

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

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## Key words

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

## Abstract

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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 Ca-

meroonian 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

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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 searching for 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,

Scencedirect, 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, Bignoniaceae, 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, xanthenes, and coumarins. Later in this report, we will discuss the use of the

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## Bibliography

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**Table 1** Alphabetic list of the microbial species.

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

(–) 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 12 000 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 <sup>a</sup>	Traditional treatment	Plant part used	Bioactive (or potentially active) compounds	Screened activity <sup>b</sup> for crude plant extract
Annonaceae	<i>Monodora myristica</i>	headache, constipation, sores, guinea worm infections [77]	seeds	not identified but the active essential oil from fruits contained $\alpha$ -phellandrene; <i>p</i> -cymene; $\alpha$ -pinene; <i>cis</i> -sabinol; limonene [77]	(fruits essential oils) <b>Q:</b> Af, Bc, Bs, Cgl, Ec, Kp, Sa, Sf [77]
	<i>Xylopia aethiopica</i>	cough, bronchitis, dysentery, female sterility [77]	seeds	not identified but the active essential oil from fruits contained $\beta$ -pinene; terpinen-4-ol; sabinene; $\alpha$ -phellandrene; $\alpha$ -terpineol; $\alpha$ - and <i>trans</i> - $\beta$ -ocimene [77]	(fruits essential oils) <b>S:</b> Af, Bc, Ec, Sa, Sf; <b>Q:</b> Cgl [77]
Apocynaceae	<i>Tabernaemontana crassa</i> Benth. (43449/HNC)	gonorrhoea 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) <b>W:</b> Ca, Ck, Ec, Kp, Ng, Pa, Pv, Sa, Sd, Sf, Sp, St [76]
Asteraceae	<i>Emilia coccinea</i> (Sims) G. Don (6297/Leuwenberg)	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) <b>W:</b> Ec, Sa, St [80]
	<i>Crepis cameroonica</i> Bab.	diarrhea, wounds and fungal infections [81]	not specified	3 $\beta$ ,9 $\beta$ -dihydroxyguaian-4(15),10(14),11(13)-trien-6,12-olide; 8 $\alpha$ -hydroxy-4 $\alpha$ (13),11 $\beta$ (15)-tetrahydrozaluzanin C; 8-desacylcynaropicrin [81]	(aerial part methanol extract) <b>Q:</b> Ec, Sa [81]
Bignoniaceae	<i>Newbouldia laevis</i> Seem. (1754/SRFK)	diarrhea, dysentery, worms, malaria, sexually transmitted diseases, dental caries [83]	leaves, stem bark, roots	newbouldiaquinone A [82]; chrysoeriol; newbouldiaquinone; 2-acetyluro-1,4-naphthoquinone; 2-hydroxy-3-methoxy-9,10-dioxo-9,10-dihydroanthracene-1-carbaldehyde; lapachol; $\beta$ -sitosterol-3-O- $\beta$ -dglucopyranoside; oleanolic acid; canthiic acid; newbouldiamide; 2-(4-hydroxyphenyl)-ethyl trioctanoate [48]	(bark methanol extract) <b>S:</b> Bc, Bm, Bs, Bst; <b>M:</b> Ca, Ck, Cg, Ea, Ec, Ecl, Cf, Mm, Kp, Pa, Pm, Pv, Sd, Sfl, Sf, St; <b>W:</b> Sa [48]
	<i>Stereospermum zenkeri</i> K. Schum. ex De Wild (1022/SRFK)	bronchitis, microbial infections [84]	leaves, stem bark	zenkequinone A and B, sterequinone-F, <i>p</i> -coumaric acid [84]	crude extract was not investigated but zenkequinone B presented a MIC value of 9.50 $\mu$ g/mL on <i>P. aeruginosa</i> [84]
Caesalpiaceae	<i>Erythrophleum suaveolens</i> (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	<i>Diospyros crassiflora</i> (4924/SRFK)	gonorrhoea and other bacterial and fungal infections, tuberculosis [49, 86–88]	stem bark	crassiflorone; diospyrone; plumbagin [49, 86–88]	(bark dichloromethane : methanol 1 : 1 extract) <b>W:</b> An, Af, Asp, Ca, Cg, Ck, Ct, Csp, Cn, Fsp, Gc, Psp [88]
	<i>Diospyros canaliculata</i> (9653/SRF/cam)	gonorrhoea and other bacterial and fungal infections, tuberculosis [49, 86]	stem bark	diospyrone; plumbagin [49, 86]	(Bark methanol extract) <b>S:</b> Ms, Mtb, Ng [49]
Euphorbiaceae	<i>Bridelia grandis</i> 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) <b>M:</b> Sm, San, So, Sp [90]
	<i>Bridelia ferruginea</i>	dysentery, diabetes, thrush mycotic stomatitis in children, antidote for snakebite, gonorrhoea, 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) <b>W:</b> Bs, Ec, Sa, Sf [92]
	<i>Mallotus oppositifolium</i>	diarrhea and dysentery [93]	leaves	not yet identified	(leave methanol extract) <b>W:</b> Sd [93]
Fabaceae	<i>Eriosema glomerata</i> 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 <sub>2</sub> Cl <sub>2</sub> -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 <sup>a</sup>	Traditional treatment	Plant part used	Bioactive (or potentially active) compounds	Screened activity <sup>b</sup> for crude plant extract
Guttiferae	<i>Mammea Africana</i> 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]
	<i>Allablackia gabonensis</i> (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 xanthenes were isolated from the stem bark [56]
	<i>Calophyllum inophyllum</i> L. (32189/SRF/Cam)	cicatrissant, 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 <sub>2</sub> Cl <sub>2</sub> -MeOH (1:1) extract) <b>Q</b> : Sa [96]
	<i>Garcinia kola</i> Heckel	infectious diseases, respiratory tract infections [97]	fruits	not yet identified	(fruits ethanol extract) <b>S</b> : Sa, Sp, Spn, Hi [97]
	<i>Garcinia smeathmanii</i> 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) <b>S</b> : Bm, Bs, Ea, Ec, Kp, Mm, Pa, Pv, Sf, St; <b>M</b> : Bc, Bst, Ca, Cg, Ck, Cf, Ecl, Pm, Sd [51]
	<i>Garcinia staudtii</i> Engl (167341/HNC)	bacterial infections, cancer [98]	stem bark	staudtiixanthone A; staudtiixanthone B (2); $\alpha$ -mangostin; gartanin; staudtiixanthenes C; staudtiixanthenes D; demethylcalabaxanthone garcinone B [98]	crude extract was not investigated but isolated compounds were active on <i>S. aureus</i> [98]
	<i>Symphonia globulifera</i> Linn f. (syn. <i>S. gabonensis</i> 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) <b>W</b> : Ec, Sa, Sf, Kp [100]
					(roots bark CH <sub>2</sub> Cl <sub>2</sub> -MeOH extract) <b>S</b> : Bs, Sa, Va [56]
	<i>Vismia guineensis</i> (Linn.) Choisy. (75346/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; O1-demethyl-3',4'-deoxyprospermin-3',4'-diol; 6-deoxyisojacareubin; 1,7-dihydroxyxanthone (barks) [53]; friedelin; 1,8-dihydroxy-6-methoxy-3-methylanthraquinone; kaempferol (leaves) [53]	(leaves methanol extract) <b>S</b> : Ca, Cf, Ecl, Mm, Sfl, Tm, Tr; <b>M</b> : Bs, Bst, Cg, Ea, Ec, Kp, Ms, Pm, Pv, Sa, Sd, St
					(bark methanol extract) <b>S</b> : Ca, Bst, Ecl, Mm, Sfl, Tm, Tr; <b>M</b> : Bs, Ca, Cf, Cg, Ea, Ec, Kp, Ms, Pm, Pv, Sa, Sd, St
					(roots methanol extract) <b>S</b> : Ca, Bst, Ecl, Mm Ms, Mtb, Sfl, Tm, Tr; <b>M</b> : Bs, Ca, Cf, Cg, Ea, Ec, Kp, Ms, Pm, Pv, Sa, Sd, St [53]
	<i>Vismia rubescens</i> 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) <b>M</b> : Sa, St; <b>W</b> : Pa, Ca [102]
Irvingiaceae	<i>Irvingia gabonensis</i> (Aubry Lecomte ex O'Rorke) Baill. (28054/HNC)	gonorrhoea, 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) <b>S</b> : Bst, Ca, Cf, Ea, Ecl, Mm, Ng, Pa, Pm, Pv, Sa, Sd; <b>M</b> : Bc, Bm, Bs, Ck, Ec, Kp, Sfl, St, Sf [39]
Lamiaceae	<i>Ocimum gratissimum</i>	pulmonary antiseptic, antitussive, antispasmodic [108]	leaves	not identified but essential oils from fruits contained thymol; $\gamma$ -terpinene; <i>p</i> -cymene; limonene; $\alpha$ -terpinolene; $\alpha$ -phellandrene; 1,8-cineole; $\alpha$ -terpineol; $\beta$ -caryophyllene; dehydro- <i>p</i> -cymene; 3,9-epoxy- <i>p</i> -mentha-1,8-diene [108]	(essential oil) <b>Q</b> : Bc, Bs, Cgl, Ec, Sa, Sf [102]
	<i>Thymus vulagrif</i> L. 42851/HNC	fungal infections [109]	whole plant	essential oil, with nonidentified components [109]	(essential oil) <b>Q</b> : Ao [109]

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

Family	Species <sup>a</sup>	Traditional treatment	Plant part used	Bioactive (or potentially active) compounds	Screened activity <sup>b</sup> for crude plant extract
Lauraceae	<i>Beilschmiedia anacardioides</i> (Engl. & K. Krause) Robyns & Wilczek	uterine tumors, <i>Rubella</i> , 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	<i>Dorstenia angusticornis</i> Engl. (28165/SRFCam)	gastroenteritis, diarrheal infections [42]	whole plant	gancaonin Q; stipulin; angusticornin B; bartericin A [42]	(twigs methanol extract) <b>S:</b> Bc, Bm, Ca, Ck, Ea, Ng, Pm, Pv, Sa, Sd, Sf, Sfl; <b>M:</b> Bs, Bst, Cg, Cf, Ec, Ecl, Ec, Kp, Mm, Pa, St [42]
	<i>Dorstenia barteri</i> Bureau (44016/HNC)	snakebite, rheumatic, infectious diseases, arthritis [111–113]	whole plant	isobavachalcone; stipulin; 4-hydroxylochocarpin; kanzonol C; amentoflavone [5]	(twigs methanol extract) <b>S:</b> Bc, Bm, Bs, Bst, Ca, Cg, Cf, Ck, Ea, Ec, Ecl, Kp, Ma, Mm, Pa, Pm, Pv, Sa, Sd, Sf, Sfl; <b>M:</b> St, Tr [5]
	<i>Dorstenia elliptica</i> Bureau (44018/HNC)	eye infections [114]	whole plant	psoralen; O-[3-(2,2-dimethyl-3-oxo-2H-furan-5-yl)-butyl]bergaptol or dorstenin; bergapten; O-[3-(2,2-dimethyl-3-oxo-2H-furan-5-yl)-3-hydroxybutyl]bergaptol; 3-(3,3-dimethylallyl)-4,2',4'-trihydroxychalcone [43]	(twigs methanol extract) <b>S:</b> Bm, Bst, Ca, Cf, Ea, Ec, Ecl, Pm, Pv, Sf, Sfl; <b>M:</b> Bc, Bs, Cg, Kp, Ma, Pa, Pv, Sa, St, Tr [43]
	<i>Dorstenia turbinata</i> Engl. (28158/SRF/Cam)	gastroenteritis, skin infections, gastroenteritis, skin infections, rheumatism [6]	whole plant	5-methoxy-3-[3-( $\beta$ -glucopyranosyloxy)-2-hydroxy-3-methylbutyl]psoralen; 5-methoxy-3-(3-methyl-2,3-dihydroxybutyl)psoralen; (2',5,3'-R)-3'-hydroxymarmesin; 4-hydroxy-3-ethoxybenzaldehyde; 4-methoxyphenol, psoralen; kanzonol C; 4-hydroxylochocarpin; umbelliferone [6]	(twigs methanol extract) <b>S:</b> Ca, Cf, Cg, Ec, Kp, Ma, Pa, Sa, Sd, St, Tr [6]
	<i>Ficus chamydocarpa</i> Mildbraed & Burret. (35446/HNC)	filaris, diarrheal infections and tuberculosis [44]	stem bark	$\beta$ -amyirin; alpinumisoflavone; genistein; laburnetin; luteolin [44]	(bark methanol extract) <b>M:</b> Bc, Bst, Ca, Cg, Ecl, Mm, M, Pm, Sa [44]
	<i>Ficus cordata</i> Thunb. 35446/HNC)	filaris, diarrheal infections and tuberculosis [44]	stem bark	$\beta$ -amyirin; $\beta$ -sitosterol-3-O- $\beta$ -glucopyranoside; catechin; epiafzelechin [44]	(bark methanol extract) <b>S:</b> Ca, Cg, Ms, Mtb, Cf, Ec, Ecl, Kp, Mm, Pm, Sd, St; <b>M:</b> Pa [44]
	<i>Ficus ovata</i> Vahl., 26996SRF/Cam	infectious diseases, gastrointestinal infections, diarrhea, anti-poison [109]	leaves, stem bark	3-friedelanone; taraxeryl acetate; betulinic acid; oleanoic acid; 2'-hydroxyisoprunetin; 6,7-(2-isopropenyl furo)-5,2',4'-trihydroxyisoflavone; Cajanin; protocathechuic acid [115]	(Bark methanol extract) <b>M:</b> Bc, Ca, Cf, Ec, Kp, Pa, Sa, Sd, St [115]
	<i>Morus mesozygia</i> 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) <b>S:</b> Bc, Ca, Ec; <b>M:</b> Kp, Pa, Sa, Sd, Sf, St [45]
	<i>Treulia acuminata</i> 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) <b>S:</b> Bm, Ea, Ecl, St; <b>M:</b> Ca, Cg, Ck, Ec, Pa, Pm, Pv, Bs [62]
	<i>Treulia africana</i> Decaisne (29053/SRF/Cam)	treat skin diseases, dental allergy, amoebic dysentery and AIDS [117, 118]	leaves, stem bark, roots	phylloucoumarin; catechin; 6,9-dihydroxymegastigmane-3-one [62]	(leaves methanol extract) <b>S:</b> Bs, Ca, Cf, Ck, Ea, Ec, Kp, Mm, Pm, Pv, Sd, Sf; <b>M:</b> Bst, Cg, Ea, Pa, Sa, St [62]
	<i>Treulia obovoidea</i> 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-2H-furan-5-yl) butyl]bergaptol [22]	(twigs methanol extract) <b>S:</b> Bc, Bs, Ca, Cf, Ck, Pv; <b>M:</b> Bm, Bst, Cg, Ec, Ecl, Kp, Pa, Sa, Sd, Sf, St [22]
Hypericaceae	<i>Harungana madagascariensis</i> <sup>c</sup> 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 <i>B. cereus</i> [119]

continued next page

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

Family	Species <sup>a</sup>	Traditional treatment	Plant part used	Bioactive (or potentially active) compounds	Screened activity <sup>b</sup> for crude plant extract
Meliaceae	<i>Turreanthus manii</i> (Baill.) (18312/SRF/Cam)	infectious diseases [120]	stem bark	16-acetoxy-12,15-epoxy-15 $\beta$ -hydroxylabda-8 (17),13-diene [120]	(stem bark methanol extract) <b>Q:</b> <i>Bs, Ec, Mmi, Cv, Ss</i> [120]
Meliantaceae	<i>Bersama engleriana</i> 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) <b>S:</b> <i>Bst, Ms, Kp, Mm, Pa, St</i> ; <b>M:</b> <i>Bc, Bs, Ca, Cf, Cg, Ec, Ecl, Sd, Sf, Sa, Sfl</i> [122] (bark methanol extract) <b>S:</b> <i>Bs, Bst, Ca, Cf, Cg, Ec, Ecl, Kp, Mm, Ms, Mtb, Pa, Sd, Sf, Sa, Sfl, St</i> [122] (roots methanol extract) <b>S:</b> <i>Bs, Bst, Ca, Cf, Cg, Ec, Ecl, Kp, Mm, Ms, Mtb, Pa, Sd, Sf, Sa, Sfl, St</i> [122]
Ochnaceae	<i>Campylospermum glaucum</i> <sup>c</sup> (Tiegh) Farron (28192/SRF/Cam)	–	stem bark	not identified	(bark methanol extract) <b>W:</b> <i>Eh, Sa, Ssp</i> [123]
	<i>Ouratea sulcata</i> Van Tiegh (ex Keay) (10133/SRF/Cam)	upper respiratory tract infections, dysentery, diarrhea, toothache [114]	leaves	sulcatone A, 3-hydroxy-2,3-dihydroapigenyl-[1-4',O, 11-3']-dihydrokaempferol, amentoflavone [124]	(leaves methanol extract) <b>W:</b> <i>Bs, Sa, Va</i> [124] (leaves CH <sub>2</sub> Cl <sub>2</sub> -MeOH extract) <b>M:</b> <i>Bs, Sa, Va</i> [124]
	<i>Ouratea tumarea</i> (Hook) Hutch & Dalz <sup>c</sup> (10134/SRF/Cam)	–	stem bark	not identified	(bark methanol extract) <b>W:</b> <i>Eh, Sa, Ssp</i> [123]
Poaceae/ Gramineae	<i>Cymbopogon citratus</i> (DC) Stapf. (18628/SRF/Cam)	fungal infections [109]	leaves	essential oil, with non-identified components [109]	(essential oil) <b>Q:</b> <i>Ao</i> [109]
Rhamnaceae	<i>Maesopsis emini</i> (Engler) (234/SRF/Cam)	diuretic, purgative, emetic, and antidiarrhetic, abortifacient [125, 126]	stem bark	1 $\alpha$ ,3 $\beta$ -dihydroxybauer-7-en-28-oic acid [125]	crude extract was not investigated; a diterpenoid 1 $\alpha$ ,3 $\beta$ -dihydroxybauer-7-en-28-oic acid isolated from the stem bark was active on <i>B. cereus</i> [125]
Rutaceae	<i>Tecla afzelii</i> Engl. (10674/SRF/Cam)	wound infections, abdominal pains, cough, fever, asthma [127]	stem bark	kokusaginine; maculine; kolbisine; lupeol [41]	(bark methanol extract) <b>S:</b> <i>Bs, Ca, Cg, Ec, Ma, St</i> ; <b>M:</b> <i>Ms</i> [41]
	<i>Oriciopsis glaberrima</i> Engl. (1888/HNC)	infections, hypotension, mycoses, dermatitis [114]	Stem bark	oriciacridone A and B, lichexanthone [128]	(bark CH <sub>2</sub> Cl <sub>2</sub> -MeOH extract) <b>Q:</b> <i>Bs, Ca, Cv, Cs, Mmi, Sa, Ss, Sv</i> [128]
	<i>Zanthoxylum lepieurii</i>	gonorrhoea, kidney pain, sterility [77]	not specified	Not identified but essential oils from fruits contained <i>trans</i> - $\alpha$ -ocimene; $\alpha$ -terpinolene; 3- $\delta$ -carene; limonene; myrcene; $\alpha$ -pinene; <i>p</i> -cymene [77]	(fruits essential oils) <b>S:</b> <i>Sa</i> [77]
	<i>Zanthoxylum xanthoxyloides</i>	enteritis, dysentery, diarrhea, guinea worm, urethritis and as an antidontalgic [77]	not specified	not identified but essential oils from fruits contained $\alpha$ -pinene; <i>trans</i> - $\beta$ -ocimene; citronellol; sabinene; myrcene; limonene; cytronellyl acetate; $\alpha$ -phellandrene [77]	(fruits essential oils) <b>S:</b> <i>Ec, Bc, Bs, Af, Kp, Sa, Sf</i> [77]
Sapotaceae	<i>Tridesmostemon omphalocarpoides</i> 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) <b>S:</b> <i>Ec</i> ; <b>M:</b> <i>Ca, Ck, Sd, Kp, Sa, Sf</i> [129]

continued next page

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

Family	Species <sup>a</sup>	Traditional treatment	Plant part used	Bioactive (or potentially active) compounds	Screened activity <sup>b</sup> for crude plant extract
Solana- ceae	<i>Solanum tortuosum</i> Sw. (49427/HNC)	bacterial and fungal in- fections, HIV, herpes simplex virus type I and II infections [76, 130– 132]	leaves, stem bark, fruits	steroidiques glycosides, chlorogenone, neochloro- genone [131, 132], solasodine, lupeol [76]	(fruits ethanol 70% extract) <b>M:</b> Ca, Ck, Ec, Ng, Pa, Pv, Sd, Sfl, Sa, St, Sf [76]
Zingibera- ceae	<i>Zingiber officinale</i>	infectious diseases, res- piratory tract infections [98]	roots	not yet identified	(roots ethanol extract) <b>S:</b> Sa, Sp, Spn, Hi [98]

<sup>a</sup> HNC or SRFK: Cameroon national herbarium code; <sup>b</sup> 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 typhi*; Sv: *Streptomyces viridochromogenes*; Tm: *Trichophyton mentagophytes*; Tr: *Trichophyton rubrum*; Va: *Vibrio anguillarum*; SSp: *Staphylococcus saprophyticus*; <sup>c</sup> 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 trichorabdol 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  $\beta$ -caryophyllene. A terpenoid, 3-oxo-(20S,24S)-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 hardwickic 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. morgani*, *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

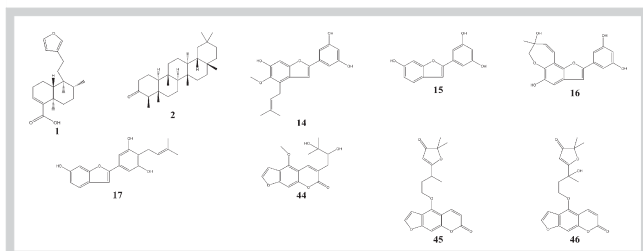
**Flavonoids:** Several flavonoids isolated from Cameroonian medicinal plants have been reported for their antimicrobial activities (● Fig. 2). Such compounds comprise largely chalcones, flavones and isoflavones. Chalcones were isolated primarily from plants of the family Moraceae and the genus *Dorstenia* 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. morgani* 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-hydroxylochocarpin (**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-prenylchalcone; **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'-trihydroxychalcone (**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 in-

cludes 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'-hydroxyisoprunein, 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  $\mu$ g/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  $\mu$ g/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.



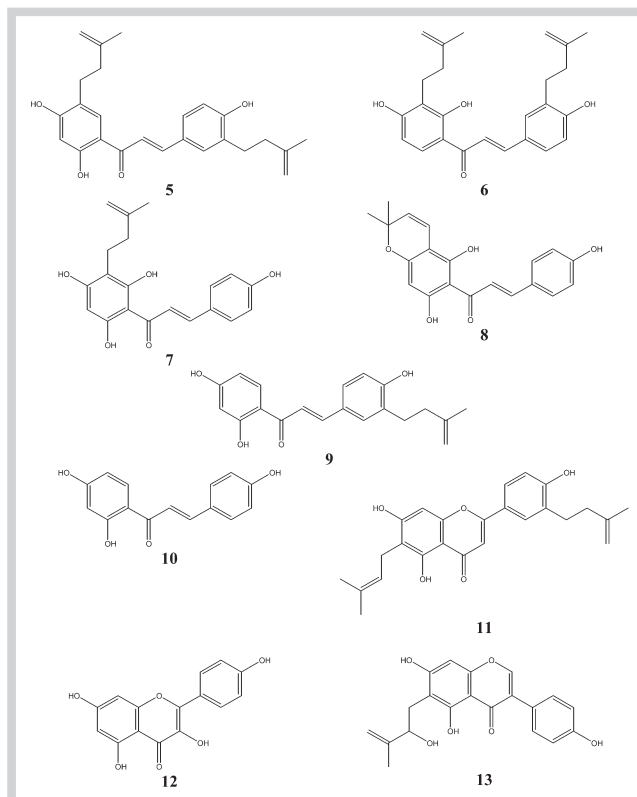


**Fig. 1** Antimicrobial terpenoids (1 and 2), arylbenzofurans (14 – 17) and coumarins (44 – 46).

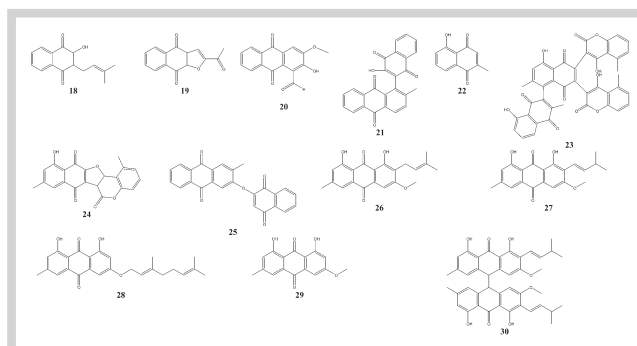
**Xanthones:** Several xanthones (● Fig. 4) with good antimicrobial properties have been isolated from various medicinal plants of Cameroon. They have been isolated mostly from plants of the family Guttiferae, including members of the genus *Garcinia* such as *Garcinia smeathmanii* [51] and *Garcinia 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*<sup>1</sup>-demethyl-3',4'-deoxy-psorospermin-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 globulixanthonones C (41), D (42) and E (43) also exhibited antimicrobial activities against *S. aureus*, *B. subtilis* and *Vibrio anguillarum* [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 *Treulia* (Moraceae), including *Treulia africana*, *Treulia acuminata* and *Treulia 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-2H-furan-5-yl)butyl]bergaptol (46) also had very good, but selective antimicrobial activities against yeasts of the genus *Candida*, gram-positive 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-me-



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



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

thoxybenzaldehyde, 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].

### 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–

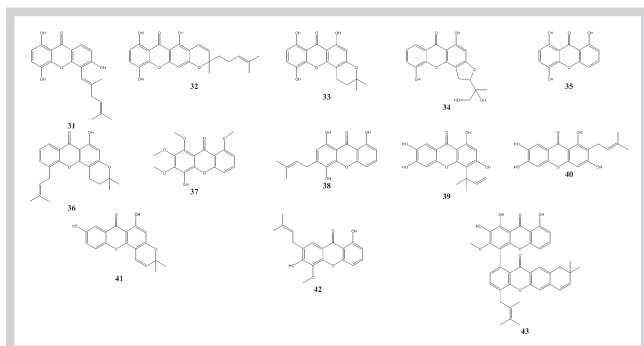


Fig. 4 Antimicrobial xanthenes (31 – 43).

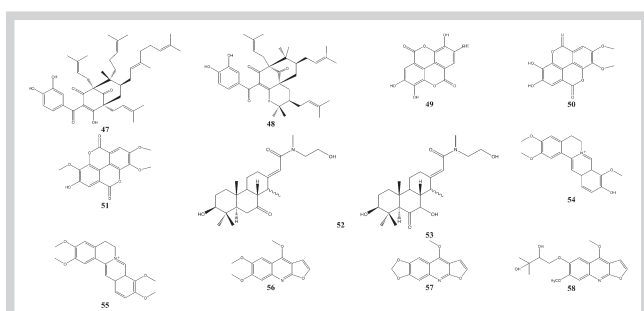


Fig. 5 Antimicrobial benzophenones (47, 48), ellagic acid (49) and its derivatives (50, 51), and alkaloids (52 – 58).

F [64,65], nitrogen-containing sugar analogues (castanospermine and 1-deoxyojirimycin) [66,67], sesquiterpene pyridine alkaloids (triptonines A and B) [68], the  $\beta$ -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], Caesalpinaceae (*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, norcassaide (52) and norerythrosuaveolide (53) isolated from *Erythrophleum suaveolens* exerted significant inhibitory (MIC < 10  $\mu$ g/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  $\mu$ g/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-hydroxylyonchocarpin isolated from *Dorstenia* spp., plumbagin, crassiflorone and diospyrone isolated from *Diospyros* spp., and also newboudiaquinone, lapachol and newboudiaquinone isolated from *Newbouldia laevis*. Some of the bioactive compounds such as diospyrone (23), crassiflorone (24), newboudiaquinone (21), newboudiaquinone A (25), laurentixanthone A (36), laurentixanthone B (37), norcassaide (49), norerythrosuaveolide (50) [50], smeathxanthone B (32), cheffouxanthone (31) banganaxanthone A (38), moracin T (14), moracin U (16), globulixanthenes 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  $\mu$ g/mL (for extracts) and 10  $\mu$ g/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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## References

- Céspedes CL, Avila G, Martinez A, Serrato B, Calderon-Mugica JC, Salgado-Garciglia R. Antifungal and antibacterial activities of Mexican tarracon (*Tagetes lucida*). *J Agric Food Chem* 2006; 54: 3521–3527
- Penso G. *Index Plantarum Medicinalium Totius Mundicorunque Synoni Morum*. Milano: Organizzazione Editoriale Medico Farmaceutica; 1982

- 3 Biyiti L, Pesando D, Puiseux-Dao S. Antimicrobial activity of two flavanones isolated from the Cameroonian plant *Erythrina sigmoidea*. *Planta Med* 1988; 54: 126–128
- 4 Kuete V, Tangmouo JG, Beng VP, Nguemfo EL, Mofo F, Etoa FX, Lontsi D, Samreen IA. Activités antibactérienne et cytotoxique *in vitro* de différents extraits des écorces du tronc de *Diospyros canaliculata* (Ebenaceae). *West Afr J Pharmacol Drug Res* 2004; 30: 22–25
- 5 Mbaveng AT, Ngameni B, Kuete V, Konga Simo I, Ambassa P, Roy R, Bezabih M, Etoa FX, Ngadjui BT, Abegaz BM, Meyer JJM, Lall N, Beng VP. Antimicrobial activity of the crude extracts and five flavonoids from the twigs of *Dorstenia barteri* (Moraceae). *J Ethnopharmacol* 2008; 116: 483–489
- 6 Ngameni B, Kuete V, Konga Simo I, Mbaveng AT, Awoussong PK, Patnam R, Roy R, Ngadjui BT. Antibacterial and antifungal activities of the crude extract and compounds from *Dorstenia turbinata* (Moraceae). *S Afr J Bot* 2009; 75: 256–261
- 7 WHO. WHO Guideline for the Assessment of herbal Medicines, WHO expert committee on specification for pharmaceutical preparation. Technical Report series No 863. Geneva: WHO; 1996
- 8 GLOBAL: Microbes don't know geography – WHO report. <http://www.irisnews.org/Report.aspx?ReportId=73901>. Accessed on 2 August 2009
- 9 WHO. International spread of disease threatens public health security: The world health report 2007 focuses on building a safer future. Geneva. Available at: (<http://www.who.int/mediacentre/news/releases/2007/pr44/en/>) 2007. Accessed on August 02, 2009
- 10 Zager EM, Mc Nerney R. Multidrug-resistant tuberculosis. *BMC Infect Dis* 2008; 8: 10
- 11 Cameroon major infectious diseases. [http://www.indexmundi.com/cameroon/major\\_infectious\\_diseases.html](http://www.indexmundi.com/cameroon/major_infectious_diseases.html). Accessed on August 02, 2009
- 12 Ammah A, Nkuo-Akenji T, Ndip R, Deas JE. An update on concurrent malaria and typhoid fever in Cameroon. *Trans R Soc Trop Med Hyg* 1999; 93: 127–129
- 13 Noeske J, Kuaban C, Cunin P. Are smear-positive pulmonary tuberculosis patients a 'sentinel' population for the HIV epidemic in Cameroon? *Int J Tuberc Lung Dis* 2004; 8: 346–351
- 14 McGaw LJ, Lall N, Meyer JJM, Eloff JN. The potential of South African plants against *Mycobacterium* infections. *J Ethnopharmacol* 2008; 119: 482–500
- 15 Jones KDJ, Hesketh T, Yudkin J. Extensively drug-resistant tuberculosis in sub-Saharan Africa: an emerging public-health concern. *Trans R Soc Trop Med Hyg* 2008; 102: 219–224
- 16 Donald PR, Sirgel FA, Venter A, Parkin DP, Seifart HI, van deWal BW, Maritz JS, Fourie PB. Early bactericidal activity of antituberculosis agents. *Expert Rev Anti Infect Ther* 2003; 1: 141–145
- 17 Cragg GM, Newman DJ, Snader KM. Natural products in drug discovery and development. *J Nat Prod* 1997; 60: 52–60
- 18 Cowan MM. Plant products as antimicrobial agents. *Clin Microbiol Rev* 1999; 12: 564–582
- 19 Chung GAC, Aktar Z, Jackson S, Duncan K. High-throughput screen for detecting antimycobacterial agents. *Antimicrob Agents Chemother* 1995; 39: 2235–2238
- 20 Eloff JN. A sensitive and quick microplate method to determine the minimal inhibitory concentration of plant extracts for bacteria. *Planta Med* 1998; 64: 711–713
- 21 Babula P, Adam V, Kizek R, Sladky Z, Havel L. Naphthoquinones as allelochemical triggers of programmed cell death. *Environ Exp Bot* 2009; 65: 330–337
- 22 Kuete V, Metuno R, Ngameni B, Tsafack AM, Ngandeu F, Fotso GW, Bezabih M, Etoa FX, Ngadjui BT, Abegaz BM, Beng VP. Antimicrobial activity of the methanolic extracts and compounds from *Treulia obovoidea* (Moraceae). *J Ethnopharmacol* 2007; 112: 531–536
- 23 Adjanohoun JE, Aboubakar N, Dramane K, Ebot ME, Ekpere JA, Enow-Orcock EG, Focho D, Gbile ZE, Kamanyi A, Kamsu Ko J, Keita A, Mbenkum T, Mbi CN, Mbiele AL, Mbome IL, Miburur NK, Nancy WL, Nkongmeneck B, Satabie B, Sofowora A, Tamze V, Wirmum CK. Traditional Medicine and Pharmacopoeia: Contribution to ethnopharmacological and floristic Studies in Cameroon. *Lago: OAU/STRC*; 1996: 299
- 24 Tekeu JC. Rapport sur la Pratique des Etudes d'Impact Environnemental (EIE) au Cameroun. Préparé pour la Commission Economique pour l'Afrique des Nations Unies. Available at: <http://www.uneca.org/sdd/documents/ReportEIACameroonFinal.pdf>. 2004. Accessed on August 03, 2008
- 25 Aligiannis N, Kalpotzakis E, Mitaku S, Chinou IB. Composition and antimicrobial activity of the essential oils of two *Origanum* species. *J Agric Food Chem* 2001; 40: 4168–4170
- 26 Jimenez-Arellanes A, Meckes M, Ramirez R, Torres J, Luna-Herrera J. Activity against multidrug-resistant *Mycobacterium tuberculosis* in Mexican plants used to treat respiratory diseases. *Phytother Res* 2003; 17: 903–908
- 27 Tosun F, Akyüz KC, Sener B, Vural M, Palittapongarnpim P. Antimycobacterial screening of some Turkish plants. *J Ethnopharmacol* 2004; 95: 273–275
- 28 Molina-Salinas GM, Ramos-Guerra MC, Vargas-Villarreal J, Mata-Cardenas BD, Becerril-Montes P, Said-Fernández S. Bactericidal activity of organic extracts from *Flourensia cernua* DC against strains of *Mycobacterium tuberculosis*. *Arch Med Res* 2006; 37: 45–49
- 29 Borges-Argáez R, Canche-Chay CI, Peña-Rodríguez LM, Salvador Said-Fernández S, Molina-Salinas GM. Antimicrobial activity of *Diospyros anisandra*. *Fitoterapia* 2007; 78: 370–372
- 30 Rios JL, Recio MC. Medicinal plants and antimicrobial activity. *J Ethnopharmacol* 2005; 100: 80–84
- 31 Cos P, Maes L, Sindambiwe JB, Vlietinck AJ, Berghe VD. Bioassays for antibacterial and antifungal activities. Biological screening of plant constituents. Training manual. Trieste: UNIDO-ICS (United Nations Industrial Development Organization and the International Centre for Science and High Technology); 2006: 19–28
- 32 De las Heras B, Rodríguez B, Boscá L, Villar AM. Terpenoids: sources, structure elucidation and therapeutic potential in inflammation. *Curr Top Med Chem* 2003; 3: 171–185
- 33 Fujioka T, Kashiwada Y. Anti-AIDS agents. 11. Betulinic acid and platanic acid as anti-HIV principles from *Syzgium claviflorum*, and the anti-HIV activity of structurally related triterpenoids. *J Nat Prod* 1994; 57: 243–247
- 34 Ragasa CY, Ha HK, Hasika M, Maridable JB, Gaspillo PD, Rideout JA. Antimicrobial and cytotoxic terpenoids from *Cymbopogon citratus* Stapf. *Philipp Sci* 2008; 45: 111–122
- 35 Kadota S, Basnet P, Ishii E, Tamura T, Namba T. Antibacterial activity of trichorabdal from *Rabdosia trichocarpa* against *Helicobacter pylori*. *Zentralbl Bakteriol* 1997; 286: 63–67
- 36 Prabuseenivasan S, Jayakumar M, Ignacimuthu S. *In vitro* antibacterial activity of some plant essential oils. *BMC Complement Altern Med* 2006; 6: 39
- 37 John AJ, Karunakran VP, George V. Chemical composition an antibacterial activity of *Neolitsa foliosa* (Nees) Gamble var. *caesia* (Meisner) Gamble. *J Essent Oil Res* 2007; 19: 498–500
- 38 Nasimul Islam AKM, Abas Ali M, Sayeed A, Syed M, Salam A. An antibacterial terpenoid from *Caesalpinia pulcherrima* Swartz.: its characterization, antimicrobial and cytotoxic activities. *Asian J Plant Sci* 2003; 2: 1162–1665
- 39 Kuete V, Wabo GF, Ngameni B, Tsafack AM, Metuno R, Etoa FX, Ngadjui BT, Beng VP. Antimicrobial activity of the methanolic extract and compounds from the stem bark of *Irvingia gabonensis* (Ixonanthaceae). *J Ethnopharmacol* 2007; 114: 54–60
- 40 Kuete V, Nguemeving JR, Beng VP, Azebaze AGB, Etoa FX, Meyer M, Bodo B, Nkengfack AE. Antimicrobial activity of the methanolic extracts and compounds from *Vismia laurentii* De Wild (Guttiferae). *J Ethnopharmacol* 2007; 109: 372–379
- 41 Kuete V, Wansi JD, Mbaveng AT, Kana Sop MM, Tadjong AT, Beng VP, Etoa FX, Wandji J, Meyer JJM, Lall N. Antimicrobial activity of the methanolic extract and compounds from *Teclaea afzelii* (Rutaceae). *S Afr J Bot* 2008; 74: 572–576
- 42 Kuete V, Simo IK, Beng VP, Bigoga JD, Kapguez RN, Etoa FX, Ngadjui BT. Antimicrobial activity of the methanolic extract, fractions and four flavonoids from the twigs of *Dorstenia angusticornis* Engl. (Moraceae). *J Ethnopharmacol* 2007; 112: 271–277
- 43 Kuete V, Ngameni B, Tsafack AM, Ambassa IK, Simo P, Roy R, Bezabih M, Etoa FX, Ngadjui BT, Abegaz BM, Beng VP. Antimicrobial activity of the extract from the twigs of *Dorstenia elliptica* (Moraceae). *Pharmacologyonline* 2007; 1: 573–580
- 44 Kuete V, Ngameni B, Fotso Simo CC, Kengap Tankeu R, Tchaleu Ngadjui B, Meyer JJM, Lall N, Kuiate JR. Antimicrobial activity of the crude extracts and compounds from *Ficus chlamydocarpa* and *Ficus cordata* (Moraceae). *J Ethnopharmacol* 2008; 120: 17–24
- 45 Kuete V, Fozing DC, Kapche WFGD, Mbaveng AT, Kuiate JR, Ngadjui BT, Abegaz BM. Antimicrobial activity of the methanolic extract and compounds from *Morus mesozygia* stem bark. *J Ethnopharmacol* 2009; 124: 551–555

- 46 Kapche GDWF, Fozing CD, Donfack JH, Fotso FW, Amadou D, Tchana AN, Bezabih M, Moundipa PF, Ngadjui BT, Abegaz BM. Moracin Q–U, new antioxidant prenylated arylbenzofuran derivatives from *Morus mesosygia*. *Phytochemistry* 2009; 70: 216–221
- 47 Aslam SN, Stevenson PC, Kokubun T, Hall DR. Antibacterial and antifungal activity of cicerfuran and related 2-arylbenzofurans and stilbenes. *Microbiol Res* 2009; 164: 191–195
- 48 Kuete V, Eyong KO, Beng VP, Folefoc GN, Hussain H, Krohn K, Nkengfack AE, Saeftel M, Sarite SR, Hoerauf A. Antimicrobial activity of the methanolic extract and compounds isolated from the stem bark of *Newbouldia laevis* Seem. (Bignoniaceae). *Pharmazie* 2007; 62: 552–556
- 49 Kuete V, Tangmouo JG, Marion Meyer JJ, Lall N. Diospyrone, crassiflorone, and plumbagin, three antimicrobial and anti-gonorrheal naphthoquinones from two *Diospyros* species. *Int J Antimicrob Agents* 2009; 34: 322–325
- 50 Stern JL, Hagerman AE, Steinberg PD, Mason PK. Phorotannin protein interactions. *J Chem Ecol* 1996; 22: 1887–1889
- 51 Kuete V, Komguem J, Beng VP, Tangmouo JG, Meli AL, Etoa FX, Lontsi D. Antimicrobial components of the methanolic extract from the stem bark of *Garcinia smeathmannii* Oliver (Clusiaceae). *S Afr J Bot* 2007; 73: 347–354
- 52 Kuete V, Meli AL, Komguem J, Louh GN, Tangmouo JG, Lontsi D, Marion Meyer JJ, Lall N. Antimicrobial, antibacterial and antifungal activities of the methanolic extract and compounds from *Garcinia polyantha*. *Pharmacologyonline* 2007; 3: 87–95
- 53 Mbaveng AT, Kuete V, Nguemeving JR, Krohn K, Nkengfack AE, Meyer JJM, Lall N. Antimicrobial activity of the extracts and compounds from *Vismia guineensis* (Guttiferae). *AJTM* 2008; 3: 211–223
- 54 Nguemeving JR, Azebaze AGB, Kuete V, Carly NNE, Beng VP, Meyer M, Bodo B, Nkengfack AE. Laurentixanthonones A and B, antimicrobial xanthonones from *Vismia laurentii*. *Phytochemistry* 2006; 67: 1341–1346
- 55 Azebaze AGB, Ouahouo BMW, Vardamides JC, Valentin A, Kuete V, Acebey L, Beng VP, Nkengfack AE, Meyer M. Allaxanthonones A and B, antimicrobial xanthonones from *Allablackia gabonensis*. *Nat Prod Res* 2008; 4: 333–341
- 56 Nkengfack AE, Mkounga P, Meyer M, Omum ZT, Bodo B. Globulixanthonones C, D and E: three prenylated xanthonones with antimicrobial properties from the root bark of *Symphonia globulifera*. *Phytochemistry* 2002; 61: 181–187
- 57 Berkada B. Preliminary report on warfarin for the treatment of *Herpes simplex*. *J Ir Coll Physicians Surg* 1978; 22: 56
- 58 Hoult JRS, Paya M. Pharmacological and biochemical actions of simple coumarins: natural products with therapeutic potential. *Gen Pharmacol* 1996; 27: 713–722
- 59 Casley-Smith JR, Casley-Smith JR. Coumarin in the treatment of lymphoedema and other high-protein oedemas. In: O'Kennedy R, Thornes RD, editors. *Coumarins: biology, applications and mode of action*. New York: John Wiley and Sons, Inc.; 1997: 348
- 60 De Souza SM, Monache FD, Smânia Jr A. Antibacterial activity of coumarins. *Z Naturforsch C* 2005; 60: 693–700
- 61 Razavi SM, Imanzadeh G, Davari M. Coumarins from *Zosima absinthifolia* seeds, with allelopathic effects. *EurAsia J BioSci* 2010; 4: 17–22
- 62 Kuete V, Metuno R, Ngameni B, Tsafack AM, Ngandeu F, Fotso GW, Bezabih M, Etoa FX, Ngadjui BT, Abegaz BM, Beng VP. Antimicrobial activity of the methanolic extracts and compounds from *Treculia obovoidea* (Moraceae). *S Afr J Bot* 2008; 74: 111–115
- 63 Cos P, Maes L, Vlietinck A, Pieters L. Plant-derived leading compounds for chemotherapy of human immunodeficiency virus (HIV) infection – an update (1998–2007). *Planta Med* 2008; 74: 1323–1337
- 64 Hallock YF, Manfredi K, Dai J, Cardellina II JH, Gulakowski RJ, McMahon JB, Schäffer M, Stahl M, Gulden KP, Bringmann G, François G, Boyd MR. Michellamines D–F, new HIV-inhibitory dimeric naphthylisoquinoline alkaloids, and korupensamine E, a new antimalarial monomer, from *Ancistrocladus korupensis*. *J Nat Prod* 1997; 60: 677–683
- 65 White EL, Chao WR, Ross LJ, Borhani DW, Hobbs PD, Upende V, Dawson MI. Michellamine alkaloids inhibit protein kinase C. *Arch Biochem Biophys* 1999; 365: 25–30
- 66 Karpas A, Fleet GWJ, Dwek RA, Petrusson S, Namgoong SK, Ramsden NG, Jacob GS, Rqdemqcher TW. Aminosugar derivatives as potential anti-human immunodeficiency virus agents. *Proc Natl Acad Sci USA* 1988; 85: 9229–9233
- 67 Watson AA, Fleet GWJ, Asano N, Molyneux RJ, Nash RJ. Polyhydroxylated alkaloids – natural occurrence and therapeutic applications. *Phytochemistry* 2001; 56: 265–295
- 68 Duan H, Takaishi Y, Imakura Y, Jia Y, Li D, Cosentino M, Lee KH. Sesquiterpene alkaloids from *Tripterygium hypoglaucum* and *Tripterygium wilfordii*: a new class of potent anti-HIV agents. *J Nat Prod* 2000; 63: 357–361
- 69 Ishida J, Wang HK, Oyama M, Cosentino ML, Hu CQ, Lee KH. Anti-AIDS agents. 46. Anti-HIV activity of harman, an anti-HIV principle from *Symplocos setchuensis*, and its derivatives. *J Nat Prod* 2001; 64: 958–960
- 70 Meragelman KM, McKee TC, Boyd MR. Siamenol, a new carbazole alkaloid from *Murraya siamensis*. *J Nat Prod* 2000; 63: 427–428
- 71 Jones Jr SB, Luchsinger AE. *Plant systematics*. New York: McGraw-Hill Book Co.; 1986
- 72 Atta-ur-Rahman, Choudhary MI. Diterpenoid and steroidal alkaloids. *Nat Prod Rep* 1995; 12: 361–379
- 73 Yi ZB, Yu Y, Liang YZ, Zeng B. Evaluation of the antimicrobial mode of berberine by LC/ESI-MS combined with principal component analysis. *J Pharm Biomed Anal* 2007; 44: 301–304
- 74 Bruneton J. *Pharmacognosie: Phytochimie, Plantes médicinales*, 3rd edition. Paris: Tec & Doc; 1999: 263–309
- 75 Ngounou FN, Manfouo RN, Tapondjou LA, Lontsi D, Kuete V, Penlap V, Etoa FX, Dubois MAL, Sondengam BL. Antimicrobial diterpenoid alkaloids from *Erythrophleum suaveolens* (Guill. & Perr.) Brenan. *Bull Chem Soc Ethiop* 2005; 19: 221–226
- 76 Kuete V. Evaluation des propriétés antimicrobiennes de deux plantes médicinales Camerounaises utilisées dans le traitement des maladies infectieuses: *Solanum trivum* (Solanaceae) et *Tabernaemontana crassa* (Apocynaceae) [dissertation]. Yaoundé: Université de Yaoundé I; 2005
- 77 Tatsadjieu LN, Essia Ngang JJ, Ngassoum MB, Etoa FX. Antibacterial and antifungal activity of *Xylopia aethiopica*, *Monodora myristica*, *Zanthoxylum xanthoxyloides* and *Zanthoxylum leprieurii* from Cameroon. *Fito-terapia* 2003; 74: 469–472
- 78 Burkill HM. *The Useful plants of west tropical Africa*, Vol. 1. Kew: Royal Botanic Gardens; 1985: 186–187
- 79 Wagner WL, Herbst DR, Sohmer SH. *Manual of the Flowering Plants of Hawaii*: revised ed. Honolulu: University of Hawaii Press; 1999: 312
- 80 Ngo Teke G, Kuate JR, Ngouateu OB, Gatsing D. Antidiarrhoeal and antimicrobial activities of *Emilia coccinea* (Sims) G. Don extracts. *J Ethnopharmacol* 2007; 112: 278–283
- 81 Ndom JC, Mbafor JT, Wansi JD, Kamdem AW, Meva'a LM, Vardamides JC, Toukam F, Pegyemb D, Ngando TM, Laatsch H, Fomum ZT. Sesquiterpene lactones from *Crepis cameroonica* (Asteraceae). *Nat Prod Res* 2006; 20: 435–442
- 82 Eyong KO, Folefoc GN, Kuete V, Beng VP, Krohn K, Hussain H, Nkengfack AE, Saeftel M, Sarite SR, Hoerauf A. Newbouldiaquinone A: a naphthoquinone-anthraquinone ether coupled pigment, as a potential antimicrobial and antimalarial agent from *Newbouldia laevis*. *Phytochemistry* 2006; 67: 605–609
- 83 Eyong OK, Krohn K, Hussain H, Folefoc NG, Nkengfack AE, Schulz B, Hu Q. Newbouldiaquinone and newbouldiamide: A naphthoquinone-anthraquinone couple pigment and a new ceramide from *Newboudia laevis*. *Chem Pharm Bull* 2005; 53: 616–619
- 84 Lenta BN, Weniger B, Antheaume C, Nougoué DT, Ngouela S, Assob JCN, Vonthron-Sénécheau C, Fokou PA, Devkota KP, Tsamo E, Sewald N. Anthraquinones from the stem bark of *Stereospermum zenkeri* with antimicrobial activity. *Phytochemistry* 2007; 68: 1595–1599
- 85 Hutchinson J, Dalziel JM. *Flora of West Tropical Africa*, 2nd edition. London: Crown Agents; 1958
- 86 Tangmouo JG, Lontsi D, Ngounou FN, Kuete V, Meli AL, Manfouo RN, Kamdem HW, Tane P, Beng VP, Sondengam BL, Connolly JD. Diospyrone, a new coumarinylbinaphthoquinone from *Diospyros canaliculata* (Ebenaceae): structure and antimicrobial activity. *Bull Chem Soc Ethiop* 2005; 19: 81–88
- 87 Tangmouo JG, Meli AL, Komguem J, Kuete V, Ngounou FN, Lontsi D, Beng VP, Choudhary MI, Sondengam BL. Crassiflorone, a new naphthoquinone from *Diospyros crassiflora* (Hien). *Tetraedron Lett* 2006; 47: 3067–3070
- 88 Dzoyem JP, Tangmouo JG, Lontsi D, Etoa FX, Lohoue PJ. *In vitro* antifungal activity of extract and plumbagin from the stem bark of *Diospyros crassiflora* Hiern (Ebenaceae). *Phytother Res* 2007; 21: 671–674
- 89 Dimo T, Laure NE, Benoit NT, Anatole AGB, Paul AA, Emmanuel TV, Pierre K. Antinociceptive and anti-inflammatory effects of the ethyl acetate stem bark extract of *Bridelia scleroneura* (Euphorbiaceae). *Inflammopharmacology* 2006; 14: 42–47

- 90 Nguem TA, Brusotti G, Marrubini G, Grisoli P, Dacarro C, Vidari G, Finzi PV, Caccialanza G. Validation of use of a traditional remedy from *Bridelia grandis* (Pierre ex Hutch) stem bark against oral Streptococci. *J Ethnopharmacol* 2008; 120: 13–16
- 91 Dalziel JM. The useful plants of west tropical Africa. London: The Crown Agents for the Colonies; 1937: 140–141
- 92 Talla E, Djamen D, Djouldé DR, Tatsadjeu L, Tantoh D, Mbafor JT, Fomum ZT. Antimicrobial activity of *Bridelia ferruginea* leaves extracts. *Fito-terapia* 2002; 73: 343–345
- 93 Kamgang R, Pouokam Kamgne EV, Fonkoua MC, Beng VP, Biwolé SM. Activities of aqueous extracts of *Mallotus oppositifolium* on *Shigella dysenteriae* A1-induced diarrhoea in rats. *Clin Exp Pharm Physiol* 2006; 33: 89–94
- 94 Awouafack MD, Kouam FS, Hussain H, Ngamga D, Tane P, Schulz B, Green IR, Krohn K. Antimicrobial prenylated dihydrochalcones from *Eriosema glomerata*. *Planta Med* 2008; 74: 50–54
- 95 Ouahouo BMW, Azebaze AGB, Meyer M, Bodo B, Fomum ZT, Nkengfack AE. Cytotoxic and antimicrobial coumarins from *Mammea africana*. *Ann Trop Med Parasitol* 2004; 98: 733–739
- 96 Yimdjo MC, Azebaze AGB, Nkengfack AE, Meyer AM, Bodo B, Fomum ZT. Antimicrobial and cytotoxic agents from *Calophyllum inophyllum*. *Phytochemistry* 2004; 65: 2789–2795
- 97 Akoachere JF, Ndip RN, Chenwi EB, Ndip LM, Njock TE, Anong DN. Antibacterial effect of *Zingiber officinale* and *Garcinia kola* on respiratory tract pathogens. *East Afr Med J* 2002; 79: 588–592
- 98 Ngoupayo J, Tabopda TK, Shaiq Ali M. Antimicrobial and immunomodulatory properties of prenylated xanthenes from twigs of *Garcinia staudtii*. *Bioorg Med Chem* 2009; 17: 5688–5695
- 99 Aubreville A. Flore forestière soudano-guinéenne A.O.F. Cameroun-A. E.F. Paris: Société d'Édition Géographique Maritime et Coloniales; 1950: 148–150
- 100 Ngouela S, Ndjakou BL, Tchamo DN, Zelejack F, Tsamo E, Connolly JD. A prenylated xanthone with antimicrobial activity from the seeds of *Symphonia globulifera*. *Nat Prod Res* 2002; 19: 23–27
- 101 Menan H, Banzouzi JT, Hocquette A, Pelissier Y, Blache Y, Kone M, Mallie M, Ake Assi L, Valentin A. Antiplasmodial activity and cytotoxicity of plants used in West African traditional medicine for the treatment of malaria. *J Ethnopharmacol* 2006; 105: 131–136
- 102 Tamokou JDD, Tala MF, Wabo HK, Kuate JR, Tane P. Antimicrobial activities of methanol extract and compounds from stem bark of *Vismia rubescens*. *J Ethnopharmacol* 2009; 124: 571–575
- 103 Berhaut J. Flore illustrée du Sénégal, Dicotylédones, Linacées à Nymphéacées, Tome VI. Dakar: Gouvernement du Sénégal, Ministère du Développement Rural et de l'Hydraulique, Direction des eaux et Forêts; 1979: 466–481
- 104 Adamson I, Okafor C, Abu-Bakare A. A supplement of Dikanut (*Irvingia gabonensis*) improves treatment of type II diabetics. *West Afr J Med* 1990; 9: 108–115
- 105 Okolo C, Johnson P, Abdulrahman F, Abdu-Aguye I, Hussaini I. Analgesic effect of *Irvingia gabonensis* stem bark extract. *J Ethnopharmacol* 1995; 45: 125–129
- 106 Adamson I, Okafor C, Abu-Bakare A. Erythrocyte membrane ATPases in diabetes: effect of Dikanut (*Irvingia gabonensis*). *Enzyme* 1986; 36: 212–215
- 107 Ngondi J, Oben J, Minka S. The effect of *Irvingia gabonensis* seeds on body weight and blood lipids of obese subject in Cameroon. *Lipids Health Dis* 2005; 4: 12
- 108 Ngassoum MB, Essia-Ngang JJ, Tatsadjeu LN, Jirovetz L, Buchbauer G, Adjoudjia O. Antimicrobial study of essential oils of *Ocimum gratissimum* leaves and *Zanthoxylum xanthoxyloides* fruits from Cameroon. *Fito-terapia* 2003; 74: 284–287
- 109 Nguéfack J, Lekagne Dongmo JB, Dakole CD, Leth V, Vismar HF, Torp J, Guemdjom EFN, Mbeffo M, Tamgue O, Fotio D, Amvam Zollo PH, Nkengfack AE. Food preservative potential of essential oils and fractions from *Cymbopogon citratus*, *Ocimum gratissimum* and *Thymus vulgaris* against mycotoxigenic fungi. *Int J Food Microbiol* 2009; 131: 151–156
- 110 Chouna JR, Nkeng-Efoet PA, Lenta BN, Devkota PK, Neumann B, Stammler HG, Kimbu SF, Sewald N. Antibacterial endiandric acid derivatives from *Beilschmiedia anacardioides*. *Phytochemistry* 2009; 70: 684–688
- 111 Thomas DW, Thomas JM, Bromely WA, Mbenkum FT. Korup ethnobotany survey: WWF Survey. 1989: A31
- 112 Abegaz BM, Ngadjui TB, Dongo E, Tamboue H. Prenylated chalcones and flavones from the leaves of *Dorstenia kameruniana*. *Phytochemistry* 1998; 49: 1147–1150
- 113 Tsopmo A, Tene M, Kamnaing P, Ayafor JF, Sterner A. A new Diels-Alder type adduct flavonoids from *D. barteri*. *J Nat Prod* 1999; 62: 1432–1434
- 114 Bouquet A. Féticheurs et médecines traditionnelles du Congo Brazzaville. Paris: Orstom; 1969: 178–202
- 115 Kuete V, Nana F, Ngameni B, Mbaveng AT, Keumedjio F, Ngadjui BT. Antimicrobial activity of the crude extract, fractions and compounds from stem bark of *Ficus ovata* (Moraceae). *J Ethnopharmacol* 2009; 124: 556–561
- 116 Noumi E, Dibakto TW. Medicinal plants used for peptic ulcer in the Bangangté region, western Cameroon. *Fito-terapia* 2002; 71: 406–512
- 117 Bokesch HR, Charan RD, Merangelman KM, Beutler JA, Gardella R, O'keefe BR, Meke TC, Memahon JB. Isolation and characterization of anti-HIV peptides from *Dorstenia contrajerva* and *Treulia obovoidea*. *FEBS Lett* 2004; 567: 287–290
- 118 Kouam SF, Yapna DB, Krohn K, Ngadjui BT, Ngoupayo J, Choudhary MI, Schultz B. Antimicrobial prenylated anthracene derivatives from the leaves of *Harungana madagascariensis*. *J Nat Prod* 2007; 70: 600–603
- 119 Vardamides JC, Sielenou VT, Ndemangou B, Nkengfack AE, Fomum ZT, Poumale HMP, Laatsch H. Diterpenoids from *Turraeanthus mannii*. *Planta Med* 2007; 5: 491–495
- 120 Njike NE, Watch P, Nguéfack T, Kamanyi A. Hypoglycaemic activity of the leaves extracts of *Bersama engleriana* in rats. *Afr J Trad CAM* 2005; 2: 215–221
- 121 Watcho P, Makemdjio A, Nguéfack BT, Kamanyi A. Sexual stimulation effects of the aqueous and methanolic extracts from the leaves of *Bersama engleriana* in adult male rats. *Pharmacologyonline* 2007; 1: 464–476
- 122 Kuete V, Tsafack AM, Tsafack M, Beng VP, Etoa FX, Nkengfack AE, Meyer JJM, Lall N. Antitumor, antioxidant and antimicrobial activities of *Bersama engleriana* (Melianthaceae). *J Ethnopharmacol* 2008; 115: 494–501
- 123 Zintchem AA, Ngono Bikobo D, Théodore Atchadé AT, Ngo Mbing J, Gangoue-Pieboji J, Ghogomu Tih R, Blond A, Pegnyemb DE, Bodo B. Nitrile glucosides and serotobenine from *Campylospermum glaucum* and *Ouratea turnarea*. *Phytochemistry* 2008; 69: 2209–2213
- 124 Pegnyemb DE, Ngo Mbing J, Atchade AT, Ghogomu Tih R, Sondengam BL, Blond A, Bodo B. Antimicrobial biflavonoids from the aerial parts of *Ouratea sulcata*. *Phytochemistry* 2005; 66: 1922–1926
- 125 Irvine RF. Woody plant of Ghana. London: Oxford University Press; 1961: 223–226; 480–481
- 126 Fokou PA, Stammler HG, Neumann B, Huber T, Lontsi D, Kemami Wangun HV, Sewald N. Triterpenes from *Maesopsis eminii*. *J Nat Prod* 2004; 67: 2124–2126
- 127 Adnan JA, Mohammad SA, Ilias M, Assad AA, Herman PP. Furoquinoline alkaloids from *Teclea nobilis*. *Phytochemistry* 2003; 66: 1405–1411
- 128 Wansi JD, Wandji J, Waffo AF, Ngeufa HE, Ndom JC, Fotso S, Maskey RP, Njamen D, Fomum TZ, Laatsch H. Alkaloids from *Oriciopsis glaberrima* Engl. (Rutaceae). *Phytochemistry* 2006; 67: 475–480
- 129 Kuete V, Tangmouo JG, Beng VP, Ngoumou MF, Lontsi D. Antimicrobial activity of *Tridesmostemon omphalocarpoides* Engl. Sapotaceae. *J Ethnopharmacol* 2006; 104: 5–11
- 130 Megne BC. Contribution à l'étude des plantes médicinales du Camerounaises: Inventaire de quelques plantes utilisées dans le traitement des MST dans la région de Dschang (Ouest-Cameroun) [Mémoire de Maîtrise]. Dschang: Université de Dschang; 1998
- 131 Arthan D, Svasti J, Kittakoop P, Pittayakhachonwut D, Tanticharoen M, Thebtaranonth Y. Antiviral isoflavonoidsulphate and steroidal glycosides from the fruits of *Solanum torvum*. *Phytochemistry* 2002; 59: 459–464
- 132 Chah KF, Muko KN, Oboegbulem SI. Antimicrobial activity of methanolic extract of *Solanum torvum* fruit. *Fito-terapia* 2000; 71: 187–189