National Inventory of Medicinal Plants Used to Treat Sheep and Goats Diseasesin Benin (West Africa): Effect of Socioeconomic and Environmental Factors

Esaïe TCHETAN
Universite d'Abomey-Calavi Faculte des Sciences Agronomiques

Pascal Abiodoun OLOUNLADE (abiodouno@yahoo.fr)
Universite d'Abomey-Calavi Faculte des Sciences Agronomiques https://orcid.org/0000-0003-1173-3536

Thierry Dehouegnon HOUEHANOU
Universite de Parakou

Erick Virgile Bertrand AZANDO
Universite de Parakou

Josette Afiavi KANEHO
Universite d'Abomey-Calavi Faculte des Sciences Agronomiques

Marcel Romuald Benjamin HOUINATO
Universite d'Abomey-Calavi Faculte des Sciences Agronomiques

Sylvie Mawule HOUNZANGBE-ADOTE
Universite d'Abomey-Calavi Faculte des Sciences Agronomiques

Joëlle QUETIN-LECLERCQ
Universite catholique de Louvain

Fernand Ahokonou GBAGUIDI
Laboratoire de Pharmacognoise, Centre Béninois de la Recherche Scientifique et Technique (CBRST)

Research

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Abstract

Background: Small ruminant health problems still represent a major constraint in Benin. Thus, to treat goats and sheep diseases, breeders use medicinal plants. However, little scientific work has been done on the traditional knowledge of these plants.The specific objectives of the current study were (i) to document the traditional knowledge regarding the disease groups treated and the medicinalplants used in the health and zootechnical management of small ruminants in Benin and (ii) to assess the effect of sex, ethnicity, agroecological zone and herd sizeassociatedwith them.

Methods: To achieve these objectives, an ethnoveterinary survey was conducted in different agroecological zones from September 2018 to February 2019. A semi-structured questionnaire was administered to 506 breeders and farmers and took into account the identity of the respondents, the plants used to treat the ailmentsfor improving the productivity of sheep and goats, the parts used and the method of preparation of the recipes. The data were analyzed through the calculation the Relative Frequency of Citation (RFC), Fidelity Level (FL), and Consensus Factor of the Informant (CFI). Descriptive statistics and multivariate analyses were applied to our data using the software R and Minitab. The symptoms recordedfrom the respondents were categorized into 10 disorder groups using the second version of the International Classification of Primary Care (ICPC).

Results: Ten (10) categories of disorders were treated by the people surveyed. These are mainly disorders of the digestive system (D) (49.34%) and disorders related to pregnancy and parturition (W) (20.15%). A total of 101 species medicinal plantsbelonging to 42 families and 90 genera were recorded. The most represented families are Leguminosae (21.57%) and Euphorbiaceae (6.86%). The most cited speciesare Zanthoxylumzanthoxyloides (Lam.) Watermann, Khayasenegalensis (Desr.) A. Juss, Strigahermonthica (Delile) Benth. and Adansoniadigitata L. Sex, ethnicity, agroecological zone and herd size are the socioeconomic and environmental factors that influence the level of ethnoveterinary knowledge.

Conclusions: Results showedthe high diversity of medicinal species used to treat small ruminant’sdiseasesin Benin. Chemical and biological analyzes are needed to test the effectiveness of the main inventoried plants. Keywords : Ethnoveterinary, sheep, goats, Benin.

Introduction

Livestock has played a major role in the development of the world food economy in recent decades [1]. In sub-Saharan Africa, it is estimated that over 60% of the population earn their income from livestock [2]. Poultry and small ruminants are the main sources of income for poor families. In Benin, the number of small ruminants in 2017 was estimated at 3,368,288 (1,871,977 goats and 1,496,311 sheep) and come in second position after the one of poultry [3]. Small ruminants mainly play an economic role and secondary a social, cultural and religious function [4, 5, 6]. Sheep and goats are very resistant and adapt very well to all agroecological zones [7]. Of all the farming systems practiced in Benin, that of small ruminants is the most widely dispersed and remains the most widely adopted by the populations. Small ruminants are

found in almost all farms and even in many households of periphery and in urban areas in West Africa [5].

However, many studies agree on the low productivity of small ruminants. From the analysis of the different results, animal health problems are among the main constraints that hinder the performance of sheep and goats [4, 6, 7; 8]. Thus, to manage the health of small ruminants, breeders usually use synthetic chemicals drugs that are increasingly limiting due to the availability and accessibility of these products [2], the cost of acquiring products, and the development of pathogen resistance [9]. Moreover, the demand of consumers are increasingly turned to organic products without chemical inputs. Faced with these limitations, many techniques for the management and health monitoring of small ruminants have been developed. This includes the strengthening of animal resistance to pathogens [10], the rotational management of pastures, the practice of rearing stabling, the use of nematophagous fungi and medicinal plants as alternatives for managing small ruminant diseases. However, the use of medicinal plants to treat small ruminant diseases is seen as the most promising alternative because of the multiple benefits such as low cost of treatments, accessibility and availability in rural areas where the majority of livestock is raised [8, 11, 12].

The use of plants to treat animals or to improve their productivity is an old practice that continues to be practiced. Thus, numerous studies have been conducted around the world to evaluate traditional knowledge related to the use of medicinal plants to treat animal diseases [11, 13, 14, 15]. Several Beninese researchers have also addressed the same issue by attempting to list the medicinal plants used to treat livestock [8, 16, 17, 18, 19]. However, most ethnoveterinary surveys conducted in Benin have focused on the inventory of medicinal plants used to treat all domestic animals diseases [16, 17, 20]. The medicinal plants as well as the traditional recipes offered by breeders could depend on the animal species targeted. For example, Ouachinou et al. [19] only focused on medicinal plants used to treat cattle diseases in Benin. Furthermore, the rare studies conducted exclusively on ethnoveterinary practices in sheep and goats farming in Benin have been limited to the South of the country [8, 12], while small ruminants are well distributed over the entire country [5].

Breeders and phytotherapists do not know how to make a differential diagnosis of diseases [8, 21]. Thus, the many ethnobotanical surveys conducted are content to report the symptoms evoked by the respondents. This sometimes leads to bias and makes data analysis and interpretation difficult [21]. Indeed, some authors report their own interpretations of the symptoms evoked by traditional practitioners and go as far as naming the diseases without having made a differential diagnosis [15, 16, 17]. To remedy this, many tools including the International Classification of Primary Care (ICPC) can be used by researchers to classify and categorise symptoms into disease groups [21].

Ethnoveterinary knowledge is a function of several environmental factors, including the ecological zone [22]. Furthermore, many studies have shown that traditional knowledge is influenced by socioeconomic factors such as gender and ethnicity [14, 22, 23, 24]. Similarly, previous explorations have shown that the practice of the ethnoveterinary in livestock farms could be a function of income level [2]. Thus, livestock

size appears to be a crucial parameter that provides information on the income level or comfort level of a farmer and can be used to test the possible link between income level and ethnoveterinary practice.

Thus, considering the variation in the use of plants according to localities and the distribution of small ruminants throughout the country, it therefore appears necessary to extend the study to the entire extent of the territory. This study aims to inventory the medicinal plants used to treat and improve the productivity of small ruminants as well as the socioeconomic and environmental factors that are related to the use of these plants. Research questions which support this study are as follows:

a. What are the disease group encountered in sheep and goats farming?
b. What are the medicinal plants used to treat each category of disorder?
c. / and environmental factors that influence the level of traditional knowledge related to the use of medicinal plants to treat small ruminants' diseases?

Material And Methods

Study area

The study was conducted in Benin (West Africa) in 6 agroecological zones among 8 defined (Fig.1). SICC / Benin [25] defines these areas as follows:

- Zone 1 (Far North Zone of Benin): It is a zone which contains the largest part of the forest reserve called W National Park of Niger. Its climate is of the Sudano-Sahelian type and includes two municipalities including Karimama. Temperatures are excessive and reach 40 ° C in the shade in the dry season.
- Zone 3 (Food-producing area of South-Borgou): It is essentially characterized by a very high availability of agricultural land. It includes 8 municipalities including N'Dali. This is the area of Sudan's humid climate marked by a rainy season from April to September and a dry season that lasts almost five months.
- Zone 4 (West-Atacora Zone): This zone benefits from the presence of the Atacora chain which gives it a particular climate where the temperatures are cooler and thunderstorms more frequent than in the other zones. The depths of rainwater vary from 800 to 1350 mm depending on the year. The main river is the Pendjari with its tributaries. It covers 8 municipalities including Toucoutouna and Boukoumbé.
- Zone 6 (Bar ground zone): It is located in the southern part of Benin and includes 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). The heights of rainwater vary between 1000 to 1400 mm.
- Zone 7 (Depression zone): It is the smallest of the 8 agroecological zones in terms of area and takes into account 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 (Fishing area): One of the main characteristics of this zone is the development of continental and maritime fishing in addition to plant and animal production. Geographically, it is the most southerly and occupies the fluvio-lacustrine zone of the Atlantic, Mono, Oueme and Zou departments. It covers 13 municipalities including Bopa.

The total population in 2019 was estimated at 12,118,842. Fon, Adja, Yoruba, Bariba, Dendi, Peulh, Otamari, Yoa and Lokpa are the main socio-cultural groups encountered [26]. Christianity, Islam and vodoun are the main religions practiced. Agriculture, livestock and crafts are the main activities. According to FAO estimates, the number of small ruminants in Benin in 2017 is estimated at 3,368,288 (1,871,977 goats and 1,496,311 sheep) and comes in second place after the poultry [3]. The choice of the zones and the towns to host the study was based on the predominance of small ruminants breeding and poorest level of the population. In each town, 4 villages was chosed based on their accessibility and the ethnoveterinary practice to treat small ruminant diseases. In total, 08 towns practicing small ruminant breeding and ranked among the poorest in Benin were selected to host the survey.

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

Sampling

A baseline survey was conducted beforehand and this allowed to identify 04 villages per town to house the survey. It was carried out with the support of NGOs and state structures that intervene in the target towns and made it possible to choose the villages where the populations have a strong knowledge in herbal medicine and in small ruminants breeding. This helps us to determine the proportion (p) of the population that uses medicinal plants to treat diseases of small ruminants. Thus, the size of the sample (n) per town was determined by the Dagnelie [27] formula, which is as follows:

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

With n, the sample size of the population to be surveyed by town, $U^2_{1-\frac{\alpha}{2}} = 1{,}96$ obtained from the standard distribution table of the normal distribution with α = 0.05, p (p = 80%) the proportion of the population using medicinal plants to treat small ruminant diseases and d (d = 0.075) the margin of error we fixed. Formula application allowed us to interview at least 56 persons per town. The choice of respondents was based on their availability and willingness to participate in the study.

Data collection: semi-structured interview

The ethnobotanical survey was conducted from September 2018 to February 2019 and surveyed 506 people across the entire territory (Table 1). A survey form was developed and took into account among other things the characteristics of the respondents (sex, age, ethnicity, name and surname, …), the main plants used to treat small ruminants symptoms and improve their productivity, the parts used (roots, bark, leaves), recipe preparation, difficulties related to plant research and 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. Herbarium samples were made to identify the inventoried plants.

Table 1
Distribution of people surveyed in the different agro-ecological zones.

Agroecological zones	Town	Sex	Ethnicity	Number
Zone 1	Karimama	Man	Dendi	38
			Peulh	15
		woman	Dendi	13
Zone 3	N'Dali	Man	Bariba	10
			Peulh	42
			Otammari	1
		woman	Bariba	3
			Peulh	1
Zone 4	Boukoumbé	Man	Otammari	58
		woman	Otammari	3
	Toucountouna	Man	Wama	22
			Natimba	18
			Otammari	10
			Peulh	2
		woman	Wama	1
			Natimba	1
			Otammari	6
Zone 6	Covè	Man	Fon	44
		woman	Fon	17
	Za-kpota	Man	Fon	26
		woman	Fon	36
Zone 7	Lalo	Man	Adja	40
		woman	Adja	23
Zone 8	Bopa	Man	Sahouè	34
		woman	Sahouè	29

Data analysis

Diversity of inventoried medicinal plant species

Specimens were deposited and identified at the national herbarium of Benin. The collected data were used to establish the list of inventoried plants to treat small ruminant diseases. The number of species by genus and family was determined. To assess the diversity of plants used to treat diseases of small ruminants, the Generic Coefficient (Rgc) which is the ratio number of species (Ns) over number of genus (Ng) (the inverse of the ratio defined by Fan et al. [28] was determined:

$$\mathrm{Rgc} = \frac{\mathrm{Ns}}{\mathrm{Ng}}$$

With N_S the number of inventoried species, N_G the number of genus and Rgc the Generic Coefficient. If Rgc = 1, then the plants used to treat small ruminant diseases have low diversity. Otherwise each inventoried genus has only one specie. On the other hand, if Rgc> 1, this means that there is a high generic diversity within plants used to treat small ruminant diseases.

Recorded small ruminant disease groups from local knowledge

The symptoms cited by the respondents were categorized into 10 diseases groups using the second version of the International Classification of Primary Care (ICPC). The Relative Frequency of Citation (RFC) and the Consensus Factor of the Informant (CFI) of Heinrich et al. [29] 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:

$$\mathrm{CFI} = \frac{\mathrm{Nur} - \mathrm{Nt}}{\mathrm{Nur} - 1}$$

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

Main plants per groups of disorders

The analysis of the collected data made it possible to make a list of plants used to treat each category of disorder. 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 Fidelity Level (FL) of Friedman et al. [30] was calculated according to the formula below:

$$FL = \frac{Np}{N}$$

With Np: the number of informants who mention a species for the treatment of a disease category p; N: the number of informants who mention the species for any category of affection and FL: 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 is more appropriate to trait this class of diseases.

Assessment of effects of socioeconomic and environmental factors on ethnoveterinary knowledge

A matrix was constructed using socioeconomic and environmental factors (age, sex, main activity, ethnicity, agroecological zone, religion, household size, educational level, the size of the small ruminant livestock and the origin of the knowledge) as independent variables and the number of plants cited for the treatment of small ruminant diseases as a dependent variable. The classification analysis based on the decision tree has been applied to the matrix to access socioeconomic and environmental factors which affect local knowledge to treat small ruminants' diseases with plants. The analyses were carried out in the software R 3.5.2. and the differences were considered significant at the 5% level. An analysis of the variance was performed to assess the influence of factors affecting knowledge of the plants used to treat small ruminants by using Minitab 18 software.

Results

socioeconomic characteristics of respondents

A total of 506 phytotherapists, traditional healers and small ruminant breeders were surveyed. They belong to 09 sociocultural groups of Benin. They are Fon (24.90%), Otammari (15.42%), Peulh (12.45%), Sahouè (12.25%), Adja (12.06%), Dendi (9.49%), Wama (4.94%), Natimba (4.55%) and Bariba (3.95%). The average age of the respondents is 49 ± 16 years. The respondents were categorized into 4 age groups. The majority of the people surveyed are men (72.87%) and illiterate (67.19%) (Table 2). The average size of the small ruminant flock per respondent is 10 ± 11.

Table 2
Socioeconomic characteristics of respondents.

Variables	Description	Relative Frequency of Citation
Sex	Male	366 (72.33%)
	Female	140 (27.67%)
Sociocultural groups	Fon	126 (24.90%)
	Otammari	78 (15.42%)
	Peulh	63 (12.45%)
	Sahouè	62 (12.25%)
	Adja	61 (12.06%)
	Dendi	48 (9.49%)
	Natimba	23 (4.55%)
	Wama	25 (4.94%)
	Bariba	25 (3.95%)
Age	[20 40[	141 (27.87%)
	[40 60[	220 (43.48%)
	[60 80[	108 (21.34%)
	[80 100[	37 (7.31%)
Religion	Animist	241 (47.63%)
	Christian	144 (28.46%)
	Muslim	121 (23.91%)
Level of education	Illiterate	340 (67.19%)
	Alphabet in local language	34 (6.72%)
	Primary level	80 (15.81%)
	Secondary level	40 (7.91%)
	University level	12 (2.37%)
Main activity	Agriculture	369 (72.92%)
	Breeding	54 (10.67%)
	Craft	43 (8.30%)
	Phytotherapy	41 (8.10)

Diversity of known medicinal species

A total of 101 species of medicinal plants belonging to 42 families and 90 genera were inventoried during the survey. Forty-three point ninety percent (43.90%) of families are represented by more than one species. The richest families are Leguminosae (22 species, 21.57%), Euphorbiaceae (7 species, 6.86%), Combretaceae (5 species, 4.90%), Rubiaceae (4 species, 3.92%), Moraceae (4 species, 3.92%), Meliaceae (4 species, 3.92%) and Asteraceae (4 species, 3.92%). The Generic Coefficient is about 1.13, which indicates the high diversity of medicinal species used to treat small ruminant's diseases. This mean that there are genera with more than one species. The genera with the largest number of species are Ficus (4 species), Acacia (3 species), Sena (3 species), Cissus (2 species), Euphorbia (2 species) and Vigna (2 species). The most cited species are *Zanthoxylum zanthoxyloides* (Lam.) Watermann, *Khaya senegalensis* (Desr.) A. Juss, *Striga hermonthica* (Delile) Benth. and *Adansonia digitata* L., 1753. On the other hand, *Ximenia americana* L., *Senna siamea* (Lam.) H. S.Irwin & Barneby. and *Rourea coccinea* (Thonn, ex Schumach.) Benth are rarely cited.

Main diseases groups of small ruminants

In general, respondents do not know how to make a differential diagnosis of diseases. They are therefore based on the symptoms observed on animals to offer traditional treatments. The symptoms encountered were classified into ten disease categories using the second version of the International Classification of Primary Care (ICPC). These are mainly disorders of the digestive system (D) (diarrhea, indigestion, anorexia, gastrointestinal parasitic infection) cited by 49.34% of respondents. This group of disorders is followed respectively by diseases related to pregnancy and parturition (W) (dystocia, mastitis, agalactia, increase in milk production, retained placenta), general and non-specific disorders (A) (fever, stinging hairs) and respiratory system disorders (R) (cough, nasal discharge) cited respectively by 20.15%, 10.57% and 7.16% of the respondents. Skin disorders (S) (wound, crust, scab), metabolic and nutritional diseases (T) (vitamin deficiency, dwarfism, growth acceleration), blood and hematopoietic organ disorders (B) (blood non-coagulation, blood infection), disorders related to the musculoskeletal system (L) (fracture), eye diseases (F) (tearing, watering) and neurological disorders (N) (agitation, nervous disorders, nervousness) are rarely mentioned (Fig. 2). The calculation of the Consensus Factor of the Informer (CFI) gives 84.12%; 81.87%; 80%; 75%; 70.53%; 70% and 62.50% respectively for group disorders D; W; B; L; A; T and R. This indicates the high degree of consensus between the respondents in relation to the plants used to treat these different categories of disease. On the other hand, the CFI of disorders of groups N; S and F are very low (≤ 50%), so the respondents do not agree too much on the plants used to treat these disease group.

Fig. 2 Relative Frequency of Citation of disease groups encountered in small ruminant flocks in Benin.

Legend: A: general and non-specific disorders; B: blood and hematopoietic organ disorders; D: disorders of digestive system; F: eye diseases; L: disorders related to the musculoskeletal system; N: neurological disorders; R: respiratory system disorders; S: skin disorders; T: metabolic and nutritional diseases and W: diseases related to pregnancy and parturition.

Plants used to treat different groups of small ruminant disorders

A total of 72 medicinal plant species are listed to treat disorders of the digestive system against 34 for diseases related to pregnancy and parturition. Neurological diseases are treated with 2 species of medicinal plants. *An additional table file shows this in more detail [See Additional file 1].* The determination of the Fidelity Level (FL) made it possible to identify 20 plants most indicated to treat the disorders of the digestive system. These are: *Zanthoxylum zanthoxyloides* (Lam.) Watermann; *Striga hermonthica* (Delile) Benth.; *Khaya senegalensis* (Desr.) A.Juss.; *Adansonia digitata* L., 1753; *Morinda lucida* Benth.; *Spondias mombin* L.; *Elaeis guineensis* Jacq.; *Caesalpinia bonduc* (L.) Roxb.; *Azadirachta indica* A. Juss; *Newbouldia laevis* (P. Beauv.) Seem; *Carica papaya* L; *Momordica charantia* L., 1753; *Anogeissus leiocarpa* (DC.) Guill. & Perr.; *Vitex doniana* Sweet, 18271; *Crossopteryx febrifuga* (Afzel, ex G. Don) Benth; *Parkia biglobosa* (Jacq.) R. Br. Ex G. Don; *Mitragyna inermis* (Willd.) Kuntze; *Ximenia americana* L.; *Bridelia ferruginea* Benth. and *Vitellaria paradoxa* CFGaertn., 1807. These different plants have a Fidelity Level between 52.73% and 96.83%, which indicates a high degree of consensus among the respondents to use these plants to treat diseases of the digestive system. On the other hand, the determination of the Fidelity Level allowed the identification of 7 plants which are unanimous among the respondents to treat disorders related to pregnancy and parturition. They are: *Vigna unguiculata* (L.) Walp. (100%); *Rhodognaphalon brevicuspe* (Sprague) Roberty (93.33%); *Solanum dasyphyllum* Schumach. & Thonn (92.86%); *Cissus populnea* Guill. & Perr (85.71%); *Ficus sycomorus* L., 1767 (76.92%); *Spondias mombin* L. (75.24%) and *Annona senegalensis* Pers (66.67%).

Recipe preparation

The majority of the recipes proposed are composed exclusively of plants. The leaves (64.17%), the barks (17.20%) and the whole plant (7.28%) for the herbaceous plants are the main parts used (Fig. 3). In addition, some recipes are obtained from a combination of two or more parts of the same or different plants. *An additional table file shows this in more detail [See Additional file 2].* The majority of recipes are in the form of fresh leaves to be grazed by small ruminants (45.20%). The other methods of preparation encountered are as follows: maceration (21.50%), decoction (10.80%), pounding (8.71%), powder (6.95%) and trituration (6.84%) (Fig. 4).

Fig. 3 Percentage of plant parts used for recipes preparation.

Fig. 4 Percentage of preparation modes of remedies.

Influence of socioeconomic and environmental factors on traditional knowledge of plants use to treat small ruminants diseases

Results from the decision tree-based classification analysis show that the size of the small ruminant livestock ($P < 0.01$), the sex of the respondent ($P < 0.05$), the agro-ecological zone ($P < 0.01$) and the respondent's ethnicity ($P < 0.05$) significantly influenced knowledge on the plants use to treat small ruminant diseases (Fig. 5). On the other hand, religion, age, educational level, main activity, household size and source of knowledge do not significantly influence ($P > 0.05$) knowledge on the plants use to treat diseases of small ruminants.

Fig. 5 Decision tree showing the socioeconomic and environmental factors that influence plant knowledge used to treat small ruminant diseases.

Influence of herd size on the knowledge of the plants used

Analysis of the variance showed that the number of plants used varied significantly ($P < 0.05$) depending on the size of the herd. In fact, the larger the size of the herd, the lower the number of plants used (Fig. 6). For the small flock class ($1 \leq Chep1 < 10$), respondents use an average of 3 plants compared to 1 for the large flock ($60 \leq Chep7 < 70$).

Fig. 6 Evolution of the relative plant frequency used to treat small ruminant diseases as a function of herd size.

Class of herd size: $1 \leq Chep1 < 10$; $10 \leq Chep2 < 20$; $20 \leq Chep3 < 30$; $30 \leq Chep4 < 40$; $40 \leq Chep5 < 50$; $50 \leq Chep6 < 60$; $60 \leq Chep7 < 70$.

Influence of sex on the knowledge of the plants used

The results showed that the sex influenced plant knowledge used to treat small ruminant diseases ($P < 0.05$). Indeed, men know more plants (on average 3 plants) than women (on average 2 plants) as part of the treatment of small ruminant diseases.

Influence of sociocultural groups on the knowledge of the plants used

The number of plants used to treat small ruminant diseases varies significantly ($P < 0.01$) according to sociocultural groups. The structuring of the average made it possible to identify three categories. The first concerns Dendi and Fulani who have a strong knowledge (on average 3 plants per respondent) on plants used to treat small ruminant's diseases. The second groups Sahouè, Fon and Bariba who have average knowledge (on average 2 plants per respondent). The third category has low knowledge (on average 1.5

plants per respondent) on plants used to treat small ruminant diseases. These are Adja, Wama, Otammari, Natimba.

Influence of the agroecological zone on the knowledge of the plants used

The knowledge of the plants used to treat small ruminant diseases varies very significantly ($P < 0.01$) according to the agroecological zones. Zone 1 (Karimama) respondents have a strong knowledge (on average 3 plants) of the plants used to treat small ruminant diseases (Fig. 7). They are followed by those in zone 8 (Bopa), which use an average of 2.5 plants (Figure 7). In addition, the persons surveyed in zone 6 (Covè, Za-kpota), zone 7 (Lalo) and zone 3 (N'Dali) have the same level of knowledge (on average 2 plants). The respondents in zone 4 (Toucountouna and Boukombe) have little knowledge (on average 1.5 plants) on the plants used to treat small ruminant diseases.

Fig. 7 Variation in the level of knowledge on plants used to treat small ruminant diseases according to agroecological zones.

Legend

Zone 1: Zone of the extreme north of Benin

Zone 3: Food zone of South Borgou

Zone 4: West Zone-Atacora

Zone 6: Area of bar ground

Zone 7: Zone of depression

Zone 8: Fishery area

Discussion

The use of medicinal plants to treat and improve the productivity of farmed animals appears today as the only promising alternative in view of the limits that the use of synthetic drugs and the low purchasing power of breeders present. Although some studies have addressed the inventory of plants used to treat diseases of small ruminants in southern Benin [8, 12], this study updates and extends the inventory throughout the national territory and identifies socioeconomic and environmental factors that are related.

Socioeconomic characteristics of the respondents

Our results showed that the average age of the respondents is 49 ± 16 years old and the majority of them are male. This would be due to the choice of respondents who are mostly heads of households. These

results corroborate those who concluded that small ruminants are mostly breeding by men [6, 8, 20, 31]. Indeed, for cultural reasons, women are not called upon to speak publicly, especially about traditional knowledge. The interview with the women in the context of this work took place in case of absence of the husband (head of the household) or with the widows. Most of those surveyed are uneducated and had agriculture and livestock as their main activities. These results confirm the observations of Ogni et al. [16]; Usha et al. [15]; Ouachinou et al. [19] who showed that the breeding is mainly done by uneducated people. In fact, the rearing of small ruminants is mainly done in rural areas, which concentrate the majority of the uneducated [2], although more and more sheep and goats farming is noticed in the periphery of urban area [5]. In average, those surveyed have 10 ± 11 heads of small ruminants. This average is relatively high compared to that found by Hounzangbé-Adoté [8] and Lakew et al. [6]. This would be related to the choice of the study environment. Indeed, our work has been conducted in agroecological zones where small ruminants breeding is predominant.

Diversity of inventoried medicinal species

A total of 101 species of medicinal plant belonging to 42 families and 90 genera were inventoried during the survey. The diversity of species used to treat small ruminants is very high compared to those obtained by Tamboura et al. [11]; Hounzangbé-Adoté [8]; Yineger et al. [13]; Dassou et al. [20]; Usha et al. [15], Ahoyo et al. [32] but weak compared to those obtained by Dassou et al. [17]; Ouachinou et al. [19]. This difference would be justified by the probable variation of knowledge between the sociocultural groups but especially by the inequality between the sizes of the sample. The high diversity observed in this study also testifies to the importance of ethnoveterinary in the health care of sheep and goats. Indeed, herbal remedies are first offered to animals after observations of pathological signs and it is after the failure of these that the breeders call on the veterinarian or technician in breeding.

Ethno veterinary knowledge and main diseases groups of small ruminants

Of the ten disease categories identified in our survey, diseases related to the digestive system are the most common. The main symptoms encountered are diarrhea, indigestion and bloating of abdomen. These results corroborate those of Hounzangbé-Adoté [8], Dossa et al. [4], Ogni et al. [16], Lakew et al. [6] who found that the main pathologies encountered in small ruminant farms are diarrhea, anorexia and digestive parasitosis, which lead to high mortality. These diseases are more common in the rainy season and are probably related to moisture that promotes the development of pathogens. Diseases related to pregnancy and parturition are the second category of disorders that were frequently cited by respondents. Ogni et al. [16] and Dassou et al. [17] made the same observations in some Beninese farms. Indeed, this category of disorders includes cases of dystocia, mastitis, and agalactia. This is 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 addition, uncontrolled reproduction between different breeds may be the basis of cases of dystocia observed.

Plants used to treat different groups of disorders

The results show that there is a strong correlation between the Relative Frequency of Citation for each disease group and the number of plants cited for their treatment. In fact, the groups of diseases most frequently encountered, such as disorders of the digestive system (D), disorders related to pregnancy and parturition (W), and general non-specific diseases are treated respectively by 72, 34 and 29 medicinal plant species. On the other hand, the disorders related to the musculoskeletal system (L), the disorders of the eye (F) and the neurological disorders (N) are treated respectively with 6, 5 and 2 species of medicinal plants. Whatever the category of disease, the main plants inventoried in this study are: *Spondias mombin* L.; *Zanthoxylum zanthoxyloides* (Lam.) Watermann; *Khaya senegalensis* (Desr.) A. Juss; *Morinda lucida* Benth.; *Moringa oleifera* Lam; *Striga hermonthica* (Delile) Benth.; *Adansonia digitata* L.1753; *Ocimum gratissimum* L.; *Caesalpinia bonduc* (L.) Roxb.; *Elaeis guineensis* Jacq. and *Azadirachta indica* A. Juss. These different species were previously inventoried during ethnobotanical surveys [8, 12, 17, 19, 33]. Most of the listed plants are used to treat two or more disease categories. Thus, their Fidelity Level was put to contribution to clear the most indicated plants to treat each category of diseases. For the treatment of diseases of the digestive system for example, among the 72 plants used, twenty were selected which worth further research. It is mainly *Zanthoxylum zanthoxyloides* (Lam.) Watermann; *Striga hermonthica* (Delile) Benth.; *Khaya senegalensis* (Desr.) A. Juss.; *Adansonia digitata* L., 1753; *Morinda lucida* Benth.; *Spondias mombin* L.; *Elaeis guineensis* Jacq.; *Caesalpinia bonduc* (L.) Roxb.; *Azadirachta indica* A. Juss; *Newbouldia laevis* (P. Beauv.) Seem; *Carica papaya* L; *Momordica charantia* L.1753; *Anogeissus leiocarpa* (DC.) Guill. & Perr.; *Vitex doniana* Sweet, 18271; *Crossopteryx febrifuga* (Afzel, ex G. Don) Benth; and *Parkia biglobosa* (Jacq.) R. Br. ex G. Don. Several previous studies have already shown that these plants are used to treat digestive disorders in domestic animals [8, 12, 13, 15, 19, 333, 34]. In addition, chemical and biological studies have been conducted and confirmed the *in vivo* and *in vitro* efficacy of some of these plants [35, 36, 37, 38, 39, 40]. Nevertheless, *Striga hermonthica; Momordica charantia* L., 1753 and *Elaeis guineensis* Jacq. are less studied. Some medicinal species have been versatile and therefore well-suited for the treatment of several disease categories. Thus, *Adansonia digitata* L. is also indicated for the treatment of diseases related to metabolism and nutrition (T). Similarly, *Spondias mombin* L. can be used to treat diseases related to pregnancy and parturition. This corroborates the results of Adedokun et al. [41], Gbolade and Adeyemi, [42] who respectively found that the plant can be used in the treatment of diseases related to pregnancy and parturition and digestive parasitic infection.

Influence of socioeconomic and environmental factors on traditional knowledge of plants used to treat small ruminants

The analysis of the results shows that the size of the small ruminant livestock, the sex of the respondent, the agroecological zone, and the ethnicity of the respondent significantly influence the knowledge of the plants used to treat small ruminant diseases. These results corroborate those of Dassou et al. [22] who showed that agroecological and phytogeographic zones, ethnicity and educational level influence knowledge in traditional veterinary medicine in Benin. Respondents from agroecological zone1 (Karimama) have a high level of knowledge compared to other zones considered in our study. This would be justified by the lack of money, the absence of veterinary services and the inaccessibility to sanitary products in the municipality of Karimama. Thus, to cope with the sanitary management of the animals, populations are forced to turn to ethnoveterinary practices. Le Gall and Leboucq [2] 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 work has revealed that the practice of ethnoveterinary in small ruminant farms depends on the size of the herd. In fact, the larger the livestock size, the less the breeders use the plants to treat small ruminants. This could be justified by the fact that breeders who have a large flock may have difficulty in preparing plant-based recipes for all animals. Similarly, these farmers would have more financial capacity than those who have a small flock and therefore able to buy veterinary products and pay veterinary service. 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 the size of the herd and the level of knowledge in ethnoveterinary [19, 22, 43, 44]. Like herd size, ethnicity is also linked to the knowledge of the plants used to treat small ruminants. These results are consistent with those of Assogbadjo et al. [23]; Kouchade et al. [44] and Loko et al. [24] who found that traditional knowledge varies according to sociocultural groups in Benin. Indeed, Dendi and Fulani have a strong knowledge compared to other sociocultural groups involved in this study. This can be linked to the fact that these two sociocultural groups are herders of origin and therefore attach a price to the welfare of their animals.

Conclusion

Ethnoveterinary is an ancestral practice that continues to contribute to the improvement of animal production. The present study shows that it is used by the majority of small ruminant's breeders in Benin either to treat diseases or to improve livestock productivity. The main diseases to treat are those of the digestive system and those related to pregnancy and parturition. Sex, agro-ecological zone, sociocultural group (ethnicity) and herd size are the factors that significantly influence the level of knowledge of plants used to treat sheep and goats diseases. The main inventoried plants are: *Zanthoxylum zanthoxyloides* (Lam.) Watermann; *Khaya senegalensis* (Desr.) A. Juss; *Morinda lucida* Benth.; *Moringa oleifera* Lam and *Striga hermonthica* (Delile) Benth. Chemical and biological studies are needed to test the properties attributed to the main inventoried plants.

Abbreviations

RFC: Relative Frequency of Citation; FL: Fidelity Level; CFI: Consensus Factor of the Informant; ICPC: International Classification of Primary Care; SICC-Benin: Système d'Information sur les Changements Climatiques au Bénin; FAO: Food and Agriculture Organization of the United Nations.

Declaration

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Authors' contributions

ET, PAO, MRBH, FAG, JQL participated in the study design and funding the study. ET and JAK carried out interview work. ET analysed, interpreted the data and drafted the manuscript. TDH, PAO, EVBA, JQL, SMHA and FAG corrected the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

Raw and treated data generated during study are presented in this article (Table 13).

Ethics approval and consent to participate

All work conducted was carried out under the stipulations of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity. The right to use and authorship of any traditional knowledge of all participants is maintained, and any use of this information, other than for scientific publication, does require additional prior consent of the traditional owners, as well as a consensus on access to benefits resulting from subsequent use.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1] Laboratoire d'Ethnopharmacologie et de Santé Animale, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 01 BP 526 Cotonou, Bénin. [2] Laboratoire de Biotechnologie et d'Amélioration Animale, Faculté des Sciences Agronomiques, Institut des Sciences Biomédicales Appliquées (ISBA), Université d'Abomey-Calavi, 01 BP 526 Cotonou, Bénin. [3] Laboratoire de Pharmacognosie/Centre Béninois de la Recherche Scientifique et Technique (CBRST)/ UAC, 01 BP 06 Oganla Porto-Novo. [4] Université catholique de Louvain, Louvain Drug Research Institute, Pharmacognosy Research Group, Avenue E. Mounier, B1.72.03, B-1200 Brussels, Belgium. [5] Laboratoire des Sciences Animale et Halieutique (LaSAH), Unité de Recherches Zootechnique et Système d'élevage, Ecole Doctorale des Sciences Agronomiques et de l'Eau, Université Nationale d'Agriculture, 01 BP 55 Bénin. [6] Laboratoire d'Ecologie Appliquée, Faculté des Sciences Agronomiques, Université´ d'Abomey-Calavi, 01 BP 526, Cotonou, Bénin. [7] Laboratoire d'Ecologie, de Botanique et de Biologie Végétale, Faculté d'Agronomie, Université de Parakou (FA/UP), 03 BP 125, Parakou, République du Benin. [8] Laboratoire de Biomathématiques et d'Estimations Forestières, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 04 BP 1525, Cotonou, Bénin. [9] Laboratoire d'Écologie, de Santé et de Productions Animales, Département des Sciences et Techniques de Production Animale et Halieutique, Faculté d'Agronomie, Université de Parakou, 01 BP 2115, Cotonou, Bénin.

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Figures

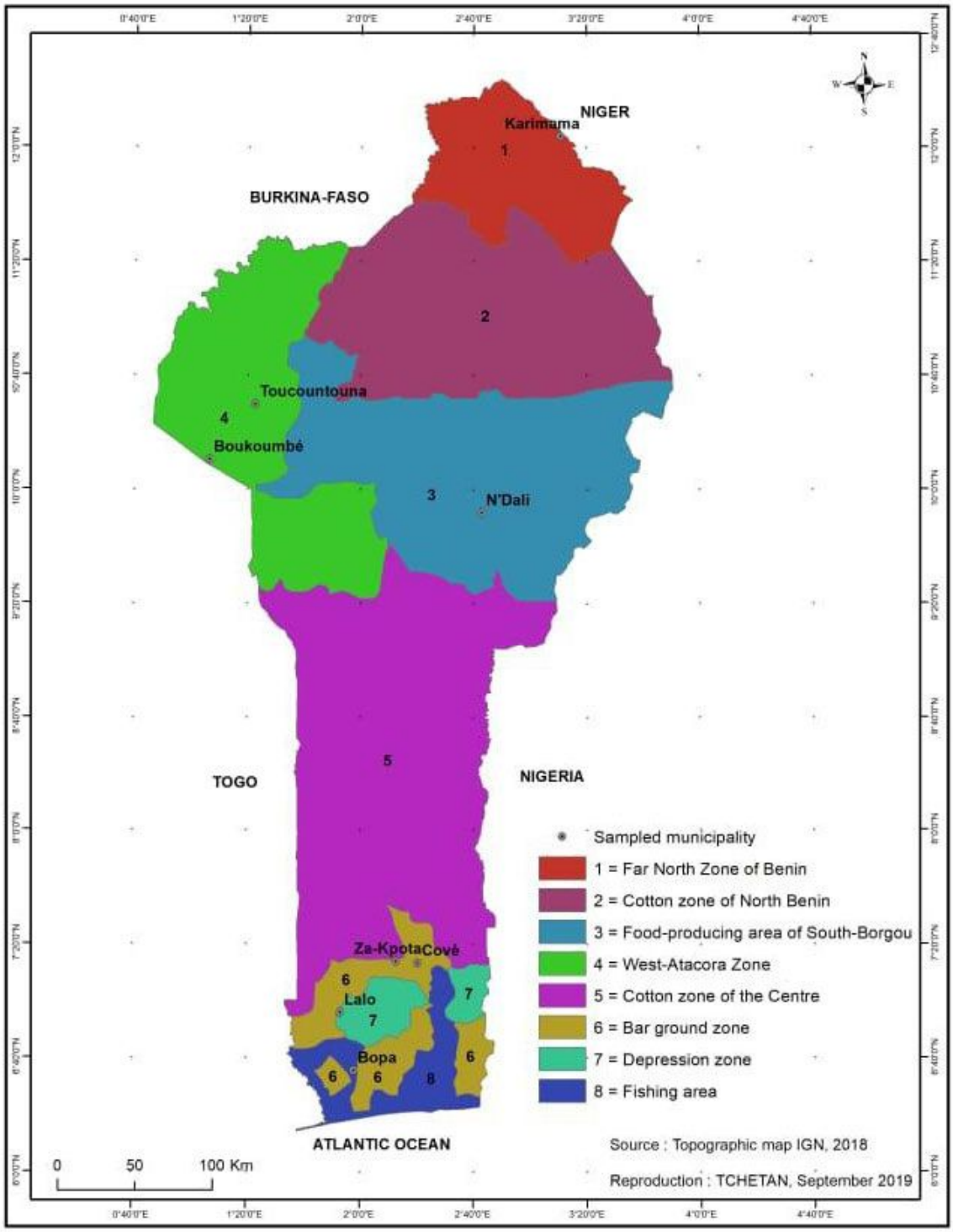

Figure 1

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

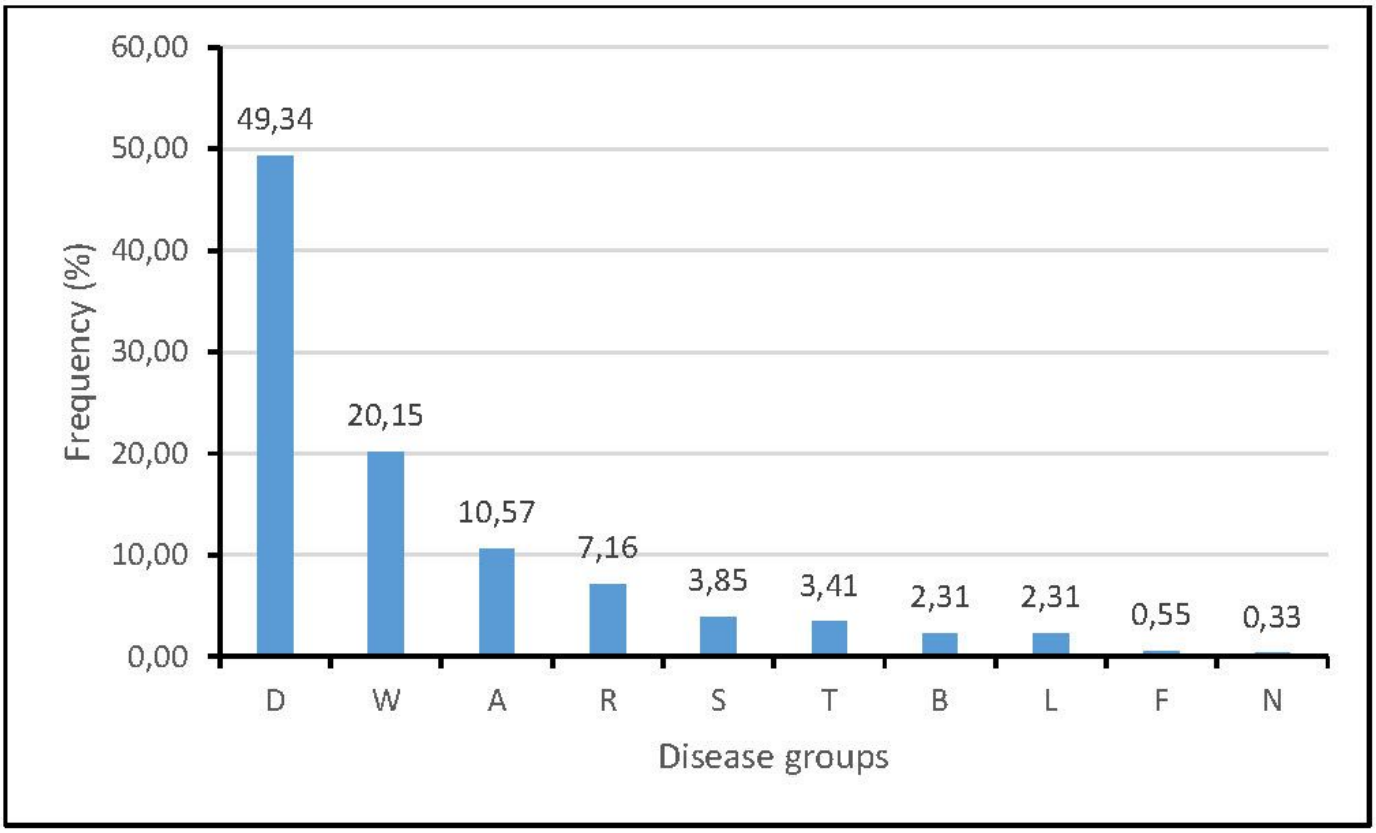

Figure 2

Relative Frequency of Citation of disease groups encountered in small ruminant flocks in Benin.

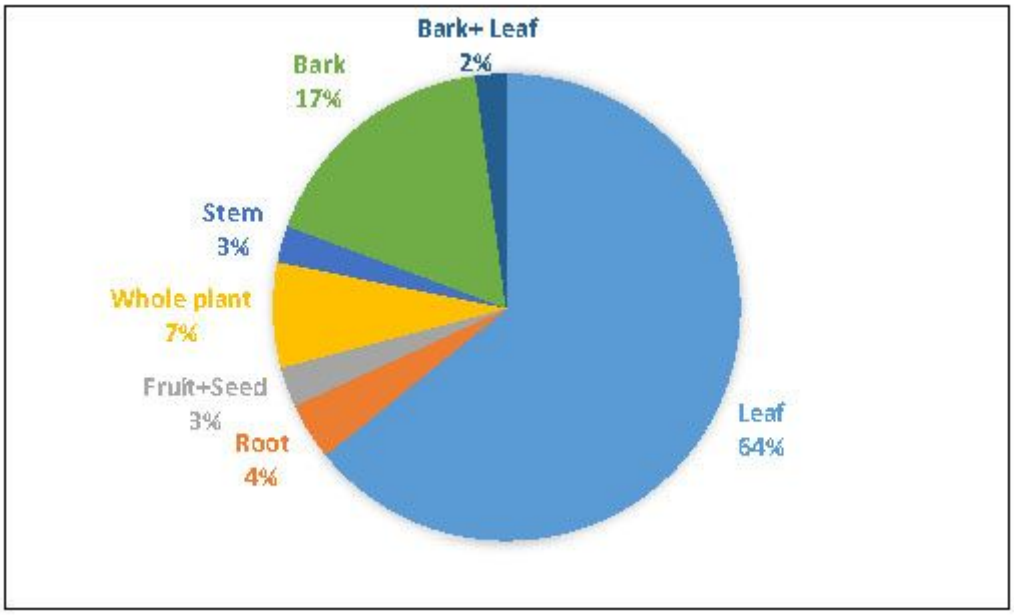

Figure 3

Percentage of plant parts used for recipes preparation.

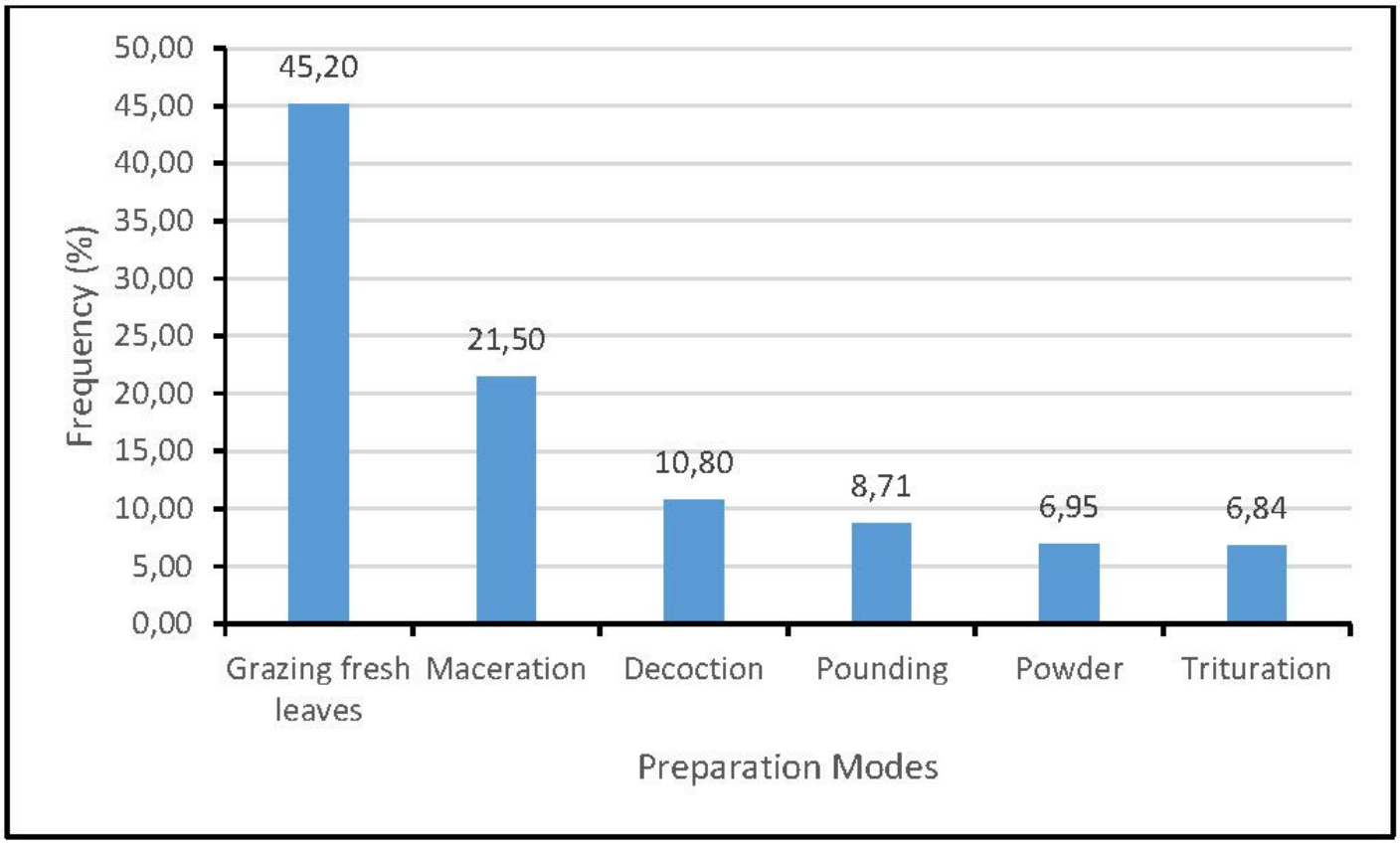

Figure 4

Percentage of preparation modes of remedies.

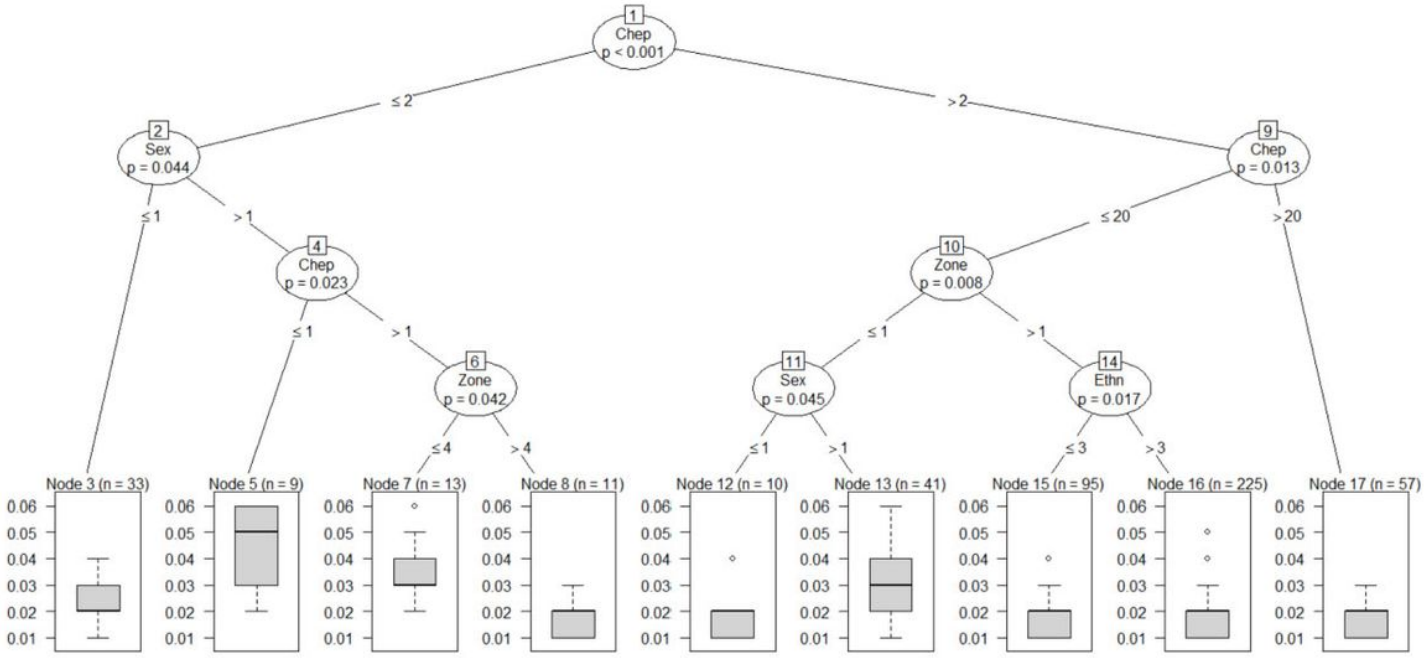

Figure 5

Decision tree showing the socioeconomic and environmental factors that influence plant knowledge used to treat small ruminant diseases.

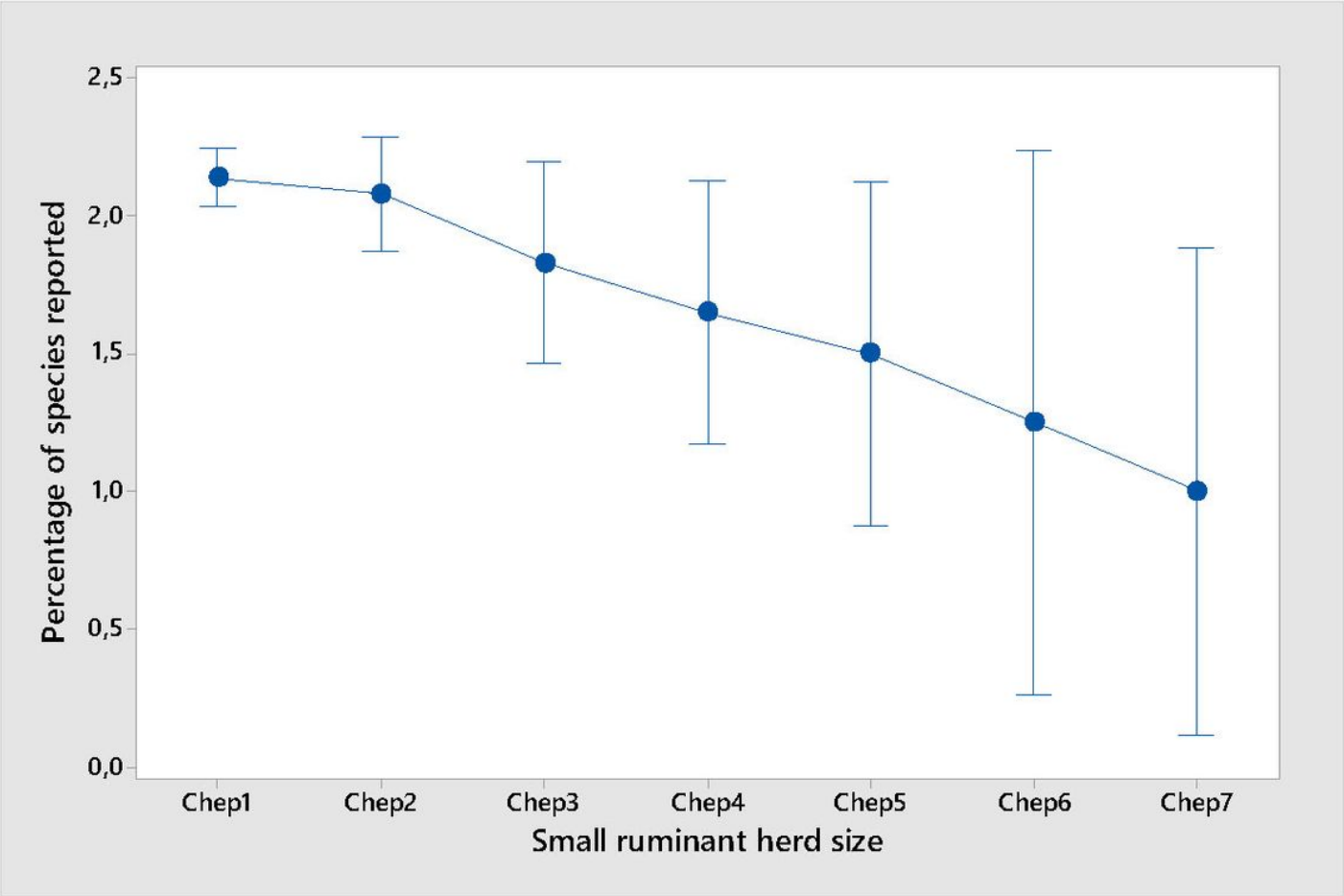

Figure 6

Evolution of the relative plant frequency used to treat small ruminant diseases as a function of herd size.

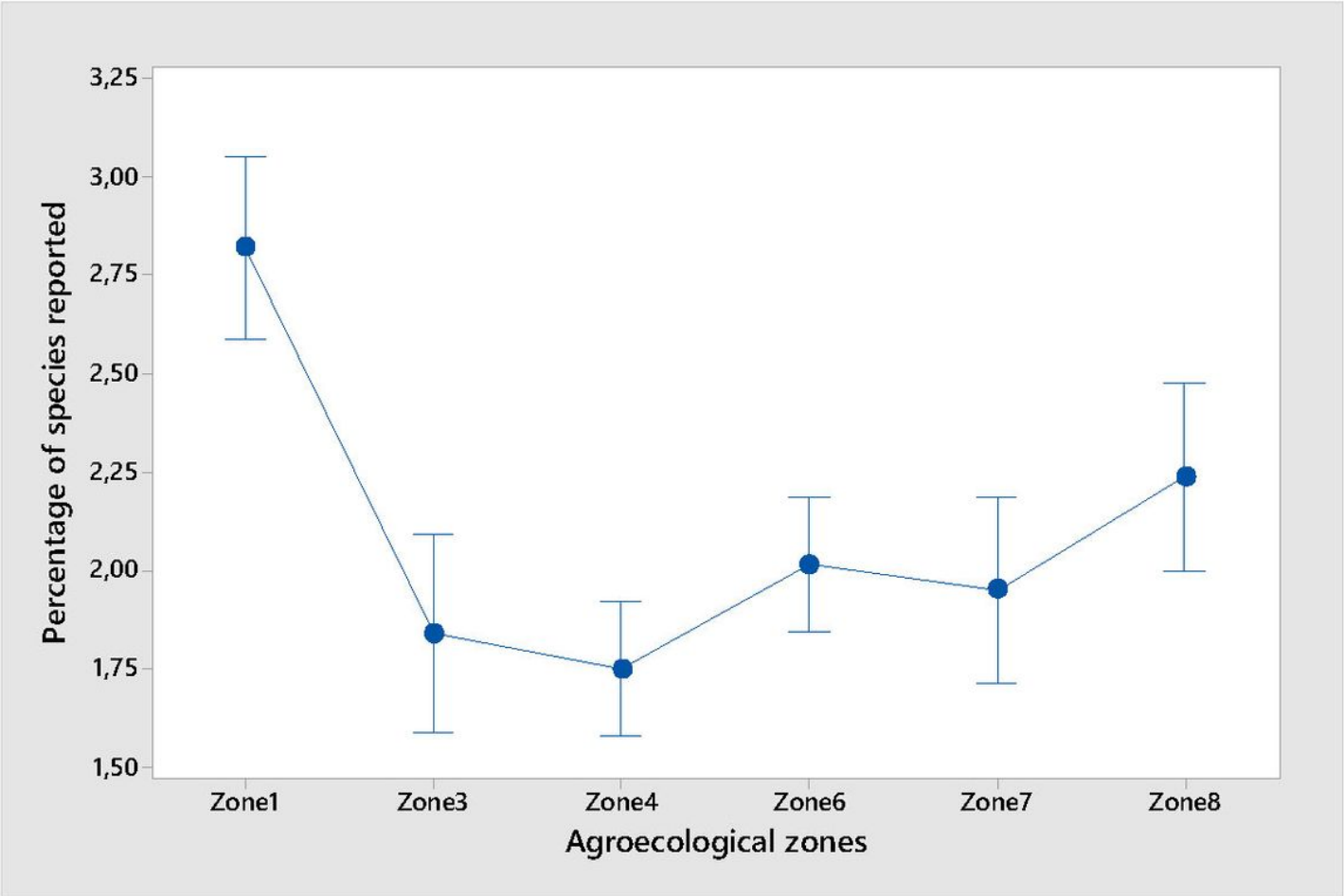

Figure 7

Variation in the level of knowledge on plants used to treat small ruminant diseases according to agroecological zones.

Supplementary Files

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