Potential of Cameroonian Plants and Derived Products against Microbial Infections: A Review

Author Victor Kuete

Affiliation Department of Biochemistry, University of Dschang, Dschang, Cameroon

Key words
- infectious diseases
- bacteria
- fungi
- medicinal plants
- bioactive compounds
- Cameroon

Abstract

In Cameroon, infectious diseases are amongst the most commonly notified diseases and largest cause of mortality. Many plants are used locally in traditional medicine for their treatment. The aim of the present review is to summarize currently available evidence and knowledge concerning Cameroonian plants used to treat bacterial and fungal infections, and the efficacy of plant-derived extracts and compounds. The traditional uses of plants in the treatment of infectious diseases have been collected and tabulated. The antimicrobial activity of the extracts and the chemical constituents of most of these plants are summarized in this report. Plants used traditionally in Cameroonian medicine, with laboratory work on any part or products, have been documented. Numerous extracts and compounds have been tested for antimycobacterial, antibacterial and antifungal efficacy and some of them were significantly active. Most of the bioactive compounds isolated were phenolics and alkaloids. In conclusion, many plant species are used in traditional medicine in Cameroon to treat infectious diseases, and several interesting openings have originated for further inquiry following *in vitro* antimicrobial activity evaluation. However, much work is still to be done to standardize methods and cut-off points for describing the antimicrobial activity, and on the study of the mechanisms of action.

Introduction

The importance of medicinal plants as a source of new antimicrobials is well established today. Approximately 25% of the active substance prescriptions in the United States come from plant material [1]. It is estimated that as many as 20000 species from several families are useful for these purposes [2]. In the two last decades, the search for antimicrobial potential of medicinal plants in Cameroon has experienced a tremendous growth. Significant numbers of scientific publications have been produced and many research teams have addressed this area. When searchingfor publications relative to the antimicrobial activity of Cameroonian medicinal plants or compounds from natural sources, it was found that the first works were published in 1988 by Biyiti et al. [3]. Evidence of the efficiency of herbal drugs used in Cameroonian medicine in the treatment of microbial infections is being provided continuously and intensively today [4–6]. More than a hundred studies were published from 1987 to 2009, according to scientific websites such as Pubmed, Sciencedirect, Scirus and Scopus. This paper summarizes the currently available knowledge on Cameroonian plants used to treat microbial diseases, and the efficacy of plant-derived extracts and compounds. Numerous medicinal plants are commonly used in both urban and rural areas in Cameroon as well as in most African countries, in the treatment of infectious diseases. The WHO [7] estimated that 80% of the African population is concerned and believes that this practice, if applied appropriately, could significantly contribute to improve public health. In the plant kingdom, medicinal plants from several families are used for therapeutic purposes. This review will be focused on the plant families Moraceae, Irvingiaceae, Melianthaceae, Rutaceae, Guttiferae, Bignogniaceae, Ebenaceae, etc., reported for their antimicrobial activities. Several classes of secondary metabolites have been characterized as the active principles of the plants, including terpenoids, alkaloids and phenolic compounds such as chalcones, flavones, isoflavones, anthraquinones, naphthoquinones, xanthones, and coumarins. Later in this report, we will discuss the use of the

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Correspondence
Dr. Victor Kuete
Department of Biochemistry
University of Dschang
P. O. Box 67
Dschang 237
Cameroon
Phone: + 23 7 77 35 59 27
Fax: + 23 7 22 22 60 18
kuetevictor@yahoo.fr

Table 1 Alphabetic list of the microbial species.

Microorganisms	Abbreviation	Microorganisms	Abbreviation	Microorganisms	Abbreviation
Aspergillus niger	*A. niger*	*Cladosporium sp.*	–	*Salmonella typhi*	*S. typhi*
Aspergillus flavus	*A. flavus*	*Enterococcus hirae*	*E. hirae*	*Pseudomonas aeruginosa*	*P. aeruginosa*
Alternaria sp.	–	*Escherichia coli*	*E. coli*	*Scenedesmus subspicatus*	*S. subspicatus*
Bacillus subtilis	*B. subtilis*	*Fusarium sp.*	–	*Shigella dysenteriae*	*S. dysenteriae*
Bacillus stearothermophilus	*B. stearothermophilus*	*Geotrichum candidum*	*G. candidum*	*Shigella flexneri*	*S. flexneri*
Bacillus cereus	*B. cereus*	*Klebsiella pneumoniae*	*K. pneumoniae*	*Staphylococcus aureus*	*S. aureus*
Bacillus megaterium	*B. megaterium*	*Microsporum audouinii*	*M. audouinii*	*Staphylococcus saprophyticus*	*S. saprophyticus*
Aspergillus ochraceus	*A. ochraceus*	*Citrobacter freundii*	*C. freundii*	*Streptococcus anginosus*	*S. anginosus*
Enterobacter cloacae	*E. cloacae*	*Cryptococcus neoformans*	*C. neoformans*	*Streptococcus faecalis*	*S. faecalis*
Enterobacter aerogenes	*E. aerogenes*	*Morganella morganii*	*M. morganii*	*Streptococcus mutans*	*S. mutans*
Candida glabrata	*C. glabrata*	*Mucor miehei*	*M. miehei*	*Streptococcus oralis*	*S. oralis*
Corynebacterium glutamicum	*C. glutamicum*	*Mycobacterium smegmatis*	*M. smegmatis*	*Streptococcus pneumoniae*	*S. pneumoniae*
Candida albicans	*C. albicans*	*Mycobacterium tuberculosis*	*M. tuberculosis*	*Streptococcus pneumoniae*	*S. pneumoniae*
Haemophilus influenza	*H. influenza*	*Neisseria gonorrhoeae*	*N. gonorrhoeae*	*Streptococcus pyogenes*	*S. pyogenes*
Chlorella sorokiniana	*C. sorokiniana*	*Penicillium sp.*	–	*Streptomyces viridochromogenes*	*S. viridochromogenes*
Candida krusei	*C. krusei*	*Penicillium verrucosum*	*P. verrucosum*	*Trichophyton mentagophytes*	*T. mentagophytes*
Candida tropicalis	*C. tropicalis*	*Proteus mirabilis*	*P. mirabilis*	*Trichophyton rubrum*	*T. rubrum*
Chlorella vulgaris	*C. vulgaris*	*Proteus vulgaris*	*P. vulgaris*	*Vibrio anguillarium*	*V. anguillarium*

(−) Only provided when the species is determined

studied plants in traditional therapy, the antimicrobial activity of extracts of the plants studied in each family, and finally the plant-derived metabolites characterized to date in Cameroon.

Impact of Infectious Disease Worldwide and in Cameroon

With the advent of globalization, health threats have become much more serious in an increasingly interconnected world, characterized by higher mobility of people, animals and goods, economic interdependence and electronic connectivity [8]. According to the WHO, at least 39 new pathogens have been identified since 1967, including HIV, Ebola and Marburg hemorrhagic fevers [9]. In addition, "centuries-old threats" like influenza, malaria and tuberculosis continue to thrive due to a combination of biological mutations, rising resistance to antibiotics and weak health systems [9]. In the last five years, the WHO has verified more than 1100 epidemic events worldwide [8]. Infectious diseases cause about 70% of deaths in children in developing countries and more than a third of those deaths occur in neonates [8]. More than 80% of tuberculosis cases occur in Asia and Africa [10]. In Cameroon, the major infectious diseases associated with a high degree of risk within the population include food or waterborne diseases (bacterial and protozoal diarrhea, hepatitis A and E, and typhoid fever), vector borne diseases (malaria and yellow fever), water contact disease (schistosomiasis), respiratory disease (meningococcal meningitis), and animal contact disease (rabies) [11]. Very often, there is a coexistence of many infectious diseases. Ammah et al. [12] demonstrated that a high proportion of patients (33%) had malaria coexisting with *S. typhimurium, S. paratyphi,* and *S. typhi* infections. In our population, the lifetime risk of developing active tuberculosis once infected, in the absence of HIV infection, is about 10%, meanwhile this risk increases tenfold in HIV-infected individuals [13]. The unsatisfactory case management of the whole infectious diseases in general, and particularly bacterial and fungal infections throughout the continent, which allows partially treated and relapsed patients to become sequentially resistant, may play a significant role in the development of resistance [14,15]. Effective treatment of microbial infections is challenging for various reasons including lack of accessibility and elevated expense of drugs and low adherence owing to toxicity of second-line drugs [14,15]. It is all too likely that the emergence of even more resistant microbial strains will be experienced in the future, exhausting the current arsenal of chemical defenses at our disposal [14]. For this purpose, new antimicrobial agents are urgently needed, and research programs into alternative therapeutics should be encouraged. It has been suggested that the best available *in vitro* indicator of possible therapeutic activity is the early microbicidal activity of medicinal plants [7], drugs or combinations of drugs [16].

Investigation of Plants and Derived Products as Sources of New Antimicrobial Agents

Plants produce a great diversity of substances that could be active in many fields of medicine. Natural products from plants are proven templates for new drug development [17], and have shown many interesting biological activities. In a review of medicinal plants as antimicrobial agents [18], it was estimated that at least 12000 active compounds have been isolated from plants, representing less than 10% of the total. Several recent reviews have highlighted the underutilized potential of plant species and natural products as sources of antimicrobial drugs [14]. Plant-derived antimicrobial compounds belong to an exceptionally wide

Table 2 Plants used in Cameroon to treat infectious diseases, with evidence of their activities.

Family	Species[a]	Traditional treatment	Plant part used	Bioactive (or potentially active) compounds	Screened activity[b] for crude plant extract
Annonaceae	*Monodora myristica*	headache, constipation, sores, guinea worm infections [77]	seeds	not identified but the active essential oil from fruits contained α-phellandrene; *p*-cymene; α-pinene; *cis*-sabinol; limonene [77]	(fruits essential oils) **Q:** *Af, Bc, Bs,Cgl, Ec, Kp, Sa, Sf* [77]
	Xylopia aethiopica	cough, bronchitis, dysentery, female sterility [77]	seeds	not identified but the active essential oil from fruits contained β-pinene; terpinen-4-ol; sabinene; α-phellandrene; α-terpineol; α- and *trans*-β-ocimene [77]	(fruits essential oils) **S:** *Af, Bc, Ec, Sa, Sf;* **Q:** *Cgl* [77]
Apocynaceae	*Tabernaemontana crassa* Benth. (43449/HNC)	gonorrhea fungal infections, ovarian trouble, anthrax, headache, constipation, disinfections, homeostasis [78]	leaves, stem bark, sap	dehydrocorydalmine; palmatine; isoursenol; acetate of isoursenol; lupeol [76]	(bark methanol extract) **W:** *Ca, Ck, Ec, Kp, Ng, Pa, Pv, Sa, Sd, Sf, Sp, St* [76]
Asteraceae	*Emilia coccinea* (Sims) G. Don (6297/Leeuwenberg)	diarrhea, stomachache, bowel, bladder disorders, wounds disinfection [79]	leaves	not identified but preliminary phytochemical study of active methanol leaf extract revealed the presence of alkaloids, flavonoids, tannins, saponins and cardiac glycosides [80]	(leaves methanol extract) **W:** *Ec, Sa, St* [80]
	Crepis cameroonica Babc.	diarrhea, wounds and fungal infections [81]	not specified	3β,9β-dihydroxyguaian-4(15),10(14),11(13)-trien-6,12-olide; 8α-hydroxy-4α(13),11β(15)-tetrahydrozaluzanin C; 8-desacylcynaropicrin [81]	(aerial part methanol extract) **Q:** *Ec, Sa* [81]
Bignoniaceae	*Newbouldia laevis* Seem. (1754/SRFK)	diarrhea, dysentery, worms, malaria, sexually transmitted diseases, dental caries [83]	leaves, stem bark, roots	newbouldiaquinone A [82]; chrysoeriol; newbouldiaquinone; 2-acetylfuro-1,4-naphthoquinone; 2-hydroxy-3-methoxy-9,10-dioxo-9,10-dihydroanthracene-1-carbaldehyde; lapachol; β-sitosterol-3-*O*-β-dglucopyranoside; oleanolic acid; canthic acid; newbouldiamide; 2-(4-hydroxyphenyl)-ethyl trioctanoate [48]	(bark methanol extract) **S:** *Bc, Bm, Bs, Bst;* **M:** Ca, Ck, Cg, Ea, Ec Ecl, Cf, Mm, Kp, *Pa, Pm, Pv, Sd, Sfl, Sf, St;* **W:** *Sa* [48]
	Stereospermum zenkeri K. Schum. ex De Wild (1022/SRFK)	bronchitis, microbial infections [84]	leaves, stem bark	zenkequinone A and B, sterequinone-F, *p*-coumaric acid [84]	crude extract was not investigated but zenkequinone B presented a MIC value of 9.50 µg/mL on *P. aeruginosa* [84]
Caesalpiniaceae	*Erythrophleum suaveolens* (Guill. & Perr.) Brenan, (2644/SRFK)	inflammation, analgesic, bacterial and fungal infections, chickenpox, gangrenous sores, cardiovascular diseases [85]	stem bark	norcassaïde; norerythrosuaveolide [75]	crude extract was not investigated but active diterpenoid alkaloids were isolated from the stem bark [75]
Ebenaceae	*Diospyros crassiflora* (4924/SRFK)	gonorrhea and other bacterial and fungal infections, tuberculosis [49, 86–88]	stem bark	crassiflorone; diospyrone; plumbagin [49, 86–88]	(bark dichloromethane : methanol 1 : 1 extract) **W:** *An, Af, Asp, Ca, Cg, Ck, Ct, Csp, Cn, Fsp, Gc, Psp* [88]
					(Bark methanol extract) **S:** *Ms, Mtb, Ng* [49]
	Diospyros canaliculata (9653/SRF/cam)	gonorrhea and other bacterial and fungal infections, tuberculosis [49, 86]	stem bark	diospyrone; plumbagin [49, 86]	**S:** *Ms, Mtb, Ng* [49]
Euphorbiaceae	*Bridelia grandis* Pierre ex Hutch (BWPV01)	rheumatism, arthritis, abdominal pain, thrush, oral cavity affection [89, 90]	stem bark, leaves, roots, fruits	not identified but qualitative phytochemical analyses and colorimetric assays, together with preliminary chromatographic separations of the most active bark extracts, clearly suggested the presence of condensed tannins as main constituents of the phytocomplex responsible for the biological activity [90]	(bark water extract) **M:** *Sm, San, So, Sp* [90]
	Bridelia ferruginea	dysentery, diabetes, thrush mycotic stomatitis in children, antidote for snakebite, gonorrhea, poisons [91]	stem bark, leaves, fruits	not identified but qualitative phytochemical analyses of the plant revealed the presence of triterpenes, steroids, tannins, saponins, flavonoids [92]	(leave methanol extract) **W:** *Bs, Ec, Sa, Sf* [92]
	Mallotus oppositifolium	diarrhea and dysentery [93]	leaves	not yet identified	(leave methanol extract) **W:** *Sd* [93]
Fabaceae	*Eriosema glomerata* 643/HNC	infectious diseases [94]	whole plant	erioschalcones A, erioschalcones B, quercetin, isoluteolin [94]	Crude extract was not investigated but active compounds were isolated from CH_2Cl_2-MeOH extract of the whole plant [94]

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Table 2 Plants used in Cameroon to treat infectious diseases, with evidence of their activities. *(continued)*

Family	*Species*[a]	Traditional treatment	Plant part used	Bioactive (or potentially active) compounds	Screened activity[b] for crude plant extract
Guttiferae	*Mammea Africana* 4221/ SRF/CAM	stomach pains, scabies, skin diseases, rheumatic pain, cough [95]	stem bark, fruit	mammea A/AA, mammea C/OB [95]	crude extract was not tested but active coumarins were isolated from the stem bark [95]
	Allablackia gabonensis (Pellegr.) Bamps (23255/HNC)	dysenteries, cold, tooth aches [56]	stem bark	allanxanthone A; allanxanthone D; 1,3,6,7-tetrahydroxy-2-(3-methylbut-2-enyl)xanthone [56]	crude extract was not investigated but active xanthones were isolated from the stem bark [56]
	Calophyllum inophyllum L. (32189/SRF/ Cam)	cicatrisant,analgesic, wounds and herpes infections [74]	stem bark, roots, fruits	caloxanthone A, calophynic acid, brasiliensic acid, inophylloidic acid, calaustralin, calophyllolide, inophyllum C, inophyllum E [96]	[(root bark and fruits CH_2Cl_2-MeOH (1 : 1) extract] **Q:** *Sa* [96]
	Garcinia kola Heckel	infectious diseases, respiratory tract infections [97]	fruits	not yet identified	(fruits ethanol extract) **S:** *Sa, Sp, Spn, Hi* [97]
	Garcinia smeathmanii oliver (35 169/ HNC)	bacterial and fungal infections [51]	stem bark	cheffouxanthone; 1,5 dihydroxyxanthone; 1,3,5-trihydroxyxanthone; bangangxanthone A; smeathxanthone B; smeathxanthone A; guttiferone I; isoxanthochymol; friedelin; triacontanyl caffeate [51]	(bark methanol extract) **S:** *Bm, Bs, Ea, Ec, Kp, Mm, Pa, Pv, Sf, St;* **M:** *Bc, Bst, Ca, Cg, Ck, Cf, Ecl, Pm, Sd* [51]
	Garcinia staudtii Engl (167341/ HNC)	bacterial infections, cancer [98]	stem bark	staudtiixanthone A; staudtiixanthone B (2); α-mangostin; gartanin; staudtiixanthones C; staudtiixanthones D; demethylcalabaxanthone garcinone B [98]	crude extract was not investigated but isolated compounds were active on *S. aureus* [98]
	Symphonia globulifera Linn f. (syn. S. gabonensis Pierre) (2235/ SRFK)	laxative for pregnant women, fatigue, bacterial infections [56, 99, 100]	stem bark, fruits	globuliferin [100]; globulixanthone C; globulixanthone D; globulixanthone E [56]	(seeds methanol extract) **W:** *Ec, Sa, Sf, Kp* [100]
					(roots bark CH_2Cl_2-MeOH extract) **S:** *Bs, Sa, Va* [56]
	Vismia guineensis (Linn.) Choisy. (75 346/HNC)	malaria, skin diseases, bacterial infections [53, 101]	leaves, stem bark, roots	3-geranyloxy-6-methyl-1,8-dihydroxyanthraquinone; vismiaquinone; vismiaquinone B; betulinic acid (roots) [53]; vismiaquinone; caloxanthone J; *O*1-demethyl-3′,4′-deoxypsorospermin-3′,4′-diol; 6-deoxyisojacareubin; 1,7-dihydroxyxanthone (barks) [53]; friedelin; 1,8-dihydroxy-6-methoxy-3-methylanthraquinone; kaempferol (leaves) [53]	(leaves methanol extract) **S:** *Ca, Cf, Ecl, Mm, Sfl, Tm, Tr;* **M:** *Bs, Bst, Cg, Ea, Ec, Kp, Ms, Pm, Pv, Sa, Sd, St*
					(bark methanol extract) **S:** *Ca, Bst, Ecl, Mm, Sfl,Tm, Tr;* **M:** *Bs, Ca, Cf, Cg, Ea, Ec, Kp, Ms, Pm, Pv, Sa, Sd, St*
					(roots methanol extract) **S:** *Ca, Bst, Ecl, Mm Ms, Mtb, Sfl, Tm, Tr;* **M:** *Bs, Ca, Cf, Cg, Ea, Ec, Kp, Ms, Pm, Pv, Sa, Sd, St* [53]
	Vismia rubescens Oliver 43288/HNC	skin diseases, diarrhea and venereal diseases [102]	stem bark, roots	1,4,8-trihydroxyxanthone; 1,7-dihydroxyxanthone; physcion; friedelin; friedelanol [102]	(bark methanol extract) **M:** *Sa, St;* **W:** *Pa, Ca* [102]
Irvingiaceae	*Irvingia gabonensis* (Aubry Lecomte ex O'Rorke) Baill. (28054/HNC)	gonorrhea, gastrointestinal and hepatic disorders, wound infections, diabetes, analgesic [103–107]	leaves, stem bark, roots, fruits	3-friedelanone; betulinic acid; oleanolic acid; 3,3,4-tri-*O*-methylellagic acid; 3,4-di-*O*-methylellagic acid; hardwickiic acid [39]	(bark methanol extract) **S:** *Bst, Ca, Cf, Ea, Ecl, Mm, Ng, Pa, Pm, Pv, Sa, Sd;* **M:** *Bc, Bm, Bs, Ck, Ec, Kp, Sfl, St, Sf* [39]
Lamiaceae	*Ocimum gratissimum*	pulmonary antiseptic, antitussive, antispasmodic [108]	leaves	not identified but essential oils from fruits contained thymol; γ-terpinene; *p*-cymene; limonene; α-terpinolene; α-phellandrene; 1,8-cineole; α-terpineol; β-caryophyllene; dehydro-*p*-cymene; 3,9-epoxy-*p*-mentha-1,8-diene [108]	(essential oil) **Q:** *Bc, Bs,Cgl, Ec, Sa, Sf* [102]
	Thymus vulagris L. 42851/HNC	fungal infections [109]	whole plant	essential oil, with nonidentified components [109]	(essential oil) **Q:** *Ao* [109]

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Table 2 Plants used in Cameroon to treat infectious diseases, with evidence of their activities. *(continued)*

Family	*Species*[a]	Traditional treatment	Plant part used	Bioactive (or potentially active) compounds	Screened activity[b] for crude plant extract
Lauraceae	*Beilschmiedia anacardioides* (Engl. & K. Krause) Robyns & Wilczek	uterine tumors, *Rubella*, female genital infections, rheumatism [110]	stem bark	beilschmiedic acid A, B and C [110]	crude extract was not investigated but active endiandric acid derivatives were isolated from the stem bark [110]
Moraceae	*Dorstenia angusticornis* Engl. (28165/SRFCam)	gastroenteritis, diarrheal infections [42]	whole plant	gancaonin Q; stipulin; angusticornin B; bartericin A [42]	(twigs methanol extract) **S:** *Bc, Bm, Ca, Ck, Ea, Ng, Pm, Pv, Sa, Sd, Sf, Sfl;* **M:** *Bs, Bst, Cg, Cf, Ec, Ecl, Ec, Kp, Mm, Pa, St* [42]
	Dorstenia barteri Bureau (44016/HNC)	snakebite, rheumatic, infectious diseases, arthritis [111–113]	whole plant	isobavachalcone; stipulin; 4-hydroxylonchocarpin; kanzonol C; amentoflavone [5]	(twigs methanol extract) **S:** *Bc, Bm, Bs, Bst, Ca, Cg, Cf, Ck, Ea, Ec, Ecl, Kp, Ma, Mm, Pa, Pm, Pv, Sa, Sd, Sf, Sfl;* **M:** *St, Tr* [5]
	Dorstenia elliptica Bureau (44018/HNC)	eye infections [114]	whole plant	psoralen; *O*-[3-(2,2-dimethyl-3-oxo-2*H*-furan-5-yl)-butyl]bergaptol or dorstenin; bergapten; *O*-[3-(2,2-dimethyl-3-oxo-2*H*-furan-5-yl)-3-hydroxybutyl]bergaptol; 3-(3,3-dimethylallyl)-4,2′,4′-trihydroxychalcone [43]	(twigs methanol extract) **S:** *Bm, Bst, Ca, Cf, Ea, Ec, Ecl, Pm, Pv, Sf, Sfl;* **M:** *Bc, Bs, Cg, Kp, Ma, Pa, Pv, Sa, St, Tr* [43]
	Dorstenia turbinata Engl. (28158/SRF/Cam)	gastroenteritis, skin infections, gastroenteritis, skin infections, rheumatism [6]	whole plant	5-methoxy-3-[3-(*β*-glucopyranosyloxy)-2-hydroxy-3-methylbutyl]psoralen; 5-methoxy-3-(3-methyl-2,3-dihydroxybutyl)psoralen; (2′*S*,3′*R*)-3′-hydroxymarmesin; 4-hydroxy-3-ethoxybenzaldehyde; 4-methoxyphenol, psoralen; kanzonol C; 4-hydroxylonchocarpin; umbelliferone [6]	(twigs methanol extract) **S:** *Ca, Cf, Cg, Ec, Kp, Ma, Pa, Sa, Sd, St, Tr* [6]
	Ficus chamydocarpa Mildbraed & Burret. (35446/HNC)	filaris, diarrheal infections and tuberculosis [44]	stem bark	*β*-amyrin; alpinumisoflavone; genistein; laburnetin; luteolin [44]	(bark methanol extract) **M:** *Bc, Bst, Ca, Cg, Ecl, Mm, M, Pm, Sa* [44]
	Ficus cordata Thunb. 35446/HNC)	filaris, diarrheal infections and tuberculosis [44]	stem bark	*β*-amyrin; *β*-sitosterol-3-*O*-*β*-D-glucopyranoside; catechin; epiafzelechin [44]	(bark methanol extract) **S:** *Ca, Cg, Ms, Mtb,Cf, Ec, Ecl, Kp, Mm, Pm, Sd, St;* **M:** *Pa* [44]
	Ficus ovata Vahl., 26996SRF/Cam	infectious diseases, gastrointestinal infections, diarrhea, anti-poison [109]	leaves, stem bark	3-friedelanone; taraxeryl acetate; betulinic acid; oleanoïc acid; 2′-hydroxyisoprunetin; 6,7-(2-isopropenyl furo)-5,2′,4′-trihydroxyisoflavone; Cajanin; protocatechuic acid [115]	(Bark methanol extract) **M:** *Bc, Ca, Cf, Ec, Kp, Pa, Sa, Sd, St* [115]
	Morus mesozygia Stapf. (4228/SRFK)	arthritis, rheumatism, malnutrition, debility; pain-killers, stomach disorders, wound infections, gastroenteritis, peptic ulcer, infectious diseases [78, 116]	stem bark	marsformoxide B; moracin Q; moracin T; artocarpesin; cycloartocarpesin; moracin R; moracin S; moracin U; moracin C; moracin M [45]	(bark methanol extract) **S:** *Bc, Ca, Ec;* **M:** *Kp, Pa, Sa, Sd, Sf, St* [45]
	Treculia acuminata Baillon (2921/SRF/Cam)	treat skin diseases, dental allergy, amoebic dysentery and AIDS [117, 118]	leaves, stem bark, roots	catechin; 6,9-dihydroxymegastigmane-3-one; 2,3-dihydroxypropylhexadecanoate [62]	(twigs methanol extract) **S:** *Bm, Ea, Ecl, St;* **M:** *Ca, Cg, Ck, Ec, Pa, Pm, Pv, Bs* [62]
	Treculia africana Decaisne (29053/SRF/Cam)	treat skin diseases, dental allergy, amoebic dysentery and AIDS [117, 118]	leaves, stem bark, roots	phyllocoumarin; catechin; 6,9-dihydroxymegastigmane-3-one [62]	(leaves methanol extract) **S:** *Bs, Ca, Cf, Ck, Ea, Ec, Kp, Mm, Pm, Pv, Sd, Sf;* **M:** *Bst, Cg, Ea, Pa, Sa, St* [62]
	Treculia obovoidea N. E. Brown (44055/HNC)	treat skin diseases, dental allergy, amoebic dysentery and AIDS [117, 118]	leaves, stem bark, roots	psoralen; bergapten; 7-methoxycoumarin; 7-hydroxycoumarin; 4,2′,4′-trihydroxychalcone; 4,2′,4′-trihydroxy-3-prenylchalcone; 3-hydroxy-4-methoxybenzoic acid; *O*-[3-(2,2-dimethyl-3-oxo-2*H*-furan-5-yl) butyl]bergaptol [22]	(twigs methanol extract) **S:** *Bc, Bs, Ca, Cf, Ck, Pv;* **M:** *Bm, Bst, Cg, Ec, Ecl, Kp, Pa, Sf, Sa, Sfl, St* [22]
Hypericaceae	*Harungana madagascariensis*[c] Lam. ex. Poir (HNC 32358)	–	leaves	harunmadagascarin D, 1,7-dihydroxyxanthone [119]	crude extract not investigated but harunmadagascarin D isolated from leaves was active on *B. cereus* [119]

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Table 2 Plants used in Cameroon to treat infectious diseases, with evidence of their activities. *(continued)*

Family	*Species*[a]	Traditional treatment	Plant part used	Bioactive (or potentially active) compounds	Screened activity[b] for crude plant extract
Meliaceae	*Turreanthus manii* (Baill.) (18312/SRF/Cam)	infectious diseases [120]	stem bark	16-acetoxy-12,15-epoxy-15*β*-hydroxylabda-8 (17),13-diene [120]	(stem bark methanol extract) **Q:** *Bs, Ec, Mmi, Cv, Ss* [120]
Meliantha-ceae	*Bersama engleriana* Gurke (24725/HNC)	cancer, spasms, infectious diseases, male infertility, diabetes [121]	leaves, stem bark, roots	not identified but flavonoids, phenols, triterpenes, saponins and anthraquinones were detected in all parts of the plant [122]	(leaves methanol extract) **S:** *Bst, Ms, Kp, Mm, Pa, St;* **M:** *Bc, Bs, Ca, Cf, Cg, Ec, Ecl, Sd, Sf, Sa, Sfl* [122]
					(bark methanol extract) **S:** *Bs, Bst, Ca, Cf, Cg, Ec, Ecl, Kp, Mm, Ms, Mtb, Pa, Sd, Sf, Sa, Sfl, St* [122]
					(roots methanol extract) **S:** *Bs, Bst, Ca, Cf, Cg, Ec, Ecl, Kp, Mm, Ms, Mtb, Pa, Sd, Sf, Sa, Sfl, St* [122]
Ochnaceae	*Campylospermum glaucum*[c] (Tiegh) Farron (28192/SRF/Cam)	–	stem bark	not identified	(bark methanol extract) **W:** *Eh, Sa, Ssp* [123]
	Ouratea sulcata Van Tiegh (ex Keay) (10133/SRF/Cam)	upper respiratory tract infections, dysentery, diarrhea, toothache [114]	leaves	sulcatone A, 3-hydroxy-2,3-dihydroapigenyl-[I-4′,O, II-3′]-dihydrokaempferol, amentoflavone [124]	(leaves methanol extract) **W:** *Bs, Sa, Va* [124]
					(leaves CH_2Cl_2-MeOH extract) **M:** *Bs, Sa, Va* [124]
	Ouratea turnarea (Hook) Hutch & Dalz[c] (10134/SRF/Cam)	–	stem bark	not identified	(bark methanol extract) **W:** *Eh, Sa, Ssp* [123]
Poaceae/Gramineae	*Cymbopogon citratus*(DC) Stapf. (18628/SRF/Cam)	fungal infections [109]	leaves	essential oil, with non-identified components [109]	(essential oil) **Q:** *Ao* [109]
Rhamna-ceae	*Maesopsis eminii* (Engler) (234/SRF/Cam)	diuretic, purgative, emetic, and antidiarrhetic, abortifacient [125, 126]	stem bark	1*α*,3β-dihydroxybauer-7-en-28-oic acid [125]	crude extract was not investigated; a diterpenoid 1*α*,3*β*-dihydroxybauer-7-en-28-oic acid isolated from the stem bark was active on *B. cereus* [125]
Rutaceae	*Tecla afzelii* Engl. (10674/SRF/Cam)	wound infections, abdominal pains, cough, fever, asthma [127]	stem bark	kokusaginine; maculine; kolbisine; lupeol [41]	(bark methanol extract) **S:** *Bs, Ca, Cg, Ec, Ma, St;* **M:** *Ms* [41]
	Oriciopsis glaberrima Engl. (1888/HNC)	infections, hypotension, mycoses, dermatitis [114]	Stem bark	oriciacridone A and B, lichexanthone [128]	(bark CH_2Cl_2-MeOH extract) **Q:** *Bs, Ca, Cv, Cs, Mmi, Sa, Ss, Sv* [128]
	Zanthoxylum leprieurii	gonorrhea, kidney pain, sterility [77]	not specified	Not identified but essential oils from fruits contained *trans*-*α*-ocimene; *α*-terpinolene; 3-δ-carene; limonene; myrcene; *α*-pinene; *p*-cymene [77]	(fruits essential oils) **S:** *Sa* [77]
	Zanthaxylum xanthoxyloides	enteritis, dysentery, diarrhea, guinea worm, uretritis and as an antiodontalgic [77]	not specified	not identified but essential oils from fruits contained *α*-pinene; *trans*-*β*-ocimene; citronellol; sabinene; myrcene; limonene; cytronellyl acetate; *α*-phellandrene [77]	(fruits essential oils) **S:** *Ec, Bc, Bs, Af, Kp, Sa, Sf* [77]
Sapota-ceae	*Tridesmostemon omphalocarpoides* Engl. (3829/HNC)	gastroenteritis, skin lesions [129]	stem bark	not identified but preliminary phytochemical studies reported the presence of alkaloids, phenols, polyphenols, saponins, tannins, triterpenes, anthraquinones and steroids in bark methanolic extract and their variation in active fractions [129]	(bark methanol extract) **S:** *Ec*; **M:** *Ca, Ck, Sd, Kp, Sa, Sf* [129]

continued next page

Table 2 Plants used in Cameroon to treat infectious diseases, with evidence of their activities. *(continued)*

Family	*Species*[a]	Traditional treatment	Plant part used	Bioactive (or potentially active) compounds	Screened activity[b] for crude plant extract
Solanaceae	*Slonanum tovum* Sw. (49427/HNC)	bacterial and fungal infections, HIV, herpes simplex virus type I and II infections [76, 130–132]	leaves, stem bark, fruits	steroidiques glycosides, chlorogenone, neochlorogenone [131, 132], solasodine, lupeol [76]	(fruits ethanol 70% extract) **M:** *Ca, Ck, Ec, Ng, Pa, Pv, Sd, Sfl, Sa, St, Sf* [76]
Zingiberaceae	*Zingiber officinale*	infectious diseases, respiratory tract infections [98]	roots	not yet identified	(roots ethanol extract) **S:** *Sa, Sp, Spn, Hi* [98]

[a] HNC or SRFK: Cameroon national herbarium code; [b] Screened activity: significant, S: MIC < 100 µg/mL), moderate (MIC: 100 < MIC ≤ 625 µg/mL), weak (W: MIC > 625 µg/mL), Q: qualitative activity based on inhibition zone determination; *An: Aspergillus niger; Af: Aspergillus flavus; Asp: Alternaria sp.; Ao: Aspergillus ochraceus; Bc: Bacillus cereus; Bm: Bacillus megaterium; Bs: Bacillus subtilis; Bst: Bacillus stearothermophilus; Ca: Candida albicans; Cn: Cryptococcus neoformans; Cf: Citrobacter freundii; Cg: Candida glabrata; Cgl: Corynebacterium glutamicum; Ck: Candida krusei; Cs: Chlorella sorokiniana; Csp; Cladosporium sp.; Ct: Candida tropicalis; Cv: Chlorella vulgaris; Ea: Enterobacter aerogenes; Ec: Escherichia coli; ECl: Enterobacter cloacae; Eh: Enterococcus hirae; Fsp: Fusarium sp; Gc: Geotrichum candidum; Hi: Haemophilus influenzae; Kp: Klebsiella pneumoniae; Ma: Microsporum audouinii; Mm: Morganella morganii; Mmi: Mucor miehei; Ms: Mycobacterium smegmatis; Mtb: Mycobacterium tuberculosis; Ng: Neisseria gonorrhoeae; Pa: Pseudomonas aeruginosa; Pm: Proteus mirabilis; Pv: Proteus vulgaris; Psp: Penicillium; Pv: Penicillium verrucosum; Sa: Staphylococcus aureus; Sd: Shigella dysenteriae; Sf: Streptococcus faecalis; Sm: Streptococcus mutans; San: Streptococcus anginosus; So: Streptococcus oralis; Spn: Streptococcus pneumoniae; Sp: Streptococcus pyogenes; Sfl: Shigella flexneri; Sp: Streptococcus pneumoniae; Ss: Scenedesmus subspicatus; St: Salmonella typh; Sv: Streptomyces viridochromogenes; Tm: Trichophyton mentagophytes; Tr: Trichophyton rubrum; Va: Vibrio anguillarium; SSp: Staphylococcus saprophyticus;* [c] Plant with no reference for the use in the treatment of infectious diseases, but that extract or derived product showed antimicrobial activity

diversity of classes, such as alkaloids, terpenoids, peptides and phenolics [18]. Numerous assay systems and organisms have been used to screen plant extracts and constituents of active plants for antimicrobial activity. The microbroth dilution method seems to be more appropriate when investigating the activity of compounds. However, this method has several advantages compared to another method used in the past; the agar diffusion method. The microbroth dilution method is quantitative, allows the use of small quantities of compounds or plant extracts as well as culture media, and is well adapted for drugs intended for systemic use [19]. Colorimetric microbroth techniques using various reagents such as tetrazolium salts [20, 21], or color indicators [22] allow easy MIC detection and increase the credibility of this method. For the antimycobacterial tests of plant-derived substances, a number of bioassay systems has been used including agar diffusion and dilution assays, radiorespirometry (using the BACTEC 460 instrument), and broth macro- and micro-dilution assays to reporter gene assays [14].

Biological Activity Screening of Plant Extracts for Antimicrobial Effects in Cameroon

Plants extracts are widely used in many parts of Cameroon to treat infectious diseases or related symptoms including abdominal pains, itching, urinary and respiratory ailments, fever and coughing, diarrhea. Adjanohoun et al. [23] provided a useful review of the traditional use of medicinal plants in Cameroon, although much work remains to be done regarding the documentation of existing ethnobotanical knowledge. Cameroon possesses a very rich and diverse flora, with an estimated 8260 species [24]. This paper is the first review on Cameroonian medicinal plants and derived products as a source of antimicrobial agents. It is important to note that a minimal inhibitory concentration (MIC) value of 100 µg/mL was used as a criterion for antimicrobial activity classification in accordance with some authors who consider a MIC value between 100–200 µg/mL as positive for plant extracts [25–29]. The plants with scientific reports on their activities of any part or derived products against microorganisms (**Table 1**) are summarized in **Table 2**. In this review, the activity of plant extracts or compounds will also be discussed, but not classified if the documented results were based only on the inhibition zone determinations. However, in this paper, the activity of plant extracts will be classified as significant (MIC < 100 µg/mL), moderate (100 < MIC ≤ 625 µg/mL) or weak (MIC > 625 µg/mL).

It appears from the results of **Table 2** that a number of crude extracts were significantly active. Some of them include extracts of *Bersama engleriana, Dorstenia angusticornis, Dorstenia turbinata, Dorstenia barteri, Newbouldia laevis, Vismia laurentii, Vismia guineensis,* etc. Numerous active metabolites were isolated from these plants and include several classes.

Antimicrobial Compounds from Cameroonian Medicinal Plants

Most of the antimicrobial substances isolated from Cameroonian medicinal plants belong to three main classes of secondary metabolites, i.e., terpenoids, phenolic compounds and alkaloids. The classification criterion is highly stringent, but several authors agree to keep the level of 10 µg/mL or 50 µM as the threshold for acceptable activity [30, 31]. In this study, we will set the value as follows: significant activity (MIC < 10 µg/mL), moderate (10 < MIC ≤ 100 µg/mL), and low or negligible (MIC > 100 µg/mL).

Terpenoids

Terpenoids are the largest and most widespread class of secondary metabolites, mainly in plants and lower invertebrates. A few of them have been used for therapeutic purposes for centuries; but in recent decades the level of research activity in isolating and studying new terpenoids has shown no sign of abating [32]. Generally, terpenoids have low antimicrobial potentials, compared to phenolic compounds. Several terpenoids have been isolated and tested, but a few of them presented an acceptable activity, both antibacterial and antifungal. Nevertheless, some of the terpenoids such as the triterpenoid betulinic acid has been shown to inhibit HIV [33]. Two terpenoids, cymbopogonol and

citral showed antifungal activity against *C. albicans* [34]. Also the diterpenoid trichorabdal A [35] was found to be active against *Helicobacter pylori*. Plant oils, which contain terpenoids, have shown increasing promise *in vivo*, inhibiting multiple species of bacteria. For example, cinnamon oil has shown broad-spectrum activity against *Pseudomonas aeruginosa* [36]. Also, John et al. [37] found that plant oils from *Neolitsea foliosa*, which also exhibited some antibacterial properties, included sesquiterpenes such as *β*-caryophyllene. A terpenoid, 3-oxo-(20*S*,24*S*)-epoxydammarane 19,25-diacetate isolated from the barks of *Caesalpinia pulcherrina* also exhibited significant antibacterial activity and a prominent antifungal activity [38]. The mechanism of action of terpenoids is not fully understood but is speculated to involve membrane disruption by the lipophilic compounds. Among the terpenoids isolated from Cameroonian medicinal plants, both hardwiickic acid (**1**) and friedelin (**2**) (**Fig. 1**) exhibited interesting antimicrobial effects on gram-positive bacteria and against the gram-negative bacteria [39,40]. Compound **1** however, presented moderate activity on many other bacterial species and *Candida* spp. [39]. Compound **2** also presented a significant antibacterial activity against *C. freundii, M. morganii, Shigella* spp., *Proteus* spp., *P. aeruginosa, Bacillus* spp., *S. faecalis* and *Candida* spp. [40]. Lupeol and many others triterpenoids were also isolated from Cameroonian plants and tested on a panel of bacteria and yeasts, but most of them exhibited poor activities [41].

Phenolic compounds

Flavonoids: Several flavonoids isolated from Cameroonian medicinal plants have been reported for their antimicrobial activities (**Fig. 2**). Such compounds comprise largely chalcones, flavones and isoflavones. Chalcones were isolated primarily from plants of the family Moraceae and the genus *Dortenia* such as *Dorstenia angusticornis* [42], *Dorstenia elliptica* [43], *Dorstenia turbinata* [6], and *Dorstenia barteri* [5]. Among the chalcones, diprenylated compounds such as angusticornin B (**3**) and bartericin A (**4**) were reported to be very active vis-à-vis many gram-positive and gram-negative bacteria as well as yeasts such as *C. albicans, C. glabrata* and *C. krusei* [42]. It has been demonstrated that hydroxylation of the prenyl groups of stipulin (**5**) leads to compounds **3** and **4**, inducing a significant increase of the antimicrobial activity [42]. Mbaveng et al. [5] also demonstrated that transposition of prenyl from the 5′- (stipulin) to the 3′-position leads to kanzanol C (**6**), and induces an increase of antimicrobial activity, with compound **6** exhibiting significant antimicrobial activities against *M. morganii* and *S. flexneri* while **5** was not so active. A monoprenylated chalcone, isobavachalcone (**7**), was more active than most of the diprenylated chalcones tested so far, with significant inhibitory effects observed on several bacteria and fungi [5]. Cyclization of this molecule, leading to 4-hydroxylonchocarpin (**8**), induced a significant reduction of the activity [5]. Kuete et al. [22] also demonstrated that the shift of the prenyl group from C-3 of compound **7** to position 3′ (4,2′,4′-trihydroxy-3-prenylchacone; **9**), reduced the specificity of compound **9** against gram-negative bacteria, while activity remained significant on the gram-positive bacteria and yeasts. Also, the absence of prenyl groups leading to 4,2′,4′-trihydroxychacone (**10**) further reduced this activity. This allows us to conclude that the prenyl group plays an important role in the activity and selectivity of microorganisms to chalcones. Some flavones such as gancaonin Q (**11**) and kaempferol (**12**) were significantly active against *E. aerogenes, S. dysenteriae* and *Bacillus* spp. [40,42]. Several other flavonoids have shown moderate antimicrobial activities. This includes luteolin, catechin, epiafzelcetin, phyllocoumarin, amentoflavone, artocarpesin, and cycloartocarpesin [5,22,42,44,45]. Many bioactive isoflavonoids were also isolated from Cameroonian medicinal plants. Although isoflavonoids such as laburnetin (**13**) [44] showed significant activity against *M. tuberculosis*, activities against gram-positive and gram-negative bacteria and fungi, and those of genistein, alpium isoflavone, 2′-hydroxyisoprunetin, 6,7-(2-isopropenylfuro)-5,2′,4′-trihydroxyisoflavone and cajanin were found to be selective, moderate or negligible [44,45]. Similarly to chalcones, it has also been demonstrated that the cyclization of flavones (e.g., artocarpesin to cycloartocarpesin) reduced the antimicrobial activity [45].

Arylbenzofuran: Arylbenzofurans (**Fig. 1**) were isolated from *Morus mesozygia*, including 2-arylbenzofurans of the moracin series (C, M, Q, R, S, T and U) [45,46]. Although very few arylbenzofurans have so far been isolated, it has been shown that compounds of the moracin series have moderate activities. Nevertheless, some of them such as moracin T (**14**) were very active (MIC < 10 µg/mL) on *E. coli, S. dysenteriae, P. aeruginosa, K. pneumoniae, S. typhi, B. cereus, S. aureus, S. faecalis,* and *C. albicans* [45]. Significant activities of moracin M (**15**) against *P. aeruginosa*, moracin U (**16**) against *E. coli,* and *B. cereus* and moracin C (**17**) against *S. dysenteriae, P. aeruginosa* and *S. typhi* were also reported [45]. The antimicrobial activities of other 2-arylbenzofurans such as 6,6′-dihydroxy-4′-methoxy-2-arylbenzofuran, cicerfuran and benzofuran derivatives [46] have, however, been documented [47]. Kuete et al. [45] demonstrated that the prenylation of arylbenzofuran increases the antimicrobial activity, with monoprenylated compounds being generally more active. Similarly to chalcones and flavones, it was shown that the degree of activity depends on the position of the prenyl group, with compound **14** (with C-4 prenylation) being more active than compound **17** (with C-4′ prenylation) [45]. It was also reported that the cyclization of arylbenzofurans reduces their antimicrobial activities [45].

Quinones: Several naphthoquinones isolated from Cameroonian medicinal plants were reported for their activities against bacteria and fungi (**Fig. 3**). MICs < 10 µg/mL were documented for many of them including lapachol (**18**), 2-acetylfuro-1,4-naphthoquinone (**19**), 2-hydroxy-3-methoxy-9,10-dioxo-9,10-dihydroanthracene-1-carbaldehyde (**20**), newbouldiaquinone (**21**) [48]. Very interesting activities of plumbagin (**22**), diospyrone (**23**) and crassiflorone (**24**) were reported against *M. tuberculosis, M. smegmatis* and *N. gonorrhoeae* [49]. Several other quinones (**Fig. 3**) also demonstrated significant antifungal and antibacterial activities, namely newbouldiaquinone A (**25**), vismiaquinone C (**26**), vismiaquinone (**27**), 3-geranyloxy-6-methyl-1,8-dihydroxyanthraquinone (**28**), 1,8-dihydroxy-6-methoxy-3-methylanthraquinone (**29**), and bivismiaquinone (**30**) [40,48]. Despite the important structural differences between these quinones, the antibacterial and antifungal activities were found to be significant and close to each other, indicating that the presence of the skeleton of naphthoquinones and anthraquinones is the basis of their antimicrobial activities. It has been demonstrated that quinones complex irreversibly with nucleophilic amino acids of microbial proteins, leading to the loss of function and consequently to the death of the pathogens [50]. The reactivity of cluster-based quinones explains why most of these molecules exert significant antimicrobial activities. However, previous studies [48] also proved that the cyclization and the prenylation of naphthoquinones act on the specificity of the antimicrobial activity.

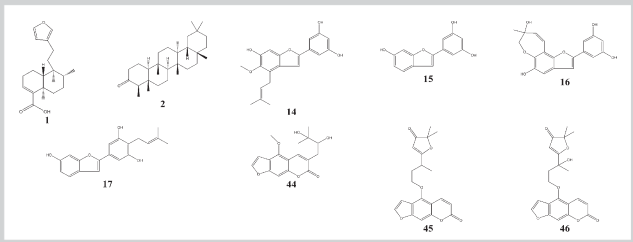

Fig. 1 Antimicrobial terpenoids (**1** and **2**), arylbenzofurans (**14** – **17**) and coumarins (**44** – **46**).

Xanthones: Several xanthones (**Fig. 4**) with good antimicrobial properties have been isolated from various medicinal plants of Cameroon. They have been isolated mostly from plants of the family Guttiferae, including members of the genus *Garcinia* such as *Garcinia smeathmanii* [51] and *Garcinia polyantha* [52], and the genus *Vismia* such as *Vismia laurentii* [40], and *Vismia guineensis* [53]. Many of them, such as cheffouxanthone (**31**) smeathxanthone B (**32**) [51], 6-deoxyisojacareubin (**33**), O^1-demethyl-3′,4′-deoxypsorospermin-3,4′-diol (**34**), 1,3,7-trihydroxyxanthone (**35**) [40], laurentixanthone A (**36**), and laurentixanthone B (**37**) [54] presented selective and significant activities on several bacteria and yeasts of the genus *Candida*. Banganxanthone A (**38**) presented a significant antimycobacterial activity against *M. tuberculosis* and *M. smegmatis* [52]. Azebaze et al. [55] reported allaxanthone D (**39**) as a significantly active antimicrobial xanthone. Other bioactive compounds of this class were also documented. These include 1,3,6,7-tetrahydroxy-2-(3-methylbut-2-enyl)xanthone (**40**) that was active against *E. cloacae, K. pneumoniae, P. aeruginosa, S. faecalis, S. aureus, B. megaterium, B. subtilis* and *C. glabrata* [55]. Compounds such as globulixanthones C (**41**), D (**42**) and E (**43**) also exhibited antimicrobial activities against *S. aureus, B. subtilis* and *Vibrio anguillarium* [56].

Coumarins: Several coumarins have antimicrobial properties [57–61]. They have been found to stimulate macrophages [59], which could have an indirect negative effect on infections. More specifically, coumarin has been used to prevent recurrences of cold sores caused by HSV-1 in humans [57]. Phytoalexins, which are hydroxylated derivatives of coumarins, are produced in carrots in response to fungal infection and can be presumed to have antifungal activity [58]. Osthenol also exhibited good activity against gram-positive bacteria [60]. Most of the coumarins isolated so far from Cameroonian medicinal plants (**Fig. 1**) were found in plants of the genus *Treculia* (Moraceae), including *Treculia africana, Treculia acuminata* and *Treculia obovoidea* [22, 62]. They exhibited moderate antibacterial and antifungal activities [6, 22]. Nevertheless, compounds such as 5-methoxy-3-(3-methyl-2,3-dihydroxybutyl)psoralen (**44**), 5-methoxy-3-[3-(*β*-glucopyranosyloxy)-2-hydroxy-3-methylbutyl]psoralen (**45**) exhibited significant antifungal activities with MIC values comparable to those of nystatin [6]. *O*-[3-(2,2-Dimethyl-3-oxo-2*H*-furan-5-yl)butyl]bergaptol (**46**) also had very good, but selective antimicrobial activities against yeasts of the genus *Candida*, gram-postive and gram-negative bacteria [22].

Other phenols, benzophenones, ellagic acid derivatives: Several other compounds including simple phenolics, benzophenones, cinnamic and ellagic acid derivatives (**Fig. 5**) were identified as active antimicrobial principles of some Cameroonian medicinal plants. Though simple phenolics such as 4-hydroxy-3-methoxybenzaldehyde, 4-methoxyphenol and 3-hydroxy-4-methoxybenzoic acid had weak inhibitory potentials [22], benzophenones presented better activities [51]. This is the case of guttiferone I (**47**) with MIC < 10 µg/mL reported on *C. freundii, E. cloacae, P. vulgaris, B. megaterium* and *S. faecalis* [51]. Isoxanthochymol (**48**) also exhibited significant activity against *B. cereus* and *B. stearothermophilus* [51]. Ellagic acid (**49**) and its derivatives 3,4-di-*O*-methylellagic acid (**50**) and 3,3′,4′-tri-*O*-methylellagic acid (**51**) were significantly active against a wide range of bacteria and yeasts [39].

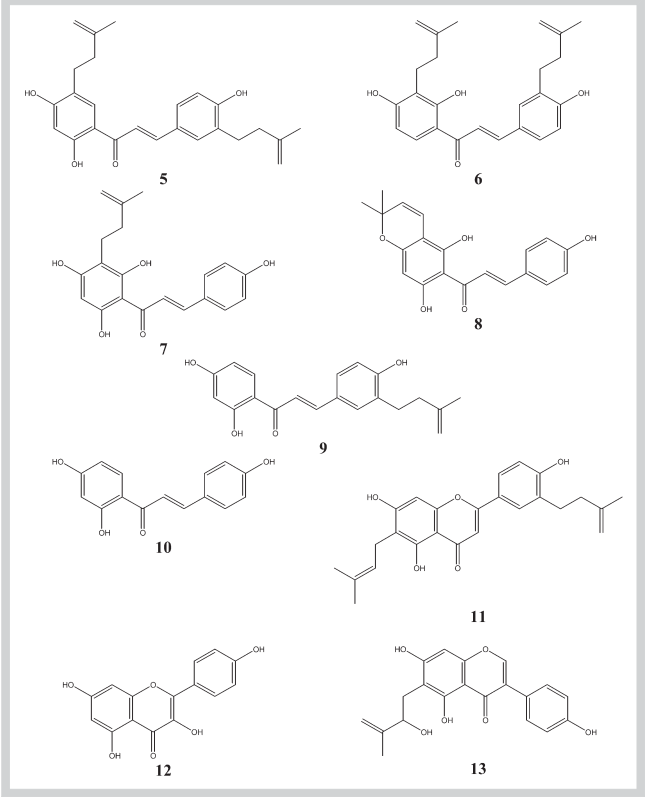

Fig. 2 Antimicrobial flavonoids (**3** – **13**).

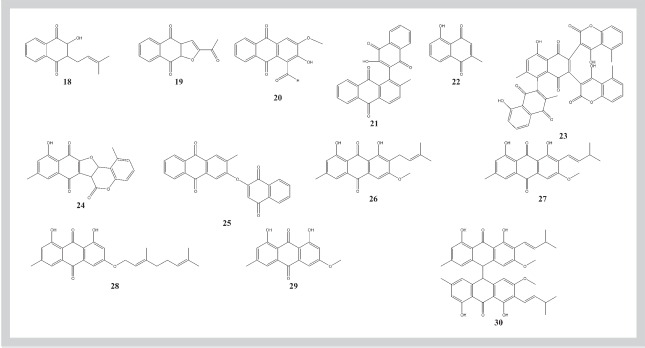

Fig. 3 Antimicrobial quinones (**18** – **30**).

Alkaloids

Natural alkaloids are known for their anti-infective activities. A review of anti-HIV compounds of plant origin by Cos et al. [63] summarized published data on several classes of alkaloids including naphthylisoquinoline alkaloid dimers (michellamines A–

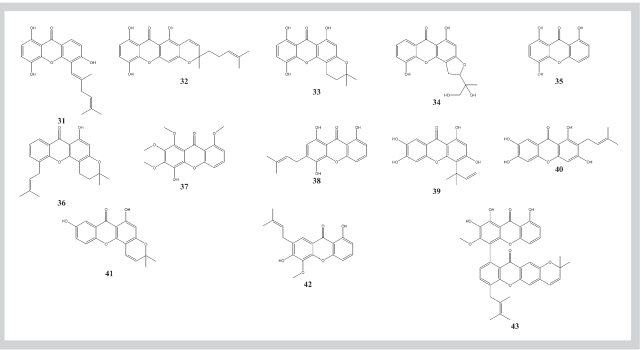

Fig. 4 Antimicrobial xanthones (**31** – **43**).

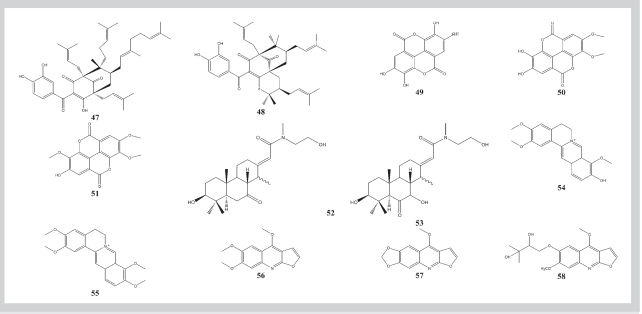

Fig. 5 Antimicrobial benzophenones (**47, 48**), ellagic acid (**49**) and its derivatives (**50, 51**), and alkaloids (**52** – **58**).

F [64,65], nitrogen-containing sugar analogues (castanospermine and 1-deoxynojirimycin) [66,67], sesquiterpene pyridine alkaloids (triptonines A and B) [68], the *β*-carboline alkaloid harman [69], and the carbazole alkaloid, siamenol [70]. Diterpene alkaloids, commonly isolated from the plants of the Ranunculaceae, or buttercup [71] family [72], were found to have antimicrobial properties. Berberine, an important representative of the alkaloid group was also found to be active against *S. aureus* with RNA being suggested as its possible target [73]. Compared with phenolics and terpenoids, very few antimicrobial alkaloids have been isolated so far from Cameroonian medicinal plants. This is due to the fact that few numbers of the plant families contain this class of compounds [74]. Alkaloids from Cameroonian medicinal plants (**Fig. 5**) were mostly isolated in three families including Rutaceae (*Tecla afzelii*) [34], Caesalpiniaceae (*Erythrophleum suaveolens*) [75] and Apocynaceae (*Tabernaemontana crassa*) [76]. The presence of alkaloids in these plant families has also been reported [74]. Amongst the antimicrobial alkaloids (**Fig. 5**) isolated from such plants, norcassaside (**52**) and norerythrosuaveolide (**53**) isolated from *Erythrophleum suaveolens* exerted significant inhibitory (MIC < 10 µg/mL) activities against selected microbial strains like *K. pneumoniae, N. gonorrhoeae, C. albicans,* and *C. krusei* [75]. Dehydrocorydalmine (**54**) and palmatine (**55**) from *Tabernaemontana crassa* also presented a good activity on *N. gonorrhoeae* and *C. krusei* [76]. Kokusaginine (**56**), maculine (**57**) and nkolbisine (**58**) isolated from the stem bark of *Tecla afzelii* presented rather low or moderate activities, but MICs below 10 µg/mL were recorded on some bacterial species [41].

Conclusions

This review, the first of its kind on Cameroonian medicinal plants as potential antimicrobials, is intended to serve as the scientific baseline information for the use of the documented plants, as well as a starting point for future studies, leading to the production of improved plant medicines. The paper also draws attention to some active metabolites, which could probably lead to new antimicrobial drugs. The present review will inevitably show the richness of Cameroon medicinal flora as antimicrobial resources and demonstrates that many of them that are used traditionally are effective. Some of the Cameroonian plant extracts distinguished themselves by their exceptional inhibitory power on both bacteria and fungi. Among these are *Bersama engleriana, Dorstenia angusticornis, Dorstenia barteri, Diospyros canaliculata, Diospyros crassiflora, Newbouldia laevis*, and *Ficus cordata*. Some of the isolated compounds were also highly active. This was the case for isobavachalcone, kanzanol C and 4-hydroxylonchocarpin isolated from *Dorstenia* spp., plumbagin, crassiflorone and diospyrone isolated from *Diospyros* spp., and also newboudiaquinone, lapachol and newbouldiaquinone isolated from *Newbouldia laevis*. Some of the bioactive compounds such as diospyrone (**23**), crassiflorone (**24**), newboudiaquinone (**21**), newbouldiaquinone A (**25**), laurentixanthone A (**36**), laurentixanthone B (**37**), norcassaïde (**49**), norerythrosuaveolide (**50**) [50], smeathxanthone B (**32**), cheffouxanthone (**31**) banganxanthone A (**38**), moracin T (**14**), moracin U (**16**), globulixanthones C (**41**), D (**42**) and E (**43**) and many other compounds were isolated and characterized for the first time in Cameroonian medicinal plants. Presently, there is an urgent necessity for standardizing plant drugs from the investigated plants, as their use is still empirical. There is also an urgent requirement to standardize methods and cut-off points for describing antimicrobial activities, as some authors report activities of extracts at more than 10 mg/mL while others, including ourselves, believe that only MIC values less than 100 µg/mL (for extracts) and 10 µg/mL (for compounds) are worthy of the label active. Other recommendations are to include a parallel screening of mammalian cytotoxicity tests to preclude nonspecific cytotoxicity from being interpreted as antimicrobial efficacy following *in vitro* screening. This is being done in some studies to provide useful selective data, but few research teams in the country are concerned. The study of the mechanism of action and resistance was initiated in our research team at the University of Dschang on active metabolites or extracts, and we recommend that where antimicrobial testings are going on, this should be a priority.

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