum glutinosum Perr. ex De	Bousson (o)	From the wild	16	0.032
	Guiera senegalensis J.F. Gmel	Gueloké (p)	From the wild	2	0.004
	Pteleopsis suberosa Engl. & Diels	Kouantouanibou (w)	From the wild	1	0.002
	Terminalia avicennioides Guill. & Perr.	Tigéréi (p)	From the wild	3	0.006
Connaraceae	Rourea coccinea (Thonn. ex Schumach.) Benth.	Gbèdégbèdé (f)	From the wild	3	0.006
Crassulaceae	*Bryophyllum pinnatum* (Lam.) Oken	Dodoèti (a)	From the wild	1	0.002
Cucurbitaceae	*Momordica charantia* L.1753	Gninsikin (f)	From the wild	12	0.024
Dichapetalaceae	*Dichapetalum madagascariense* Poir.	Gbaglo (f)	From the wild	1	0.002
Dioscoreaceae	*Dioscorea hirtijlora Benth.*	Dinanton (o)	From the wild	20	0.04
Ebenaceae	*Diospyros mespiliformis* Hochst. ex A. Rich	Wonyibu (b)	From the wild	4	0.008
Euphorbiaceae	*Bridelia ferruginea* Benth.	Hlinhon (s)	From the wild	2	0.004
	Euphorbia balsamifera Aiton	Tchouloyi (p)	From the wild	3	0.006
	Euphorbia poissonii Pax	Lokoto (d)	From the wild	4	0.008
	Flueggea virosa (Roxb. ex Willd.) Voigt	Gbayikuntin (f)	From the wild	1	0.002
	Jatropha eureas L.	Nyikpotin (f)	From the wild	2	0.004
	Manihot esculenta Crantz	Ajangun (f)	From the farm	4	0.008
	Margaritaria discoidea (Baill.) Webster	Wusu poyi (b)	From the wild	1	0.002
Icacinaceae	*Icacina trichantha* Oliv.	Agbebetin (f)	From the wild	2	0.004
Irvingiaceae	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill.	Aslotin (f)	From the garden	1	0.002
Lamiaceae	*Hyptis suaveolens* (L.) Poit.	Azongbidi (f)	From the farm	3	0.006
	Ocimum gratissimum L.	Tchayo (f)	From the garden	35	0.069
	Platostoma africanum P.Beauv.	Siman (f)	From the wild	1	0.002
Leguminosae	*Acacia gourmaensis* A. Chev	Taani (p)	From the wild	11	0.022
	Acacia macrostachya Reichenb. ex DC	Sacounwa (p)	From the wild	1	0.002
	Acacia nilotica (L.) Willd. ex Del.	Gawaï (p)	From the wild	2	0.004
	Afzelia africana Smith ex Pers	Kparcabou (w)	From the wild	2	0.004
	Caesalpinia bonduc (L.) Roxb.	Ajikuntin (f)	From the garden	26	0.051
	Cajanus cajan (L.) Millsp.	Ottriri (w)	From the farm	3	0.006
	Gliricidia sepium (Jacq.) Kunth ex Walp.	Tchantaré (w)	From the farm	5	0.01
	Leucaena leucocephala (Lam.) De Wit	Fofitin (f)	From the farm	2	0.004
	Mucuna pruriens (L.) DC. var. pruriens	Kpassahonti (f)	From the farm	2	0.004
	Parkia biglobosa (Jacq.) R. Br. ex G. Don	Ahwatin (f)	From the farm	4	0.008
	Pericopsis laxiflora (Benth.) van Meeuwen	Wesaju (f)	From the wild	2	0.004
	Piliostigma reticulatum (DC.) Hochst	Klànloma (f)	From the wild	1	0.002
	Piliostigma thonningii (Schumach.) Milne-Redh	Klànloma (f)	From the wild	4	0.008
	Prosopis africana (GuilI. & Perr.) Taub	Kohi (p)	From the wild	3	0.006
	Pterocarpus erinaceus Poir	Gbèngètin (f)	From the wild	15	0.03
	Senna alata (L.) Roxb	Amasu (f)	From the wild	1	0.002

(*continued on next page*)

Table 2 (*continued*)

Family	Specie	Vernacular name	Origin	FC	CI
	Senna occidentalis (L.) Link	Kinikiniba (f)	From the wild	3	0.006
	Senna siamea (Lam.) H.S.Irwin & Barneby	kenu ma (f)	From the wild	1	0.002
	Tamarindus indica L.	Bobose (b)	From the wild	2	0.004
	Vigna racemosa (G.Don) Hutch. & Dalziel	Azigbé (f)	From the wild	1	0.002
	Vigna unguiculata (L.) Walp.	Yimbè (p)	From the farm	4	0.008
	Vitellaria paradoxa C.F.Gaertn., 1807	Karei (p)	From the farm	6	0.012
Malvaceae	*Abelmosehus eseulentus* (L.) Moench.	Laadjè (p)	From the farm	2	0.004
	Adansonia digitata L., 1753	Kpassa (f)	From the farm	40	0.079
	Hibiscus sabdariffa L., 1753	Pomla (w)	From the wild	4	0.008
Meliaceae	*Azadirachta indica* A. Juss	Kininutin (f)	From the garden	19	0.038
	Khaya senegalensis (Desr.) A. Juss	Boukoua (o)	From the garden	61	0.121
	Pseudocedrela kotschyi (Schweinf.) Harms	Totosiré (w)	From the wild	1	0.002
Moraceae	*Ficus exasperata* Vahl	Gannou (b)	From the garden	2	0.004
	Ficus sur Forssk.	Volima (f)	From the garden	2	0.004
	Ficus sycomorus L., 1767	Moukamkambou (o)	From the garden	13	0.026
	Ficus umbellata Vahl	Voma (f)	From the garden	1	0.002
Moringaceae	*Moringa oleifera* Lam	Yovokpatin (f)	From the garden	53	0.105
Myrtaceae	*Eucalyptus camaldulensis* Dehn	Boboro (o)	From the farm	2	0.004
	Psidium guajava L.	Samporu (b)	From the wild	1	0.002
	Psidium guineense Sw.	Kenkun (f)	From the wild	6	0.012
Ochnaceae	*Lophira lanceolata* Tiegh. ex Keay	Karerei (p)	From the wild	2	0.004
Olacaceae	*Ximenia americana* L.	Minimbou (w)	From the wild	3	0.006
Opiliaceae	*Opilia amentacea* Roxb.	Soukosoukoï (p)	From the wild	1	0.002
Pedaliaceae	*Sesamum indicum* L.	Agboma (f)	From the wild	2	0.004
Poaceae	*Dendrocalamus asper* (Schult.) Backer	Bambou (b)	From the wild	1	0.002
Polygalaceae	*Securidaca longipedunculata* Fres.	Wapobou	From the wild	1	0.002
Rubiaceae	*Crossopteryx febrifuga* (Afzel. ex G. Don) Benth	Rimatajoguaï (p)	From the wild	7	0.014
	Mitragyna inermis (Willd.) Kuntze	Kabe (d)	From the wild	5	0.01
	Morinda lucida Benth.	Tchiketi (a)	From the farm	55	0.109
	Sarcocephalus latifolius (Sm.) E.A.Bruce	Godotin (f)	From the wild	2	0.004
Rutaceae	*Citrus limon* (L.) Burm.f	Yovozin (f)	From the garden	3	0.006
	Zanthoxylum zanthoxyloides (Lam.) Watermann	Hètin (f)	From the farm	63	0.125
Sapindaceae	*Blighia sapida* Koenig	Pouroumbou (w)	From the garden	1	0.002
Scrophulariaceae	*Striga hermonthica* (Delile) Benth.	Manli (d)	From the wild	52	0.103
Solanaceae	*Datura innoxia* Mill., 1768	Cocaine (w)	From the wild	4	0.008
	Nicotiana tabacum L	Titabaati (o)	From the garden	4	0.008
	Solanum dasyphyllum Schumach. &Thonn	Tibouanacard (o)	From the garden	14	0.028
Tiliaceae	*Grewia mollis* Juss.	Sahambou (w)	From the wild	1	0.002
Verbenaceae	*Gmelina arborea* Roxb.	Fofitin (f)	From the wild	1	0.002
	Vitex doniana Sweet, 18271	Goumei (p)	From the farm	8	0.016
Vitaceae	*Cissus populnea* Guill. & Perr	Lakaï (p)	From the wild	7	0.014
	Cissus quadrangularis L	Hamberiteli (p)	From the wild	4	0.008
Zygophyllaceae	*Balanites aegyptiaca* (L.) Delile	Garbè (d)	From the wild	5	0.01

Vernacular language: f = Fon; b = Bariba; o = Otammari; p = Peulh; s = Sahouè; d = Dendi; w = Wama; n = Natimba; a = Adja FC: Frequency of citation; and CI: Cultural Importance Index.

used to treat small ruminants diseases and improve their productivity, the parts used (roots, bark, leaves), recipe preparation, difficulties related to plant usage, development of the formulation and degree of satisfaction (efficacy of plants). The survey was conducted in the local languages of each community and local interpreters were used if necessary.

2.4. Plant collection and identification

At the end of each interview, voucher specimens of inventoried plants were obtained from interviewees, harvested from the wild, farm or garden. Herbarium specimens were mounted and identified at the National Herbarium of Benin, University of Abomey-Calavi, using the analytical flora of Benin (Akoègninou et al., 2006). Plant specimens were coded and deposited in the herbarium. It was not possible to obtain specimens for all plants. There were seasonal plants that were not available during the survey. We therefore deleted the data for these plants (3 plants) before data analysis.

2.5. Data analysis

2.5.1. Diversity of inventoried medicinal plants

The collected data were used to establish the list of inventoried plants to treat small ruminants diseases. The number of species by genus and family was determined. To assess the diversity of plants used to treat small ruminants diseases, the Generic Coefficient (Rgc) which is the ratio number of species (Ns) over number of genera (Ng) (the inverse of the ratio defined by Fan et al. (2017) was determined (Equation 2).

$$Rgc = \frac{Ns}{Ng} \quad (2)$$

With Ns being the number of inventoried species, Ng the number of genera and Rgc the Generic Coefficient. If Rgc = 1, then the plants used to treat small ruminants diseases have low diversity. Otherwise, each inventoried genera has only one species. If Rgc >1, there is a high generic diversity within plants used to treat small ruminants diseases.

2.5.2. Quantitative analysis of inventoried medicinal plant species

To assess the most important medicinal species in the treatment of sheep and goats diseases in Benin, the CI was determined (Tardío and Pardo-De-Santayana, 2008) (Equation 3).

$$CI = \sum_{U=u1}^{Udg} \sum_{I=1}^{In} \frac{URui}{N} \quad (3)$$

Where dg being the total number of diseases groups, N being the number of respondents, UR being Use-Report number and CI being the Cultural Importance Index. The more the CI of a plant tends towards 1, the more important it is to the community.

2.5.3. Recorded small ruminants disease groups

The symptoms cited by the respondents were categorized into 10 disease groups using the second version of International Classification of Primary Care (ICPC-2, 2003) as suggested by Staub et al. (2015) and previously used by Miara et al. (2019). The ICF of Heinrich et al. (1998) were calculated to determine the level of consensus around the plants used to treat each disease category. It is calculated according to the formula below (Equation 4).

$$ICF = \frac{Nur - Nt}{Nur - 1} \quad (4)$$

With Nur being the number of times a particular category p of disorders is mentioned, Nt being the number of plant (s) mentioned for the treatment of this particular disorders p. If ICF >0.5, then there is a high degree of consensus. In other words, the respondents agree on the plants used to treat this disease category. On the other hand, if ICF <0.5, this means that the respondents do not agree on the plants needed to treat this disease group.

2.5.4. Main plants used to treat disease groups

The analysis of the collected data made it possible to propose a list of plants used to treat each disease group. The majority of plant species are used to treat two or more disease categories. Thus, to select the most appropriate plants for the treatment of each disease category, the FL of Friedman et al. (1986) was calculated (Equation 5).

$$FL = \frac{Np}{N} \quad (5)$$

With Np being the number of informants who mentioned a species for the treatment of a disease category p; N being the number of informants who mention the species for any disease category and FL being the Fidelity level. If FL > 0.5, then there is a high degree of consensus around the use of this species for the treatment of this disease category p and therefore this plant seems appropriate to treat this type of disease.

2.5.5. Socioeconomic and environmental factors affecting ethnoveterinary knowledge level

A matrix was constructed using socioeconomic and environmental factors (age, gender, ethnicity, agro-ecological zone, religion, household size, educational level, small ruminants herd size and the origin of the knowledge) as independent variables and the number of plants cited for the treatment of small ruminants diseases as a dependent variable. A classification analysis based on a decision tree was applied to the matrix to access socioeconomic and environmental factors which affect local knowledge to treat small ruminants diseases with plants. The analysis were carried out in R software (R Core Team, 2013), using rpartordinal package as describing by Archer (2010) and the differences were considered significant at the 5% level. Analyse of variance was performed for each factor affecting ethnoveterinary knowledge level, to access how factors influence ethnoveterinary practices.

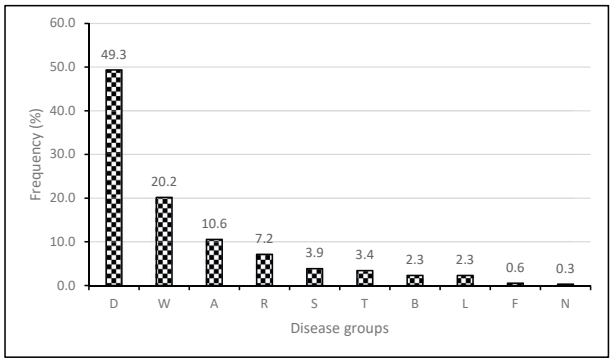

Figure 2. Disease groups encountered in small ruminants flocks in Benin. A: general and non-specific disorders; B: blood and hematopoietic organ disorders; D: digestive disorders; F: eye diseases; L: musculoskeletal disorders; N: neurological disorders; R: respiratory disorders; S: skin disorders; T: metabolic and nutritional diseases and W: reproductive disorders.

3. Results and discussion

3.1. Socioeconomic characteristics of the respondents

A total of 506 small ruminants breeders were surveyed. They belonged to 9 sociocultural groups across Benin, namely Fon (24.9%), Otammari (15.4%), Peulh (12.5%), Sahoue (12.3%), Adja (12.1%), Dendi (9.5%), Wama (4.9%), Natimba (4.6%) and Bariba (3.9%). The average age of the respondents was 49 ± 16 years. The majority of the people surveyed were men (72.9%) (Table 1). This was probably due to the purposive selection of respondents who were mostly heads of households. Indeed, for cultural reasons, women are not called upon to speak publicly, especially about traditional knowledge. During the survey, some women who own small ruminants preferred to let their husbands speak because they felt that their husbands had a better knowledge of this aspect of animal breeding. This confirms the observations of Hounzangbé-Adoté (2001) who concludes that women have practically no knowledge of ethnoveterinary practices. Interviews with the women during the survey took place in case of absence of the husband (head of the household) or with widows. Most of those surveyed personne were

Table 3. Informant Consensus Factor (ICF) of each disease category.

Disease category	Nur	Nt	ICF
Digestive dosorders (D)	448	72	0.8
Reproductive disorders (W)	183	34	0.8
Blood and hematopoietic organ disorders (B)	21	5	0.8
Musculoskeletaldisorders (L)	21	6	0.8
General and non-specific disorders (A)	96	29	0.7
Metabolic and nutritional diseases (T)	31	10	0.7
Respiratory disorders (R)	65	25	0.6
Neurological disorders (N)	3	2	0.5
Skin disorders (S)	35	19	0.5
Eye diseases (F)	5	5	0.0

Nur: Number of times a particular category p of disorders is mentioned, Nt: Number of plant (s) mentioned for the treatment of this particular disorders groups, ICF: Informant Consensus Factor.

Table 4. List of traditional recipes used to treat small ruminants diseases in Benin.

Plant	FC	CS	VN	PP	PM	AR
Digestive disorders (D)						
Zanthoxylum zanthoxyloides (Lam.) Watermann	61	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Gr	Ora
Striga hermonthica (Delile) Benth.	46	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Wp	Po	Ora
Adansonia digitata L., 1753	31	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Po	Ora
Khaya senegalensis (Desr.) A.Juss.	31	Dia, Ind, Ano	Misrasra (f) Domédédé (a)	Ba,	Ma, De	Ora
Morinda lucida Benth.	29	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Gr	Ora
Spondias mombin L.	23	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Gr	Ora
Moringa oleifera Lam.	22	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Po, De	Ora
Elaeis guineensis Jacq.	20	Dia, Ind,	Dan do homé (d) Vlonkou le home (o)	Le	Gr	Ora
Caesalpinia bonduc (L.) Roxb.	19	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	De, Gr	Ora
Azadirachta indica A. Juss	14	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le, Ba	Ma, Po	Ora
Pterocarpus erinaceus Poir	13	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ba, Le	Po, Ma	Ora
Newbouldia laevis (P. Beauv.) Seem	12	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Tr, Gr	Ora
Vernonia amygdalina Delile	11	Dia, Gap	Dan do homé (d) Vlonkou le home (o)	Le	Gr, Tr	Ora
Ocimum gratissimum L.	10	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Tr, De	Ora
Carica papaya L.	9	Dia, Ind	Dan do homé (d) Vlonkou le home (o)	Se	Po	Ora
Momordica charantia L., 1753	7	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Tr, Ma	Ora
Anogeissus leiocarpa (DC.) Guill. & Perr.	6	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le, Ba	Ma, De	Ora
Vitex doniana Sweet, 18271	5	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ba	De, Ma	Ora
Balanites aegyptiaca (L.) Delile	4	Ind, Gap	Dan do homé (d) Vlonkou le home (o)	Se	Ma	Ora
Datura innoxia Mill., 1768	4	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Ma	Ora
Euphorbia poissonii Pax	4	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	St, Le	Ma	Ora
Psidium guineense Sw.	4	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Gr,	Ora
Crossopteryx febrifuga (Afzel. ex G. Don) Benth	3	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le, Ba	Po	Ora
Hibiscus sabdariffa L., 1753	3	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	De	Ora
Mangifera indica L.	3	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le, Ba	Ma, Gr	Ora
Ximenia americana L.	3	Dia, Ind	Dan do homé (d) Vlonkou le home (o)	Ro	Po, De	Ora
Acacia nilotica (L.) Willd. ex Delile	2	Dia, Ind	Dan do homé (d) Vlonkou le home (o)	Se	De	Ora
Bridelia ferruginea Benth.	2	Dia, Ind	Dan do homé (d) Vlonkou le home (o)	Le	Gr	Ora
Citrus limon (L.) Burm.f	2	Dia, Ind	Dan do homé (d) Vlonkou le home (o)	Le	Po, De	Ora
Ficus sycomorus L., 1767	2	Dia, Ind	Dan do homé (d) Vlonkou le home (o)	Le	Gr	Ora
Gliricidia sepium (Jacq.) Walp.	2	Dia, Ind	Dan do homé (d) Vlonkou le home (o)	Le	Gr	Ora
Icacina trichantha Oliv.	2	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Gr, De	Ora
Jatropha eureas L.	2	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ro	Ma	Ora
Manihot esculenta Crantz	2	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Gr	Ora
Mitragyna inermis (Willd.) Kuntze	2	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ba	Ma	Ora
Parkia biglobosa (Jacq.) R. Br. ex G. Don	2	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ba, Se	Ma, Po	Ora
Senna occidentalis (L.) Link	2	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Gr	Ora
Terminalia avicennioides Guill. & Perr.	2	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ro	De,	Ora
Thevetia peruviana (Pers.) K.Sehum.	2	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Tr	Ora
Abelmosehus eseulentus (L.) Moench.	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	St	De	Ora
Acanthospermum hispidum De.	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Tr	Ora
Blighia sapida Koenig	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le, Ba	Po	Ora
Cajanus cajan (L.) Millsp.	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Gr	Ora
Chromolaena odorata (L.) R.M.King	1	Dia	Misrasra (f) Domédédé (a)	Le	Gr	Ora
Cissus quadrangularis L.	1	Dia, Ind	Misrasra (f) Ehodjidji (w)	St	Ma,	Ora
Dichapetalum madagascariense Poir.	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Gr	Ora
Diospyros mespiliformis Hochst. ex A. Rich	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Ma, Gr	Ora
Eucalyptus camaldulensis Dehn	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le, Ba	Ma	Ora
Grewia mollis Juss.	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ba	Tr	Ora
Hyptis suaveolens (L.) Poit.	1	Dia, Ind,	Misrasra (f) Ehodjidji (w)	Le, St	De	Ora
Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill.	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Gr	Ora
Lophira lanceolata Tiegh. ex Keay	1	Dia, Ind	Misrasra (f) Ehodjidji (w)	Ba, Le	De	Ora
Maranthes polyandra (Benth.) Prance	1	Dia, Ind	Misrasra (f) Ehodjidji (w)	Ba, Ro	Po, De	Ora
Margaritaria discoidea (Baill.) Webster	1	Dia, Ind	Misrasra (f) Ehodjidji (w)	Ba	Po	Ora
Mucuna pruriens (L.) DC. var. pruriens	1	Dia, Ind	Misrasra (f) Ehodjidji (w)	Le	Gr	Ora
Nicotiana tabacum L.	1	Dia, Ind	Misrasra (f) Ehodjidji (w)	Le, St	De, Po	Ora
Pericopsis laxiflora (Benth.) van Meeuwen	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ba	Ma, Po	Ora

(*continued on next page*)

Table 4 (*continued*)

Plant	FC	CS	VN	PP	PM	AR
Piliostigma reticulatum (DC.) Hochst	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ba	Ma	Ora
Piliostigma thonningii (Schumach.) Milne-Redh.	1	Ind	Adogo houn (p)	Le	Ma, De	Ora
Prosopis africana (GuilI. & Perr.) Taub	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ba	Po, De	Ora
Pseudocedrela kotschyi (Schweinf.) Harms	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ba	Po	Ora
Psidium guajava L.	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Po	Ora
Pteleopsis suberosa Engl. & Diels	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ba	De	Ora
Pupalia lappacea (L.) Juss.	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Tr, Gr	Ora
Rhodognaphalon brevicuspe (Sprague)Roberty	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Gr, Tr	Ora
Saba senegalensis (A. DC.) Pichon	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	De	Ora
Sarcocephalus latifolius (Sm.) E.A.Bruce	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Ba, Ro	Ma	Ora
Securidaca longipedunculata Fres.	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Po	Ora
Solanum dasyphyllum Schumach. &Thonn	1	Dia, Ind, Gap	Misrasra (f) Domédédé (a)	Le	Po	Ora
Tridax procumbens L.	1	Ind, Ano	Enoumado (n) Ehodjidji (a)	Le	Tr, Gr	Ora
Vigna racemosa (G.Don) Hutch. & Dalziel	1	Dia	Misrasra (f)	Le	Gr	Ora
Vitellaria paradoxa C.F.Gaertn., 1807	1	Dia, Ind	Misrasra (f) Ehodjidji (a)	Ba	Ma, De	Ora
Reproductive disorders (W)						
Spondias mombin L.	79	Dys, Rep	Evi djidji gbonnou (a) Viko tonan (f)	Le	Tr	Loc
Rhodognaphalon brevicuspe (Sprague)Roberty	14	Dys, Rep, Aga	Sin ton do anonminan (w)	Le	Gr, Tr	Ora
Solanum dasyphyllum Schumach. &Thonn	13	Dys, Rep	Evi djidji gbonnou (a) Viko tonan (f)	Wp	-	Loc
Acacia gourmaensis A. Chev	11	Dys, Rep	Evi djidji gbonnou (a) Viko tonan (f)	Ba	Po	Ora
Ficus sycomorus L., 1767	10	Dys, Rep	Evi djidji gbonnou (a) Viko tonan (f)	Le	Gr	Ora
Cissus populnea Guill. & Perr	6	Dys, Rep, Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	St, Ro	Po	Ora
Newbouldia laevis (P. Beauv.) Seem	5	Dys, Rep	Evi djidji gbonnou (a) Viko tonan (f)	Le	Tr, Gr	Ora
Vigna unguiculata (L.) Walp.	4	Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Se	Po, Gr	Ora
Crossopteryx febrifuga (Afzel. ex G. Don) Benth	3	Dys, Rep, Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le, Ba	Po	Ora
Euphorbia balsamifera Aiton	3	Dys, Rep, Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le, St	De	Ora
Rourea coccinea (Thonn. ex Schumach.) Benth.	3	Dys, Rep, Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	Gr, Tr	Ora
Striga hermonthica (DeliIe) Benth.	3	Dys, Rep	Evi djidji gbonnou (a) Viko tonan (f)	Wp	Po	Ora
Annona senegalensis Pers	2	Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	Gr,	Ora
Calotropis procera (Ait.) Ait. f	2	Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	De	Ora
Manihot esculenta Crantz	2	Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	Gr	Ora
Morinda lucida Benth.	2	Dys, Rep, Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	Gr	Ora
Moringa oleifera Lam.	2	Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	Po, De	Ora
Sesamum indicum L.	2	Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	Gr	Ora
Zanthoxylum zanthoxyloides (Lam.) Watermann	2	Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	Gr	Ora
Abelmosehus eseulentus (L.) Moench.	1	Dys, Rep	Evi djidji gbonnou (a) Viko tonan (f)	St	De	Ora
Adansonia digitata L., 1753	1	Dys, Mas	Evi djidji gbonnou (a) Anon dor (b)	Ba, Le	Po,	Ora
Afzelia africana Smith ex Pers	1	Dys, Rep, Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	Po	Ora
Caesalpinia bonduc (L.) Roxb.	1	Dys, Rep, Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	De, Gr	Ora
Chromolaena odorata (L.) R.M.King	1	Dys, Rep, Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	Tr, Ma, Gr	Der, Ora
Diospyros mespiliformis Hochst.	1	Dys, Rep	Evi djidji gbonnou (a) Viko tonan (f)	Le	Ma, Gr	Ora
Ficus sur Forssk.	1	Dys, Rep	Evi djidji gbonnou (a) Viko tonan (f)	Le	Gr, De	Ora
Leptadenia hastata (Pers.) Decne	1	Rep, Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le	Ma	Ora
Mangifera indica L.	1	Dys, Aga, Mas	Sin ton do anonminan (w) Anon dor (b)	Le, Ba	Ma, Gr	Ora
Mitragyna inermis (Willd.) Kuntze	1	Dys, Rep, Aga, Mas	Evi djidji gbonnou (a) Viko tonan (f)	Ba	Ma	Ora
Pergularia daemia (Forssk.) Chiov.	1	Dys, Rep, Aga, Mas	Evi djidji gbonnou (a) Viko tonan (f)	Le	Tr	Ocu
Piliostigma thonningii (Schumach.) Milne-Redh	1	Aga, Mas	Anon macorchi (d)	Le	Ma, De	Ora
Prosopis africana (GuilI. & Perr.) Taub	1	Dys, Mas	Evi djidji gbonnou (a) Anon dor (b)	Ba	Po, De	Ora
Psidium guineense Sw.	1	Dys	Evi djidji gbonnou (a)	Le	Gr,	Ora
Vernonia amygdalina Delile	1	Dys	Evi djidji gbonnou (a)	Le	Gr, Tr	Ora
Respiratory disorders (R)						
Ocimum gratissimum L.	20	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Le	Tr	Nas
Mangifera indica L.	10	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Le, Ba	Ma, Gr	Ora
Khaya senegalensis (Desr.) A.Juss.	7	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Ba,	Ma, De	Ora
Dioscorea hirtijlora Benth.	3	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Ro	Ma, Po	Ora
Vernonia amygdalina Delile	3	Cou	Kpin (f) Ekpin (a)	Le	Gr, Tr	Ora
Azadirachta indica A. Juss	2	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Le, Ba	Ma, Po	Ora
Parkia biglobosa (Jacq.) R. Br. ex G. Don	2	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Ba, Se	Ma, Po	Ora
Adansonia digitata L., 1753	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Ba, Le	Po,	Ora

(*continued on next page*)

Table 4 (*continued*)

Plant	FC	CS	VN	PP	PM	AR
Caesalpinia bonduc (L.) Roxb.	1	Cou	Kpin (f)	Le	De, Gr	Ora
Cissus quadrangularis L.	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	St	Ma	Ora
Dendrocalamus asper (Schult.) Backer	1	Cou	Kpin (f)	St	De	Nas
Lophira lanceolata Tiegh. ex Keay	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Ba, Le	De	Ora
Momordica charantia L.	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Le	Tr, Ma	Ora
Morinda lucida Benth.	1	Nad	Hontchichou (w)	Le	Gr	Ora
Newbouldia laevis (P. Beauv.) Seem	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Le	Tr, Gr	Ora
Opilia amentacea Roxb.	1	Nad	Hontchichou (w)	Le	De	Ora
Platostoma africanum P.Beauv.	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Le	Ma	Ora
Psidium guineense Sw.	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Le	Gr,	Ora
Pterocarpus erinaceus Poir	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Ba, Le	Po, Ma	Ora
Senna occidentalis (L.) Link	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Le	Gr	Ora
Senna siamea (Lam.) H.S.Irwin & Barneby	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Le	De	Ora
Stereospermum kunthianum Cham	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Ba	De	Ora
Striga hermonthica (Delile) Benth.	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Wp	Po	Ora
Tamarindus indica L.	1	Cou, Nad	Kpin (f) Ekpin (a) Amisin (f)	Le	De	Ora
Vitellaria paradoxa Gaertn. f	1	Nad	Hontchichou (w)	Ba	Ma, De	Ora
General and non-specific disorders (A)						
Morinda lucida Benth.	23	Fev, Prh	Xoxo (f) Efou tchite (a)	Le	Gr	Ora
Khaya senegalensis (Desr.) A. Juss	16	Fev	Xoxo (f)	Ba,	Ma, De	Ora
Moringa oleifera Lam.	16	Fev, Prh	Foun tchité (b) zoozou (o)	Le	Po, De	Ora
Caesalpinia bonduc (L.) Roxb.	5	Fev, Prh	Foun tchité (b) zoozou (o)	Le	De, Gr	Ora
Anogeissus leiocarpa (DC.) Guill. & Perr.	2	Prh	Efou tchite (a)	Le, Ba	Ma, De	Ora
Azadirachta indica A.Juss.	2	Fev, Prh	Foun tchité (b) zoozou (o)	Le, Ba	Ma, Po	Ora
Cajanus cajan Harms	2	Fev, Prh	Foun tchité (b) zoozou (o)	Le	Gr	Ora
Cissus quadrangularis L.	2	Fev	Xoxo (f)	St	Ma,	Ora
Hyptis suaveolens (L.) Poit.	2	Fev, Prh	Xoxo (f) Efou tchite (a)	Le, St	De	Ora
Mitragyna inermis (Willd.) Kuntze	2	Fev, Prh	Xoxo (f) Efou tchite (a)	Ba	Ma	Ora
Momordica charantia L.	2	Fev, Prh	Xoxo (f) Efou tchite (a)	Le	Tr, Ma	Ora
Newbouldia laevis (P. Beauv.) Seem	2	Fev, Prh	Xoxo (f) Efou tchite (a)	Le	Tr, Gr	Ora
Ocimum gratissimum L.	2	Fev, Prh	Xoxo (f) Efou tchite (a)	Le	De	Ora
Spondias mombin L.	2	Fev, Prh	Xoxo (f) Efou tchite (a)	Le	Gr, Tr	Ora
Vitellaria paradoxa C.F.Gaertn., 1807	2	Fev, Prh	Xoxo (f) Efou tchite (a)	Ba	Ma, De	Ora
Afzelia africana Smith ex Pers	1	Fev, Prh	Xoxo (f) Efou tchite (a)	Le	Po	Ora
Bryophyllum pinnatum (Lam.) Oken	1	Prh	Efou tchite (a)	Le	Gr	Ora
Ficus sur Forssk.	1	Fev, Prh	Foun tchité (b) zoozou (o)	Le	Gr, De	Ora
Flueggea virosa (Roxb. ex Willd.) Voigt	1	Fev, Prh	Foun tchité (b) zoozou (o)	Le	Gr	Ora
Gliricidia sepium (Jacq.) Kunth ex Walp.	1	Fev, Prh	Foun tchité (b) zoozou (o)	Le	Gr	Ora
Gmelina arborea Roxb.	1	Fev, Prh	Foun tchité (b) zoozou (o)	Le	Gr	Ora
Leucaena leucocephala (Lam.) De Wit	1	Fev, Prh	Foun tchité (b) zoozou (o)	Le	Gr	Ora
Prosopis africana (GuilI. & Perr.) Taub	1	Fev, Prh	Foun tchité (b) zoozou (o)	Ba	Po, De	Ora
Pterocarpus erinaceus Poir	1	Fev, Prh	Foun tchité (b) zoozou (o)	Ba, Le	Po, Ma	Ora
Pupalia lappacea (L.) Juss.	1	Fev	zoozou (o)	Le	Gr	Ora
Senna alata (L.) Roxb	1	Fev, Prh	Foun tchité (b) zoozou (o)	Le	De	Ora
Striga hermonthica (Delile) Benth.	1	Fev, Prh	Foun tchité (b) zoozou (o)	Wp	Po	Ora
Tridax procumbens L.	1	Fev, Prh	Foun tchité (b) zoozou (o)	Le	Tr, Gr	Ora
Vernonia amygdalina Delile	1	Fev	Xoxo (f)	Le	Tr	Ora
Skin disorders (S)						
Khaya senegalensis (Desr.) A. Juss	7	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Ba,	Ma, De	Loca
Nicotiana tabacum L.	3	Wos	Tchaabè (p) Akli (f)	Le, St	De, Po	Der
Ocimum gratissimum L.	3	Sca	Edjekpo (a)	Le	Tr, De	Der
Pupalia lappacea (L.) JUSS.	3	Sca	Edjekpo (a)	Le	Tr	Der
Vitex doniana Sweet	3	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Ba	De, Ma	Ora
Chromolaena odorata (L.) R.M.King	2	Sca	Edjekpo (a)	Le	Tr	Der
Vitellaria paradoxa C.F.Gaertn., 1807	2	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Ba	Ma, De	Ora
Acacia macrostachya Reichenb. ex DC	1	Wos	Tchaabè (p) Akli (f)	Ba, Le	De	Ora
Annona senegalensis Pers.	1	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Le, Ba	Ma, De	Ora
Azadirachta indica A. Juss	1	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Le, Ba	Ma, Po	Ora
Carica papaya L.	1	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Se	Po	Der

(*continued on next page*)

Table 4 (*continued*)

Plant	FC	CS	VN	PP	PM	AR
Guiera senegalensis J.F.Gmel	1	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Le, Ba	Po	Ora
Mangifera indica L.	1	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Le, Ba	Ma, Gr	Ora
Maranthes polyandra (Benth.) Prance	1	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Ba, Ro	Po, De	Ora
Momordica charantia L.	1	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Le	Tr, Ma	Ora
Moringa oleifera Lam.	1	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Le	Po, De	Ora
Piliostigma thonningii (Schumach.) Milne-Redh	1	Sca	Edjekpo (a)	Le	Ma, De	Ora
Sarcocephalus latifolius (Sm.) E.A.Bruce	1	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Ba, Ro	Ma	Der
Spondias mombin L.	1	Sca, Wos	Tchaabè (p) Akli (f) Akpa (d)	Le	Tr	Loc
Metabolism, nutrition and endocrine disorders (T)						
Moringa oleifera Lam.	11	Ano, Avi, Stg	Esouya (f) Enoumado (a)	Le	Gr, Po, De	Ora
Adansonia digitata L., 1753	7	Stg	Esouya (f) Ehoueou yihoue (a)	Ba, Le	Po,	Ora
Elaeis guineensis Jacq.	4	Stg	Esouya (f) Ehoueou yihoue (a)	Le	Gr	Ora
Ficus exasperata Vahl	2	Stg	Esouya (f) Ehoueou yihoue (a)	Le	Po	Ora
Gliricidia sepium (Jacq.) Kunth ex Walp.	2	Stg	Esouya (f) Ehoueou yihoue (a)	Le	Gr	Ora
Ficus sycomorus L., 1767	1	Stg	Esouya (f) Ehoueou yihoue (a)	Le	Gr	Ora
Ficus umbellata Vahl	1	Stg	Esouya (f) Ehoueou yihoue (a)	B	Po	Ora
Khaya senegalensis (Desr.) A. Juss	1	Stg	Esouya (f) Ehoueou yihoue (a)	Ba,	Ma, De	Ora
Leucaena leucocephala (Lam.) De Wit	1	Avi, Stg	Esouya (f) Vitamine houedi (d)	Le	Gr	Ora
Momordica charantia L.	1	Ano, Stg	Esouya (f) Vitamine houedi (d)	Le	Tr, Ma	Ora
Blood and hematopoietic organs disorders (B)						
Dioscorea hirtijlora Benth.	17	Hae, Ana	Houn ton mandoté (f) Ehoun wedo (a)	Ro	Ma, Po	Ora
Crossopteryx febrifuga (Afzel. ex G. Don) Benth	1	Hae, Ana	Houn ton mandoté (f) Ehoun wedo (a)	Le, Ba	Po	Ora
Guiera senegalensis J.F. Gmel	1	Hae, Ana	Houn ton mandoté (f) Ehoun wedo (a)	Le, Ba	Po	Ora
Mucuna pruriens (L.) DC. var. pruriens	1	Hae, Ana	Houn ton mandoté (f) Ehoun wedo (a)	Le	Gr	Ora
Tamarindus indica L.	1	Hae, Ana	Houn ton mandoté (f) Ehoun wedo (a)	Le	De	Ora
Musculoskeletal disorders (L)						
Combretum glutinosum Perr. ex De	16	Bof	Ewin (o) Ehin (n)	Ba	Ma	Loc
Diospyros mespiliformis Hochst. ex A. Rich	1	Bof	Ewin (o) Ehin (n)	Le	Ma, Gr	Loc
Eucalyptus camaldulensis Dehn	1	Bof	Ewin (o) Ehin (n)	Le, Ba	Ma	Ora
Moringa oleifera Lam.	1	Bof	Ewin (o) Ehin (n)	Le	Po, De	Ora
Pericopsis laxiflora (Benth.) van Meeuwen	1	Bof	Ewin (o) Ehin (n)	Ba	Ma, Po	Ora
Piliostigma thonningii (Schumach.) Milne-Redh	1	Bof	Ewin (o) Ehin (n)	Le	Ma, De	Loc
Eye disorders (F)						
Balanites aegyptiaca (L.) Del.	1	Eyd, Ree	Nounkoun-mian (f)	Se	Ma	Ocu
Citrus limon (L.) Burm.f	1	Eyd	Ouncouvi ko nachi (a)	Le	Po, De	Ora
Hibiscus sabdariffa L., 1753	1	Eyd	Ouncouvi ko nachi (a)	Le	De	Ocu
Pergularia daemia (Forssk.) Chiov.	1	Eyd, Ree	Nounkoun-mian (f)	Le	Tr	Ocu
Terminalia avicennioides Guill. & Perr.	1	Eyd	Ouncouvi ko nachi (a)	Ro	De	Ora
Neurological disorders (N)						
Cissus populnea Guill. & Perr	1	Ner, Agi	Hominsin (f) Dormesi (p)	St, Ro	Po	Ora
Diospyros mespiliformis Hochst. ex A. Rich	1	Ner, Agi	Ewlawla (b) Hlahla (s)	Le	Ma, Gr	Ora

Notes: FC: Frequency of Citation; CS: Clinical signs (Dia: Diarrhea, Ind: Indigestion, Gap: Gastrointestinal parasitosis, Ano: Anorexia, Dys: Dystocia, Rep: Retained placenta, Aga: Agalactia, Mas: Mastitis, Cou: Cough, Nad: Nasal discharge, Fev: Fever, Prh: Prickly hairs, Sca: Scabies, Wos: Wound on the skin, Avi: Avitaminosis, Stg: Stunted growth, Hae: Haemorrhage Ana: Anaemia, Bof: Bone fracture, Eyd: Eye discharge, Ree: Red eye, Ner: Nervousness, Agi: Agitation); VN: Vernacular name (f = Fon; b = Bariba; o = Otammari; p = Peulh; s = Sahouè; d = Dendi; w = Wama; n = Natimba; a = Adja) PP: Plant Part (Le: Leaves, Ba: Bark, Se: Seed, Ro: Root, St: Stem, Wp: Whole plant); PM: Preparation Modes (Ma: Maceration, Gr: Grazing, Tr: Trituration, De: Decoction, Po: Powder); AR: Administration Route (Ora: Oral; Der: Dermal, Ocu: Ocular, Nas: Nasal, Loc: Local).

uneducated (67.2%) and had agriculture and livestock as their main activities. These results confirm the observations of Ogni et al. (2014), Usha et al. (2016) and Ouachinou et al. (2019) who showed that breeding is mainly done by uneducated people. In fact, small ruminants breeding is mainly done in rural areas, which concentrate the majority of the uneducated (Le Gall and Lebroucq, 2003), although more and more sheep and goats farming is encountered in periurban areas (Dossa et al., 2015). On average, those surveyed kept 10 ± 11 heads of small ruminants, which is relatively high compared to that found by Hounzangbé-Adoté (2001) and Lakew et al. (2017). This could be related to the choice of agro-ecological zones where small ruminants breeding is predominant.

3.2. Diversity of inventoried medicinal plants

A total of 101 species of medicinal plants belonging to 42 families and 90 genera were inventoried during the survey (Table 2). The richest families were Leguminosae (22 species, 21.6%), Euphorbiaceae (7 species, 6.9%), Combretaceae (5 species, 4.9%), Rubiaceae (4 species, 3.9%), Moraceae (4 species, 3.9%), Meliaceae (4 species, 3.9%) and Asteraceae (4 species, 3.9%). The Rgc was 1.1, which indicates the high diversity of medicinal species used to treat small ruminants diseases. This implies that each genera holds in average more than one specie. The genera with high species number were Ficus (4 species), Acacia (3 species) and Sena (3 species).This diversity is very high compared to those

obtained by Tamboura et al. (1998), Hounzangbé-Adoté (2001), Yineger et al. (2007), Usha et al. (2016), Ahoyo et al. (2017) and Kebede et al. (2018) but low compared to values of Dassou et al. (2015a) and Ouachinou et al. (2019). This difference may be explained by variation of knowledge between the sociocultural groups. This high diversity could also be explained by the fact that the study covered multiple agro-ecological zones that contain different plant species. Indeed, Houinato and Sinsin (2002) have shown that vegetation varies according to agro-ecological zones. A high diversity of small ruminants diseases can justify also the high diversity of medicinal plants used by breeders.The high diversity observed in this study testifies the importance of ethno-veterinary practices in the health care of sheep and goats. Indeed, according to the breeders, herbal remedies are first offered to animals after observations of pathological signs and it is after the failure of these that they call the veterinarian or technician. The CI ranged from 0.002 to 0.208. The most important plants in the treatment of sheep and goats diseases were *Spondias mombin*, *Zanthoxylum zanthoxyloides*, *Khaya senegalensis*, *Morinda lucida* and *Moringa oleifera* with CI of 0.208, 0.125, 0.121, 0.109 and 0.105, respectively. These different species were previously inventoried in ethnobotanical surveys (Hounzangbé-Adoté, 2001; Kabore et al., 2007; Attindéhou et al., 2012; Dassou et al., 2015a; Ouachinou et al., 2019).

3.3. Ethnoveterinary knowledge and main disease groups of small ruminants

Ten disease categories were identified in our survey. These were mainly digestive disorders (D: diarrhea, indigestion, anorexia, gastrointestinal parasitosis) cited by 49.3% of respondents. This disease group was followed by reproductive disorders (W: dystocia, mastitis, agalactia, retained placenta), general and non-specific disorders (A: fever, anorexia) and respiratory disorders (R: cough, nasal discharge) cited respectively, by 20.2%, 10.6% and 7.2% of the respondents (Figure 2). These results corroborate those of Hounzangbé-Adoté (2001), Dossa et al. (2007), Ogni et al. (2014) and Lakew et al. (2017) who found that the main symptoms encountered in small ruminants farms are diarrhea, anorexia and gastrointestinal parasitosis, which lead to high mortality. According to the breeders, these diseases are more common in the rainy season and are probably related to moisture that promotes the development of pathogens. Indeed, Underwood et al. (2015) have shown that, ruminants breeding environment contains multiple pathogenic bacteria and fungi which cause diseases. According to these authors, the development of these pathogens is depending of several environmental factors, including moisture and temperature. Reproductive disorders (W) are the second category of disorders that was frequently cited by respondents. Ogni et al. (2014) and Dassou et al. (2015a) made the similar observations in some Beninese farms. Indeed, this category of disorders includes cases of dystocia, mastitis and agalactia. This was probably due to the lack of hygiene in the farms, which promotes the development of infectious agents and contamination of reproductive organs such as udders. In fact, Al-Momani et al. (2008) have shown that small ruminants agalactia in northern Jordan is associated with some production and health management practices. In addition, uncontrolled mating between different breeds may be the reason of dystocia observed. In West-Africa, small ruminants flocks are characterised by the presence of multiple genotypes and uncontrolled mating (Dossa et al., 2015). ICF calculation yielded 0.8, 0.8, 0.8, 0.8, 0.7, 0.7 and 0.6 respectively, for group disorders D, W, B, L, A, T and R (Table 3). This indicates the high degree of consensus between the respondents in relation to the plants used to treat these different disease groups.

3.4. Plants used to treat different disorders groups

The results showed that disease groups frequently encountered, such as digestive disorders (D), reproductive disorders (W) and general non-specific diseases (A) were treated, respectively, with 72, 34 and 29 medicinal plants (Table 4). On the other hand, musculoskeletal disorders (L), eye disorders (F) and neurological disorders (N) were treated, respectively, with 6, 5 and 2 medicinal plants. Most of the listed plants were used to treat two or more disease categories. Thus, their FL was used to identify the frequently plants used to treat each disease group (Table 5). For the treatment of digestive diseases for example, among the 72 plants used, 20 were selected which merit further research. These are *Zanthoxylum zanthoxyloides*; *Striga hermonthica*; *Khaya senegalensis*; *Adansonia digitata*; *Morinda lucida*; *Spondias mombin*; *Elaeis guineensis*; *Caesalpinia bonduc*; *Azadirachta indica*; *Newbouldia laevis*; *Carica papaya*; *Momordica charantia*; *Anogeissus leiocarpa*; *Vitex doniana*; *Parkia biglobosa* and *Crossopteryx febrifuga*, with FL, respectively, 0.9, 0.8, 0.5, 0.7, 0.5, 0.6, 0.8, 0.7, 0.7, 0.6, 0.9, 0.5, 0.7,0.6 0.5 and 0.4. Previous studies have already shown that these plants are used to treat digestive disorders in domestic animals (Hounzangbé-Adoté, 2001; Kabore et al., 2007; Yineger et al., 2007; Djoueche et al., 2011; Attindéhou et al., 2012; Usha et al., 2016; Ouachinou et al., 2019). In addition, chemical and biological studies have been conducted and confirmed the *in vivo* and *in vitro*

Table 5. List of three main medicinal plants used to treat each disease group of small ruminants in Benin.

Plants	FC	F L
Digestive disorders (D)		
Zanthoxylum zanthoxyloides (Lam.) Watermann	61	0.9
Striga hermonthica (Delile) Benth.	46	0.8
Adansonia digitata L., 1753	31	0.7
Reproductive disorders (W)		
Spondias mombin L.	79	0.7
Rhodognaphalon brevicuspe (Sprague) Roberty	14	0.9
Solanum dasyphyllum Schumach. &Thonn	13	0.9
Respiratory disorders (R)		
Ocimum gratissimum L.	20	0.5
Mangifera indica L.	10	0.6
Khaya senegalensis (Desr.) A.Juss.	7	0.1
General and non-specific disorders (A)		
Morinda lucida Benth.	23	0.4
Khaya senegalensis (Desr.) A. Juss	16	0.2
Moringa oleifera Lam.	16	0.3
Skin disorders (S)		
Khaya senegalensis (Desr.) A. Juss	7	0.1
Nicotiana tabacum L.	3	0.7
Pupalia lappacea (L.) JUSS.	3	0.6
Metabolism, nutrition and endocrine disorders (T)		
Moringa oleifera Lam.	11	0.2
Adansonia digitata L., 1753	7	0.1
Elaeis guineensis Jacq.	4	0.1
Blood and hematopoietic organs disorders (B)		
Dioscorea hirtijlora Benth.	17	0.8
Crossopteryx febrifuga (Afzel. ex G. Don) Benth	1	0.1
Guiera senegalensis J.F. Gmel	1	0.5
Musculoskeletal disorders (L)		
Combretum glutinosum Perr. ex De	16	1.0
Diospyros mespiliformis Hochst. ex A. Rich	1	0.2
Eucalyptus camaldulensis Dehn	1	0.5
Eye disorders (F)		
Balanites aegyptiaca (L.) Del.	1	0.2
Citrus limon (L.) Burm.f	1	0.3
Hibiscus sabdariffa L., 1753	1	0.2
Neurological disorders (N)		
Cissus populnea Guill. & Perr	1	0.1
Diospyros mespiliformis Hochst. ex A. Rich	1	0.2

FC: Frequency of Citation; FL: Fidelity Level.

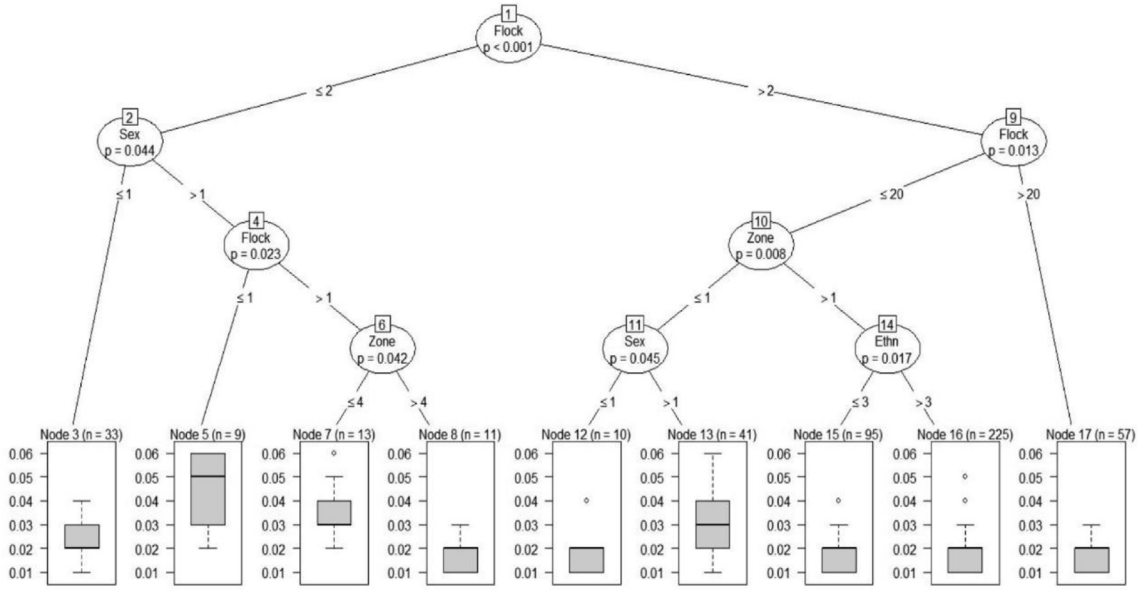

Figure 3. Decision tree showing socioeconomic and environmental factors that influence significantly ethnoveterinary knowledge level within small ruminants breeders in Benin. Flock: Small ruminant flocks size, Sex: Respondent sex, Zone: Agro-ecological zone and Ethn: Ethnicity of the respondent. Each node indicates the factor that significantly influences ethnoveterinary knowledge level and specifies at which level the difference lies. For example, node 1 indicates that flocks size significantly (P = 0.001) influences ethnoveterinary knowledge level and specifies that farmers with a flocks size of 2 or less have a different level of knowledge than those with a flocks size of more than 2.

efficacy of some of these plants (Chandrawathani et al., 2006; Agaie and Onyeyili, 2007; Kabore et al., 2009; Azando et al., 2011; Olounladé et al., 2011; Koné et al., 2012). In previous studies, *Z. zanthoxyloides, A. indica*, *A. leiocarpa* and *S. mombin* have shown a strong activity in treatement of gastrointestinal parasitosis of small ruminants (Chandrawathani et al., 2006; Agaie and Onyeyili Kabore et al., 2009; Azando et al., 2011), this may be explained traditional usage of these plants. Chemical analysis of these plants revealed that they contain maintly, tannins, flavonoids, alkaloids and anthraquinones (Igwe et al., 2010; Barku et al., 2013), that may be the reason for their effectiveness. Nevertheless, *S. hermonthica*; *M. charantia* and *E. guineensis* were less studied. Some medicinal plants inventoried during the survey are versatile and therefore well-suited for the treatment of several disease categories. As an example *A. digitata* is also indicated for the treatment of metabolism and nutrition disorders (T). Similarly, *S. mombin* can be used to treat reproductive disorders (W). This corroborates the results of Adedokun et al. (2010) and Gbolade and Adeyemi (2008), who found that these plants can be used in the treatment of reproductive disorders and gastrointestinal parasitosis, respectively.

The majority of the recipes proposed were composed exclusively of plants. The leaves (64.2%), the barks (17.2%) and the whole plants (7.3%), are the main parts used. The majority of recipes are prescribed in the form of fresh leaves to be grazed by small ruminants (45.2%). Other methods of preparation were maceration (21.5%), decoction (10.8%), pounding (8.7%), powder (6.9%) and trituration (6.8%).

3.5. Influence of socioeconomic and environmental factors on traditionnal knowledge

Ethnoveterinary medicine involves natural resources use (plants, minerals, animal organs) and supernatural resources (prayers, incantations, magic) to treat animals (Wanzala et al., 2005). However, magico-religious practices contribution to livestock treatments remains to be proven according to several authors (Assogbadjo et al., 2011; Dassou et al., 2015b). Thus, natural resources use, especially plants, appears to be a key element to evaluate the ethnoveterinary knowledge level of livestock farmers (Kouchade et al., 2017; Miara et al., 2019). However, the number of medicinals plants cited alone to measure the level of knowledge related to ethnoveterinary practices appears insufficient because ethnoveterinary medicine covers many other aspects not taken into account. Sometimes there is a gap between knowledge and actual use of medicinal plants. Indeed, farmers consider ethnoveterinary knowledge as a family secret and do not share all the information with outsiders. This is one of the major limitations for ethnoveterinary surveys.

The results showed that size of the small ruminants flock (P = 0.001), gender of respondents (P = 0.045), agro-ecological zone (P = 0.008) and ethnicity of respondents (P = 0.017) significantly influenced the level of knowledge related to plants used to treat small ruminants diseases (Figure 3). These results corroborate those of Assogbadjo et al. (2011) and Dassou et al. (2015b) who showed that agro-ecological and phytogeographic zones, ethnicity and educational level influence traditional knowledge. Analyse of variance results showed that respondents from agro-ecological zone 1 (Karimama) have a high level of knowledge compared to other zones considered in our study (P = 0.00797). This may be explained by the lack of money, the absence of veterinary services and the inaccessibility of sanitary products in the municipality of Karimama (INSAE, 2016). Thus, to cope with the sanitary management of their animals, breeders are forced to turn to ethnoveterinary practices. Le Gall and Leboucq (2003) have shown that the absence of veterinary services and the inaccessibility of health products are the main constraints to livestock development in sub-Saharan Africa. In addition, our study reveales that the practice of ethnoveterinary medicine in small ruminants farms depends on herd size (P = 0.023). In fact, analyse of variance results showed that, the larger the herd size, the less breeders use plants to treat small ruminants diseases. For small flocks class (1 ≤ Flock <10), respondents use an average 3 plants compared to 1 for large flocks (60 ≤ Flock <70). This may be explained by the fact that breeders who have a large flock may have difficulty in preparing traditional recipes for all animals. Similarly, these farmers could have more financial capacity than those who have a small flock and are therefore able to buy veterinary products and

pay veterinary services. Although several ethnobotanical surveys have been conducted to evaluate the effect of certain factors on the level of knowledge, the present work remains the only one to prove that there is a link between herd size and the level of knowledge in ethnoveterinary practice. Like herd size, ethnicity is also linked to the knowledge of the plants used to treat small ruminants disorders. These results are consistent with those of Assogbadjo et al. (2011) and Kouchade et al. (2017) who found that traditional knowledge varies according to sociocultural groups in Benin. Indeed, the results showed that Dendi and Peulh have a strong knowledge (on average 3 plants per respondent) compared to Adja, Wama, Otammari and Natimba (on average 1.5 plants per respondent). This can be linked to the fact that these two sociocultural groups are herding societies and therefore strongly care for welfare of their animals (Dassou et al., 2020).

4. Conclusions

Traditional ethnoveterinary practices continue to contribute to the improvement of animal production. The present study demonstrated that it is used by a majority of small ruminants breeders in Benin to treat livestock diseases. The main disease groups encountered were those of digestive system and those related to reproductive organs. Gender, agro-ecological zone, sociocultural group and herd size are factors that significantly influence the level of knowledge of plants used to treat sheep and goats diseases. The most frequently plants were *Z. zanthoxyloides*, *K. senegalensis, M. lucida, M. oleifera* and *S. hermonthica*. Chemical and biological studies have been conducted on several of these plants. Nevertheless, certain inventoried plants namely, *S. hermonthica*, *E. guineensis*, *C. febrifuga* and *M. charantia* were less studied.Thus, chemical and biological studies are needed to test the properties attributed to these plants and characterize active compounds responsible to the probables biological activities.

Declarations

Author contribution statement

Esaïe Tchetan: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Abiodoun Pascal Olounlade: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Thierry Dehouegnon Houehanou: Analyzed and interpreted the data; Wrote the paper.

Erick Virgile Bertrand Azando; Sylvie Mawule Hounzangbe-Adote: Contributed reagents, materials, analysis tools or data.

Josette Afiavi Kaneho: Performed the experiments.

Marcel Romuald Benjamin Houinato; Fernand Ahokannou Gbaguidi; Joëlle Quetin-Leclercq: Conceived and designed the experiments.

Funding statement

This work was supported by the Kingdom of Belgium through the "Académie de Recherche et d'Enseignement Supérieur" (ARES).

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

References

Adedokun, M.O., Oladoye, A.O., Oluwalana, S.A., Mendie, I.I., 2010. Socio-economic importance and utilization of *Spondias mombin* in Nigeria. Asian Pacific Journal of Tropical Medicine 232–234.

Agaie, B.M., Onyeyili, P.A., 2007. Anthelmintic activity of the crude aqueous leaf extracts of *Anogeissus leiocarpus* in sheep. Afr. J. Biotechnol. 6 (13), 1511–1515.

Ahoyo, C.C., Houehanou, T.D., Yaoitcha, A.S., Prinz, K., Assogbadjo, A.E., Adjahossou, C.S.G., Hellwig, F., Houinato, M.R.B., 2017. A quantitative ethnobotanical approach toward biodiversity conservation of useful woody species in Wari-Maro forest reserve (Benin, West Africa). Environ. Dev. Sustain.

Akoègninou, A., Van der Burg, W.J., Van der Maesen, L.J.G., 2006. Flore Analytique du Bénin. Backhuys Publishers, Leiden.

Al-Momani, W., Nicholas, R.A.J., Abo-Shehada, M.N., 2008. Risk factors associated with Mycoplasma agalactiae infection of small ruminants in northern Jordan. Prev. Vet. Med. 83, 1–10.

Archer, K.J., 2010. rpartordinal: an R package for deriving a classification tree for predicting an ordinal response. J. Stat. Software 34 (7), 1–17.

Assogbadjo, A.E., GlèlèKakaï, R., Adjallala, F.H., Azihou, A.F., Vodouhê, G.F., Kyndt, T., Codjia, J.T.C., 2011. Ethnic differences in use value and use patterns of the threatened multipurpose scrambling shrub (*Caesalpinia bonduc* L.) in Benin. J. Med. Plants Res. 5, 1549–1557.

Attindéhou, S., Houngnimassoun, M.A., Salifou, S., Biaou, F.C., 2012. Inventorying of herbal remedies used to control small ruminant's parasites in Southern Benin. Int. Multidiscip. Res. J. 2 (8), 14–16.

Azando, E.V.B., Olounlade, A.P., Hounzangbe-Adote, M.S., Hoste, H., 2011. Effets anthelminthiques *in vivo* de la poudre de feuilles de *Zanthoxylum zanthoxyloïdes* et de *Newbouldia laevis* sur les nématodes parasites gastro-intestinaux des chevreaux Djallonké. Int. J. Brain Cognit. Sci. 5 (3), 1054–1062.

Barku, V.Y.A., Boye, A., Ayaba, S., 2013. Phytochemical screening and assessment of wound healing activity of the leaves of *Anogeissus leiocarpus*. Eur. J. Exp. Biol. 3 (4), 18–25.

Chandrawathani, P., Chang, K.W., Nurulaini, R., Waller, P.J., Adnan, M., Zaini, C.M., Jamnah, O., Khadijah, S., Vincent, N., 2006. Daily feeding of fresh Neem leaves (*Azadirachta indica*) for worm control in sheep. Trop. Biomed. 23 (1), 23–30.

Dagnelie, P., 1998. Statistiques théoriques et appliquées. De Boeck et Larcier, Bruxelles.

Dassou, G.H., Ouachinou, Jé.M.-A.S., Adomou, A.C., Yédomonhan, H., Tossou, M., Favi, A., Djidohokpin, D., Gbèdolo, E., Akoègninou, A., 2020. Plant and natural product based homemade remedies for veterinary uses by the Peul community in Benin. J. Ethnopharmacol.

Dassou, G.H., Ogni, C.A., Yédomonhan, H., Adomou, A.C., Tossou, M., Dougnon, J.T., Akoègninou, A., 2014. Diversité, ethnobotanique et vulnérabilité des plantes à usages vétérinaires au Nord-Bénin. Int. J. Brain Cognit. Sci. 8 (1), 189–210.

Dassou, G.H., Adomou, A.C., Yédomonhan, H., Ogni, A.C., Tossou, G.M., Dougnon, J.T., Akoègninou, A., 2015a. Flore médicinale utilisée dans le traitement des maladies et symptômes animaux au Bénin. Journal of Animal &Plant Sciences 26, 4036–4057.

Dassou, H.G., Yédomonhan, H., Adomou, A.C., Ogni, C.A., Tossou, M.G., Akoègninou, A., 2015b. Facteurs socioculturels et environnementaux déterminant la connaissance ethnovétérinaire au Bénin. Afrique Science 11, 335–360.

Djoueche, C.M., Azebaze, A.B., Dongmo, A.B., 2011. Investigation of plants used for the ethnoveterinary control of gastrointestinal parasites in Bénoué region, Cameroon. Tropicultura 29, 205–211.

Dossa, L.H., Wolln, C., Gauly, M., 2007. Smallholders' perceptions of goat farming in southern Benin and opportunities for improvement. Trop. Anim. Health Prod. 39, 49–57.

Dossa, H.L., Sangaré, M., Buerkert, A., Schlecht, E., 2015. Production objectives and breeding practices of urban goat and sheep keepers in West Africa: regional analysis and implications for the development of supportive breeding programs. Springer plus 4 (281), 1–12.

Fan, C., Tan, L., Zhang, C., Zhao, X., von Gadow, K., 2017. Analysing taxonomic structures and local ecological processes in temperate forests in North Eastern China. BMC Ecol. 17 (33), 1–11.

Faostat, 2018. Statistics of Food and Agriculture Organization of the United Nations (Online). Available from: from. http://www.fao.org/faostat/fr/#data/QA. (Accessed 15 May 2019).

Friedman, J., Yaniv, Z., Dafni, A., Palewith, D., 1986. A preliminary classification of the healing potential of medicinal plants, based on a rational analysis of an ethnopharmacological field survey among Bedouins in the Negev desert, Israel. J. Ethnopharmacol. 16, 275–287.

Gbolade, A.A., Adeyemi, A.A., 2008. Anthelmintic activities of three medicinal plants from Nigeria. Fitoterapia 79, 223–225.

Heinrich, M., Ankli, A., Frei, B., Weimann, C., Sticher, O., 1998. Medicinal plants in Mexico: healers' consensus and cultural importance. Soc. Sci. Med. 47 (11), 1859–1871.

Houinato, M., Sinsin, B., 2002. Analyse phytogéographique de la région des Monts Kouffé au Bénin. Syst. Geogr. Plants 71 (1), 889–910.

Houndje, E.M.B., Ogni, C.A., Noudeke, N., Farougou, S., Youssao, A.K.I., Kpodekon, M.T., 2016. Recettes ethno-vétérinaire à base de plantes médicinales utilisées pour le traitement de la fièvre aphteuse au Bénin. Int. J. Brain Cognit. Sci. 10 (5), 2090–2107.

Hounzangbé-Adoté, M.S., 2001. L'élevage face à la pharmacopée en médecine vétérinaire au Sud du Bénin. Bulletin de la Recherche Agronomique 33, 1–9.

Igwe, C.U., Onyeze, G.O.C., Onwuliri, V.A., Osuagwu, C.G., Ojiako, A.O., 2010. Evaluation of the chemical compositions of the leaf of Spondias mombin Linn from Nigeria. Australian Journal of Basic and Applied Sciences 4 (5), 706–710.

INSAE (Institut National de la Statistique et de l'Analyse Economique), 2016. Principaux indicateurs socio-demographiques et economiques (RGPH-4, 2013), (Imprimérie tundé, Cotonou).

IPCP 2, 2003. International Classification of Primary Care, second ed. (ICPC-2). Available from: http://docpatient.net/3CGP/QC/ICPC_desk.pdf. (Accessed 14 March 2019).

Kabore, A., Tamboura, H.H., Belem, A.M.G., Traoré, A., 2007. Traitements ethno-vétérinaires des parasitoses digestives des petits ruminants dans le plateau central du Burkina Faso. Int. J. Brain Cognit. Sci. 1 (3), 297–304.

Kabore, A., Belem, A.M.G., Tamboura, H.H., Traore, A., Sawadogo, L., 2009. *In vitro* anthelmintic effect of two medicinal plants (*Anogeissus leiocarpus* and *Daniellia oliveri*) on *Haemonchus contortus*, an abosomal nematode of sheep in Burkina Faso. Afr. J. Biotechnol. 8 (18), 4690–4695.

Kebede, E., Mengistu, M., Serda, B., 2018. Ethnobotanical knowledge of pastoral community for treating livestock diseases in Somali regional state, eastern Ethiopia. Trop. Anim. Health Prod.

Koné, W.M., Vargas, M., Keiser, J., 2012. Anthelmintic activity of medicinal plants used in Côte d'Ivoire for treating parasitic diseases. Parasitol. Res. 110, 2351–2362.

Kouchade, A.S., Adomou, A.C., Dassou, G.H., Akouegninou, A., 2017. Facteurs socioculturels et environnementaux déterminant la connaissance des plantes utilisées pour les soins infantiles au Sud du Bénin. Int. J. Brain Cognit. Sci. 11 (3), 1272–1287.

Lakew, A., Melesse, A., Banerjee, S., 2017. Traditional sheep production systems and breeding practice in Wolayita Zone of Southern Ethiopia. Afr. J. Agric. Res. 12 (20), 1689–1701.

Le Gall, F., Leboucq, N., 2003. Le rôle du contrôle des maladies animales dans la poursuite des objectifs en matière de réduction de la pauvreté, d'innocuité des aliments, d'accès aux marchés et de sécurité alimentaire en Afrique. Banque Mondiale, Washington.

Mensah, S.E.P., Adégbola, P.Y., Edénakpo, A.K., Ahoyo, N.A., Tossa, I.G., Fatunbi, A.O., 2018. Innovation Opportunities in Small Ruminants Livestock Sector in Benin. Guide Book 2, Forum for Agricultural Research in Africa, p. 48.

Miara, M.D., Bendif, H., Ouabed, A., Rebbas, K., Hammou, M.A., Amirat, M., Greene, A., Teixidor-Toneu, I., 2019. Ethnoveterinary remedies used in the Algerian steppe: exploring the relationship with traditional human herbal medicine. J. Ethnopharmacol. 244, 112–164.

Ogni, C.A., Kpodekon, M.T., Dassou, G.H., Boko, C.K., Koutinhouin, B.G., Dougnon, J.T., Youssao, A.K.I., Yedomonhan, H., Akoegninou, A., 2014. Inventaire ethno-pharmacologique des plantes utilisées dans le traitement des pathologies parasitaires dans les élevages extensifs et semi-intensifs du Bénin. Int. J. Brain Cognit. Sci. 8 (3), 1089–1102.

Olounladé, P.A., Hounzangbé-Adoté, M.S., Azando, E.V.B., Tamha, T.B., Brunet, S., Moulis, C., Fabre, N., Fouraste, I., Hoste, H., Valentin, A., 2011. Etude *in vitro* de l'effet des tanins de *Newbouldia laevis* et de *Zanthoxylum zanthoxyloïdes* sur la migration des larves infestantes de *Haemonchus contortus*. Int. J. Brain Cognit. Sci. 5 (4), 1414–1422.

Omoike, A., 2006. Prevalence of diseases among sheep and goats in edo state, Nigeria. J. Agric. Soc. Res. 6 (2), 23–31.

Ouachinou, J.M.A.S., Dassou, G.H., Idohou, R., Adomou, A.C., Yédomonhan, H., 2019. National inventory and usage of plant-based medicine to treat gastrointestinal disorders with cattle in Benin (West Africa). South Afr. J. Bot. 122, 432–446.

R Core Team, 2013. A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/. (Accessed 15 February 2019).

SICC/Bénin (Système d'Information sur les Changements Climatiques au Bénin), 2016. Zones agro-écologiques de la république du Bénin (Online). Available from: https://www.changementsclimatiques.bj/zones-agro-ecologiques-de-la-republique-du-benin/. (Accessed 14 March 2019).

Staub, P.O., Geck, M.S., Weckerle, C.S., Casu, L., Leonti, M., 2015. Classifying diseases and remedies in ethnomedicine and ethnopharmacology. J. Ethnopharmacol. 174, 514–519.

Tamboura, H., Kaboré, H., Yaméogo, M.S., 1998. Ethnomédecine vétérinaire et pharmacopée traditionnelle dans le plateau central du Burkina Faso : cas de la province du Passoré. Biotechnologie, Agronomie, Société et Environnement 2 (3), 181–191.

Tardío, J., Pardo-De-Santayana, M., 2008. Cultural importance indices: a comparative analysis based on the useful wild plants of southern Cantabria (Northern Spain). Econ. Bot. 62 (1), 24–39.

Underwood, W.J., Blauwiekel, R., Delano, M.L., Gillesby, R., Mischler, S.A., Schoell, A., 2015. Biology and Diseases of Ruminants (Sheep, Goats, and Cattle). Laboratory animal medicine, pp. 623–694.

Usha, S., Rajasekaran, C., Siva, R., 2016. Ethnoveterinary medicine of the shervaroy hills of eastern ghats, India as alternative medicine for animals. J. Trad. Compl. Med. 6, 118–125.

Wanzala, W., Zessin, K.H., Kyule, N.M., Baumann, M.P.O., Mathias, E., Hassanali, A., 2005. Ethnoveterinary medicine: a critical review of its evolution, perception, understanding and the way forward. Livest. Res. Rural Dev. 17 (11), 1–41.

Yineger, H., Kelbessa, E., Bekele, T., Lulekal, E., 2007. Ethnoveterinary medicinal plants at bale mountains national Park, Ethiopia. J. Ethnopharmacol. 112, 55–70.