

Review

A review on antimicrobial potential of species of the genus *Vernonia* (Asteraceae)

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Natural products are sources of various biologically active chemicals. Therefore, ethnopharmacological and ethnobotanical studies are essential to discover new substances for the treatment of diseases. In this context, many studies have been conducted of the Asteraceae family demonstrating medicinal properties of its representatives, such as species of the genus *Vernonia*, which are rich in bioactive substances like sesquiterpene lactones, flavonoids, tannins and steroids. This review presents an overview of *Vernonia* species with antimicrobial potential, their main phytochemical characteristics and ethnomedicinal uses.

Key words: Compositae, Vernonieae, phytochemistry, biological activity, antimicrobial, antibacterial, antifungal.

INTRODUCTION

Humans have always used plants for therapeutic purposes to control microbial infections and other medical conditions (Rangel et al., 2001). The increase of bacterial and fungal infections and the development of microbial resistance to synthetic drugs have led to renewed interest in recent years to investigate plants as natural sources of substances for therapy against microorganisms of medical and veterinary importance (Denning, 2002; Rocha et al., 2011; Nascimento et al., 2000; Bautista-Baños et al., 2003). Numerous plants have been used for prophylactic purposes and to cure infections. In this context, many studies have been conducted to find plant species with antimicrobial

potential, such as assays of essential oils with antimicrobial properties against a variety of microorganisms (Silva et al., 2012).

The Asteraceae family (Compositae) has about 24,000 described species, belonging to 1,600 to 1700 genera distributed in 17 tribes and three sub-families (Funk et al., 2009; Petacci et al., 2012). They have cosmopolitan distribution and are widely found in the tropics, subtropics and temperate regions (Teles and Bautista, 2006; Hattori and Nakajima, 2008). Representing to the largest family of the eudicotyledons, Asteraceae is relevant for its cosmetic, aromatic and therapeutic properties (Nakajima and Semir, 2001; Hattori and Nakajima,

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2008). Together with *Calyceraceae*, *Campanulaceae*, *Menyanthaceae* and *Goodeniaceae*, it forms a clade; the Asterales order (Pozner et al., 2012). The main genera of Asteraceae are *Aster* L., *Inula* L., *Xanthium* L., *Eupatorium* L., *Carpesium* L., *Saussurea* DC., *Vernonia* Schreb. and *Taraxacum* Zinn. (Wu et al., 2006).

Of the tribe Vernonieae, the genus *Vernonia* is one of the largest, predominantly in Africa and South America (Costa et al., 2008). Its species have wide ethnopharmacological use for treatment of several diseases as snakebite antidote, and as food in some African regions (Toyang and Verpoorte, 2013). Numerous phytochemical studies of the genus *Vernonia* have revealed the presence of diterpenes (Kos et al., 2006), triterpenes (Liang and Min, 2003), steroids (Tchinda et al., 2003), and the most frequently isolated chemical constituents are flavonoids (Carvalho et al., 1999) and sesquiterpene lactones (Buskuhl et al., 2010). This article presents a review of the antimicrobial potential, focusing on the antibacterial and antifungal activities of the species of the genus *Vernonia*, highlighting the biological, phytochemical and ethnopharmacological properties of the genus.

METHODOLOGY

The current review was achieved using an organized search of the scientific data published about antimicrobial activity, focusing on the antibacterial and antifungal activities of the species of the genus *Vernonia*. The search was conducted between November 1 and December 28, 2014, using the keyword search term "*Vernonia* antimicrobial activity". The searches were carried out using various databases, including PubMed (<http://www.ncbi.nlm.nih.gov/pubmed>), Science Direct (<http://www.sciencedirect.com/>), Scopus (<http://www.scopus.com/>), Scielo (<http://www.scielo.org/>) and Google Scholar (<http://www.scholar.google.com/>).

Antimicrobial potential of the genus *Vernonia*

Vernonia is one of the largest genus of plants belonging to the tribe Vernonieae (Cichorioideae), Asteraceae family, with about 1,500 described species, being the largest genus of the tribe (Silva et al., 2013). *Vernonia* species are found in temperate, tropical and sub-tropical areas, especially in South America, Asia, Africa (Costa et al., 2008; Dematteis and Pire, 2006) and North America (Redonda-Martínez et al., 2012). More than 500 of these *Vernonia* plants are distributed in Africa and Asia and approximately 300 species distributed in tropical areas, from Mexico to Argentina (Yeap et al., 2010). This genus is named in honour of the English botanist William Vernon, who first identified this genus in the region that is now Maryland in the USA in the late 1600s (Toyang and Verpoorte, 2013).

In Brazil; country with the highest genetic diversity of the world (Lewinsohn and Prado, 2005), there are over 200 species of *Vernonia*, in the form of herbs, shrubs or trees with foliage in various habitats. As for the morpho-anatomical features, they present solitary capitulum that are racemose, paniculated or scorpioid with flowers of various colors. The fruits are cipselas and can be angled or *costadas*, glabrous or sericeous. They nearly always have a couple pappus formed by an outer row of short bristles and an inner row of feathery, *barbeladas* or scabrous bristles, persistent or not (Galastri et al., 2010).

In traditional medicine, many *Vernonia* species are employed to treat various diseases. From the pharmacological point of view, species have been investigated revealing many properties, such as antiplasmodial (Stangeland et al., 2011), analgesic (Frutuoso et al., 1994), anti-inflammatory (Malafronte et al., 2009), antimicrobial (Ogundare et al., 2006), anti-diabetes (Akinola et al., 2010), antioxidant (Owolabi et al., 2011) and antitumor (Sangeetha and Venkatarathinakumar, 2011).

Phytochemical studies have indicated that the main constituents of the genus are sesquiterpene lactones, triterpenes, steroids, carotenoids, flavonoids, lignoids, alkaloids and tannins (Toigo et al., 2004). The most common constituents are flavonoids, which often have antioxidant activity (Salawu et al., 2011), and sesquiterpene lactones, the latter being considered the chemotaxonomic markers in the genus (Albuquerque et al., 2007a). Several sesquiterpene lactones have been isolated from species of the genus with different types of bioactivity, such as molluscicidal, antifungal, antitumor, cytotoxic and insecticidal against herbivores insects (Wedge et al., 2000; Freire et al., 1996c; Lopes et al., 1991). In *V. amygdalina* the sesquiterpene lactones vernolide and vernodalol (Figure 1) were isolated, with potential antibacterial and antifungal activity (Erasto et al., 2006). In an investigation of the chemical composition of hexane and ethanol extracts from aerial parts of *V. chalybaea* Mart by spectroscopic methods, terpenoids, flavonoids, alcohols and aliphatic ethers were isolated for the first time in the genus (Costa et al., 2008).

There have been numerous studies involving extracts, fixed oils and essential oils of *Vernonia* species (Table 1) with potential antimicrobial activity against strains of bacteria, protozoa and fungi that are pathogens to animals and plants, using extracts, fixed oils, and essential oils. In particular, phytochemical screening is promising to identify bioactive compounds with antimicrobial activity (Magadula and Erasto, 2009; Hamill et al., 2000).

In Ethiopia, a study of nine plants with the ethnomedicinal use indicated that *Vernonia* species are used for the treatment of eye infections, for wound healing and the treatment of bone related problems such as fractures. They are used by decoction of fresh leaves and subsequent application on the lesions or intake

Table 1. Species of the genus *Vernonia* with antimicrobial activity.

Scientific name	Part used	Biological preparation	Bioactive substances	Biological activity	Reference
<i>Vernonia adoensis</i>	L	PE	Terpenoids	Antibacterial activity: Gram-positive and gram-negative bacteria Antifungal activity: <i>Candida albicans</i> yeast	Kisangau et al. (2007)
<i>Vernonia ambigua</i>	AP	CE/EE	Alkaloids, flavonoids, saponins, tannins, glycosides, cardiac glycosides, steroids and triterpenes	Antibacterial activity: Gram-positive and gram-negative bacteria	Aliyu et al. (2011)
	L	EAE	Sesquiterpene lactones	Antibacterial activity: Gram-positive and gram-negative bacteria	Jisaka et al. (1993)
	L	ME	Saponins, tannins and flavonoids	Antibacterial activity: Gram-positive and gram-negative bacteria Antifungal activity: <i>Candida albicans</i> yeast	Akinpelu (1999)
<i>Vernonia amygdalina</i>	L	ME/DEE/AqE	Sesquiterpene lactones and steroid glucosides	Antibacterial activity: Gram-positive and gram-negative bacteria	Otshudi et al. (1999)
	AP	ME/AE	-	Antibacterial activity: Gram-positive and gram-negative bacteria	Kambizi and Afolayan (2001)
	L	EE	Sesquiterpene lactones	Antibacterial activity: Gram-positive and gram-negative bacteria	Erasto et al. (2006)
	L	AqE	-	Antifungal activity: <i>Fusarium</i> sp filamentous fungi	Suleiman et al. (2008)
	L	ME	Sesquiterpene lactones and steroid glucosides	Antibacterial activity: Gram-positive and gram-negative bacteria	Cheruiyot et al. (2009)
	L	AE	-	Antibacterial activity: Gram-positive <i>Mycoplasma mycoides</i> subsp. <i>mycoides</i>	Muraina et al. (2010)
	L	EE/AqE	Phenolic compounds	Antibacterial activity: Gram-positive and gram-negative bacteria	Salawu et al. (2011)
	L	EE/AqE	Sesquiterpene lactones	Antibacterial activity: Gram-positive and gram-negative bacteria	Adetutu et al. (2011)
	L	ME	Alkaloids, phenols, tannins, phytosterols, flavonoids and saponins	Antibacterial activity: Gram-negative bacteria	Noumedem et al. (2013)
<i>Vernonia anthelmintica</i>	S	ME	-	Antibacterial activity: Gram-positive and gram-negative bacteria Antifungal activity: yeast and filamentous fungi	Jahan et al. (2010)
<i>Vernonia auriculifera</i>	L/St/R	HE/DE/EAE/ME	Triterpenes and sesquiterpenes	Antibacterial activity: Gram-positive and gram-negative bacteria	Kiplimo et al. (2011)
	AP	CE/EE	alkaloids, flavonoids, saponins, tannins, glycosides, cardiac glycosides, steroids and triterpenes	Antibacterial activity: Gram-positive and gram-negative bacteria	Aliyu et al. (2011)
<i>Vernonia blumeoides</i>	L	CE	Lacones	Antitrypanosomal activity: <i>Trypanosoma brucei brucei</i>	Ibrahim et al. (2013)
<i>Vernonia brasiliiana</i>	L	EO	Sesquiterpenes	Antibacterial activity: gram-positive and gram-negative bacteria	Maia et al. (2010)
<i>Vernonia cinerea</i>	AP	ME	-	Antibacterial activity: Gram-negative <i>Pseudomonas aeruginosa</i>	Latha et al. (2010)
	L	ME	-	Antifungal activity: <i>Candida albicans</i> and <i>Cryptococcus neoformans</i> yeast	Latha et al. (2011)
<i>Vernonia colorata</i>	L/St/R	ME/EAE	-	Antibacterial activity: Gram-positive and gram-negative bacteria	Kelmanson et al. (2000)
	L	HE/EAE	Sesquiterpene lactones	Antibacterial activity: Gram-positive and gram-negative bacteria	Rabe et al. (2002)
<i>Vernonia condensate</i>	AP	ME	-	Antibacterial activity: Gram-positive and gram-negative bacteria	Brasileiro et al. (2006)

Table 1. cont'd

<i>Vernonia galamensis</i>	S	FO	Amino compounds	Antibacterial activity: Gram-positive and gram-negative bacteria Antifungal activity: Yeast and filamentous fungi	Mbugua et al. (2007)
<i>Vernonia glabra</i>	AP/St/R	DE/ME	-	Antibacterial activity: Gram-positive and gram-negative bacteria Antifungal activity: Yeast and filamentous fungi	Kitonde et al. (2013)
<i>Vernonia guineenses</i>	R	DE/ME/AqE	-	Antibacterial activity: Gram-positive and gram-negative bacteria Antifungal activity: Yeast and filamentous fungi	Toyang et al. (2012)
<i>Vernonia hymenolepis</i>	L	ME	Alkaloids, phenols and flavonoids	Antibacterial activity: Gram-negative bacteria	Noumedem et al. (2013)
<i>Vernonia lasiopus</i>	L/St	AqE	-	Antibacterial activity: Gram-positive and gram-negative bacteria	Kareru et al. (2008)
<i>Vernonia ocephala</i>	AP	CE/EE	alkaloids, flavonoids, saponins, tannins, glycosides, cardiac glycosides, steroids and triterpenes	Antibacterial activity: Gram-positive and gram-negative bacteria	Aliyu et al. (2011)
<i>Vernonia polyanthes</i>	L	ME	Alkaloids, triterpenoids, coumarins and flavonoids	Antifungal activity: <i>Candida albicans</i> and <i>Cryptococcus neoformans</i> yeast Antileishmanial activity: <i>Leishmania amazonensis</i> and <i>Leishmania chagasi</i>	Braga et al. (2007)
<i>Vernonia remotiflora</i>	L St L	EO HE/CE HE/CE	Sesquiterpenes Sesquiterpene lactones Sesquiterpene lactones	Antibacterial activity: Gram-positive and gram-negative bacteria Antifungal activity: <i>Penicilium citrinum</i> Antifungal activity: <i>Penicilium citrinum</i> and <i>Aspergillus alutaceos</i>	Maia et al. (2010) Freire et al. (1996a) Freire et al. (1996b)
<i>Vernonia scorpioides</i>	AP	EO	Terpenoids	Antibacterial activity: Gram-positive and gram-negative bacteria Antifungal activity: <i>Candida albicans</i> yeast	Toigo et al. (2004)
	L	EAE	-	Antibacterial activity: Gram-positive bacteria	Kreuger et al. (2012)
<i>Vernonia smithiana</i>	AP	EO	Terpenoids	Antibacterial activity: Gram-positive and gram-negative bacteria Antifungal activity: Yeast	Vagionas et al. (2007)
<i>Vernonia species</i>	L	ME	-	Antibacterial activity: Gram-positive and gram-negative bacteria	Kalayou et al. (2012)
<i>Vernonia tenoreana</i>	L/St	ME/EAE/AE/HE	Alkaloids, tannins (including phlobaphenic tannins), cardiac glycosides and anthraquinones	Antibacterial activity: Gram-positive and gram-negative bacteria Antifungal activity: Yeast and filamentous fungi	Ogundare et al. (2006)

AP - Aerial part; L - Leaves; R - Root; S - Seed; St – Stems; AE - Acetone extract;; AqE - Aqueous extract; CE - Chloroform extract; DE - Dichloromethane extract; DEE - Diethyl ether extract; EAE - Ethyl acetate extract; EE - ethanol extract; EO - Essential oil; FO - Fixed oil; HE - Hexane extract; ME - Methanol extract; PE - Petroleum ether extract.

(Kalayou et al., 2012). This article presents an overview of ethnopharmacological uses, local prevalence and antimicrobial potential of species of the genus *Vernonia*, with corresponding information in Table 1.

***Vernonia adoensis* Sch. Bip. ex Walp.**

In Africa, this species is used in folk medicine for the treatment of various diseases, especially infectious diseases such as HIV/AIDS (Lamorde

et al., 2010), tuberculosis and gonorrhoea (Kisangau et al., 2007) and malaria (Ragunathan and Solomon, 2009). In Tanzania the petroleum ether extract of the leaves against the bacteria *Staphylococcus aureus*, *Bacillus subtilis*,

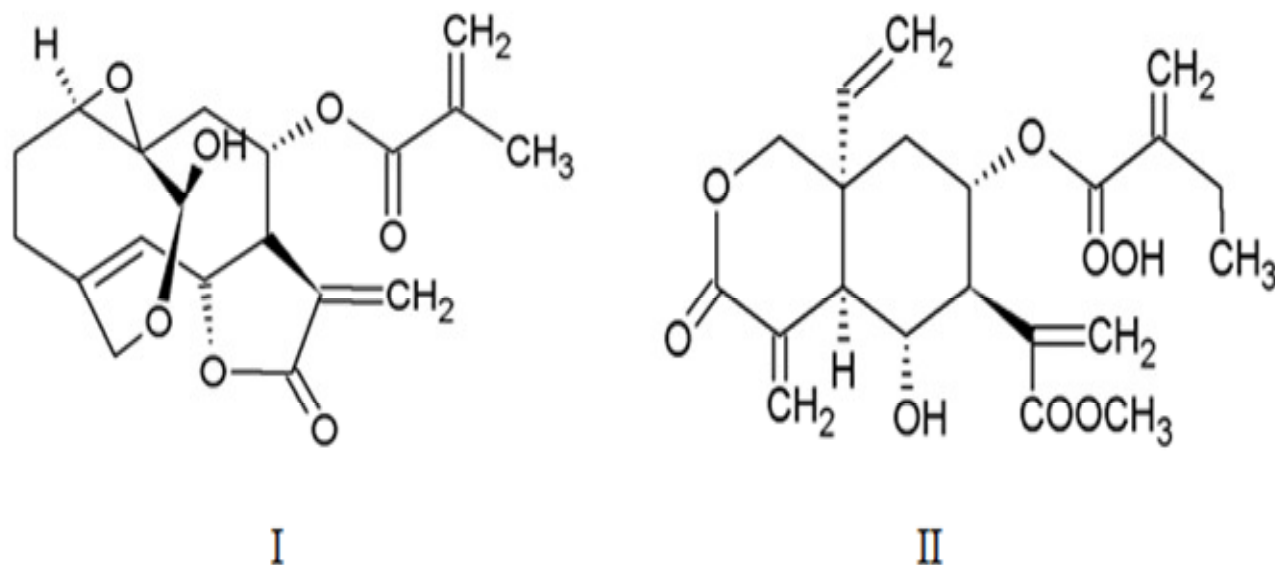


Figure 1. Chemical structure of vernolide (I) and vernodalol (II), sesquiterpene lactone found in *V. amygdalina*.

Escherichia coli and *Pseudomonas aeruginosa* was investigated, as well as against the yeast *Candida albicans*.

The authors used the disk diffusion and agar diffusion methods. The extracts only showed bioactivity against the strain of *E. coli* (Kisangau et al., 2007).

***Vernonia ambigua* Kotschy and Peyr (Asteraceae)**

In Africa, particularly in Nigeria, Cameroon and Tanzania, this species is used in folk medicine to treat urinary tract infections, cough and colds (Burkill, 1985) as well as malaria (Builders et al., 2011)

In Northern Nigeria, it is widely used in traditional medicine for the treatment of various infectious diseases (Aliyu et al., 2011). *V. ambigua* is an annual shrub, in "Yoruba" is known as "Orungo" and in "Hausa" as "Tabtaba or Tattaba" (Builders et al., 2011). A phytochemical screening revealed the presence of secondary metabolites alkaloids, flavonoids, saponins, tannins, glycosides, cardiac glycosides, steroids and triterpenes (Aliyu et al., 2011).

Antibacterial activity of ethanolic extract of leaves was reported against ten clinical bacterial strains, *Klebsiella pneumoniae* (16 mm), *Streptococcus pyogenes* (16 mm), *S. aureus* (18 mm), *Corynebacterium ulcerans* (16 mm), methicillin resistant *S. aureus* (14 mm), *Salmonella typhi* (20 mm), *P. aeruginosa* (18 mm), *Shigella dysenteriae* (0 mm), *Proteus mirabilis* (0 mm) and *Pseudomonas fluorescence* (0 mm), by the disk diffusion and broth microdilution methods. The MIC values ranged from 1.25 to 2.5 mg/mL for all the organisms tested (Aliyu et al., 2011).

***Vernonia amygdalina* Delile**

V. amygdalina is a species with wide medicinal use in African countries, to treat malaria, helminth infections, gastrointestinal disorders and fever (Hamill et al., 2000; Magadula and Erasto, 2009), to promote wound healing by decoction (Adetutu et al., 2011) and to treat microbial infections (Noumedem et al., 2013). Three sesquiterpene lactones were isolated from the ethyl acetate extract of the leaves: vernodalol, vernolide and hydroxyvernolide. In turn, vernodalol was isolated from the methanol extract. All were tested against strains of *B. subtilis*, *Micrococcus luteus*, *E. coli* and *Agrobacterium tumefaciens*, showing significant results, indicated by growth inhibition zone (Jisaka et al., 1993). Akinpelu (1999), isolated saponins, tannins and flavonoids of the methanol extract of the leaves. Sensitivity tests were performed by the agar diffusion and broth dilution methods for the bacteria *Klebsiella pneumoniae*, *B. subtilis*, *E. coli*, *P. aeruginosa*, *Proteus vulgaris*, *Serratia marcescens*, *Shigella dysenteriae* and *Staphylococcus aureus*, along with antifungal testing against the yeast *Candida albicans*.

The results showed antimicrobial activity against all tested microorganisms except *S. marcescens*, *E. coli* and *C. albicans*. Several studies have investigated the antimicrobial potential of solvent extracts of the aerial parts against gram-positive and gram-negative bacteria, using methanol, ethanol and water (Otshudi et al., 1999); methanol and acetone (Kambizi and Afolayan, 2001); ethanol (Erasto et al., 2006); methanol (Cheruiyot et al., 2009); ethanol and water (Salawu et al., 2011); ethanol and water (Adetutu et al., 2011); methanol (Noumedem et al., 2013); and acetone (Muraina et al., 2010). There

are also reports of the antifungal activity of *V. amygdalina* against *C. albicans* (Akinpelu, 1999), as well as fungi of the genus *Fusarium*, which cause superficial and systemic human infections, in addition to food contamination by the mycotoxins produced (Suleiman et al., 2008).

***Vernonia anthelmintica* (L.) Willd.**

V. anthelmintica [syn. *Centhraterum anthelminticum* (L.) Kuntze], native to Africa and Asia, has been studied to treat diabetes (Rao et al., 2010; Fatima et al., 2010) and helminth infections (Mali and Mehta, 2008). The methanol extract of the seeds was tested against strains of the bacteria *P. aeruginosa*, *Yersinia aldovae*, *Citrobacter*, *Shigella flexneri*, *E. coli* and *S. aureus*. The antifungal activity was also tested against *Saccharomyces cerevisiae*, *C. albicans*, *Aspergillus parasiticus*, *Macrophomina*, *Fusarium solani*, *Trichophyton rubrum* and *Trichophyton occidentaleis*. The extracts showed antibacterial activity against all strains tested except *Y. aldovae*. However the antifungal assay showed only inhibitory action against the dermatophyte *T. rubrum* (Jahan et al., 2010).

***Vernonia auriculifera* Hiern.**

V. auriculifera is a shrubby species whose height varies between 1 and 7.5 m. It is native to Africa and is used in folk medicine to relieve headaches (Kusamba, 2001), to treat conjunctivitis, fever, viral and bacterial infections (Muthaura et al., 2007), and for various purposes by decoction in Cameroon (Focho et al., 2009). Extracts using the organic solvents hexane, dichloromethane, ethyl acetate and methanol of roots, stems and leaves of *V. auriculifera* were conducted.

Eight triterpenes and one aminated sesquiterpene were isolated. All compounds were tested by the broth microdilution method, against *E. coli*, *P. aeruginosa*, *K. pneumoniae*, *Stenotrophomonas maltophilia*, *S. aureus*, *B. subtilis*, *Enterococcus faecium*, *Staphylococcus epidermidis* and *Staphylococcus saprophyticus*. The results showed moderate antibacterial activity (Kiplimo et al., 2011).

***Vernonia blumeoides* Hook. F.**

V. blumenoides is a perennial herb native to Africa in "Hausa" known as "Bagashi", used in traditional medicine for the treatment of various protozoans (malaria), diarrhea and other unspecified infectious diseases in Nigeria (Ibrahim et al., 2013; Aliyu et al., 2015). A study have investigated the antibacterial activity of two sesquiterpene lactones isolated and of crude extracts using hexane, dichloromethane and ethyl acetate of

aerial parts against gram-positive bacteria *B. subtilis*, *S. pyogenes*, *Staphylococcus saprophyticus*, *Staphylococcus sciuri*, *Staphylococcus xylosus*, *S. aureus* and *S. epidermidis*, by the disk diffusion method. The sesquiterpene lactone blumeoidolide - A demonstrated the better antibacterial activity (Aliyu et al., 2015). In a previous study, a phytochemical screening revealed the presence of secondary metabolites alkaloids, flavonoids, saponins, tannins, glycosides, cardiac glycosides, steroids and triterpenes (Aliyu et al., 2011).

In other studies in Nigeria, the ethanolic extracts of leaves was reported against the clinical bacterial strains, *K. pneumoniae* (22 mm), *S. pyogenes* (16 mm), *S. aureus* (22 mm), *C. ulcerans* (24 mm), methicillin resistant *S. aureus* (17 mm), *S. typhi* (18 mm) and *S. dysenteriae* (14 mm), by the disk diffusion and broth microdilution methods. The MIC values ranged from 1.25 to 2.5 mg/ml for all the organisms tested (Aliyu et al., 2011).

***Vernonia brasiliiana* (L.) Druce.**

V. brasiliiana is a species found in north eastern Brazil whose antiplasmodial activity was investigated against *Plasmodium berghei* and *P. falciparum* (Carvalho et al., 1991). The essential oil of leaves, extracted by hydrodistillation, was tested against *P. aeruginosa*, *Enterobacter aerogenes*, *Salmonella choleraesuis*, *K. pneumoniae*, *S. aureus* and *B. subtilis*, by the disk diffusion method, finding broad-spectrum antibacterial activity against all tested microorganisms (Maia et al., 2010).

***Vernonia cinerea* (L.) Less.**

V. cinerea is an herbaceous species with ethnopharmacological use in South America, Africa and Asia, to treat various diseases or ailments such as malaria (Jain and Puri, 1984; Moshi et al., 2009; Padal et al., 2010), helminths infections (Johri et al., 1995; Alagesaboopathi, 2009) and skin infections (Maregesi et al., 2007; Moshi et al., 2009). In Asia it has been documented and recommended in Thai and Indian traditional medicine, as in other countries, for smoking cessation, and relief of urinary calculi, cough, fever, asthma, malaria, and arthritis (Leelarungrayub et al., 2010; Kitikannakorn et al., 2013). In India the undergrowth includes shrub species such as *V. cinerea* (Behera and Misra, 2006). Studies on the chemical composition of extracts of the aerial parts from *V. cinerea* revealed the presence of triterpenes like α -amyrin, β -amyrin and lupeol (Gaikwad et al., 2012; Sreedevi et al., 2011).

The methanol extract of the aerial parts was tested against the bacterium *P. aeruginosa*, a prominent

opportunistic pathogen in hospital infections. The disk diffusion and broth dilution methods were used. The extract showed dose-dependent antimicrobial activity against the tested bacterium (Latha et al., 2010). The antifungal activity was tested using the methanol extract of the aerial parts against strains of the yeasts *C. albicans* and *Cryptococcus neoformans*. Assays were performed using the disk diffusion method, showing activity against both yeasts, but better activity against *C. albicans* (Latha et al., 2011).

***Vernonia colorata* (Willd) Drake.**

V. colorata is a shrub native to Africa especially found in Cameroon, Ivory Coast, Senegal, Togo, South Africa and Benin (Chukwujekwu et al., 2009), known as "Ibozane" in South Africa (Kelmanson et al., 2000). Senegalese and Togolese traditional medicine practitioners employ the decoction of *V. colorata* leaves to cure diabetes mellitus (Sy et al., 2004). It is used for the treatment of cough, fever, hepatitis, gastritis, stomach pain, gastrointestinal disorders, venereal diseases and skin eruptions (Hutchings et al., 1996; Cioffi et al., 2004). Its leaves are used in culinary art in Benin, Cameroon and Togo (Sy et al., 2005). Phytochemical studies reported the presence of sesquiterpene lactones vernolide, 11 β , 13-dihydrovernalide and vernodaline (Rabe et al., 2002). Also identified were tannins and saponosides (Sy et al., 2005).

In a study with 14 plants used in traditional Zulu medicine for treatment of ailments of an infectious nature, the methanolic and ethyl acetate extracts of *V. colorata* revealed antibacterial activity against gram-positive bacterium *S. epidermidis*, *S. aureus*, *M. luteus* and *B. subtilis* and gram-negative *E. coli* and *P. aeruginosa*, by the disk diffusion and broth microdilution methods. The ratios of the inhibition zone were expressed between 0.52 to 1.36 mm. The MIC values ranged from 1.0 to 4.0 mg/mL for *S. aureus*, *M. luteus*, *B. subtilis* and *P. aeruginosa* (Kelmanson et al., 2000). In other study in South Africa, the sesquiterpene lactones vernolide, 11 β , 13-dihydrovernalide and vernodaline were identified and tested against the bacterium *S. aureus*, *B. subtilis*, *E. coli* and *K. pneumoniae* by the direct bioautography and broth microdilution methods. The results showed that all sesquiterpene lactones were active at inhibiting bacterial growth (Rabe et al., 2002).

***Vernonia condensata* Baker.**

V. condensata is a species found in Brazil and Africa with medicinal use reported in Nigeria against the snakebite (Pereira et al., 1994). Known in Brazil as "aluma" and "alcachofra", and its leaves are mainly used to relieve muscle pain along with gastrointestinal and hepatic problems (Albuquerque et al., 2007b). A study of the methanol extract of the aerial parts showed antibacterial activity against *S. aureus* by the broth dilution method,

with minimal inhibitory concentration greater than the positive control used, chloramphenicol (Brasileiro et al., 2006).

***Vernonia galamensis* Less.**

V. galamensis is found in Africa and has added commercial value because the oil extracted from its seeds has important medicinal use for treating diabetes and other organic dysfunctions (Autamashih et al., 2011). These oils have high vernolic acid content, an unsaturated fat composed of triglycerides such as the trivernolin, present as the major constituent (Figure 2). The derivatives of fixed oils of *V. galamensis* such as aminated fats are important intermediate chemicals, also acting as additives for polyethylene films, water-based insect repellent and fungicidal compounds, among others (Watanabe et al., 1993).

A study of the fixed oil of the seeds isolated unsaturated fats, subsequently converted into aminated fats, vernolamide, tested the antimicrobial activity against the bacteria *E. coli*, *B. subtilis* and *S. aureus*, and the fungi *S. cerevisiae*, *Microsporum gypseum* and *Trichophyton mentagrophytes*. The authors have used the disk diffusion method and the results showed activity against strains of *E. coli* and *B. subtilis*, but not against the yeast and dermatophyte fungi tested (Mbugua et al., 2007).

***Vernonia glabra* (Steetz) Oliv. & Hiern**

A herbaceous species found in Africa, *V. glabra* has therapeutic use in Kenya for gastrointestinal problems by drinking tea from decoction of leaves and roots (Johns et al., 1995). It is also used in the same country as an antidote for snakebite (Owuor and Kisangau, 2006). Dichloromethane and methanolic extracts of the aerial parts, stems and roots were tested against strains of the gram-positive bacterium *S. aureus* and gram-negative *E. coli* and fungi *C. albicans* and *Aspergillus niger* by the disk diffusion method. The results showed moderate antimicrobial potential against all tested microorganisms, dependent upon the plant part used (Kitonde et al., 2013).

***Vernonia guineensis* Benth.**

This species is widely used in folk medicine in the Central African Republic, Congo and Cameroon. It has ethnopharmacological use of the roots as a stimulant, aphrodisiac, antimicrobial, snakebite antidote and to treat helminth infections (Tchinda et al., 2002; Noumi, 2010). Extracts obtained with dichloromethane, methanol and distilled water of the roots of *V. guineensis* var. *cameroonica* C. D. Adams were tested against the

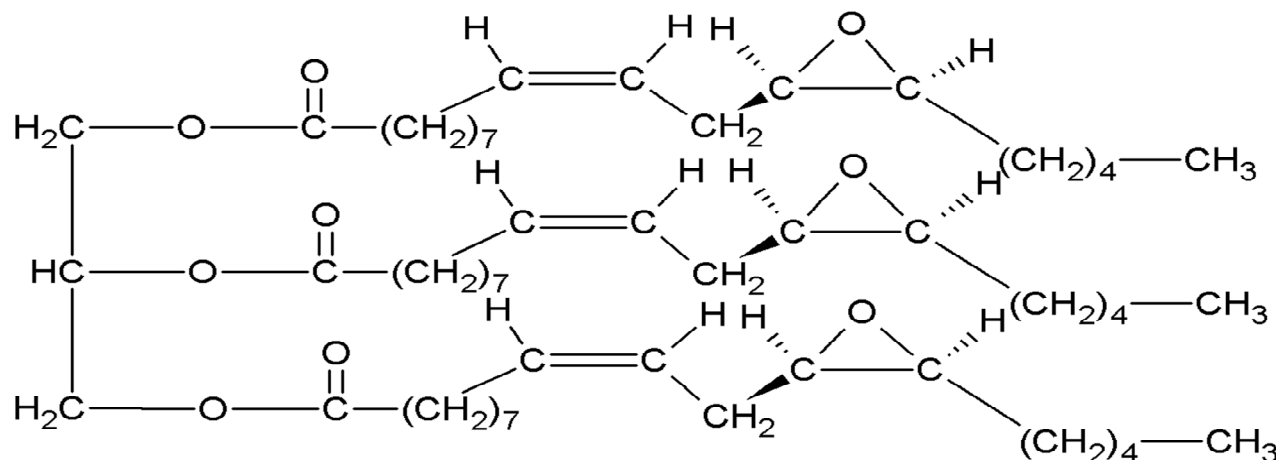


Figure 2. Trivernolin, a triglyceride of vernolic acid (cis-12,13-epoxy-cis-9-octadecenoic acid).

bacteria *Acinetobacter baumannii*, *E. coli*, *P. aeruginosa*, *Salmonella typhimurium*, *S. epidermidis* and *S. aureus* as well as a methicillin-resistant strain of *S. aureus*. In turn, antifungal tests were conducted against *Aspergillus fumigatus*, *C. albicans*, *C. neoformans* and *T. mentagrophytes*. The authors used the microdilution broth method for determination of the minimal inhibitory concentration. All extracts showed antimicrobial activity against all tested strains (Toyang et al., 2012).

***Vernonia hymenolepis* Vatke.**

Found in western Africa, the species *V. Hymenolepis* has medicinal use in Angola for treatment of respiratory system disorders and high blood pressure (Mengome et al., 2010). The methanol extract of the fresh leaves allowed isolation of alkaloids, phenols and flavonoids. The extracts were tested against the gram-negative bacteria *Providencia stuartii*, *P. aeruginosa*, *K. pneumoniae*, *E. coli*, *Enterobacter cloacae* and *E. aerogenes*. The assays were performed by the microdilution broth method, with promising results for all the tested strains of microorganisms (Noumedem et al., 2013).

***Vernonia lasiopus* O. Hoffm.**

V. lasiopus is a species native to Africa, especially found in Central African countries such as in Kenya, Tanzania, Uganda and Rwanda. It shows biological potential, being used for the treatment of malaria and helminth infections, by decoction of leaves and bark (Kareru et al., 2007). The aqueous extract of the leaves and bark was tested against strains of *E. coli*, *S. aureus* and *B. subtilis* by disk diffusion method, with positive results for *E. coli* and *B. subtilis*, indicated by growth inhibition zone (Kareru et al.,

2008).

***Vernonia oocephala* Baker.**

Distributed across Northern part of Nigeria, *V. oocephala* is an erect perennial shrub used in the folk medicine to treat malaria and a number of unspecified infectious diseases (Aliyu et al., 2014). A study of phytochemical screening with native plants from Nigeria revealed the presence of secondary metabolites alkaloids, flavonoids, saponins, tannins, glycosides, cardiac glycosides, steroids and triterpenes (Aliyu et al., 2011).

The antibacterial activity of the ethanolic extracts of leaves of *V. oocephala* was reported against the clinical bacterial strains, *K. pneumoniae* (20 mm), *S. pyogenes* (16 mm), *S. aureus* (18 mm), *C. ulcerans* (20 mm), methicillin resistant *S. aureus* (20 mm) and *P. mirabilis* (22 mm) by the disk diffusion and broth microdilution methods. The MIC values ranged from 1.25 to 2.5 mg/mL for all the organisms tested (Aliyu et al., 2011).

***Vernonia polyanthes* Less.**

V. polyanthes is native to Brazil. Extracts of its leaves and roots are used in folk for the treatment of rheumatism, bronchitis and cough (Lorenzi and Matos, 2002). The methanol extract of the leaves was found to contain alkaloids, triterpenoids, coumarins and flavonoids. The extracts were tested for antifungal and antileishmanial activity. In the antifungal assay, strains of the yeast *C. albicans* and *C. neoformans* were tested by the broth dilution and agar diffusion methods to determine the minimum inhibitory concentration. For the antileishmanial tests, the protozoa *Leishmania amazonensis* and *L. chagasi* were used. In all cases, the results were indicated by inhibition of parasite growth.

The results were satisfactory for leishmanicidal activity, though the extract showed no antifungal activity (Braga et al., 2007).

***Vernonia remotiflora* Rich.**

V. remotiflora [syn. *Lepidaploa remotiflora*] is a species found in north eastern Brazil. Preliminary phytochemical studies allowed the identification and isolation of sesquiterpene lactones (Valdés et al., 1998) and a flavone (Jacobs et al., 1986). A study of the essential oil, extracted by hydrodistillation from the fresh leaves, investigated the antibacterial activity to *P. aeruginosa*, *E. aerogenes*, *Salmonella choleraesuis*, *K. pneumoniae*, *S. aureus* and *B. subtilis*, by the disk diffusion method. The essential oil inhibited the growth of all tested microorganisms (Maia et al., 2010).

***Vernonia scorpioides* (Lam.) Pers.**

It is popularly known in Brazil by many names, *V. scorpioides* is a lianous, perennial, branched herb, considered to be a weed widely distributed throughout Brazil, usually growing in poor soils and deforested areas, behaving as ruderal parantropophyte plant (Rauh et al., 2011, Toigo et al., 2004). A study of its essential oil by gas chromatography and mass spectrometry indicated the predominant presence of sesquiterpene hydrocarbons, with the main constituents being β -caryophyllene, germacrene-D and bicyclogermacrene (Albuquerque et al., 2007a). Investigations of extracts of the aerial parts, using ethanol and hexane, allowed the isolation of triterpenes, steroids, a flavonoid and a polyacetylene lactone (Machado et al., 2013).

V. scorpioides is commonly used externally to treat a variety of skin disorders such as allergies, irritations, parasitosis, skin lesions, chronic wounds including ulcers of the lower extremities and itching (Rauh et al., 2011). It is also popularly used as an anti-hemorrhoidal and a potent antidiarrheal, employed in the form of teas for internal use and infusions for external use (Freire et al., 1996c). Evaluation of the antifungal activity of the chloroform extract of the stems of *V. scorpioides* against the fungus *Penicillium citrinum* showed the formation of growth inhibition zones up to 80 mm in diameter. Assays were performed by the agar diffusion method. The use of a low-polar solvent for the preparation of the extract allowed satisfactory obtainment of active extracts, supporting the possibility of the presence of sesquiterpene lactones, constituents with potent antifungal action (Freire et al., 1996a). A study with chloroform and hexane extracts of the stems and leaves demonstrated that the development of hyphae was incipient in the presence of extracts and that the extracts from the leaves showed less intensity, since the growth inhibition halos were smaller for both tested fungi,

Aspergillus alutaceos and *P. citrinum* (Freire et al., 1996b).

Another study investigated the antimicrobial activity of the ethyl acetate extract obtained from fresh leaves of *V. scorpioides* for healing of excisional wounds in tissues of rats with inflammatory lesions caused by *S. aureus*. Rifamycin B diethylamide was used as positive control and saline as negative control. The results pointed to effective antimicrobial activity for wound healing in infected mice with increased wound contraction, smaller area of necrotic tissue, good development of granulation tissue, extensive array of extracellular matrix and epithelial regeneration (Kreuger et al., 2012). The ethanol extract of *V. scorpioides* showed antimicrobial activity against a strain of the yeast *C. albicans* and the bacterium *S. aureus*, with inhibition zones greater than 16 mm that were concentration dependent for gram-positive cocci and greater than 15 mm for the tested yeast. These tests were performed by agar diffusion method (Toigo et al., 2004).

***Vernonia smithiana* Less.**

Native to the African continent, *V. Smithian*, which the common name in Tanzania is “umwanzuranya”, has therapeutic use for dysentery, gastrointestinal problems, eye diseases and urinary problems, mainly using extracts from the aerial parts and roots (Adjanohoun et al., 1988). A study of the essential oil extracted from the aerial parts by hydrodistillation led to isolation of 39 volatile compounds. The main constituents were sesquiterpenes and monoterpenes.

The essential oil was tested by the agar dilution method, compared to a panel of microorganisms including the bacteria *S. aureus*, *S. epidermidis*, *E. coli*, *E. cloacae*, *K. pneumoniae*, *P. aeruginosa*, *Streptococcus mutans* and *Streptococcus viridans*, the latter two oral mucosal pathogens. For the antifungal assays, the yeasts *Candida glabrata*, *C. albicans* and *C. tropicalis* were used. The results showed excellent antimicrobial activity, inhibiting all the species of microorganisms tested (Vagionas et al., 2007).

***Vernonia tenoreana* Oliv.**

V. tenoreana is a wild growing shrub found in African savannas, whose common name in the Yoruba language of Nigeria is “Ewuro Igbo”. The bark is used in some parts of Nigeria as emergency food (Sofowora, 1993). The antidiabetic biological activity was investigated in a prospective study through random biological screening (Taiwo et al., 2008). A phytochemical study of the extract of fresh leaves, using the organic solvents methanol, ethyl acetate, acetone and n-hexane allowed isolating alkaloids, tannins (including phlobaphenic tannins), cardiac glycosides and anthraquinones, which demon-

strates the phytochemical richness of this species, making it a promising target for subsequent biological studies (Ogundare et al., 2006).

The extracts above were used in antimicrobial susceptibility tests against bacteria and fungi by the agar diffusion method. The bacteria tested were *S. aureus*, *Streptococcus faecalis*, *B. subtilis*, *P. aeruginosa*, *E. coli*, *K. pneumoniae*, *Bacillus cereus*, *Proteus vulgaris*, *Shigella dysenteriae* and *Serratia marcescens* and the fungi were *C. albicans*, *Aspergillus flavus*, *A. niger*, *Rhizopus stolonifer* and *Fusarium poae*. The results showed growth inhibition for all bacteria tested, but no activity against the fungi *R. stolonifer* and *F. poae* (Ogundare et al., 2006).

CONCLUSION

This review shows that the genus *Vernonia* is rich in species with extensive ethnomedicinal use, especially in Africa, and extracts obtained by various preparation methods are used, especially from the leaves, bark and roots. There are extensive studies of *V. amygdalina* and *V. scorpioides* pointing to their use in folk medicine and confirming their biological properties, and reaffirms the genus importance in studies of the biology and chemistry of natural products.

Phytochemical tests have shown the genus to have a range of bioactive properties among the Asteraceae family, containing multiple chemical compounds, especially terpenoids, flavonoids, tannins, steroids and alkaloids. Several sesquiterpene lactones have been isolated with potential antifungal, cytotoxic, molluscicidal, insecticidal and antitumor activity. Thus, this review showed a profile of species of *Vernonia* with antimicrobial potential and their main ethnomedicinal uses, which corroborates other existing studies to the Asteraceae family and the genus *Vernonia*.

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Conflicts of interest

The authors have declared that there is no conflict of interest.

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