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Ethnoveterinary survey of trypanocidal medicinal plants of the beninese pharmacopoeia in the management of bovine trypanosomosis in North Benin (West Africa)

Christophe Iwaka [a,c,f], Erick Virgile Bertrand Azando [a,b,f,*], Thierry Dehouegnon Houehanou [c,d], Sabi Kora [a], Yaya Idrissou [a], Pascal Abiodoun Olounlade [b,e,f], Sylvie Mawulé Hounzangbe-Adote [f]

[a] *Laboratoire d'Ecologie, de Santé et de Production Animales (LESPA), Faculté d'Agronomie (FA), Université de Parakou (UP), 01 BP 123, Parakou, Benin*
[b] *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, Benin*
[c] *Laboratoire d'Ecologie, de Botanique et de Biologie Végétale, Faculté d'Agronomie, Université de Parakou, 03 BP 125, Parakou, Benin*
[d] *Laboratoire de Biomathématiques et d'Estimations Forestières, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 04 BP 1525, Cotonou, Benin*
[e] *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, Porto Novo, Benin*
[f] *Laboratoire d'Ethnopharmacologie et de Santé Animale, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 01 BP 526, Cotonou, Benin*

A R T I C L E I N F O

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A B S T R A C T

Cattle breeding is of great socio-economic importance for Benin's cattle farmers in general and those of North Benin in particular. The objective of this study is to inventory the natural products of medicinal plants of the Beninese pharmacopoeia for the management of trypanosomes in cattle in North Benin. The methodology consisted of individual and semi-structured interviews with cattle farmers on the use of medicinal plants. A total of 360 cattle farmers were selected and interviewed in twelve villages in four municipalities (Tchaourou, N'dali, Bembèrèkè and Gogounou) in northern Benin. Different quantitative ethnobotanical indices were calculated to determine the level of use of plant species. The Relative Frequency of Citation (RFC), the Informant Consensus Factor (ICF = 0.918) and the Generic Coefficient (Rg = 1.04) were evaluated. The knowledge of medicinal plants was influenced by the level of education and the main activity of those who practiced animal husbandry. The results yielded 48 medicinal plants for veterinary use belonging to 46 genera and 28 families. The Leguminosae family (12.50%) was the most represented. The most cited plants with a RFC above 10% were *K. senegalensis, P. africana, K. africana, M. inermis, S. latifolius, M. polyandra*. The parts used were leaves (46.15%); barks (24.62%) and roots (15.38%). Decoction (53.23%), plundering (32.26%) and maceration (11.26%) were the main methods of preparation. The administration was mainly by oral route. The calculated indices show a high diversity of medicinal plants with trypanocidal properties in the control of cattle trypanosomosis in the Sudanese and Sudano-Guinean zones of northern

* Corresponding author. Laboratoire d'Ecologie, de Santé et de Production Animales (LESPA), Faculté d'Agronomie (FA), Université de Parakou (UP), 01 BP 123, Parakou, Benin.
E-mail addresses: iwakachristophe@gmail.com (C. Iwaka), erickazando@gmail.com (E.V.B. Azando).

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Benin. Plant species with high citation and RFC values should be selected for comprehensive pharmacological and phytochemical research to validate this ethnomedical knowledge in the management of cattle trypanosomosis.

1. Introduction

The use of medicinal plants as a source of medicines to treat human and animal diseases is a traditional practice. Ethnoveterinary medicine often offers less expensive options than conventional products. Natural products are locally available, more readily accessible, and are generally less toxic [1,2]. Interest in medicinal plants for veterinary use has recently increased [3–7] as they do not pose, currentl, resistance problems compared to synthetic drugs such as antibiotics [8]. The abusive and sometimes inappropriate use of antibiotics have given rise to resistance phenomena in almost all bacterial species [9,10]. These resistances constitute a real public health problem and a major concern in the field of animal health. Among the animal pathologies involved, African Animal Trypanosomosis appears to be one of the major constraints to the development of cattle breeding in North Benin [11].

In cattle, trypanosomosis causes an increase of 6–20% in the annual mortality rate of calves, a decrease of 6–19% in the calving rate and makes it difficult to improve genetics and intensify animal production [12]. Thus, several methods are used to control the disease (vector control, chemicals, insecticides, breeding of trypanotolerant cattle breeds). However, only chemical control with trypanocidal

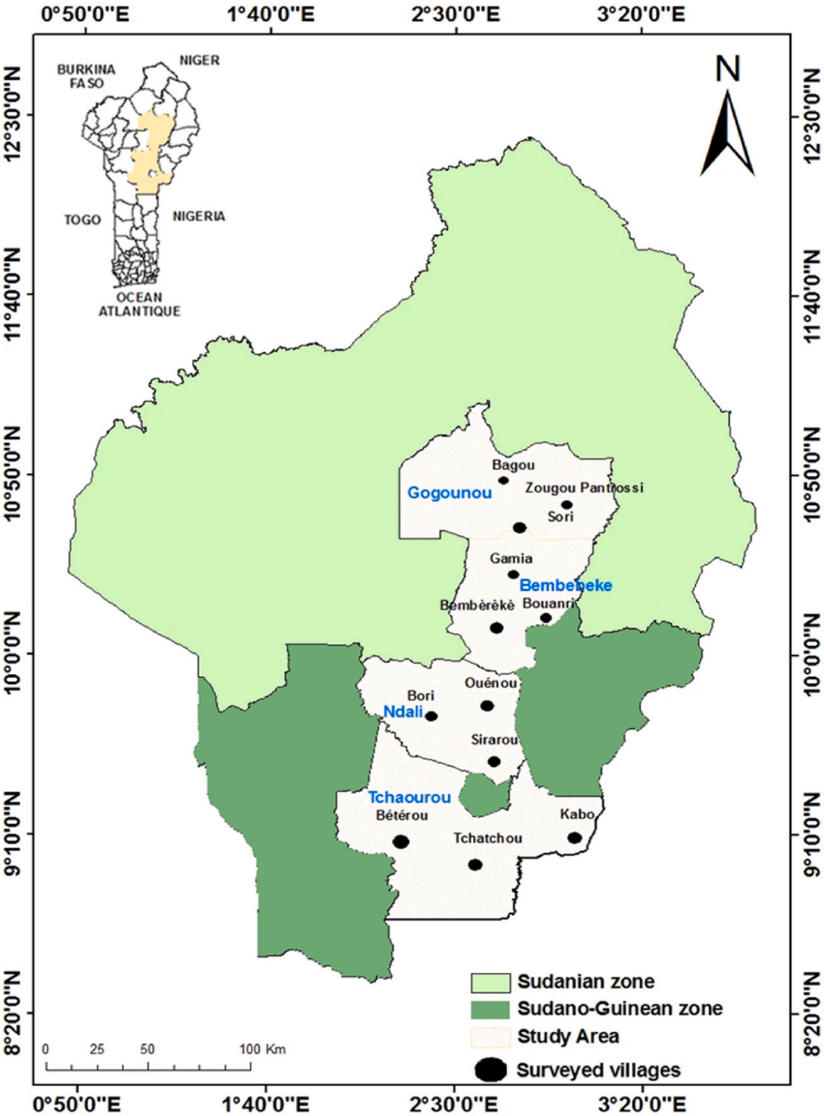

Fig. 1. Map showing the two vegetation zones and the main villages surveyed.

products is more widely used. This leads to the appearance of resistant trypanosome strains [13,14]. This phenomenon, called chemoresistance [15–17] makes us think of other forms of control.

The work carried out in Benin on medicinal plants for veterinary use in the pharmacopoeia revealed that the beninese flora abounds in a diversity of plant species for the control of several animal pathologies [18]. To be innovative and circumvent resistance mechanisms, future antibiotics will need to target new modes of action [19–23]. There are many lines of research, but one of the most promising ones encourage the use of natural plant resources because their diversity represents the largest reservoir of active substances. To face this problem, some breeders are adopting the natural products of medicinal plants of the African veterinary pharmacopoeia. Financially deprived farmers often turn to plants in their environment to treat certain diseases. The present study seeks to inventory the natural products of medicinal plants for the control of trypanosomes in cattle in northern Benin. These medicinal plants may be the starting point for the discovery of a new trypanocidal drug effective against bovine trypanosomosis.

The novelty of this study is the participatory approach involving farmers in the use of medicinal plants in order to generate sustainable solutions that are more accessible to all because plants have long been used by rural communities in traditional medicine for the preparation of natural products against certain diseases. The results of this study will help to improve the methods of control of trypanosomosis in cattle and will establish scientific knowledge on natural products in the fight against bovine trypanosomosis that can be valued by farmers in Africa and in the world. Thus, the present study inserts the use of natural products of medicinal plants of the Beninese pharmacopoeia to control the disease and increase sustainable animal production.

2. Materials and methods

2.1. Study area

The study was carried out in two vegetation zones in northern Benin: the Sudanian zone and the Sudano-Guinean zone. The Sudanian zone is located between 9°45 N and 12°25 N. Rainfall in this zone varies from 900 to 1100 mm per year. Air humidity is 18% during the harmattan. The average monthly temperature varies from 24 °C to 31 °C. The Sudanian zone is the domain of hydromorphic soils, drained soils, ferralitic cuirasses and lithosols. The Sudano-Guinean zone is located between 7°30′ N and 9°45′ N. Rainfall in this zone varies from 900 to 1100 mm per year. Relative humidity varies from 31% to 98%. Temperatures vary between 25 °C and 29 °C. In this area, there are mineral soils that are not very developed and not very fertile, and ferruginous soils on crystalline base of variable fertility [24].

The ethnobotanical survey covers 4 municipalities in northern Benin, distributed as follows: two in the Sudanian zone (Bembèrèkè and Gogounou) and two in the Sudano-Guinean zone (Tchaourou and N'dali). In addition, more than 85% of the cattle population is concentrated in these areas [25]. These areas were selected because of the presence of a high number of cattle farmers, but also because of the large influx of transhumant herds from neighboring countries such as Togo, Burkina Faso, Nigeria and Niger. In addition to location, agricultural production and livestock are the main economic activities of 55% of households in the two zones [26].

Based on the criteria defined with local technicians, six villages were selected by vegetation zone. In the Sudan-Guinea zone, the villages of Tchatchou, Béterou and Kika in the municipality of Tchaourou; the villages of Sirarou, Bori and Ouénou in the municipality of N'dali; the villages of Gamia, Bouanri and Bembèrèkè in the municipality of Bembèrèkè; and the villages of Sori, Bagou and Zougoukpantrossi in the municipality of Gogounou were identified (Fig. 1). These villages were selected based on their accessibility during the study period and the number of cattle farmers in the village (greater than or equal to 30 cattle farmers).

The study was conducted in accordance with the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of the National University of Agriculture of Porto Novo (Benin) for research and code of practice for housing, care and welfare of animals used in scientific procedures, N° 143–2018/President-CER/SA of 8 November 2018.

2.2. Data collection

The collection was done in three phases: the exploratory survey, the ethnoveterinary survey and the data processing.

2.2.1. Exploratory study

The exploratory study was previously conducted for two weeks to validate the questionnaire and to determine the sample size. The number of samples (farmers) was calculated according to Dagnelie [27] using the following equation (1):

$$N = \frac{4P(1-P)}{d^2} \quad (1)$$

where *N is* the total size of cattle farmers to be interviewed; *P* is the proportion of cattle farmers in the survey area who use or know about medicinal plants used in the prevention or treatment of bovine trypanosomosis or not and *d* is the marginal error at 5%.

2.2.2. Inclusion and exclusion criteria

Cattle farmers must be residing in the municipalities of Tchaourou, N'dali, Bèmbèrèkè and Gogounou. They had to use or know medicinal plants to treat bovine trypanosomiasis. The cattle farmer should: i) be at least 20 years old (the age limit is explained by the fact that we would like to be reassured that the herder has experience in the practice of traditional medicine), ii) be willing to divulge information about traditional veterinary medicine (this criterion was added because of the reluctance of some herders to share secrets about traditional medicine practices in some African communities), iii) have at least 15 head of cattle, iv) have herding as their main activity. The choice of the size of the cattle farmer as a criterion is justified by the fact that the size of the herd reflects the economic power of the cattle farmer and confers on him a certain social rank in society, and then the possible damage in the event of an outbreak of trypanosomosis in the herd.

Cattle farmers who were excluded from the study included: those who were visiting the municipalities and did not reside in the study area; those who had not agreed to participate in the survey. In addition, those who were unable to speak or communicate were not included.

2.2.3. Ethnoveterinary survey

Ethnoveterinary data collection took place from March to July 2021 using semi-structured individual interviews and direct observations with the help of a local translator familiar with the study setting. The baseline questionnaire was structured in three sections. The first section of the questionnaire concerned the socio-demographic characteristics of the respondent (ethnicity, age, gender, level of education, household size, livestock experience, main activity, reasons for using medicinal plants etc.).

The second section dealt with the sanitary management of the cattle farmer, i.e., the breeds raised, watering methods, housing, the most dominant pathologies in the farm, local name of the disease.

The third section concerned medicinal plants with trypanocidal potential (i) methods of preparation, (ii) routes of administration, (iii) parts used, (iv) duration of treatment, (v) dosage, (vi) name of the plant in the local language, and (vii) other animal pathologies treated. The plants mentioned by the respondents were harvested and herbed immediately for identification. During data collection, only herbal treatments were considered in this study. Remedies involving the use of ingredients such as potash, salt, sugar, or others were not considered. The medicinal plants mentioned were identified in the area where the herders usually collect them. Specimens were collected and numbered on site and then preserved in herbarium form. The identification was done at the Laboratory of Ethnopharmacology and Animal Health in University of Abomey-Calavi (Benin) using the analytical flora of Benin, in accordance with the reference herbaria of Akoègninou et al. [28]. Additional identification was performed by comparing the specimens with those previously identified and preserved at the National Herbarium of the University of Abomey-Calavi (Benin). Digital cameras were used for graphic documentation. Botanical names of plant specimens were updated according to The World Flora Online. The first cattle farmes meeting the inclusion criteria were identified and randomly selected in each municipality of the study area with the help of the heads of the municipality cells of the Agence Territoriale de Développement Agricole (ATDA). Then, the non-probabilistic "snowball" method [29] was used to identify the next cattle farmers. In this method, the first cattle farmers surveyed indicated other cattle farmers and thus became additional informants. All individuals identified in an area who met the inclusion criteria were interviewed. The ethnoveterinary survey was conducted among 360 cattle farmers in the Sudanese and Sudano-Guinean zones of northern Benin. That is, 30 respondents per village.

2.3. Data processing

The results of the ethnobotanical survey were analyzed using various quantitative indices of relative cultural importance to determine the level of knowledge and use of plant species by cattle farmers. These are the Relative Frequency of Citation (RFC), the Informant Consensus Factor (ICF) and the Generic Coefficient (Rg). These different indices were calculated to assess the importance of the recorded plant species. The different indices calculated were based on the principle that plants with high citation rates were considered more important than those with low citations. The different ethnobotanical indices were calculated using the following formulas:

2.3.1. Relative frequency of citations (RFC)

The RFC, expressed as a percentage, is the number of respondents (n) using or aware of a given medicinal plant, relative to the total number of respondents (N). It was used to estimate the local importance of the species cited [30,31]. This equation (2) was used to evaluate the RFC.

$$RFC = \frac{\mathrm{n}}{\mathrm{N}} \times 100 \tag{2}$$

2.3.2. Informant consensus factor (ICF)

It measures the degree of homogeneity of informants knowledge about diseases. It was calculated according to the ratio [30]. This equation (3) was used to evaluate the ICF.

$$\mathrm{ICF} = \frac{(\mathrm{Nur} - \mathrm{Nt})}{(\mathrm{Nur} - 1)} \tag{3}$$

where Nur is the total number of citations and Nt is the number of species cited. The ICF is between 0 and 1. The closer the ICF is to 1, the more consensus there is among informants.

2.3.3. Generic coefficient (Rg)

Rg is the ratio of the number of species (Ne) to the number of genera (Ng) [32]. This equation was used to evaluate the Rg (4).

$$Rg = \frac{\mathrm{Ne}}{\mathrm{Ng}} \tag{4}$$

with Ne the number of species inventoried, Ng the number of genera and Rg the Generic Coefficient. If Rg = 1, the recorded anti-trypanosomal flora has low generic diversity; this means that a given genus has only one species. When the Rg value is greater than 1, this indicates high generic diversity for the recorded antitrypanosomal flora.

2.4. Statistical analysis

Survey data were processed using Microsoft Excel® 2016 spreadsheets and Statistical Package for Social Sciences (SPSS) version 17 software. Data on sociodemographic characteristics were subjected to descriptive analysis. Quantitative variables were subjected to Student's T test and qualitative variables to Chi-square test (χ^2).

The collected ethnobotanical data were entered and organized using both Microsoft Excel® 2016 and R.4.1.2 [33] in order to analyze and identify the frequencies of the respondents and the number of plants used, as well as the different proportions of the parts of the plants used and the botanical families to which they belong.

Multivariate analyses were also performed using R software version R.4.1.2 [33]. The multivariate analysis consisted of a Principal Component Analysis (PCA) with the absolute values of the plants cited to treat bovine trypanosomosis to examine whether the citation was consistent with the study area. This analysis provided a representation of the municipality and species cited as projections onto planes defined by the first factorial axes.

3. Results

3.1. Socio-demographic characteristics of respondents

The respondents were all male. The majority were from the Fulani ethnic group (75.83%), followed by the Gando (19.17%) and the Bariba (5%). Their main activities were cattle farmers (56.11%), farmers (29.17%) and traditional medicine (8.61%) with 96.11% being illiterate. All the people surveyed practiced an extensive livestock system where the majority of the animals are housed in the open air. It was noted that the size of the cattle herd per farmer varied from 7 to 300 cattle, from 0 to 200 sheep, 0 to 90 goats, 0 to 7 horses and 0 to 70 poultry (Table 1).

3.2. Main constraints of cattle in North Benin

During the ethnoveterinary survey, the cattle farmers interviewed identified several pathologies that frequently affect their herds. Among these constraints, trypanosomosis (90.83%) is more dominant. Then come dermatophilosis (50.28%); bovine pasteurellosis (39.44%); brucellosis (25.56%) and ectoparasites (20.83%). The rest of the diseases have a frequency that is below 20% (PPCB, digestive parasites, placental retentions, mineral deficiencies, agalactia, snake bites, symptomatic anthrax and foot rot). Other diseases include diarrhea, scabies and bovine tuberculosis (Fig. 2).

Table 1
Demographic information of participants engaged in the study (n = 360).

Variables	Vegetation Zone		Total	X^2	*P-value*
	ZSG	ZS			
Ethnic group					
Bariba	2.78^a	7.22^a	5.00	15.44	<0.001
Gando	26.67^a	11.67^b	19.17		
Fulani	70.56^b	81.11^a	75.83		
Level of education					
Illiterate	93.89^a	98.33^a	96.11	4.96	0.17
Primary level	3.89^a	1.11^a	2.50		
Secondary level	1.67^a	0.56^a	1.11		
University level	0.56^a	0.00^a	0.28		
Main activity					
Cattle farmes	58.33^a	53.89^a	56.11	8.24	0.14
Farmers	27.78^a	30.56^a	29.17		
Artisans	3.33^a	2.22^a	2.78		
Traditional healers	7.78^a	9.44^a	8.61		
Traders	2.22^a	2.78^a	2.50		
Public servant	0.56^a	1.11^a	0.83		
Age group					
[20–40[	28.33^a	15.56^b	21.94	37.19	<0.001
[40–60[	60.56^a	46.11^b	53.33		
≥60	11.11^b	38.33^a	24.72		

a,b: values on the same line marked with different letters are significantly different at the 5% level; SGZ: Sudanese-Guinean Zone; SZ: Sudanese Zone.

3.3. Symptoms of animals with the disease

Cattle farmers described the trypanosomosis by considering its clinical signs observable on animals. According to the cattle farmers, the recognition of the disease is based on the behavior of the affected animals and the symptoms observed. Fig. 3 illustrates the main signs of the disease according to the cattle farmers. Tearing (93.89%), hair loss (75.28%), weight loss (60.28%), and anorexia (54.44%) were the most commonly cited signs/symptoms to describe trypanosomosis.

3.4. Use

According to the survey results, the use of medicinal plants to treat bovine trypanosomosis is not a widespread practice. In both climatic zones, only 36.11% (Fig. 4c) of respondents said they use medicinal plants to treat or prevent the disease ("No" refers to farmers who do not use medicinal plants in the management of AAT). Comparing the two climatic zones, we can see that the use of medicinal plants is more widespread in the Sudano-Guinean zone (40.60%) (Fig. 4a) than in the Sudanian zone (31.67%) (Fig. 4b). Respondents who do not use medicinal plants to treat bovine trypanosomosis gave as an argument their lack of knowledge about medicinal plants to treat this bovine pathology.

3.5. Reasons for using medicinal plants against trypanosomosis

To treat or control AAT, all respondents use conventional products available from public and private veterinarians. The conventional products used are isometamidium chloride (Securidium®, Trypamidium®) and diminazene aceturate (Survidim®, Veriben®) and others. However, 36.11% of respondents practice traditional veterinary medicine to treat their sick animals suffering from AAT. According to these farmers, this action is explained by the high cost of modern treatments, the frequent unavailability of veterinary agents, the difficulty of access to veterinarians, especially during transhumance periods, the resistance of trypanosomes to trypanocidal products, and the inaccessibility of camps at certain times of the year.

3.6. Diversity of medicinal plants mentioned

At the end of the survey, a total of 48 plant species were identified as medicinal plants used by cattle farmers in northern Benin to treat bovine trypanosomosis (Table 2). These identified species represented 46 genera and 28 botanical families. The Leguminosae was the most represented family with six plant species. This was followed by Rubiaceae, Fabaceae with four plant species and Meliaceae, Anacardiaceae each represented by three plant species. The other families were less represented with one or two plant species (Fig. 5). The majority of genera (44) were represented by a single species. Two genera were represented by two species. These were *Ficus* with two species (*Ficus platyphylla* Delile and *Ficus sycomorus* L.) and *Allium* with two species (*Allium sativum* and *Allium cepa*).

In Table 2, six species stand out with citation frequencies above 10%. These are *Khaya senegalensis* (28.06%), *Prosopis africana* (20.28%), *Kigelia africana* (17.50%), *Mitragyna inermis* (14.44%), *Sarcocephalus latifolius* (12.78%), *Maranthes polyandra* (10.28%). Among the species cited, *Prosopis africana*, *Kigelia africana*, *Mitragyna inermis*, *Sarcocephalus latifolius*, *Maranthes polyandra* are among the first five species mentioned above with significant ethnobotanical indices and a high citation rate. They were well known to the various cattle farmers in the study area.

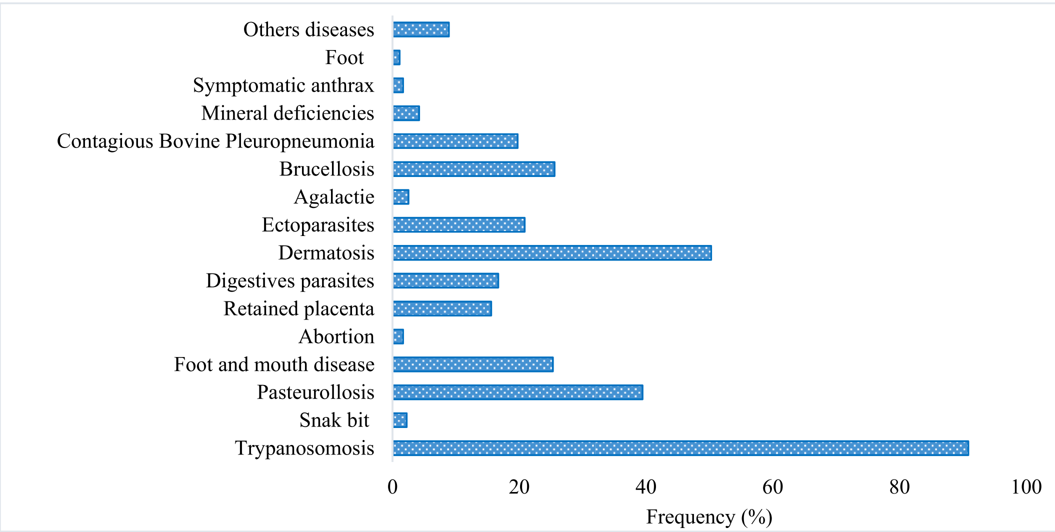

Fig. 2. Main cattle diseases in northern Benin.

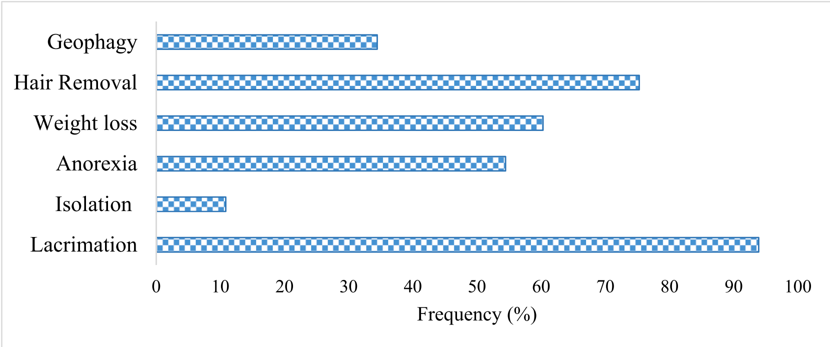

Fig. 3. Signs and symptoms reported by cattle farmers to describe the disease.

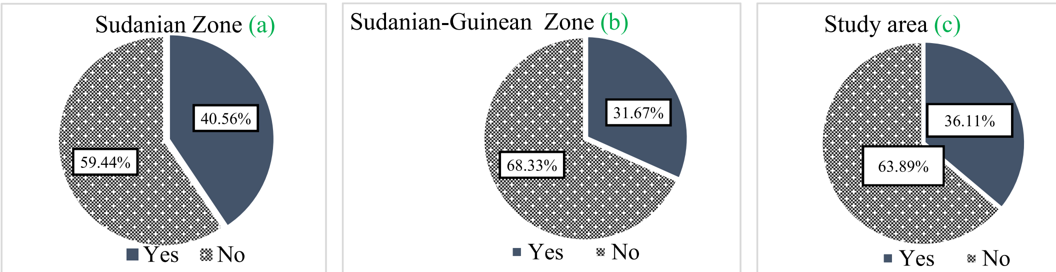

Fig. 4. Use of medicinal plants for the control of bovine trypanosomosis in northern Benin: Sudanian zone (a); Sudanian-guinean zone (b); Study area (c).

3.7. Parts of plants used, method of preparation and route of administration

The cattle farmers surveyed used different parts of the plants, however, leaves were more used (46.15%) than barks (24.62%) and roots (15.38%) in the preparation of natural products against bovine trypanosomosis (Fig. 6a).

The most common preparation methods (Fig. 6b) were decoction (53%), plundering: reduction to powder in a mortar after sun-drying (32%), maceration (11%) and calcination (3.23%). Decoction consisted of boiling the plant material in water; maceration consisted of leaving the plant material in water for two to four days and calcination consisted of reducing the plant material to ash. The oral route was the only mode of administration of natural products. Administration was in the form of powder incorporated into food for plundering and calcination and into drinking water for decoction and maceration.

3.8. Informant Consensus Factor (ICF), generic coefficient (Rg) and methods of acquiring knowledge about plants

In this study, Informant Consensus Factor was 0.92 and the Generic coefficient (Rg) was 1.04. Respondents reported several social learning processes to acquire knowledge about medicinal plants. The majority of respondents (83.85%) acquired their knowledge through ancestral inheritance from experienced relatives who used plant-based treatments (Fig. 7). Other sources included learning from traditional healers (6.92%), exchanges between cattle farmers (4.62%), formal training (3.08%) and personal observation (3.08%).

3.9. Principal component analysis (PCA)

The results of the Principal Component Analysis (PCA) show that 91.20% of the relationships between the species inventoried to treat animal trypanosomosis and the municipality are explained by the first two axes (Fig. 8), which is sufficient to guarantee the reliability of the interpretation of the results. Indeed, the projection of species and municipality on the first two axes shows that *Annona senegalensis, Maranthes polyandra, Parkia biglobosa, Adansonia digitata, Sarcocephalus latifolius, Mitragyna inermis, Kigelia africana, Khaya senegalensis, Prosopis africana, Afzelia africana, Allium sativum, and Azadirachta indica* are the species most often cited by herders in the four municipality to treat trypanosomosis in northern Benin. Overall, the use of plants to treat trypanosomosis did not vary from one municipality to another. There are a certain number of plants that are more frequently cited in the four municipality and others that are less frequently cited.

Table 2
Diversity of medicinal plants used by cattle farmers to control bovine trypanosomosis in northern Benin.

N°	Scientific name	Local name	Families	Part(s) used	Preparation methods	Administration route	DT (days)	N citation	RFC (%)
1	*Khaya senegalensis* (Desr.) A.Juss.	Kayé[P]	Meliaceae	B,L	Pl	Oral	3	101	28.06
2	*Prosopis africana* (Guill. & Perr.) Taub.	Tchinyélé[P]	Fabaceae	B	Dec	Oral	7	75	20.83
3	*Kigelia africana* (Lam.) Benth.	Djilidjalaye[P]	Bignoniaceae	B,Fr	Dec	Oral	4	63	17.5
4	*Mitragyna inermis* (Willd.) Kuntze	Koyi[P]	Rubiaceae	B,L	Dec	Oral	5	52	14.44
5	*Sarcocephalus latifolius* (Sm.) E. A. Bruce	Bakouré[P]	Rubiaceae	L	Dec	Oral	3–5	46	12.78
6	*Maranthes polyandra* (Benth.) Prance	Gorogué[P]	Chrysobalanaceae	B	Mac	Oral	7	37	10.28
7	*Afzelia africana* Sum	Wargnahi[P]	Leguminosae	L,B	Dec	Oral	3	34	9.44
8	*Adansonia digitata* L.	Boki[P]	Bombacaceae	B,L,R	Pl,Dec	Oral	3	28	7.78
9	*Annona senegalensis* Pers	Doukolhi[P]	Annonaceae	R	Pl,Mac	Oral	5	26	7.22
10	*Parkia biglobosa* (Jacq.) R. Br. Ex Benth	Naréhi[P]	Mimosaceae	L	Dec,Pl	Oral	7	17	4.72
11	*Allium sativum* L.	Garlic[B]	Amaryllidaceae	B	Dec	Oral	3	17	4.72
12	*Azadirachta indica* A. Juss	Miili[P]	Meliaceae	L,B	Mac,Pl,Dec	Oral	5	15	4.17
13	*Vitellaria paradoxa* C.F. Gaertn	Karehi[P]	Sapotaceae	B,L,R	Mac,Pl,Dec	Oral	5	14	3.89
14	*Cassia sieberiana*	Koli[P]	Caesalpinioideae	B	Dec	Oral	7	12	3.33
15	*Zea mays* L.	Kokoniri[P]	Poaceae	L	Cal,Mac	Oral	5	11	3.06
16	*Calotropis procera* (Aiton) W.T. Aiton	Bourdabey[P]	Apocynaceae	B	Pl	Oral	5	11	3.06
17	*Mangifera indica* L.	Mango[P]	Anacardiaceae	L	Dec	Oral	7	10	2.78
18	*Pseudocedrela kotschyi* (Schweinf.) Harms.	Kayiloumi[P]	Meliaceae	L	Dec	Oral	7	10	2.78
19	*Allium cepa* L.	Yamasaru[B]	Amaryllidaceae	B	Pl	Oral	3–5	10	2.78
20	*Isoberlinia doka* Craib & Stapf	Batahi[P] Guinssoba[B]	Leguminosae	B	Dec	Oral	7	10	2.78
21	*Nicotiana tabacum* L.	Taba-Gohonou[B]	Solanaceae	L	Dec	Oral	4	10	2.78
22	*Opilia celtidifolia* (Guill. & Perr)	Souka-soukayé[P]	Opiliaceae	L	Pl	Oral	7	9	2.5
23	*Pterocarpus erinaceus*	Agbannahi[P]	Leguminosae	B	Dec	Oral	7	8	2.22
24	*Ximenia americana* L.	Tchabouli[P]	Olacaceae	B	Pl,Dec	Oral	5	8	2.22
25	*Citrus limon* (L) Burm.f.	Lemunu[P]	Rubiaceae	L	Dec	Oral	3	8	2.22
26	*Ficus sycomorus* L.	Obi[P]	Moraceae	L	Pl	Oral	5	8	2.22
27	*Acacia polyacantha* Willd.	Patoucki[P]	Leguminosae	R	Dec	Oral	7	7	1.94
28	*Sorghum bicolor* (L.) Moench	Gaouri[P]	Poaceae	Fr	Pl	Oral	7	7	1.94
29	*Cleome gynandra* L.	Tchelle badje[P]	Caporaceae	B	Dec	Oral	7	7	1.94
30	*Crossopteryx febrifuga* (Afzel. ex G.Don) Benth.	Goumaré[P]	Rubiaceae	B,Fr,L	Dec	Oral	3	7	1.94
31	*Daniellia oliveri* (Rolfe)	Karlayé[P]	Fabaceae	L	Dec	Oral	5	6	1.67
32	*Detarium microcarpum* Gill. & Perr.	Konkéhi[P]	Leguminosae	B	Dec	Oral	7	6	1.67
33	*Swartzia madagascariensis* Desv.	Kokobi[P]	Leguminosae	R,B	Dec	Oral	7	6	1.67
34	*Balanites aegyptiaca*	Tawouki[P]	Zygophyllaceae	Yp	Pl	Oral	7	6	1.67
35	*Guiera senegalensis* J.F. Gmel.	Yoloko[P]	Combretaceae	L	Dec	Oral	2–4	5	1.39
36	*Lannea acida* A.Rich	Tchami[P]	Anacardiaceae	B	Pl	Oral	5–7	5	1.39
37	*Anacardium occidentale* L.	Acaju[B]	Anacardiaceae	L	Dec	Oral	3	5	1.39
38	*Ficus platyphylla* Delile	Doundéhi[P]	Moraceae	L	Pl	Oral	2–5	5	1.39
39	*Diospyros mespiliformis* Hochst. Ex A.DC.	Yinlbi[P]	Ebenaceae	B	Pl	Oral	7	4	1.11
40	*Cochlospermum planchonii* Hook.f. ex Planch.	Fadawanou[P]	Cochlospermaceae	Wp	Pl	Oral	7	4	1.11
41	*Lophira lanceolata* Tiegh. Ex Keay	Karitayé[P]	Ochnaceae	L,Fr	Pl,Dec	Oral		4	1.11
42	*Combretum collinum* Fresen.	Lactibodehi[P]	Combretaceae	B,L,R	Dec	Oral	3	3	0.83
43	*Adenia olaboensis* Forsk Fl.	Balké[P]	Passifloraceae	R	Dec	Oral	3	3	0.83
44	*Vigna unguiculata* (L.) Walp	Yeinbê[P]	Leguminosae	L,Wp	Dec	Oral	2–5	1	0.28
45	*Albizia chevalieri* (Harms)	Sabi-samporo[P]	Mimosaceae	R,L	Dec	Oral	4	1	0.28

(*continued on next page*)

Table 2 (*continued*)

N°	Scientific name	Local name	Families	Part(s) used	Preparation methods	Administration route	DT (days)	N citation	RFC (%)
46	*Hymenocardia acida* (Tul)	Salmonnaré[P]	Phyllanthaceae	L	Dec	Oral	7	1	0.28
47	*Pericopsis laxiflora* (Benth.) Meeuwen	Solkoué[P]	Fabaceae	B	Dec	Oral	3	1	0.28
48	*Tamarindus indica* L.	Jatemi[P]	cesalpinioideae	R	Dec	Oral	7	1	0.28

Legends: Parts used: L: leaves; B: bark; R: roots; Wp: whole plant; Fr: fruits; Yp: young plants. Preparation methods: Mac: maceration; Dec: Decoction; Pl: Plundering; Cal: Calcination. P: Peulh; B: Bariba; DT: Duration of treatment.

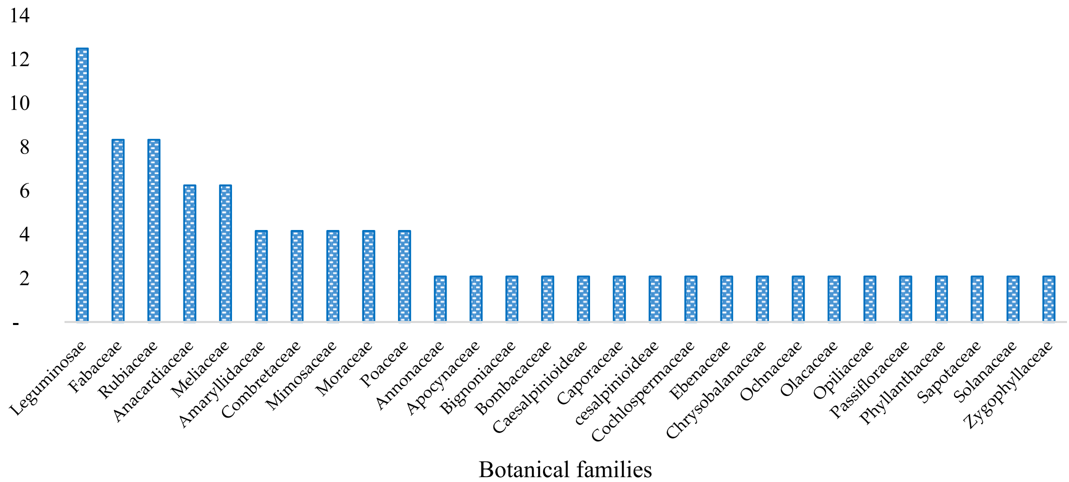

Fig. 5. Distribution of medicinal plants by botanical family.

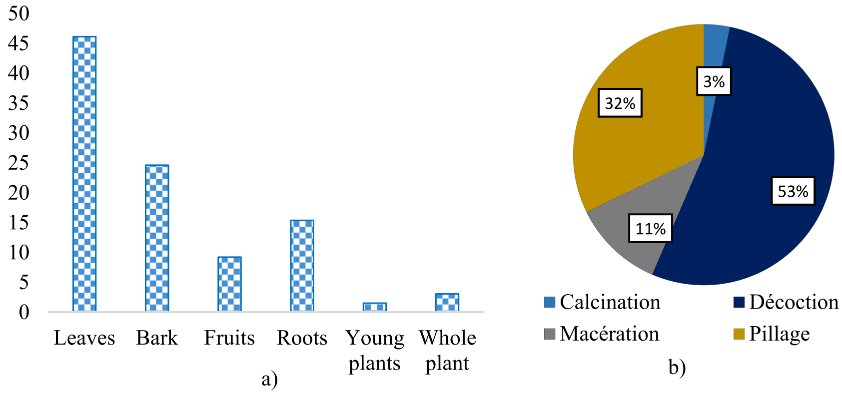

Fig. 6. (a): Parts of plants used in the preparation of remedies, (b): Main ways of preparation of medicinal plants.

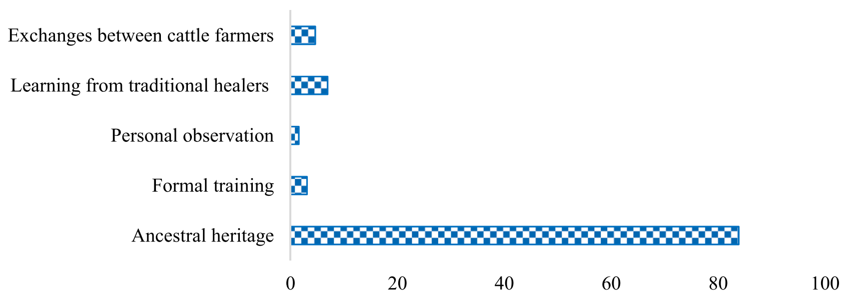

Fig. 7. Methods of acquiring knowledge about medicinal plants.

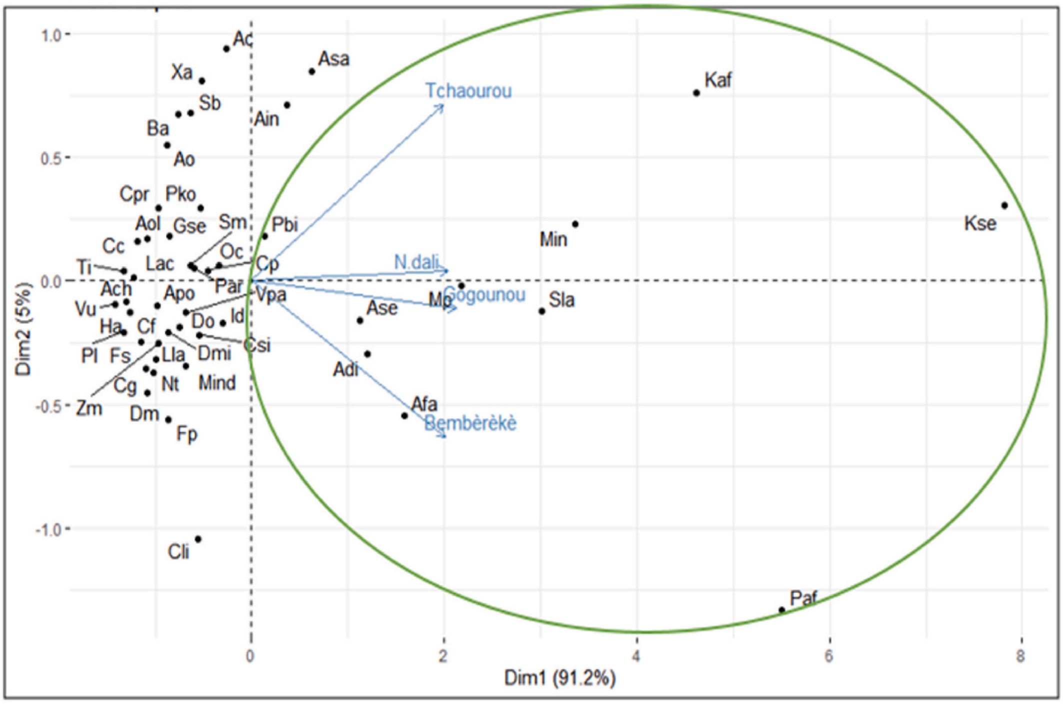

Fig. 8. Projection of the municipality and species inventoried on the first two axes of the principal component analysis.
Kse = Khaya senegalensis, Paf = Prosopis africana, Kaf = Kigelia africana, Min = Mitragyna inermis, Sla = Sarcocephalus latifolius, Mp = Maranthes polyandra, Ase = Annona senegalensis, Pbi = Parkia biglobosa, Vpa = Vitellaria paradoxa, Afa = Afzelia africana, Csi = Cassia sieberiana, Adi = Adansonia digitata, Mind = Mangifera indica, Pko = Pseudocedrela kotschyi, Asa = Allium sativum, Par = Pterocarpus erinaceus, Apo = Acacia polyacantha, Do = Daniellia oliveri, Dmi = Detarium microcarpum, Gse = Guiera senegalensis, Xa = Ximenia americana, Dm = Diospyros mespiliformis, Cpr = Calotropis procera, Cc = Combretum collinum, Lla = Lophira lanceolata, Oc = Opilia celtidifolia, Zm = Zea mays, Ain = Azadirachta indica, Cp = Cochlospermum planchonii, Lac = Lannea acida, Sb = Sorghum bicolor, Sm = Swartzia madagascariensis Desv, Vu = Vigna unguiculata, Walp, Aol = Adenia olaboensis, Ach = Albizia chevalieri, Ac = Allium cepa, Ao = Anacardium occidentale, Ba = Balanites aegyptiaca, Cli = Citrus limon, Cg = Cleome gynandra, Cf *= Crossopteryx febrifuga, Fp = Ficus platyphylla, Fs = Ficus sycomorus, Ha = Hymenocardia acida, Id = Isoberlinia doka, Nt = Nicotiana tabacum, Pl = Pericopsis laxiflora, Ti = Tamarindus indica.*

4. Discussion

4.1. Characteristics of respondents

In this ethnoveterinary study, of the 360 cattle's farmers interviewed, all were male. This profile is typical of most ethnoveterinary studies. This is because herds of animals especially cattle are usually herded by men. Similar studies conducted in Benin [5,34] reported similar results in their ethnoveterinary studies that men were in the majority in animal husbandry. On the other hand, in an ethnomedical study conducted in Algeria [35] and in Nigeria [36], these authors reported the opposite results where 69% and 70% of the respondents were women. This result could be related to the type of ethnomedical study involved, as in some cultures and traditions, household welfare and health care are the preserve of women only. The majority of respondents in this study were aged 40–60 years (53.33%). This result is similar to those found by Refs. [4,34] with respective frequencies of 56.19% and 51.40% for the 40–60 age group. It can be said that an older age is therefore an assurance of knowledge and mastery of ethnoveterinary practices. Other studies conducted by Refs. [37,38] showed that the majority of respondents were in the 50–59 and 30–59 age ranges respectively. This suggests that the elderly is living ethnomedical libraries, where knowledge of veterinary herbal medicine is retained for years.

By ethnic group, the Fulani (75.83%) represent more than half of the herders surveyed. This result is consistent with the results who reported that the Fulani were in the majority in their ethnoveterinary studies [38,39]. These results are justified by the fact that cattle production is considered a cultural practice of this ethnic group.

Most of the respondents were uneducated illiterate (96.11%) and practiced livestock raising (56.11%) as their main activities. These results support the observations of [39,40] who showed that livestock raising was the main activity of the uneducated.

4.2. Methodology used and choice of study area

This study, conducted in four municipalities in the Sudanese and Sudano-Guinean zones of northern Benin, provided information on the ethnoveterinary approach to medicinal plants used by the local population to control bovine trypanosomosis. The choice of the study area was motivated by the absence of ethnoveterinary studies on medicinal plants used to specifically treat blood parasites, particularly bovine trypanosomes. Some ethnoveterinary studies have already been carried out in Benin but on other animal pathologies. For example, we can cite the work done by Houndje et al. [37] on plants used in the treatment of foot and mouth disease in Benin [5,34] on medicinal plants used to treat pathologies of small ruminants in Benin. Other ethnoveterinary studies conducted in Benin are not specific to a single animal disease and involve several animal diseases [40,41]. However, no study has been conducted specifically on medicinal plants used in the treatment of bovine trypanosomosis in the Sudanese and Sudano-Guinean zone of northern Benin. Moreover, the cattle population of North Benin is estimated at more than 85% [25]. Other than these reasons, bovine trypanosomosis is one of the major constraints in terms of animal pathologies encountered by livestock farmers in North Benin [11].

4.3. Diversity of medicinal plants to treat AAT

For the management or treatment of bovine trypanosomosis, the reasons cited by cattle farmers for using traditional pharmacopoeia are consistent with observations made by Zongo et al. [42] in Burkina Faso. In Benin, herders use anthelmintic medicinal plants to treat small ruminants [38,43]. In addition to these reasons, the resistance of trypanosomes to conventional trypanocides is becoming more and more frequent [16,44,45]. This observation leads the scientific community and the farmers to look for other alternatives for the treatment of AATs through the use of medicinal plants that have cultural values, generally from natural resources and locally available in the rural environment.

In addition, the treatment of animals suffering from trypanosomosis continues and this is essentially based on the use of trypanocidal drugs based on two main molecules that have been used for decades [13,15,46]. These molecules are diminazene aceturate and isometamidium chloride which unfortunately are the subject of numerous cases of resistance in more than 18 African countries [47] leading to the appearance of resistant trypanosome strains [45,48,49] to these molecules that have been around for a very long time. The loss of efficacy of these molecules over time due to poor practices or deficient quality of the formulation (accidental or fraudulent) [50]. This phenomenon of resistance, described as chemoresistance [51], is becoming more widespread and suggests other forms of control of this disease. Associated with the common counterfeiting of trypanocidal formulations and the more or less important toxicity of these molecules [52], new methods of treatment and control of AATs are becoming necessary because the development of new vaccines in the near future against this scourge remains uncertain [53,54]. Trypanosomosis was reported as the main constraint in this study (90.83%). This can be explained by the fact that the sale of trypanocidal drugs represents between 20 and 25% of the veterinary products marketed in the disease endemic countries [55]. Approximately $51.89 and $58.8 million have been estimated as direct and indirect annual losses from nagana in Nigeria, respectively [56]. For example, a comparative analysis between tsetse-infested and non-tsetse-infested areas based on milk and meat production in the Niayes area of Senegal revealed that eradicating tsetse would yield approximately 2.8 million Euros annually after a 20-year period [12].

The conventional trypanocidal drugs used in this study to treat AAT are similar to those used by farmers in the Mouhoun River basin in Burkina Faso [57]. In traditional veterinary medicine, the trypanocidal plants most used by farmers are *Prosopis africana*, *Acacia polyacantha*, *Kigelia africana*, *Mitragyna inermis, Afzelia africana*, *Parkia biglobosa, Cassia sieberiana*, *Khaya senegalensis*, *Pseudocedrela kotschyi* for the treatment of trypanosomosis [41,58]. These plants are used because of their effectiveness against trypanosomes and their availability in the study area. In addition to these plants, several natural plants have been reported by other authors to have trypanocidal effects on livestock [59]. This is the case for extracts of the leaves of *Albizia gummifera* [60] hydromethanolic extracts of *Cymbopogon citratus* leaves and *Lepidium sativum* seeds [61] ethanolic and aqueous extracts of *Terminalia catappa* leaves [62] extracts of *Khaya senegalensis* [63] essential oils of four species of *Cymbopogon* [3]. These results reinforce those of Dzoyem et al. [1] on ethnoveterinary medicine which plays an important role in the management of livestock diseases in African countries. This medicine is the result of innovations generated after several years of practice and adapted to the socio-economic realities of livestock farmers in their areas of livestock production [56].

In this study, the most represented plant families are the Leguminosae. This family is well represented because it contains species that are widely used in veterinary beninese. The studies [34,43] corroborate this result but with varying percentages of Leguminosae. This result is contrary to the families recorded in Côte d'Ivoire (Solanaceae and Annonaceae) [64] and in Malawi (Papilionoideae, Mimosoideae and Euphorbiaceae) [65]. This difference could be attributed to the diversity of socio-cultural groups that vary from one country to another because the use of natural plant resources for therapeutic purposes can be correlated to the knowledge of socio-cultural groups [66]. The ethnoveterinary knowledge of the herders in the Sudanese and Sudano-Guinean zone of northern Benin is diverse and rich because of the diversity of plant species available. The climate in these two vegetation zones is different and varies according to the agro-ecological zones.

Informant Consensus Factor (ICF) was 0.92. This value shows that farmers had a strong consensus of information about trypanocidal plants. This disease is a real health problem for cattle and its effective and sustainable management remains a serious issue in the sector. This index indicates that cattle health problems are common among herders in the Sudanese and Sudano-Guinean zones of northern Benin. In this study, the value of the Generic coefficient (Rg) was 1.04. This value is greater than 1. This value is greater than 1. This indicates a high generic diversity for the recorded antitrypanosomal flora.

4.4. Part used, modes of preparation and methods of administration

The survey revealed a multitude of plants with trypanocidal value. For the plant species identified, all parts of the plant can be used. Leaves (46.20%) are widely used in the preparation of products. Several similar studies [6,67,68] corroborate that in the pharmacopoeia, leaves are more used to prepare traditional remedies [2,69]. Leaves are more commonly used because the removal of this part of the plant does not affect the viability of the species [70] and is safe for the plant itself, unlike the bark and roots. However, indiscriminate removal of leaves can impact the chlorophyll assimilation process in plants and consequently, the health of animals. In contrast [65,71] found in their respective studies that it is the roots that are more used with the respective frequencies of 72.2% and 77% in the preparation of natural products. Contrary to the use of leaves, the high use of roots threatens the conservation of medicinal plants and may lead to their extinction [72].

The oral route remains the main mode of administration; this is consistent with ethnobotanical studies [2,71,73] which reported that the oral route was the main mode of administering medicinal plant products. Water is the only solvent used in combination with salt, potash, sugar or honey because water has the advantage of dissolving alkaloid salts and glycosides better than other solvents. Studies carried out justify the use of water as a solvent in several ethnoveterinary studies for the preparation of natural products [74, 75]. The association of salt and honey is intended to facilitate the ingestion of the different preparations to be administered orally. Other preparations of natural products are in the form of plant extracts or vegetable oils used in the management of the disease [76, 77]. All prepared natural products were administered using a plastic container of variable capacity (500–1000 mL) for affected animals and sometimes double for large animals.

Decoction (53.23%) was more used as a method of preparation. Similar ethnoveterinary studies [6,69,78,79] have shown that most herbalists or cattle farmers prefer decoction as a method of preparation of natural products. This could be due to its simplicity of preparation and ease of administration. In addition, decoction allows the collection of the most active principles and attenuates or cancels the toxic effect of certain recipes [80].

4.5. Agreements on plant species conservation actions

The study shows that conservation actions of medicinal plant species for veterinary use used for the management of bovine trypanosomosis had no agreement among herders for their maintenance in the wild. For moderate logging and planting trials of these medicinal species, there was little agreement. Indeed, a study by Dassou et al. [81] showed that rural populations did not have clear ideas about the sustainable use of natural plant resources in an environment, regardless of their availability; even if these plants were not renewed. Moreover, the populations are aware of the importance of local plants in their daily life, but they do not have the culture to preserve them by plantations [82,83]. These results, like most studies in ecological analysis, show physical extraction rates over a short study period [84]. It is well established that the concept and practice of sustainable use of non-timber forest products (NTFPs) is more complex than one might imagine because it involves both social and ecological domains.

Therefore, the issue of ecological sustainability is clearly fundamental to the long-term success of operations [84]. In this context, it is crucial to think that local people do not know how to manage natural resources in a sustainable way, because the phenomenon is complex and involves several research disciplines [39]. These are problems that should be taken into account in future research in all its complexity to ensure that future generations know the merits of medicinal plant species.

4.6. Limitations of the study

The present study is an ethnoveterinary survey, so it must be emphasized that the plant may have or may not have the trypanocidal effect, at least at a given level of efficacy. The limitations of this study are related to the availability of plant species used by cattle farmers for the preparation of natural products. It should be noted that the resources used are not always available all year round (seasonal plants, hibernating, etc.) in the environment cattle farmers, so they have to travel several miles to obtain them [85]. The rejection of ethnoveterinary practices and treatments by veterinary officials is a major obstacle to the development of these practices [5,85]. Most veterinarians and livestock technicians have a negative and resistant attitude towards traditional practices and knowledge, despite the scientific evidence of the effectiveness of some remedies [61,86,87].

The ineffectiveness of some ethnoveterinary practices could cause a loss of confidence in traditional veterinary medicine. In fact, even if some traditional treatments are effective, it may take time to see full relief in the treated animal. Another limitation is related to the conservation of natural products, which also constitutes a major challenge for the improvement and valorization of traditional veterinary medicine. In fact, natural products stored in inappropriate conditions lead to the appearance and development of molds, which can alter the quality of the product. The low level of literacy among farmers could have a negative impact on traditional veterinary medicine. Because of their low level of education, cattle farmers are often unable to take initiatives to improve and modernize ethnoveterinary practices.

The remedies developed in this study come from information provided by herders based on factual endogenous knowledge because they were not accompanied by laboratory experiments to verify the scientific nature of these traditional practices. The lack of precision on the information collected from the farmers during the ethnoveterinary survey causes problems of dosages, concentrations, dosage, exact duration of treatment, toxicity of the substances and also on the phytochemical composition of the plants thus constituting major constraints to the development and improvement of traditional veterinary medicine. Even though the method of preparation and the way of administration can strongly influence the therapeutic efficacy, this information is only reported in a fragmentary way [23] by cattle farmers in rural areas to relieve animals affected by trypanosomosis.

5. Conclusion

The present study inventoried the medicinal plants that cattle farmers use for the preparation of natural products for the control of bovine trypanosomosis in northern Benin. Knowledge of veterinary medicinal plants was influenced by the level of education and the main activity of those practicing livestock. The most frequently used plants were *K. senegalensis*, *P. africana*, *K. africana*, *M. inermis*, *S. latifolius*, *M. polyandra*. The most important family was the Leguminosae and the leaves were the most used part of the plants. The most frequent mode of preparation was decoction and the oral route was the only mode of administration of the products. Thus, further chemical research is needed to test the properties attributed to these plants and characterize the active compounds responsible for the probable trypanocidal properties.

Author contribution statement

Christophe Iwaka: Conceived and designed the experiments; performed the experiments; analyzed and interpreted the data; Wrote the paper.

Erick Virgile Bertrand Azando: Conceived and designed the experiments; analyzed and interpreted the data.

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

Sabi Kora: Conceived and designed the experiments.

Yaya Idrissou: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Pascal Abiodoun Olounlade: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Sylvie Mawulé Hounzangbe-Adote: Conceived and designed the experiments.

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Consent declaration

Consent was obtained from all subjects participating in the study.

Data availability statement

Data are available from the authors upon reasonable request.

Additional information

No additional information is available for this paper.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e17697.

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