



Ethnopharmacological Properties of African Medicinal Plants for the Treatment of Neglected Tropical Diseases

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Abstract

Agriculture is considered the primary source of income and livelihood in Africa. It is rational for people to look around their environment for food and medicine. The African legacy regarding the traditional use of medicinal plants is vast and diverse, due to cultural myths and economic logic. This review briefly defines the neglected tropical diseases and surveys African medicinal plants used for neglected tropical diseases. In Africa, people may share several plants for similar diseases, e.g., *Nicotiana tabacum* L. and *Ricinus communis* L. are used for treating Buruli ulcer infection. Folkloric African plants for the treatment of bacterial, fungal, and viral neglected tropical diseases are listed and reported in the first parts. Medicinal plants for curing parasitic neglected tropical diseases are tabulated. A plethora of medicinal plants and bioactive compounds and their preparation methods, such as macerations and boiling are reported. This report reflects the richness of Africa with medicinal plants and herbal preparations being used for the treatment of various diseases, including neglected tropical diseases. Scientific investigation of these plants has yet to be conducted to isolate the active components and determine any toxic activities. Besides, knowledge of the mechanism of action behind these beneficial effects is highly required. This review will draw the attention of pharmaceutical companies and research institutions to examine the plants presented here for further laboratory analysis and experiments.

Keywords: African plants; bioactive compounds; neglected tropical diseases; traditional African medicine

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Introduction

The African community relies on agriculture for their sustenance, which represents more than half of the workforce and significantly contributes to livelihood and gross domestic product in some countries [1,2]. The African flora is diversified;

thousands of plant species are scattered along the African continent, reflecting the plants' biological importance in this productive environment [3]. Since plants are around the African people and worldwide, it is wise to use these local plants for

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therapeutic purposes [2,4]. Ancient African people have used traditional plants for treatment and cosmetic purposes, which could be attributed to their myths, culture, and low-cost reasons. Because of the importance of African plants in allopathic medicine, the World Health Organization (WHO) designated August 31st as the African Traditional Medicine (ATM) Day, which is celebrated annually [5].

Kofi-Tsekpo at Kenya Medical Research Institute, the author of "Institutionalization of African traditional medicine in healthcare systems in Africa," considers that ATM does not coincide with alternative medicine because it is an indigenous, complete healthcare system [6]. Using African plants in the treatment of ailments is part of ATM. Herbal medicine or phytomedicine is defined by the WHO as any part of plant materials, such as roots, leaves, bark, fruits, or other botanical substances, and their extracts used for treatments or beneficial effects in humans or animals [7]. The drugs obtained from plants are classified into 1) organized drugs, which are drugs gained from the cellular structures of the plants, such as leaves, barks, or roots, and 2) unorganized drugs, which are taken from acellular components of plants, such as gum, balsams, gels, oils, juices, etc. [6,7].

Numerous African plants have been used for the treatment and alleviation of several ailments. For instance, *Acacia Senegal* L., a plant grown in drier areas of sub-Saharan Africa, is effective against microbial infections caused by *Escherichia coli*, *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Klebsiella pneumoniae*, *Shigella dysenteriae*, *Salmonella typhi*, *Streptococcus pyogenes*, and *Pseudomonas aeruginosa* [8-11]. Also, *Aloe ferox* Mill, a South African native plant, has been used for its antioxidant, anti-inflammatory, analgesic, and antiseptic properties [12]. *Centella asiatica* L., a plant found in tropical regions of Africa as well as in some parts of East Asia, is utilized for treating wounds, burns, tuberculosis, and skin diseases [13-15].

Among the diseases treated using African plants are commonly caught infections as well as neglected tropical diseases. Neglected tropical diseases, such as lymphatic filariasis and leishmaniasis, are defined by WHO as communicable diseases widespread in tropical and subtropical regions but have received little

attention compared to other diseases. Neglected tropical diseases have been associated with poor environmental conditions, poor water quality, a lack of sanitation, and an imperfect healthcare system [16,17].

This article reviews medicinal plants that are used by indigenous African people for the treatment of the most prominent neglected tropical diseases in terms of the medicinal plant used, native region, the extracts, possible mechanism of action, and doses, if any, based on the neglected tropical diseases causative agents. This section will not focus on the epidemiology of specific Neglected tropical diseases. According to the WHO [18], neglected tropical diseases are divided into five classes based on the causative agents, as shown in Table 1.

Table 1. Categories of neglected tropical diseases

Bacterial NTDs	Buruli ulcer, yaws, leprosy, trachoma
Fungal NTDs	Mycetoma
Viral NTDs	Rabies, dengue
Protozoal NTDs	Chagas disease, human African trypanosomiasis (sleeping sickness), leishmaniases
Helminthic NTDs	Taeniasis and neurocysticercosis, echinococcosis, foodborne trematodiasis, onchocerciasis (river blindness), schistosomiasis, soil-transmitted helminthiases, dracunculiasis (guinea worm disease), lymphatic filariasis

NTDs: neglected tropical diseases

Methods

The information was gathered by searching the terms "neglected tropical diseases," "herbal preparations," "medicinal plants," "African traditional plants," and "ethnopharmacology of neglected tropical diseases." Search engines used included Google Scholar, PubMed, Web of Sciences, and Scopus databases between January 1996 and 2022.

Results and Discussion

African medicinal plants used for the treatment of bacterial neglected tropical diseases

Several medicinal plants are used across Africa for healing neglected tropical diseases. The following part will review the plants used in Africa based on particular infectious diseases.

Buruli ulcer

Buruli ulcer is a cutaneous disease caused by *Mycobacterium ulcerans* that is characterized by slow ulcer formation [19].

Buruli ulcer has been diagnosed in tropical areas, West Africa in particular; it is widely reported in rural areas where the first healthcare providers are traditional healers, who most probably use one of the medicinal plants available [20]. Although several steps are taken to treat Buruli ulcer such as wound curative measures, the herbal remedy remains essential [21]. To understand the mechanism of action of the plants used, we need to shed light on the pathogenicity of Buruli ulcer. Briefly, mycolactone, the main bacterial toxin, plays a crucial role in the pathogenicity of Buruli ulcer. Mycolactone binds to the Sec61 translocon during the cell cycle, inducing cell death and compromising host immunity [22,23].

The most used African plants for Buruli ulcer *Ricinus communis* L.

Ricinus communis L. is a species that belongs to the Euphorbiaceae family, a long-lived flowering seed oil plant [24]. Its main habitats in Africa are Mozambique (the highest percentage of production), Ethiopia, South Africa, and Angola [25,26]. Long ago, the plant seed extracted oil was used for its anti-inflammatory and anti-infective properties [27]. Practitioners were able to extract this oil by the different methods listed in Table 2 [28-30]. Numerous compounds were recognized, including alkaloids, flavonoids, coumarins, tocopherols, benzoic acid derivatives, and others. Ricinine (Figure 1) is the principal alkaloid to which these pharmacological activities are attributed [31,32]. Aplin and Eliseo conducted a therapeutic survey on local plants used for the treatment of Buruli ulcer in Côte d'Ivoire. The authors concluded that 80% of the participants recovered from Buruli ulcer when treated twice daily with African medicinal plants, mainly *Ricinus communis*, *Nicotiana tabacum* L., *Mangifera indica* L., *Mariscus alternifolius* Vahl., *Solanum rugosum* Dunal., and *Carica*

papaya L. [33,34]. Preparation methods are listed in Table 2. Aplin and Eliseo concluded that extracts of the plants mentioned above possessed antimycobacteriennnes activities, even though the method of extraction was old and dull.

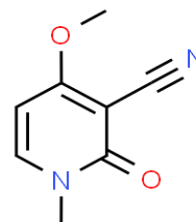


Figure 1. The chemical structure of ricinine isolated from *Ricinus communis*

When dealing with *Ricinus communis*, however, caution is advised because it has been classed as a poison plant, referring to the poisonous ricin ingredient. The lethal dose 50 (LD₅₀) was found to be 20–30 mg/kg [35]. All traditional healers used water as a solvent for preparing the drug.

Nicotiana tabacum L.

Nicotiana tabacum L. is a perennial flowering plant. It is famous for its use as tobacco. Traditionally, the plant leaves and balls have been used for the treatment of several illnesses in Africa, for anti-inflammatory, analgesic, and antimicrobial activities [33,36]. The leaves powdered after grinding are used in Ivory Coast, West Africa. In a study, the powder was applied 2-3 times a day; the outcome was reported fantastic, showing that 80% (219) of the patients in a trial healed [37]. The amount applied was not determined in the review because traditional healers are more concerned with the outcome than with the precise amount, which is a common practice among traditional healers worldwide. Noteworthy that if the active component, nicotine [38], was isolated from *N. tabacum* L., a better result could be achieved against Buruli ulcers.

Table 2. Plant preparation methods for Buruli ulcer

Scientific name	Common name	Parts used	Preparation method	Reference
<i>Ricinus communis</i> L.	Castor	Seeds	Maceration, milling, pressing, solvent extraction	[28,29]
<i>Nicotiana tabacum</i> L.	Tobacco	Stem and leaves	Maceration	[33]
<i>Mangifera indica</i> L.	Mango	Leaves	Infusion	[33]
<i>Mariscus alternifolius</i> Vahl.	Umbrella papyrus	Leaves	Maceration	[30]
<i>Solanum rugosum</i> Dunal	Soda apple	Leaves	Powder	[34]
<i>Carica papaya</i> L.	Papaya	Leaves and roots	Infusion	[33]
<i>Cleistopholis patens</i> (Benth.) Engl. & Diels	Salt and oil tree	Leaves	Extrudes from leaves	[33]

***Mangifera indica* L.**

Mangifera indica L. is a tropical and subtropical growing plant traditionally used for the treatment of diarrhoea, gastritis, inflammation, microbial infection, and ulcers in Africa. *Mangifera indica* analysis has revealed the presence of phenols, alkaloids, phytosterols, and polyphenols [39,40]. Researchers in the tropical areas of Brazil have reported that *M. indica* possesses antiulcerogenic action when aqueous decoction of plant leaves is used. The authors concluded that the two critical active components are mangiferin and C-glucosyl-benzophenone, which together produce these beneficial effects [41].

***Mariscus alternifolius* Vahl**

Mariscus alternifolius Vahl is a pantropical plant found in grassy areas and characterized by short and chunky bases [42]. A review in West Africa showed that material obtained from leaves of *M. alternifolius* maceration applied twice daily has therapeutic effects in hospitalized patients with Buruli ulcer [37]. The report did not detail whether the dose given coincided with the nature of traditional medicine. More focus is needed about this plant regarding phytochemical analysis, isolation of active components, and pharmacological studies.

***Solanum rugosum* Dunal**

Solanum rugosum Dunal is a species of the Solanaceae family, a vegetative plant grown in tropical areas of America and Africa [43]. *Solanum rugosum* has been used in traditional medicine for the treatment of sores [44] and is also used for Buruli ulcer treatment in West Africa, when leaves are dried and powdered, and applied directly to the Buruli ulcer lesion [21,37].

***Carica papaya* L.**

Carica papaya L. is an edible plant, popularly consumed as fresh fruit for its nutritional values. It grows in the tropical areas of the world, including Africa. The plant has been traditionally

used for therapeutic purposes as well [45]. A promising result was obtained when *C. papaya* was investigated for the treatment of Buruli ulcer. In vitro study of *C. papaya* roots and leaf extract of Ghanaian origin revealed that concentrations more than 250 µg/mL of *C. papaya* extract inhibited *Mycobacterium ulcerans* [46]. The plant was initially used for its anti-Buruli ulcer effects in West Africa for decades [37].

***Cleistopholis patens* Benth.**

Cleistopholis patens Benth. is a fast-growing plant, a relatively tall (~ 30 m) plant in forests. *Cleistopholis patens* is distributed throughout West African countries [47]. It has shown various pharmacological activities in African folk medicine, such as analgesic, anti-inflammatory, and anti-malarial activities [48]. *Cleistopholis patens* evaluated against *B. ulcerans* in vitro has shown the best minimum inhibitory effect (125 µg/mL) among 25 other extracts. A plant extract is considered of interest for further studies if the minimum inhibitory concentration value is equal to or lower than 250 µg/mL [49].

Other African plants used for the treatment of Buruli ulcer

Several reviews and studies in vitro or in vivo showed a protective effect against Buruli ulcers. These plants were either of low efficacy or only investigated at an in vitro level. Table 3 summarizes the plant's names, part used, method of preparation and references.

For the treatment of Buruli ulcer, traditional healers used bandages or topical application of plant extract or powder on the Buruli ulcer lesion as the primary method of administration. It might be because of its simplicity, low cost, and freshness that can be applied at a time.

For oral administration, the solvent of choice was water, which was used for decoction, maceration, and infusion. The plants showed anti-Buruli ulcer properties and are high in polyphenols and alkaloids.

Table 3. Medicinal plants used for the treatment of Buruli ulcer, their parts, and preparation methods

Scientific name	Country	Part/method	Reference
<i>Polyalthia suaveolens</i> Engl. & Diels	Cameroon	Stems/organic solvent extraction	[46]
<i>Holarrhena floribunda</i> G. Don	Benin	Leaves/organic solvent extraction	[49]
<i>Jatropha curcas</i> Linn.		Leaves/organic solvent extraction	
<i>Moringa oleifera</i> Lam.	Ghana, Cameroon	Leaves	[50,51]
<i>Aglaonema commutatum</i> Schott.		Leaves/juice	
<i>Aloe vera</i> (L.) Burm. f.		Leaves/gel	
<i>Alstonia boonei</i> De Wild.		Leaves/paste (bandage)	

Yaws

Yaws is a chronic infectious disease caused by *Treponema pallidum* subspecies *pertenue*. The disease is commonly spread in poor societies living in humid and tropical areas, including Africa, Asia, and Latin America. The WHO categorized Yaws as an neglected tropical diseases. It mostly affects children before puberty. The disease is transmitted by direct contact resulting in lesions developed on limbs in less than three months. Chemotherapy with azithromycin or penicillin successfully treats the disease in more than 95% of cases. [52,53]. Traditional medicinal plants are widely used in Africa, where rural populations may lack access to modern medical care.

African plants used for the treatment of Yaws

Yaws has not received as much attention as other neglected tropical diseases. A few studies reported the effects of medicinal plants used against yaws.

Sesbania sesban (L.) Merr.

Sesbania sesban (L.) Merr. is a leguminous-medium height plant (1 meter or more), fast-growing in a harsh dry environment [54]. A previously published report indicated that *S. sesban* leaves are pounded and soaked in water to make an infusion. This infusion is taken orally to treat yaws; however, there is little information on the dosage and effectiveness.

Heliotropium indicum L.

Heliotropium indicum L. is a plant native to pantropical regions. Although the plant is mainly found in India, it is also present in tropical Africa. In Africa, *H. indicum* is traditionally used for its analgesic, anti-wart, and anti-inflammatory effects. It has also been used for the treatment of skin conditions such as scabies, urticaria, eczema, and more interestingly, yaws. The Ngoni people of Tanzania use the extract of *H. indicum* root drink to treat yaws [55]. Limited information is available about the use of *H. indicum* for the treatment of yaws. Local researchers are encouraged to report on how local healers prepare *H. indicum* for the treatment of yaws using traditional methods.

Treatment of yaws by Africans forced to move to the West

In 1773, James Thomson, an expert in the

treatment of yaws, observed that the treatment of yaws brought to Europe by Africans was more advanced than that of Europeans. Africans used inoculation for the treatment of yaws, inserting some pinches of yaws lesion into the muscles of the limb. Old Africans also used Majoe bitters and *Picramina antidesma* SW., a small herbaceous tree whose active component is picramnioside, belonging to the Simaroubaceae family, found in tropical areas of India and Africa. The bark of the plant has a bitter taste when macerated in water to treat dysentery and malaria [56,57]. It has been reported that an old salved black woman in America that was called Majoe used *P. antidesma* for the treatment of yaws disease. As a result, the plant was named after her as Majoe bitters. *Picramina antidesma*, prepared by decoction, had provided a fantastic improvement in yaws patients [58]. The use of *P. antidesma* for the treatment of yaws was discontinued because of appearance of new more effective drugs. We hope that soon some researchers will trace the traditional methods of preparation of *P. antidesma* to treat yaws

Leprosy

Leprosy develops due to an infection caused by *Mycobacterium leprae*. Symptoms of the disease appear mainly in the skin, upper respiratory tract, eyes, and peripheral nerves. Leprosy can spread via droplets from infected patients. The disease is curable by multiple chemotherapies, but if left untreated, can lead to permanent destruction. Although the prevalence of leprosy is low, it is recorded in 159 countries [16]. A recent review reported that several side effects of chemotherapy are encountered, besides the low immunity of patients, which may aggravate the condition [59,60]. In this part, we list the anti-leprotic herbs used in Africa.

Chaulmoogra oil

Chaulmoogra oil is a substance isolated from the seed of *Calonchoba welwitsch* Hook. f. and other species of the Flacotriaceae family of tropical flowering plants, considered a folkloric treatment for leprosy. As reported by Raponda-Walker, chaulmoogra oil has been successful in the treatment of leprosy in Gabon [61,62]. However, neither method nor dose was obtainable. Until 1940s, chaulmoogra oil gained popularity for the treatment of leprosy worldwide, and its mechanism of action was thought to be bactericidal [63].

Preparation and administration of chaulmoogra oil

The extraction procedure is frequently used to prepare the chaulmoogra oil. Sulfuric ether is used to remove the seeds of chaulmoogra after they have been roasted, crushed, and extracted. The result is yellowish oil which is used topically to treat a variety of skin conditions, including leprosy. However, treated patients reported experiencing gastrointestinal disturbances such as vomiting, diarrhoea, and nausea after taking the medication orally. Encapsulating chaulmoogra oil was able to solve these issues [62]. Other African herbal plants used for the treatment of leprosy are summarized in Table 4.

Trachoma

Chlamydia trachomatis is a disease-causing bacterium. Trachoma spreads by flies, direct human contact, sex, or shared clothes. If left untreated, trachoma produces a lesion in the eyes and nose and may lead to blindness [16]. The African people, for example in Tanzania, often treat conjunctival inflammation using traditional medicines. More than 70% of the Maasai in Kenya tend to use traditional herbs for the treatment of trachoma [65,66]. Table 5 shows a list of plants used for the treatment of trachoma. The plant species as mentioned earlier in Tanzania, have been used locally for the

treatment of trachoma. However, according to the authors of the study, these plant species were not investigated for their anti-trachoma effects. Besides trachoma, several researchers have investigated the effects of bioactive components of African plants against *Chlamydiae trachomatis*. Potroz and Cho, for example, have reviewed tea polyphenols, flavonoids, quercetin, food phenols, luteolin (a common flavone of several plants), and catechins (flavones in vascular plants), lipids, peptides, and others. These materials work against trachoma causative agents by different techniques, such as cytoplasmic membrane damage, metabolism abnormalities, suppressing certain enzymes, increasing cellular apoptosis, and others [69].

Mycetoma

It is a chronic and destructive inflammatory skin infection caused by aerobic actinomycetes bacteria (actinomycetoma) or fungi (eumycetoma). Mycetoma is geographically found in what is called the mycetoma belt in Africa which includes Sudan, Chad, Ethiopia, Somalia, and Senegal. It is transmitted when the causative agent finds its way into the skin via skin trauma. Chemotherapy is still having a poor effect on mycetoma [16]; as a result, new therapies are desperately needed.

Table 4. African plants used for treating leprosy

Country	Plant scientific name	Parts used/ preparation method, route of administration	Reference
Sudan	<i>Acacia arabica</i> (Lam.) Willd.	Pods/decoction	[65]
	<i>Bauhinia rufescens</i> Lam.	Bark and root/ boiled water	
South Africa	<i>Plumbago zeylanica</i> L.	Root/powder orally and topically	[13]
	<i>Eleusine coracana</i> (L.) Gaertn.	Seeds/ powder orally and topically	
Tanzania	<i>Tamarindus indica</i> L.	Bark and root/ decoction	[61]
	<i>Stereospermum kunthianum</i> Cham.		
Nigeria	<i>Bauhinia thomningii</i> Schumach.	Bark, root, leaves/ chewing	[3]
	<i>Capparis Hausa</i> L.	Bark and root	

Table 5. African plants used for the treatment of trachoma

Country	Plant scientific name	Parts used/ preparation method, route of administration	Reference
Sudan	<i>Khaya senegalensis</i> (Desv.) A.Juss.	Bark/ maceration, orally	[65]
Tanzania	<i>Grewia bicolor</i> Juss.	Leaves/ rubbing in inverted eyelids	[66,67]
	<i>Licium</i> spp Solanaceae	Roots/ boiling in water, direct use into the eye	
	<i>Aloe volkensii</i> Engl.		
	<i>Acacia nubica</i> Benth.	Bark and green parts/ boiling in water	
	<i>Cammiphora swynnertonii</i> Burt.	Root/ boiling in water, direct use into the eye	
Ethiopia	<i>Ximenia caffra</i> Sond.	Leaf juice/ diluting with water, as eye drop	[66]
	<i>Erythrina abyssinica</i> Lam. Ex DC.	NP*	
	<i>Calpurnia aurea</i> (Aiton) Benth.	Leaves	

*NP: information not provided

Herbal treatments of mycetoma used in Africa

Dr. Alfahal, one of the world's most prominent researchers in the field of mycetoma, established the Mycetoma Research Centre at the University of Khartoum, Khartoum, Sudan. Alfahal and his team did several investigations into African plants to determine their efficacy. The researchers concluded that the most used medicinal plants by traditional healers are *Moringa oleifera*, *Acacia nilotica* (L.) Willd. Ex Del., *Citrullus colocynthis* (L.) Schrad., and *Cuminum cyminum* L. The patients who participated in the study reported no progress by either oral or local administration of the plants [70]. Another in-vitro study was undertaken in Sudan to determine the inhibitory effects of seven medicinal plant species. It was found that only three species, viz., *Boswellia papyrifera* Delile ex Caill., *Acacia nubica* Benth., and *Nigella sativa* L., possessed antifungal properties against *Madurella mycetomatis*.

Further investigation was recommended to figure out the in vivo efficacy [71]. Reports on African plants against mycetoma are limited, which might be due to the advancement in antibiotics or the absence of research in endemic areas of mycetoma. We require such investigations to disclose the African folklore regarding the treatment of mycetoma.

African plants used for the treatment of viral neglected tropical diseases

Numerous studies have been conducted to investigate the effects of various medicinal plants on neglected tropical diseases of viral origin. This review explores the most commonly used African medicinal plants for the treatment of viral tropical diseases.

Rabies

Rabies is a dog-mediated zoonotic viral disease, transmitted by saliva (bite) of an infected dog to a human. Except for the Antarctic continent, rabies is a worldwide disease. Rabies can be prevented via vaccination [16]. In this part, we report the most influential African traditional medicinal plants for the management of rabies.

African plants used for the management of rabies

In Africa, Ethiopian people were curious about finding medicinal plants to manage human rabies.

The lack of interest in seeking out traditional medicine to treat rabies might be due to the danger of infection and the availability of vaccines. A recent review in Ethiopia [16] on plant-based anti-rabies found the following plants to be the most important: 1) *Cucumis ficifolius* A. Rich. (root powder), 2) *Datura stramonium* L. (crushed leaves), 3) *Dracaena steudneri* Engil. (leaves), 4) *Euphorbia abyssinica* J.F.Gmel. (leaves and roots), 5) *Gnidia glauca* (Fresen.) Gilg. (root powder with skim milk for 7 days), 6) *Justica schimperiana* Hochst. ex Nees. (root and leaves), *Silene macroselen* (roots), 10) *Vigna membranacea* A. Rich. (powder and roots), and 11) *Zehneria scabra* (L.fil.) Sond. (roots). All these plants are given orally immediately after a dog bite [72]. Unfortunately, the report did mention the efficacy of these plants in the treatment of rabies. Nonetheless, these African plants continued to be used for the management of rabies. We found other reports, but the writing and integrity of the reports were poor.

Dengue

Dengue is a viral disease transmitted by mosquitoes of the *Aedes* species. It has been found in more than one-hundred countries, affecting people in Southeast Asia, Central, and South America. The disease is not a significant problem in Africa [16]. Dengue fever's rarity in Africa may limit Africans' ability to find local treatments.

African medicinal plants used for the treatment of Dengue fever

Several reports reviewed the herbal treatment of dengue fever, which might be due to the fact that this region is at risk for dengue fever, as highlighted by WHO.

Euphorbia hirta L., locally named Tawa-Tawa, is a plant used traditionally for the treatment of dengue in the Philippines [73]. Leaves of *E. hirta* have been studied for their anti-dengue activity due to their bioactive components, such as phenols, flavonoids, alkaloids, glycosides, and saponins. The main symptom of dengue fever is vascular haemorrhage. Bioactive components of *E. hirta*, mainly phenols and their hydroxyl and carboxyl groups, interact to form complexes-forming tannin characteristics, which improve platelet count in the blood. Besides, flavonoids stimulate megakaryocytes to form platelets [74,75]. Other plants found in Africa that can be

used for the treatment of dengue fever are *Carica papaya* L. leaf extracts, *Azadirachta indica* Juss. leaves, and *Momordica charantia* L. fruits [73]. These plants grow in Africa, and hence, their anti-dengue properties on African people infected with dengue might produce improving effects. The characteristic feature of anti-dengue plants is their rich content of flavonoids and phenols, which improves platelet count, and subsequently reduces the fever [74].

Protozoan neglected tropical diseases

Unicellular organisms cause protozoan diseases. They can infect animals or humans, inducing severe health problems that may lead to death. Protozoan diseases comprise about 15% of neglected tropical diseases. They are transmitted by insect vectors, for instance: tsetse flies (trypanosomiasis) and sandflies (leishmaniasis), which are considered the most critical protozoan disease in Africa [16,76].

African plants used for the treatment of trypanosomiasis and leishmaniasis

Recent research proved that the presence of flavonoids, quinones, alkaloids, and terpenoids is responsible for the activities of African plants

against trypanosomiasis and leishmaniasis infection [77]. Table 6 enumerates the most prominent African plants with antitrypanosomiasis and antileishmanial activities. The table represents studies and reports performed in Nigeria, Uganda, Tanzania, South Africa, Morocco, and Egypt. It has been found that *Alhizia gummifera* (J.F. Gmel.) C.A. Sm. is the most potent plant with antitrypanosomal activity when tested in vitro by a group of researchers at the Swiss Tropical Institute, Basil, Switzerland [79].

It is essential to mention that a recent review reported that species of the Annonaceae family such as *Pistacia atlantica* Desf, *Anonidium mannii* (Oliv.) Engl. & Diels, *Enantia chlorantha* Oliv., *Isolona hexaloba* Pierre ex Engl. & Diels, *Annona glauca* Schumach. & Thonn., *Annona senegalensis* Pers., and *Annickia kummeriae* (Engl. & Diels) Setten & Maas, are the most potent antileishmanial species compared to species of other plant families [83].

The authors of the study attribute the antileishmanial activities of the species of the Annonaceae family to the existence of α -pinene + α - and terpinene-4,ol compounds [83].

Table 6. African plants with antitrypanosomal and antileishmanial activities

Scientific name	Activities	Parts used/preparation method, route of administration	Reference
<i>Acacia nilotica</i> (L.) Willd.	AT		
<i>Bombax buonopozense</i> Beauverd	AT, AL	Stem bark, orally*	
<i>Pterocarpus erinaceus</i> Poir.	AT		[78]
<i>Heterotis rotundifolia</i> (Sm.) Jacq.-Fél.	AT	Whole plant, orally*	
<i>Zanthoxylum zanthoxyloides</i> (Lam.) Zepern. & Timler	AT	Fruits, oral*	
<i>Albizia gummifera</i> (J.F. Gmel.) C.A. Sm.	AT	Roots, orally*	
<i>Entuada abyssinica</i>	AT	Root/ boiled water, orally	
<i>Securinega virosa</i> (Roxb. ex Willd.) Baill.	AT	Roots/ powder, orally	[79]
<i>Vernonia subuligera</i> O.Hoffm.	AT	Roots/orally*	
<i>Ehretia amoena</i> Friedr.-Holzh.	AT	Leaves/orally*	
<i>Lantana camara</i> L.	AT	Leaves/ topically at the site of tsetse fly bite	
<i>Momordica balsamina</i> L.	AT	Pulp*	
<i>Myrtus communis</i> L.	AL	Leaves*	
<i>Arbutus unedo</i> L.	AL	Leaves*	[80]
<i>Cistus crispus</i> L.	AL	Leaves*	
<i>Origanum compactum</i> Benth.	AL	Leaves/ aqueous alcohol extract, orally	
<i>Vangueria infausta</i> Burch.	AL	Stem bark/ alcohol extract, orally	
<i>Bridelia mollis</i> Hutch.	AL	Roots/ alcohol extract, orally	
<i>Syzygium cordatum</i> Hochst. ex Krauss	AL	Leaves/ alcohol extract, orally	
<i>Xylopia parviflora</i> (A.Rich.) Benth.	AL	Roots*	[79]
<i>Ricinus communis</i> L.	AL		
<i>Corchorus olitorius</i> L.	AL	NP/ alcoholic extracts, orally	[81]
<i>Psidium guajava</i> L.	AL		
<i>Vernonia mespilifolia</i> Less.	AL	Leaves/ aqueous alcohol extract, orally	
<i>Schkuhria pinnata</i> (Lam.) Kuntze ex Thell.	AL	Whole plant/ aqueous alcohol extract, orally	[82]

AT: antitrypanosomal effect; AL: antileishmanial effect; *: method of preparation was not provided; NP: not provided

The potential mechanism underlying the antitrypanosomal and antileishmanial medicinal plants

Numerous studies have suggested that active compounds found in plant extracts such as saponins, flavonoids, alkaloids, tannins, and phenols, may be responsible for the efficacy of *Acacia nilotica* (L.) Willd. against blood protozoan parasites, particularly *Trypanosoma* and *Leishmania* [84]. Additionally, other authors suggested that some medicinal plants alter the redox balance of the parasites, thus, negatively affecting the respiratory chain, as *Kigelia africana* (Lam.) Benth. induces hydrogen peroxide production in the parasite's cell, which leads to parasite death [85]. The antileishmanial activity is attributed to the presence of bioactive components, such as sesquiterpene lactones, schkuhrin, isolated from *Schkuhria pinnata* (Lam.) Kuntze, and cynaropicrin were obtained from *Vernonia mespilifolia* Less. [82].

Helminthic neglected tropical diseases

Helminths are parasitic worms that particularly prevail in developing countries in tropical and subtropical regions; they represent the most common infectious diseases in developing nations. Helminths comprise about 50% of neglected tropical diseases- causing agents. The epidemiology of helminthic neglected tropical diseases largely depends on climate and topography. Vector-transmitted helminths, e.g., schistosomiasis affected by the environment and onchocerciasis affected by the availability of snails, are distributed in terrestrial areas [86].

These diseases are causing a heavy burden on the community. Programs were made to eradicate helminth neglected tropical diseases by 2020. However, these programs are facing numerous challenges, including fundraising, stigma connected with some neglected tropical diseases such as onchocerciasis in some inflicted regions, compliance, and patient adherence.

Traditional medicine is trusted more than the standard healthcare system in some rural and remote areas where helminth neglected tropical diseases are prevalent [87]. This confidence may reflect the richness of the African continent with anthelmintic medicinal plants.

African medicinal plants used for the treatment of helminthic neglected tropical diseases

Anthelmintic use of African plants in traditional medicine is an ancient practice which has been emphasized by several anthelmintic screenings of African plant extracts in vivo and in vitro. Table 7 shows a list of the most commonly used medicinal plants in Africa for the treatment of helminth neglected tropical diseases.

As shown in Table 5, some of the traditional healers used several plants for treatments of intestinal worms regardless of the type of infection. This reflects the multiple potentials of these plants against mixed or single helminth attacks. These plants are summarized from several reports, surveys, reviews, and studies, which have been performed in Nigeria, Côte d'Ivoire, South Africa, and Ghana.

Table 7. African medicinal plants used for the treatment of helminthic neglected tropical diseases

Scientific name	Parts used/preparation method, route of administration	Activity	References
<i>Acalypha wilkesiana</i> Muell. Arg.	Stem and roots/ steeped in alcohol, orally	Trematoda, Taeniasis,	[88,89]
<i>Bridelia ferruginae</i> Benth.	Stem and bark/ water extract, orally	Taeniasis and neurocysticercosis	[90]
<i>Azadirachta indica</i> L.	Leaves/ boiled in water, orally	Taeniasis	[88]
<i>Anthostemasenegalense</i> A. Juss.	Stem and bark	Intestinal worm	
<i>Antides mavenosum</i>	Stem and bark	Intestinal worm	
<i>Carissa edulis</i> (Forssk.)	Leave	Intestinal worm	
<i>Cassia sieberiana</i> DC.	Leaves	Intestinal worm	[90,91]
<i>Ficus congensis</i> Engil.	Leaves	Intestinal worm	
<i>Lophira lanceolata</i> Tiegh. ex Keay	Stem and leaves/orally	Intestinal worm	
<i>Acokanthera oppositifolia</i> (Lam.)	Leaves, roots, and twigs/ orally	Tapeworms	
<i>Acacia sieberiana</i> DC.	Leaves/orally	Tapeworms	[89]
<i>Carica papaya</i> L.	Seeds/orally	Tapeworms	
<i>Bryophylpinnatum</i> (Lam.) Pers	Ariel parts/ poultice, paste, decoction, topically or orally	Guinea worm	[92,93]
<i>Jatropha curcas</i> L.	Root and leaves/ poultice and decoction/ local and orally		
<i>Senna occidentalis</i> (L.) Link.	Leaves and seeds/ decoction, orally	Tape worm	[94]

Conclusion

This review considered the most common medicinal plant used among Africans for therapeutic purposes against neglected tropical diseases. The African people exploit scores of plants for the treatment of bacterial and fungal neglected tropical diseases. In contrast, the African plants employed for curing parasitic diseases are few compared with those used for microbial infections because of the high prevalence of fungal and bacterial diseases. This relatively small number of medicinal plants, particularly those used to treat worms, is known as assorted helminth infections, which can be treated with a single plant preparation. The most frequently applied techniques of preparation include maceration, decoction, infusion, percolation, and digestion. It is highly recommended to trace the African plants used for the treatment of neglected tropical diseases, isolate the active components, and investigate these active ingredients in vivo and in vitro to make new phytopharmaceuticals or semisynthetic drugs for the management and elimination of neglected tropical diseases in Africa and other tropical regions of the world.

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Author contributions

Gareeballah Osman Adam, Shang-Jin Kim, and Chukwuebuka Egbuna conceived and wrote the manuscript; Shang-Jin Kim financially supported the study; Chukwuebuka Egbuna and Hong-Geun Oh revised the manuscript. All authors have agreed to be held accountable for all aspects of the manuscript.

Declaration of interest

The authors declare that there is no conflict of interest. The authors alone are responsible for the accuracy and integrity of the paper content.

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Abbreviations

NTDs: neglected tropical diseases; WHO: World Health Organization; ATM: African traditional medicine; LD₅₀: lethal dose 50%; AT: antitrypanosomal; AL: antileishmanial; NP: not provided