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Medicinal plants of the African traditional pharmacopoeia in the management of bovine trypanosomosis: A review

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Traditional medicine has remained the most affordable and readily available source of treatment for primary care in poor African communities. Despite the increasingly common practices of traditional medicine to treat animal diseases, this rich endogenous knowledge is not sufficiently documented. The objective of this review is to synthesize information on ethnoveterinary practices to treat bovine trypanosomiasis in Africa. A systematic review was conducted in two search engines (Google scholar and Scopus) to obtain articles. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guideline was followed for the review. Boolean operators "AND" or "OR" with keywords were used to search for relevant articles. Seventy-seven articles published in french and english between 2010 and 2020 on trypanocidal medicinal plants used in veterinary medicine in cattle were considered. Thus, 62 plants belonging to 34 families including Leguminosae (11.82%), Maliaceae (8.47%) and Fabaceae (6.77%) were identified. Barks (50.20%), leaves (19.27%) and roots (14.45%) were more used. The examination revealed that decoction (35.79%) and maceration (25.69%) were the main methods of preparation of medicinal plants. The remedies are mainly administered orally. This preliminary work opens the prospect of inventorying and analyzing trypanocidal medicinal plants of the African pharmacopoeia involved in the control of bovine trypanosomosis.

Key words: Medicinal plants, Ethnoveterinary practices, Trypanocidal properties, Cattle, Africa.

INTRODUCTION

Medicinal plants are a valuable heritage for humanity and more particularly for the majority of poor communities in developing countries who depend on them for their primary health care and livelihoods (Koulibaly et al., 2016).

According to the WHO (2002), in West Africa, as in the rest of the continent, more than 80% of the population rely on traditional medicine and medicinal plants to treat themselves and their animals (Jiofack et al., 2010). In fact, out of the 300,000 plant species listed on the planet, more than 200,000 species are encountered in the tropical countries of Africa and have medicinal virtues (Salhi et al., 2010). Microbial and parasitic resistance to different drugs (Mungube et al., 2012; Raikwar and Maurya 2015; Shiferaw et al., 2015 ; Nair and Punniamurthy, 2016) is leading more and more research towards new recipes (Adeneye et al., 2006; Mbaya et al., 2007; Sowemimo et al., 2007; Jeruto et al., 2011; Kidane et al., 2014). The lack of essential medicines, the inadequacy of health care, the high cost of medicines and the socio-cultural habits of the populations explain the use of traditional practices based on medicinal plants (Doumbia, 2015; El Alami et al., 2016; Bayaga et al., 2017). The art of healing with plants has been known and practiced in Africa for a long time because it exploits knowledge transmitted orally from generation to generation to certain categories of initiated individuals who are the traditional health practitioners and herbalists (Okoli et al., 2010; Kplé et al., 2020). Medicinal plants and knowledge related to medicinal plants constitute an important heritage for the African continent (Sango, 2006; Bagayoko, 2020). It is for this reason that several studies have been carried out in Africa to identify plants with the potential to treat at least one animal disease in cattle, sheep and goats (Bum et al., 2011; Martínez and Luján, 2011; Akouedegni et al., 2012; Diatta et al., 2013; Ogni et al., 2014; Houndje et al., 2016). These plants are used by rural populations to treat themselves and to ensure the improvement on sanitary state of their animals, depending on their availability and effectiveness (Soha et al., 2019; Dzoyem et al., 2020). The objective of this study is to synthesize the studies carried out on medicinal plants with trypanocidal properties of the African pharmacopoeia used in traditional veterinary medicine in cattle. The realization of this work makes it possible to set up a document which can be valorized by livestock farmers in Africa and in the world and to deepen the research in other aspects.

METHODOLOGY

Selection of scientific publications

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline was followed for this review (Liberati et al., 2009; Moher et al., 2009a, 2009b). This review was based on field and laboratory studies conducted in Africa and published in scientific journals between 2010 and 2020 following explicit systemic recommendations and criteria for selecting and evaluating relevant research. The choice of this study period was justified by the desire to have recent information on trypanocidal medicinal plants from the last ten years. The selection of articles for this synthesis was based on the date of publication (from the year 2010), the language (English or French), and in relation to the research topic (Medicinal plants with trypanocidal properties used in traditional and veterinary medicine in Africa).

An internet search was conducted using *Scopus* and *Google Scholar* to obtain the articles. The documents were downloaded online using a combination of keywords: medicinal plants, traditional medicine, trypanocidal plants, ethnoveterinary, traditional veterinary medicine, African animal trypanosomiasis, and cattle. These keywords were used in French and then translated into English in order to obtain a maximum of documents. This search was conducted on the internet from January 18 to June 13, 2020. This led to a selection of 2754 articles that were reduced to a final set of 77 publications by a two-step process through a set of predefined criteria (Figure 1). The first selection was based on titles and abstracts. The second was based on keywords. If the terms "medicinal plants, animal trypanosomiasis, trypanocidal plants, traditional veterinary medicine" appeared in any of them or if these otherwise indicated that the use of medicinal plants could be addressed in the article, the article was downloaded and checked further. This was performed by reading the abstract and conclusion and searching the document for the terms "medicinal plants," "traditional veterinary medicine," "ethnoveterinary," "ethnobotany," "ethnopharmacology," "veterinary science," and "trypanosomiasis" via the Foxit Reader version 10.1.1 search option. Documents that did not match on at least one plant species unambiguously linked to veterinary use were ignored. This process resulted in the final selection of 77 articles. The 77 papers selected for this synthesis are not considered to be the only ones on the subject but are meant to provide a representative overview of case studies on the use of medicinal plants with trypanocidal properties in traditional veterinary medicine up to the time this synthesis was conducted.

From these 77 articles, it was possible to identify the medicinal plants with trypanocidal properties, the year of publication, the parts used, the botanical families, the modes of preparation, the way of administration, the dosage, the doses used, the lethal dose $_{50}$ (when specified) and the different authors as well as their country of origin. Information from review articles was not excluded when it did not refer to articles already included in the search. Found references were recorded in an Excel 2016 database and information about each plant was stored in a separate folder in this database. Duplicates were removed for each plant species.

Data collection

In each article, the following information on plant species unambiguously intended for veterinary use was collected: (i) plants, (ii) parts used (aerial part, bark, branches/stems, flower, flowering aerial part, fruits/seeds, leaves, roots/bulb, whole plant, other); (iii) animal species treated; (iv) method of preparation (maceration, decoction, infusion, extracts, tincture, trituration, syrups, pillage, calcination, others); (v) routes of administration (oral, cutaneous, topical, nasal, ocular, others); (vi) botanical family; (vii) duration of treatment; (viii) dosage; (ix) lethal dose; (x) therapeutic use.

For each publication, the following information was recorded: title, year of publication, corresponding author, country, continent (Africa in this case), method of data collection (laboratory animal species (laboratory animals, livestock, other); target (rural population, published literature, laboratory experiments, other); field

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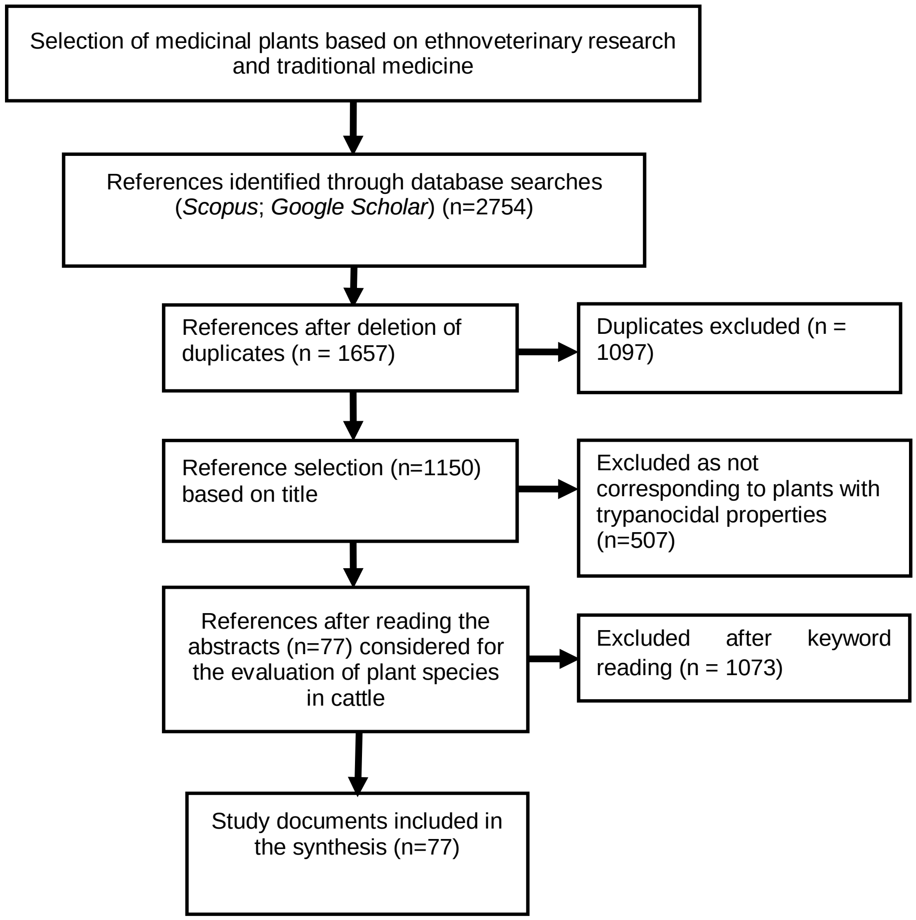

Figure 1. Flow diagram of selection of eligible studies.
Source: Iwaka et al. (2022)

of study (traditional veterinary medicine, veterinary medicine, pharmacy and others); methods of knowledge assessment (scientific knowledge, endogenous knowledge, phytochemical studies, toxicity studies, bibliographic synthesis, *in vivo* and *in vitro* activity study) and name of the journal. The questionnaire was used in order to perform some statistical tests. If no information for any of the aforementioned categories could be found, they are classified as "non available data" (Mayer et al., 2014; Ayrle et al., 2016).

Data analysis

Survey responses were entered into an Excel 2016 spreadsheet for all 77 publications. These responses were coded in the process to facilitate further analysis. Descriptive statistics were performed using R.4.0.2 software (R Core Team, 2020). The map showing the intensity of medicinal plant studies was developed with Arcgis, version 9.3.1 mapping software (Figure 2).

RESULTS

Geographical distribution of publications

The geographical distribution of publications in Africa is illustrated in Figure 2. Most of the publications on the African continent come from Benin (20, 78%), Ethiopia (12.99%), Nigeria (10.39%), Cameroon (10.39%), Ivory Coast (09.10%), Mali (06.49%) and South Africa (05.19%).

Number of publications included in this review from 2010 to 2020

The synthesis of the number of articles on medicinal plants with trypanocidal properties used in veterinary ethnomedicine for the control of pathologies in animals has seen an increase since the year 2010 and a peak in 2014 and then a sawtooth regression (Figure 3).

Parts used in the plant and method of preparation of medicinal plants

The most used parts are barks (50.20%), leaves (19.27%) and roots (14.45%) for all the identified medicinal plants (Figure 4A). Figure 4B presents the frequency histograms of the different modes of preparation of the remedies.

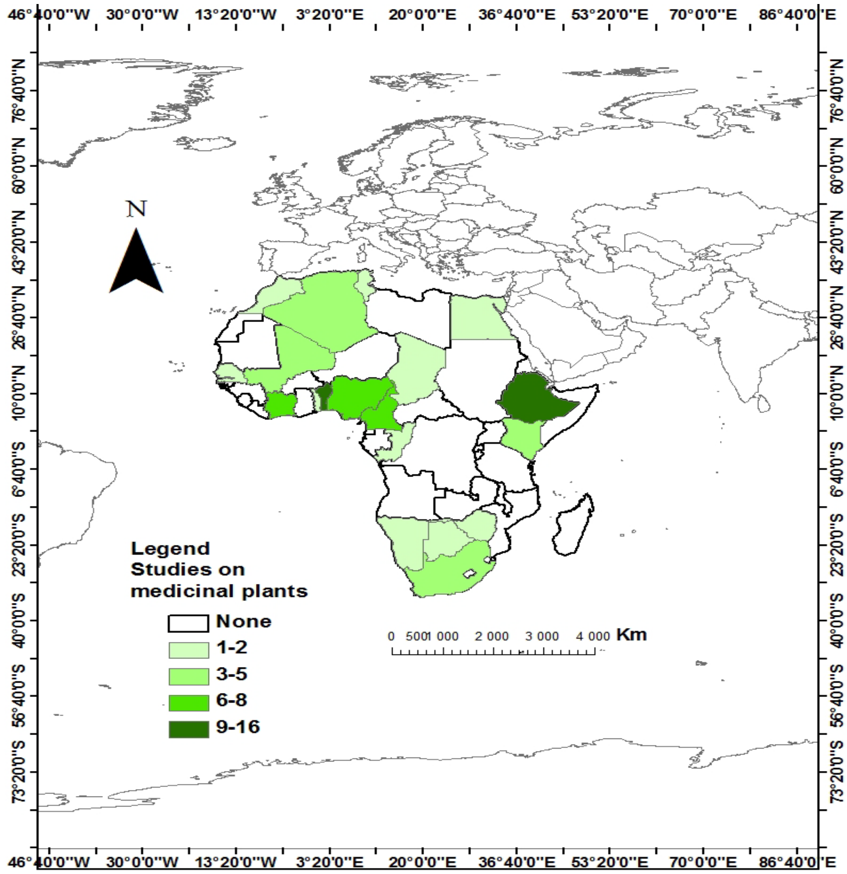

Figure 2. Overall distribution of publications on medicinal plants from 2010 to 2020 involved in this systemic review.
Source: Iwaka et al. (2022)

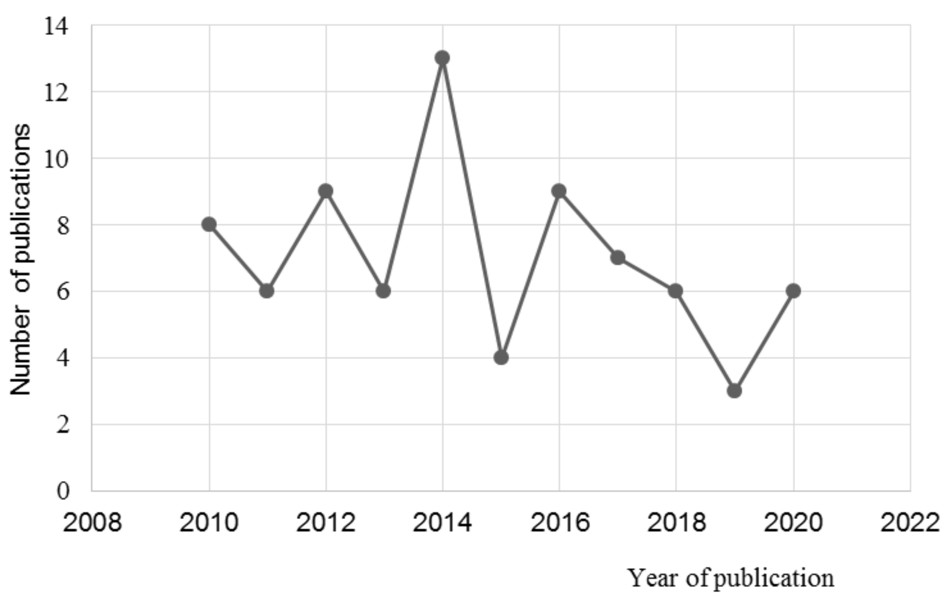

Figure 3. Number and annual distribution of publications included in this review.
Source: Iwaka et al. (2022).

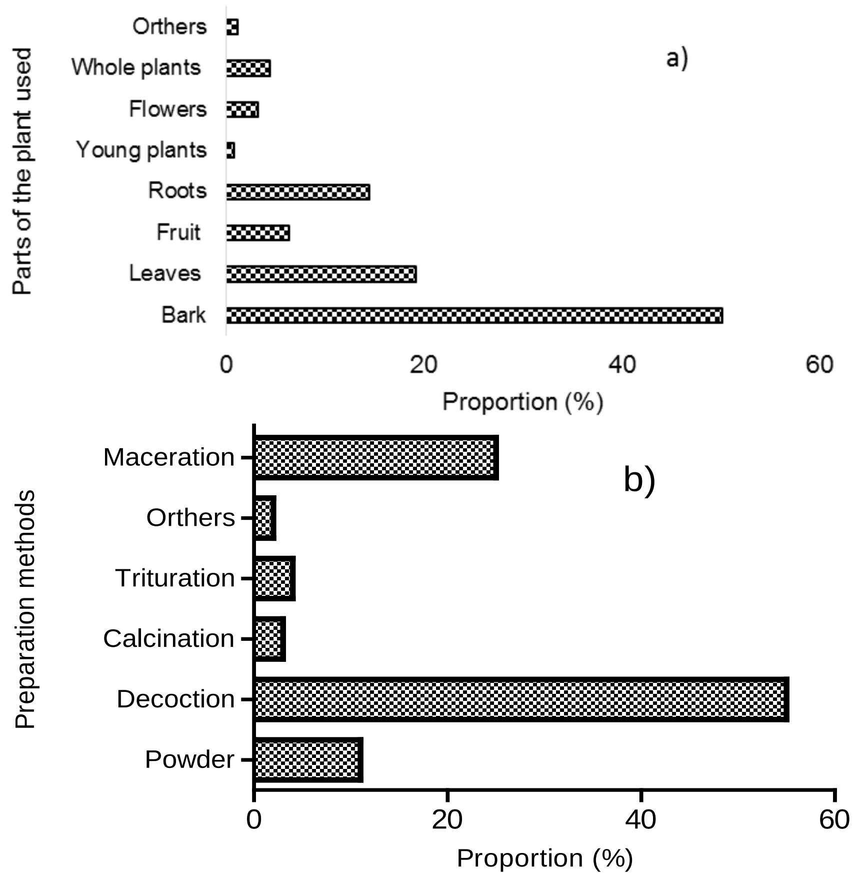

Figure 4. A) Parts used and B) Method of preparation.

Decoction (54.46%) and maceration (24.63%) are more used than powder (10.74%).

Families of medicinal plants

All the medicinal plants recorded are grouped in 34 botanical families (Figure 5). It can be seen that the families Leguminosae (11.82%), Maliaceae (8.47%), and Fabaceae (6.77%) are dominant.

Method of data collection

In the documents used for the review, ethnoveterinary surveys (44.56%) are the most used collection method than ethnobotanical surveys (29.87%) and laboratory experiments (19.48%) (Figure 6).

Knowledge assessed in the publications included in this review

Various methods are used to assess knowledge in the documents considered for this review. The most used are endogenous knowledge (70.51%); *in vitro* activities (10.25%) and *in vivo* knowledge (7.69%) (Figure 7).

DISCUSSION

Most of the authors consulted used qualitative techniques for the detection of secondary metabolites as shown in Table 1. There is a wide range of evidence-based knowledge on medicinal plants with trypanocidal properties focusing on 62 medicinal plant species within 34 families in the last 10 years based on the publications evaluated in this review on the African continent (Table 2). The emergence of multidrug resistance in human and animal diseases is leading to trends to strengthen research in alternative treatment options. Medicinal plants and their extracts could be an option to prevent and cure diseases in cattle, especially African Animal Trypanosomiasis (AAT). The analysis for this review will be done according to (i) limitations of the research method for this synthesis; (ii) treatments of AAT with plants; (iii) evaluation of methods and techniques of information collection; (iv) mode of preparation; (v) parts

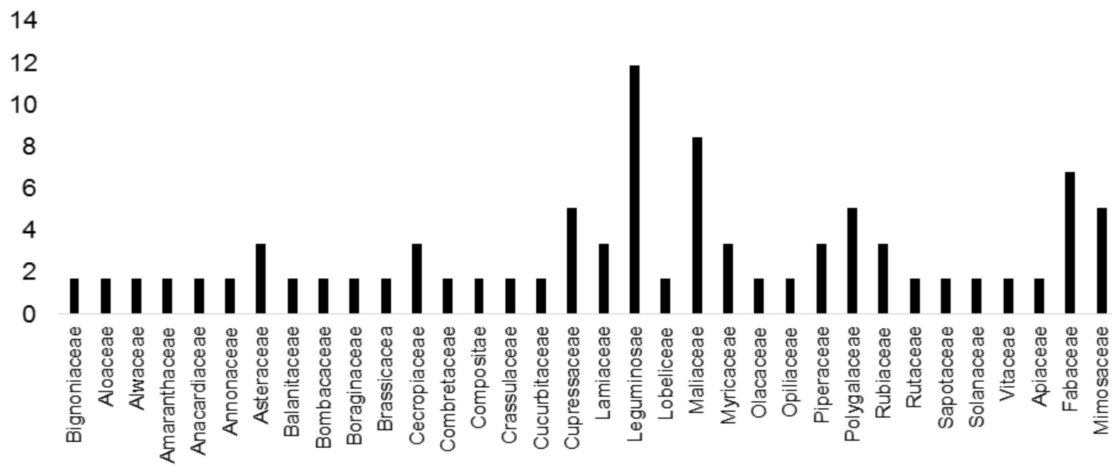

Figure 5. Botanical families of medicinal plants.
Source: Iwaka et al. (2022).

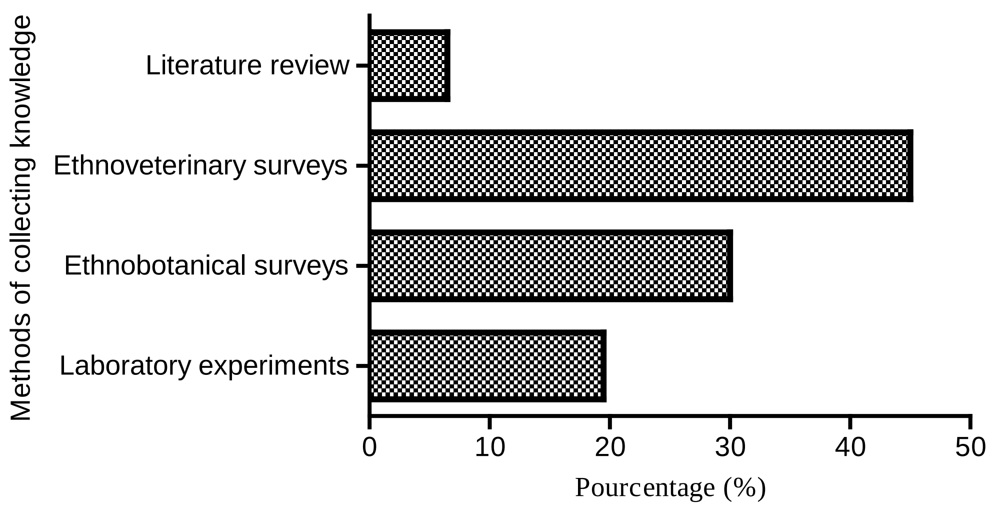

Figure 6. Method of data collection in publications.
Source: Iwaka et al. (2022).

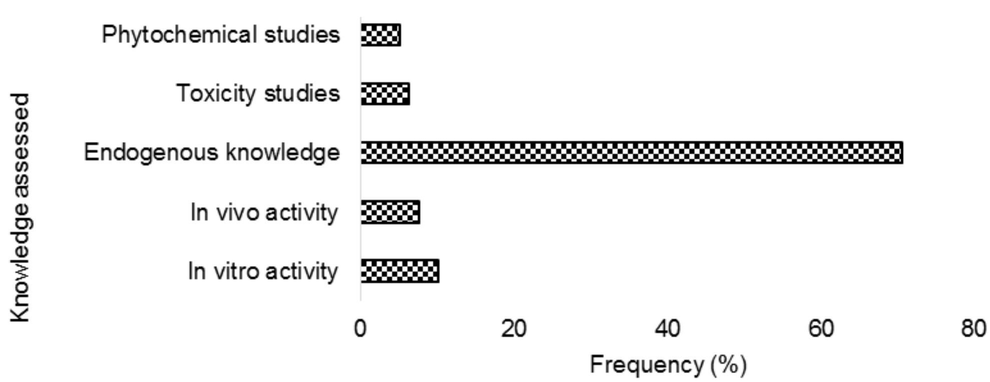

Figure 7. Frequency of knowledge assessed in the studies.
Source: Iwaka et al. (2022).

Table 1. Summary of chemical groups, identification reaction and indicators used.

Chemical groups searched	Identification reagents	Indicators
Alkaloids	Potassium iodo-bismuthite solution	Red-orange precipitate
Flavonoids	Hydrochloric acid Ammonia Zinc Copals	Orange, purplish pink and cherry red coloring.
Quinones	Concentrated ammonia	Pinkish red color in the water phase
Polyphenols	Ferric chloride (2%) Potassium ferrocyanide (1%)	Blue coloration tending to black.
Saponosides	Foam index	Appearance of a persistent foam
Terpenoids	Concentrated sulfuric acid Acetic anhydride.	Blue coloring
Catechic tannins	Formaldehyde Concentrated hydrochloric acid	Gelatinous precipitate
Gallic tannins	Sodium acetate Ferric chloride ($FeCl_3$ 1%)	Blue-black coloring
Reducing sugars	Copper Sulfate Sodium Potassium Tartrate	Brick red coloring
Anthocyanins	10% Sulfuric acid	Blue coloring

Source: Yusuf and Ekanem (2010), Badiaga (2011), Jeruto et al. (2011), Abedo et al. (2013); Saxena et al. (2013), Dhama et al. (2014), Fagbohoun (2014), Kuete (2014), Mangambu et al. (2014), Yaya et al. (2015), Atto et al. (2016), Houngnimassou et al. (2017), Kouchadé et al. (2017), Sahli (2017), Koudoro et al. (2018), Adou et al. (2018), Dongock et al. (2018), Moktari and Mebarki (2018), Ogunleye et al. (2019), and Bagayoko (2020).

used; (vi) routes of administration and (vii) valorization of medicinal plants.

Evaluation of the research method used and limitations

This systemic review was designed and conducted according to the guidelines and tools of the statement (Liberati et al., 2009; Moher et al., 2009a, 2009b). This search strategy was adopted to obtain as much information as possible on medicinal plants with trypanocidal properties. Human clinical studies, in vitro experimental studies in laboratory animals and in vivo studies were also included. In addition, the review excluded studies published before 2010 that may provide relevant information. According to Quave et al. (2012) some of the less accessible studies may be important to the understanding of the knowledge. However, it is clear that non-scientific or scientific sources not in English or French or contained in other search engines (*semantic scholar, Web of Science* etc.) may contain important ethnoveterinary information that this review would have omitted. Perhaps further reviews should focus particularly on these sources. It is likely that frequently studied plant species appear more promising than less frequently studied species (Mayer et al., 2014). Accordingly, plants including *Kigelia africana* (Lam.) Benth, *Echinops kebericho*, *Burkea africana, Balanites aegyptiaca, Cordia myxa, Bombax costatum, Pterocarpus erinanceus, Millettia ferruginea (*Hochest) Bak, *Zanthoxylum zanthoxyloides* (Lam.) Zepern Timler appeared less promising, although they are an integral part of the traditional medicine. Among the African countries, Benin is strongly represented in this review, with a total of 16 articles (20.78%) or a quarter of the papers treated, followed by Ethiopia (12.99%), Cameroon and Nigeria (10,39%) while the other countries are represented by only one or two publications. This highlights the need for ethnoveterinary research on the African continent. Due to the diversity of study programs and inconsistency or even missing data, non-detailed information on the use of medicinal plants for veterinary purposes was not available in most of the publications. Although the method of preparation and the routes of administration may strongly influence the therapeutic efficacy, this information is only reported in a fragmentary way by rural populations in half of the publications processed. Only a few articles (about 8%) are targeted (Jeruto et al., 2011; Mbaya and Ibrahim, 2011; Nganso et al., 2011; Atto et al.,

Table 2. Medicinal plants used to treat blood parasites in cattle.

Plant species	Families	Parts used	Method of preparation	Route of administration	References
Khaya senegalensis	Meliaceae	Leaves, bark, roots	Calcination, maceration, powder, decoction	Oral, dermal, topical	Dassou et al. (2014, 2020), Azokou et al. (2016), Noudèkè et al. (2017), Traoré et al. (2020)
Kigelia africana (Lam.) Benth.	Bignoniaceae	Barks, Fruits, Leaves	Decoction	Oral	Dassou et al. (2014, 2015),
Pseudocedrela kotschyi (Schweinf.)	Meliaceae	Bark	Decoction	Oral	Ogni et al. (2014), Dassou et al. (2015), Noudèkè et al. (2017)
Guieria senegalensis	Combretaceae	Fruits, leaves	Decoction		Dassou et al. (2014, 2015),
Cassia sieberiana	Fabaceae	Barks	Powder Decoction	Oral	Dassou et al. (2014, 2015), Ogni et al. (2014)
Crossopteryx febrifuga	Rubiaceae	Leaves, Fruit	Powder	Oral	Cock et al. (2018), Traoré et al. (2020)
Afzelia africana	Fabaceae	Leaves, bark	Decoction	Oral	Dassou et al. (2014, 2015), Ogni et al. (2014), Noudèkè et al. (2017), Traoré et al. (2020)
Combretum collinum	Combretaceae	Leaves, bark	Decoction, Maceration	Oral	Dassou et al. (2014, 2015), Traoré et al. (2020)
Prosopis africana (Guill. Perr.)	Leguminosae	Barks	Powder Decoction	Oral	Dassou et al. (2014, 2015), Traoré et al. (2020)
Sorghum bicolor	Poaceae	Fruit	Calcination, Powder	Oral	Dassou et al. (2014, 2015), Ogni et al. (2014)
Mangifera indica	Anacardiaceae	Barks	Decoction	Oral	Dassou et al. (2015), Noudèkè et al. (2017)
Burkea africana	Fabaceae	Barks	Decoction	Oral	Dassou et al. (2015), Noudèkè et al. (2017)
Parkia biglobosa	Fabaceae	Barks	Decoction	Oral	Dassou et al. (2015), Noudèkè et al. (2017), Traoré et al. (2020)
Vitellaria paradoxa	Sapotaceae	Barks, Roots, Leaves, Young branches	Decoction, Powder	Oral	Dassou et al. (2015), Noudèkè et al. (2017), Traoré et al. (2020)
Detarium microcapum	Fabaceae	Barks	Decoction		Dassou et al. (2015), Noudèkè et al. (2017)
Pterocarpus erinaceus	Leguminosae	Barks	Maceration, Decoction	Oral	Dassou et al. (2015), Noudèkè et al. (2017)
Acacia polyacantha Willd.	Fabaceae	Barks, Leaves, Roots	Decoction, Powder, Maceration	Oral	Dassou et al. (2015), Noudèkè et al. (2017), Traoré et al. (2020)
Swartzia madagascariensis	Fabaceae	Barks	Decoction	Oral	Dassou et al. (2015), Noudèkè et al. (2017)
Balanites aegyptiaca	Balanitaceae	Leaves, bark	Decoction	Oral, nasal	Giday and Teklehaymanot (2013), Dassou et al. (2015), Noudèkè et al. (2017)
Bombax costatum	Bombacaceae	Barks	Decoction	Oral	Dassou et al., 2015; Noudèkè et al., 2017
Ximenia americana	Olacaceae	Barks, roots, leaves	Decoction, Calcination, Powder	Oral	Ogni et al. (2014), Dassou et al. (2015), Noudèkè et al. (2017), Cock et al. (2018), Traoré et al. (2020)
Dioscorea spp.	Dioscoreaceae	Tuber	Maceration	Oral	Dassou et al. (2015), Traoré et al. (2020)
Annona senegalensis	Annonaceae	Leaves, bark	Fumigation, Decoction	Nasal, Oral	Okoye et al. (2012) and Traoré et al. (2020)
Cissus quandrangularis	Vitaceae	Whole plant	Decoction	Oral	Traoré et al. (2020)
Cordia myxa	Boraginaceae	Leaves	Decoction	Oral	Traoré et al. (2020)
Daniellia oliveri	Leguminosae	Leaves	Decoction	Oral	Traoré et al. (2020)
Opilia amentacea	Opiliaceae	Leaves	Decoction	Oral	Traoré et al. (2020)
Pterocarpus erinanceus	Fabaceae	Leaves, young plants	Decoction	Oral	Traoré et al. (2020)
Securidaca longipedunculata	Polygalaceae	Leaves, young plants	Decoction	Oral	Traoré et al. (2020)
Kalanchoe crenata (Andrews)	Crassulaceae	Leaves	Forage, Powder	Oral	Dassou et al. (2015), Traoré et al. (2020)
Detarium microcarpum Guill. Perr.	Leguminosae	Barks	Decoction, Powder,	Oral	Dassou et al. (2015), Traoré et al. (2020)
Vigina sp.	Fabaceae	Sheets	Powder	Oral	Tekle (2014)

Table 2. Cont'd.

Erythrina brucei Schwein	Fabaceae	Barks	Powder	Oral	Tekle (2014)
Zehneria scabra (Linn.) Sond	Cucurbitaceae	Root	Powder	Oral	Tekle (2014)
Iresine herbstii Lindl.	Amaranthaceae	Sheets	Decoction	Oral	Tekle (2014)
Azadirachta indica	Meliaceae	Trunk bark	Maceration	Oral	Ashafa et al. (2012), Mbaya et al. (2010)
Ocimum lamiifolium Benth.	Lamiaceae	Leaves	Decoction	Nasal	Yigezu et al. (2014_
Lepidium sativum L	Brassicacea	Fruits	Decoction	Oral, topical	Shiadeh et al. (2016)
Allium sativum	Alwaceae	Roots	Decoction	Oral, topical	Shiadeh et al. (2016)
Aloe vera	Aloaceae	Leaves	Infusion	Oral, topical	Shiadeh et al. (2016)
Aeschnomene elaphroxylon Guill	Fabaceae	Roots	Powder Decoction	Oral,	Shiadeh et al. (2016)
Trifolium burchellianum	Fabaceae	Roots, leaves, fruits	Powder	Oral	Shiadeh et al. (2016)
Albizia anthelmentica	Fabaceae	Bark	Powder	Topical	Shiadeh et al. (2016)
Millettia ferruginea (Hochest) Bak.	Fabaceae	Leaves	Powder	Topical	Shiadeh et al. (2016)
Calpurnia aurea	Fabaceae	Leaves	Powder	Topical	Shiadeh et al. (2016)
Loblia giberroa Hemsl.	Lobeliceae	Leaves	Powder Decoction	Oral, topical	Shiadeh et al. (2016)
Myrica salicifolia Hochst ex A. Rich	Myricaceae	Bark	Powder	Oral	Shiadeh et al. (2016)
Withania somnifera (L.) Dunal in	Solanaceae	Roots, leaves, fruits	Powder	Oral	Shiadeh et al. (2016)
Nicotiana tabacum	Solanaceae	Leaves	Powder Decoction	Oral, topical	Shiadeh et al. (2016)
Thuja orientalis	Cupressaceae	Leaves	Powder	Oral	Shiadeh et al. (2016)
Citrus aurantifolia	Rutaceae	Fruits	Juice + water	Oral	Shiadeh et al. (2016)
Vernonia amygdalina Delile	Asteraceae	Leaves	Decoction, grinding, Powder	Dermal, oral, topical	Kidane et al. (2014), Azokou et al.(2016), Shiadeh et al. (2016)
Echinops kebericho	Asteraceae	Roots	Powder Decoction	Oral mixture in food	Shiadeh et al. (2016)
Teradenia riparia (Hochest)	Lamiaceae	Fruits	Powder	Topical	Shiadeh et al. (2016)
Sclerocarya birrea (A. Rich.)	Anacardiaceae	Leaves	Maceration	Cutaneous	Azokou et al. (2016)
Securidaca longepedunculata Fres	Polygalaceae	Roots	Decoction	Cutaneous	Azokou et al. (2016)
Zanthoxylum zanthoxyloides (Lam.) Zepern Timler	Rutaceae	Barks, young plants	Maceration	Cutaneous	Azokou et al. (2016)
Azadiracta indica	Meliaceae	Leaves	Decoction	Oral	Tadesse et al. (2014)

Source: Authors

2016; Landoulsi, 2016; Chitura et al., 2019).

In addition, ethnoveterinary and ethnobotanical surveys are usually conducted in rural areas with wandering animals, which poses the problem of monitoring all parameters related to their health. Future surveys should provide detailed information on veterinary treatments to enrich ethnoveterinary knowledge and discuss the importance of their use in current pharmacology, veterinary medicine and clinical trials. This review focused primarily on the therapeutic options of medicinal plants. From this point of view, the relevance of possible toxicity and adverse effects or residues in cattle remains open. Nevertheless, the majority of plant species in this review are consumed by humans as spices, food products or pharmaceutical by-products. If these plant species are safe for ingestion in humans, it may be legitimate to transfer these results to other mammals with comparable equivalence. Under these circumstances, the risks to humans in terms of residues from products from food animals should be negligible.

Treatment of AAT with plants

AAT was the focus in the evaluated publications. In fact, *Khaya senegalensis, Afzelia africana*, *Vitellaria paradoxa*, *Crossopteryx febrifuga*, *Cassia sieberiana*, *Vernonia amygdalina*, and *Crossopteryx febrifuga* were the most used species (Shilema et al., 2013; Dassou et al., 2014; Dassou et al., 2015; Ogni et al., 2016; Azokou et al., 2016; Noudèkè et al., 2017). Medicinal plants such as *Allium sativum*, *Annona senegalensis*, *Ximenia Americana*, *Detarium microcarpum*, *V. amygdalina*, *Guieria senegalensis*, *B. africana*, *P. erinanceus*, *B. costatum*, *Cissus quandrangularis*, *C. myxa*, *Securidaca longipedunculata*, and *Ocimum lamiifolium* may be effective in the treatment of blood parasites such as trypanosoma. Abiodun et al. (2012) in the case of *O. lamiifolium*, the highest antitrypanosomal activity (LD_{50}= 2.08 ± 0.01 µg/ml) was shown using the leaves of *Ocimum gratissimum* Linn. (Labiatae) and a high selectivity index of 29. In addition, the extract of *Trema orientalis* (L.) Blume (Ulmaceae), *Pericopsis laxiflora* (Benth. Ex Baker) Meeuwen, *Jatropha curcas* Linn. (Euphorbiaceae), *Terminalia catappa* Linn. (Combretaceae) and *Vitex doniana* Sweet (Verbenaceae) showed remarkable antitrypanosomal activity with high selectivity indices (20-80) for trypanosomes. Plants used for disease control come from several different botanical families and vary from country to country. Thus, Abedo et al. (2013) and Ahamidé et al. (2017) recorded in their studies that plants of the Loranthaceae family are effective in the treatment of trypanosomiasis. According to Ogni et al. (2014), plants such as *Prosopis africana*, *Acacia polyacantha*, *Combretum collinum*, *Crossopteryx febrifuga*, *K. africana*, *Zea mays, A. africana*, *C. sieberiana*, *D. microcarpum*, *K. senegalensis*, *Pseudocedrela kotschyi* and *X. americana* are effective against trypanosomiasis according to their studies in Benin, but they did not specify the doses to be administered and the duration of treatment to have a satisfactory result. While the work of Okoye et al. (2012) on *Annona senegalensis* in Nigeria showed the effectiveness of this plant in the treatment of trypanosomiasis in laboratory rats. In the same direction, an acute and sub-acute toxicity study on extracts of the bark and root of *A. senegalensis* in laboratory rats revealed that the plant is relatively effective but should be used with caution at doses not exceeding 400 mg/kg. However, the extracts and constituents of *X. americana* have shown several biological activities including anti-trypanosomal (Siddaiah et al., 2011; Monte et al., 2012). The acute toxicity study of the extracts of the leaves and stem barks of this plant revealed an LD50 oral in rats higher than 5000 mg/kg. No toxicity or weight change was reported (p=0.05) (Siddaiah et al., 2011; Monte et al., 2012). These results suggest that *X. americana* is effective and has good pharmacological activity. This plant is suitable for clinical studies.

In the mini-review conducted by Fullas (2010) on Ethiopian medicinal plants, the author lists: *Allium cepa*, *Phytolacca dodecandra*, *Clutea abyssinica*, *Clausena anisata*, *Rumex nepalensis*, *Verbascum sinaticum*, and *Salvadora persica* as medicinal plants used against trypanosomiasis in animals without specifying the doses, routes of administration and parts of the plants used in the recipes. As for the experiments conducted by Olukunle et al. (2010) on *Morinda morindiodes, Tithonia diversifolia* and *Acalypha wilkesiana* to evaluate the antitrypanosomal activity in albino rats infected with *Trypanosoma brucei brucei* in Nigeria, these authors showed a decrease in parasitemia on the third day of treatment. On the other hand, Shilema et al. (2013) and Kidane et al. (2014) reported that *Vernonia amygdalina* serves simultaneously to treat animal trypanosomosis and to repel tsetse flies in their various studies. In the same direction, Shilema et al. (2013) found that garlic (*Allium sativum*) and *Lepidium sativum* were used to treat animal trypanosomiasis and repel tsetse flies in Amaro district in southern Ethiopia.

Verbascum sinaiticum Benth and *Phytolacca dodecandra* L. showed good pharmacological activity in the treatment of trypanosomiasis in cattle in three studies conducted in Ethiopia (Weldegerima et al., 2008; Yigezu et al., 2014). The work carried out by Odoh et al. (2010) in Nigeria on the study of the toxicity of *Enantia chlorantha* extracts against *Trypanosoma cruzi* trypanosomiasis in mice showed a good trypanosomal activity with the lethal dose LD_{50}= 4325 mg/kg.

Evaluation of information collection methods and techniques

The most promising plant species in this evaluation during the last 10 years have been obtained through endogenous knowledge (70.51%) and little on *in vitro* and *in vivo* activities. The studies of Bekele et al. (2012), Amuka et al. (2014), Chinsembu et al. (2014), Yigezu et al. (2014) and Ahamidé et al. (2017) are focused on a method of information collection, based on ancestral practices transmitted from generation to generation through knowledge from treatments administered to humans. It would be necessary that the complementary studies take into account the phytochemical screening, the acute toxicity activities, *in vivo* and *in vitro* to make available all the information on the use of these medicinal plants with multiple virtues.

The set of articles reviewed highlights that the rural population (71.42%) is the target of studies on ethnobotanical and ethnoveterinary surveys in the field of traditional human and veterinary medicine. The animal species targeted by these studies are mostly farm animals (67.53%) (Bum et al., 2011; Moreki, 2013; Chinsembu et al., 2014; Dassou et al., 2015; Chitura et al., 2019) and few laboratory animals (14.29%). Most of the recipes developed in these studies come from information provided by the rural population based on endogenous knowledge because they are not accompanied by laboratory experiments to verify the scientific nature of these practices. The lack of experimental data on the information collected during ethnoveterinary and ethnobotanical surveys causes problems with dosages, posology, duration of treatment, toxicity of substances and also on the phytochemical composition of plants, thus constituting major constraints to the development of traditional veterinary medicine.

Method of preparation of medicinal plants

Plants containing several bioactive metabolites may have very different actions depending on how they are prepared. The review showed that decoction (35.79%) and maceration (25.69%) are the main modes of preparation (Rahmatullah et al., 2010; Yédomonhan et al., 2012; Ahmed and Murtaza, 2015; Yapi and Zirihi, 2015; Diarra et al., 2016; Kouadio et al., 2016; Nga et al., 2016). The decoction allows to collect the most active principles and attenuates or cancels the toxic effect of certain recipes (Salhi et al., 2010). Cultural exchanges between ethnic groups could be one of the factors that favored the popularization of the different preparation methods (Dongock et al., 2018). The recipes of these preparations are monospecific or in association of several species (multispecific), which would allow to complete and reinforce the effectiveness. All the modes of preparation are employed for the sheets, with a clear predominance of the decoction. The other modes of preparation, i.e. infusion, fumigation, grinding, calcination, trituration, syrups, heating, extracts and dyeing are rarely used. Benamoud and Dilmi (2019), distinguish three main modes of preparation: decoction, infusion and maceration in the ethno-veterinary study of medicinal plants of the region of Dirrah in Algeria.

Parts of the medicinal plants used

All parts of plants are used for the preparation of recipes in traditional human and veterinary medicine. These parts can be roots, barks, leaves, fruits, seeds, bulbs, stems, flowers, sometimes the whole plant or others. In this review barks (50.20%) are the most used organs followed by leaves (19.27%) and then roots (14.45%). However, Gueye et al. (2012), Maroyi (2012), Mishra (2013), Dougnon et al. (2017), Kisangau et al. (2017), Matowa et al. (2020), Tembo et al. (2021) have also mentioned in the studies that leaves are the main parts of plants most used in traditional medicine. The works of Teklehaymanot, (2009), Djoueche et al. (2011), Amuka et al. (2014) and Feyera et al. (2017) found that roots and leaves are the most used plant organs in traditional medicine. The parts used also vary depending on the species and the diseases to be treated. Seeds, whole plant, fruit, young branches, seed oil, and powdered bark (Yadav et al., 2014) are sometimes necessary in the preparation of remedies. A single plant can be used to treat certain diseases as well as the combination of two or more. In the study conducted by Tiwari and Pande (2010) and Ghasemi et al. (2013), they reported that the seed is most used in traditional veterinary medicine. On the other hand the work of Habeeb (2010), Benamoud and Dilmi (2019) show that after the flowers and aerial parts, the leaves are the most used. Other studies show that it is the roots, fruits and leaves that are used in the treatment (Cho et al., 2010).

The parts used of the plant, the method of preparation, the route of administration and the post-harvest methods can be factors affecting the chemical composition of the plants. Environmental factors and harvesting procedures are likely to explain the variable efficacy of a medicinal plant in different studies as reported for Echinacea (Toselli and Gillam, 2009). Therefore, the comparison of the results of the studies is difficult especially because of the lack of information regarding the phytochemical composition and the material used. The future use of the pharmacopoeia in research must guarantee a well-defined quantity and quality of constituents in each medicinal plant (Guarrera et al., 2005). This information is to be taken with reservations, especially since the quantity and the parts of the plant which enter in the composition of these recipes are not known. All this causes problems of dosage (under- or overdosing) at the level of the animals (cattle) to be treated when the weight and the stage of the disease are involved.

Route of administration of medicinal plants

From this review, the main routes of administration of medicinal plants are: oral, cutaneous, nasal, topical and others. The most commonly used route is the oral route. The work of Maphosa and Masika (2010), Khatun et al. (2011), Moreki (2013), Mesfin et al. (2013) and Tekle (2014) justify that the oral route is more used. Some authors did not provide a precision on the routes of administration of the recipes. The lack of information on the absorption of herbal compounds administered orally and the effective concentrations in the case of AAT can be explained by the fact that research in traditional veterinary medicine is a relatively young science that has developed rapidly in recent years. On the other hand, in humans, information on Human African Trypanosomiasis (HAT) is almost totally available on toxicity studies (Malebo et al., 2009; Ashafa et al., 2012; Adamu et al., 2013; Ebiloma et al., 2017; Chechet et al., 2018) in vivo activities (Adeiza et al., 2010; Enyanwu et al., 2018;

Mann and Ogbadoyi, 2012; Mesfin et al., 2013) and in vitro (Adeiza et al., 2010; Mann and Ogbadoyi, 2012; Tesfaye et al., 2015; Enyanwu et al., 2018). In contrast, in cattle, the scientific knowledge is not sufficiently documented to be transferred to practical use.

Valuation of medicinal plants

Plants are valorized in two types of recipes that are mono-specific or made from several plants. The valorization of traditional medicine is thus of growing interest. According to WHO, nearly 80% of the population depends on traditional medicine. Considerable economic benefits in the development of traditional medicine and in the use of medicinal plants for the treatment of various diseases have been recorded (Dongock et al., 2018). This knowledge is generally bequeathed by the ancestors and mainly concerns the knowledge of the virtues of the plants used, for example, as inputs or recipes in traditional medicine (Zabouh, 2014). Some plant species have magical values or totems that must be respected within the communities at the risk of seeing their therapeutic effect ineffective (Badjaré et al., 2018; Kouassi et al., 2020). In this same context, some livestock farmers and sellers in livestock markets use medicinal fodder plants for the treatment of certain animal and human pathologies (Kouassi et al., 2020). The valorization of fodder species with pharmacological character requires the research of their effectiveness through in-depth phytochemical and pharmacological studies. The confident use of safe and effective traditional products can improve the health and productivity of livestock in terms of income and the quality of life of poor households owning animals. The development of ethno-veterinary medicine and the promotion of its rational use can improve its status, thus adding to the self-esteem of its users. This may help in the development of endogenous knowledge and its use in several fields of study such as pharmacology, chemistry, pharmacy, toxicology, phytochemistry, ethnobotany, taxonomy, anthropology and veterinary science (Yadav et al., 2014; Atolani et al., 2021). Other studies highlight the methods of identification of medicinal plant compounds (Table 1).

Conclusion

This review identified 62 plants belonging to 34 families in the management of African Animal Trypanosomiasis. The most commonly used parts of medicinal plants are barks, leaves and roots. Leguminosae, Maliaceae and Fabaceae represent the most cited families and include most plant species. The results of this review show that decoction and maceration are the main modes of preparation and administration is mainly by oral route. This synthesis highlights the relevance of research in Africa as a source of information and justification for the use of trypanocidal medicinal plants in the control of bovine trypanosomiasis. The identified medicinal plants can be used as a future and potential therapeutic option to treat African Animal Trypanosomiasis in cattle. This synthesis will therefore stimulate further ethnoveterinary research, *in vitro, in vivo* and clinical trials, to re-establish veterinary herbal medicine as an integral part of sustainable animal health treatments.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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