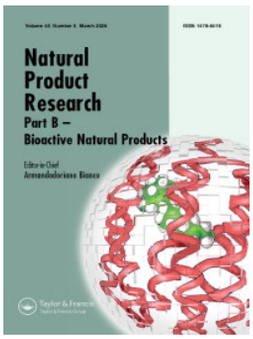


Natural Product Research

Formerly Natural Product Letters

ISSN: 1478-6419 (Print) 1478-6427 (Online) Journal homepage: www.tandfonline.com/journals/gnpl20

Diterpenoids in *Burnatia enneandra* micheli (alismataceae) are active constituents by demonstrating its antibacterial activities

Honoré Wangso , Gaetan Bayiha Ba Njock , Alphonse Laya , Bosco Peron Leutcha , Isaac Silvère Gade , Albert Atangana Fouda , Benoît Koubala Bargui , Celine Henoumont , Sophie Laurent & Emmanuel Talla

To cite this article: Honoré Wangso , Gaetan Bayiha Ba Njock , Alphonse Laya , Bosco Peron Leutcha , Isaac Silvère Gade , Albert Atangana Fouda , Benoît Koubala Bargui , Celine Henoumont , Sophie Laurent & Emmanuel Talla (03 Mar 2026): Diterpenoids in *Burnatia enneandra* micheli (alismataceae) are active constituents by demonstrating its antibacterial activities, Natural Product Research, DOI: 10.1080/14786419.2026.2630362

To link to this article: https://doi.org/10.1080/14786419.2026.2630362

NATURAL PRODUCT RESEARCH
https://doi.org/10.1080/14786419.2026.2630362

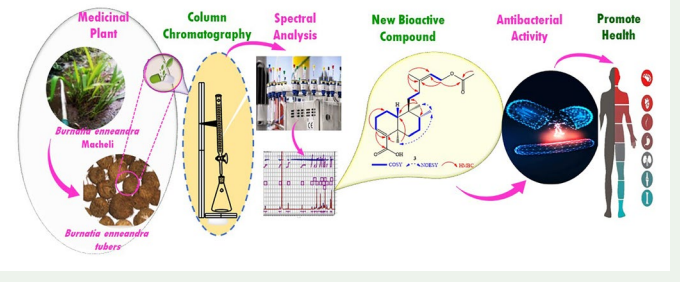
Diterpenoids in *Burnatia enneandra* micheli (alismataceae) are active constituents by demonstrating its antibacterial activities

Honoré Wangso[a,b], Gaetan Bayiha Ba Njock[a], Alphonse Laya[c,d], Bosco Peron Leutcha[b], Isaac Silvère Gade[b], Albert Atangana Fouda[b], Benoît Koubala Bargui[b,c], Celine Henoumont[e], Sophie Laurent[e] and Emmanuel Talla[f]

[a]Department of Chemistry, Faculty of Science, University of Garoua, Garoua, Cameroon; [b]Department of Chemistry, Faculty of Science, University of Maroua, Maroua, Cameroon; [c]Department of Life and Earth Sciences, Higher Teacher's Training College of Maroua, University of Maroua, Maroua, Cameroon; [d]Department of refining and Petrochemistry, National Advanced School of Mines and Petroleum Industries, University of Maroua, Maroua, Cameroon; [e]Department of General, Organic Chemistry and Biomedical, Laboratory of NMR and molecular Imaging, university of MONS, Belgium; [f]Department of Chemistry, Faculty of Science, University of Ngaoundere, Ngaoundere, Cameroon

ABSTRACT

Burnatia enneandra was traditionally used across the world for medicinal purposes. In Cameroon, this plant treats injuries, stomach aches and some intestinal parasites. Therefore, the bioactive molecules responsible for these potentials and their mechanisms of action remain unknown. This study investigates, for the first time, the antibacterial effects of isolated compounds from *B. enneandra* and their effective use for therapeutic purposes without side effects. The bioactive molecules of *B. enneandra* were obtained from ethyl acetate extract (**EA.E**) by applying various chromatographic methods. The structures were elucidated using HR-ESI-MS and 1D- & 2D-NMR spectroscopic data in addition to literature. The antibacterial activity was evaluated on four bacteria strains. As a results, one new diterpenoid of the clerodane (**1**) type, together with five known diterpenoids (**2, 3, 4, 5, 6**), was isolated in the **EA.E** of *B. enneandra* tubers. All tested negative-gram bacteria strains showed high MIC against isolated compound **(1)** at 0.04 μmol/mL.



ARTICLE HISTORY
Received 12 August 2025
Accepted 8 February 2026

KEYWORDS
Burnatia enneandra; alismataceae; antibacterial activity; constituents; diterpenoids

CONTACT Wangso Honoré honorewangso@gmail.com
Supplemental data for this article can be accessed online at https://doi.org/10.1080/14786419.2026.2630362.

1. Introduction

Nowadays, populations in developing countries, including Africa and Asia, mostly refer to traditional healers concerning their health issues (Liu et al. 2021; Negash 2021; Tefere et al. 2022; Morobe et al. 2023). *Burnatia enneandra* Micheli is a semi-aquatic herbaceous plant of the Sudano-Sahelian region, belonging to the family of Alismataceae, which is well distributed in Cameroon and Sudan. In Cameroon this plant grows mainly in swampy areas of the North and Far-North regions. The plant was used in old traditions across the world as functional food and for medicinal purposes. *B. enneandra* is called "*Anjakooje*" in Fulfuldé and "*tigna'ri*" in Toupouri (Taira et al. 2019) and its dried tubers are used to sweeten pap. Moreover, its latex is commonly used to treat injuries and some intestinal parasites of children. The previous chemical studies carried out on *B. enneandra* reveal its high contents of proteins and minerals (Ca, Fe, K, Na, Mg, Mn and Zn) (Klang et al. 2014). To the best of our knowledge no phytochemical study has been done on this plant. On the other hand, only one of the biological activities, such as the amylolytic activity, was evaluated to date. In this line, it has assessed the bioactive secondary metabolites from medicinal plants. The present study investigated the ethyl acetate crude extract of *B. enneandra* tubers. One new diterpenoid, including the clerodane (**1**) type, together with three other known diterpernoids (**2, 3, 4, 5, 6**) is herein reported (Figure 1). The antibacterial activity of the ethyl acetate extract and the isolated compounds was also evaluated.

2. Results and discussion

The ethyl acetate crude extract of *B. enneandra* tubers was purified using normal phase column chromatography, leading to the isolation of four compounds (**1–6**). They were characterised and identified as diterpenoid derivatives, among which was an unprecedented naturally acetylated clerodane 13-(*Z*)-kolavic acid 15-acetate (**1**) together with two known diterpenoids (**2, 3, 4, 5** and **6**) (Figure 1).

Guiskreoic acid, or compound **1**, was obtained as a white powder. $C_{22}H_{34}O_4$ was established as the molecular formula of compound **1** deduced from its HR-ESI-MS spectrum, which reveals a sodium ion peak $[M+Na]^+$ at *m/z* 385.2343 (*m/z* calcd. 385.2355 for $C_{22}H_{34}O_4Na^+$), indicating six degrees of unsaturation (Figure S2). The IR spectrum of compound **1** has shown broad absorption bands at 2,980, 1,710–1,644 and 1,146 cm^{-1} typical of conjugated hydroxyl and ester functions (Lin et al. 2020) (Figure S3). Its ^{13}C-NMR coupled with DEPT-135 spectra (Table S2 and Figure S5) reveal the signals of twenty-two carbon atoms characteristic of an acetylated diterpenoid derivative. The carbons were sorted into five methyls, seven methylenes, among which one is oxygenated at δ_C 61.6, four methines, among which two are olefinic at δ_C 137.5 and 118.9, and six quaternary carbon atoms among, which are two carboxyl groups at δ_C 171.9 and 169.7, two olefinic carbons at δ_C 143.5 and 143.1, and two sp^3 hybridised carbons at δ_C 39.3 and 38.1. The above data are closely related to that of kolavenic acid 15-methyl ester, which is a clerodane derivative (Misra et al. 1964; Ciavatta et al. 1994; García et al. 2006; Tchinda et al. 2007; Delazar et al. 2008). The ^{1}H-NMR spectrum (Table S2 and Figure S4) reveals the signals of two olefinic protons at δ_H 6.68 (dd, J = 4.8, 2.8 Hz, 1H) and 5.32–5.35 (m, 1H) characteristic of clerodane

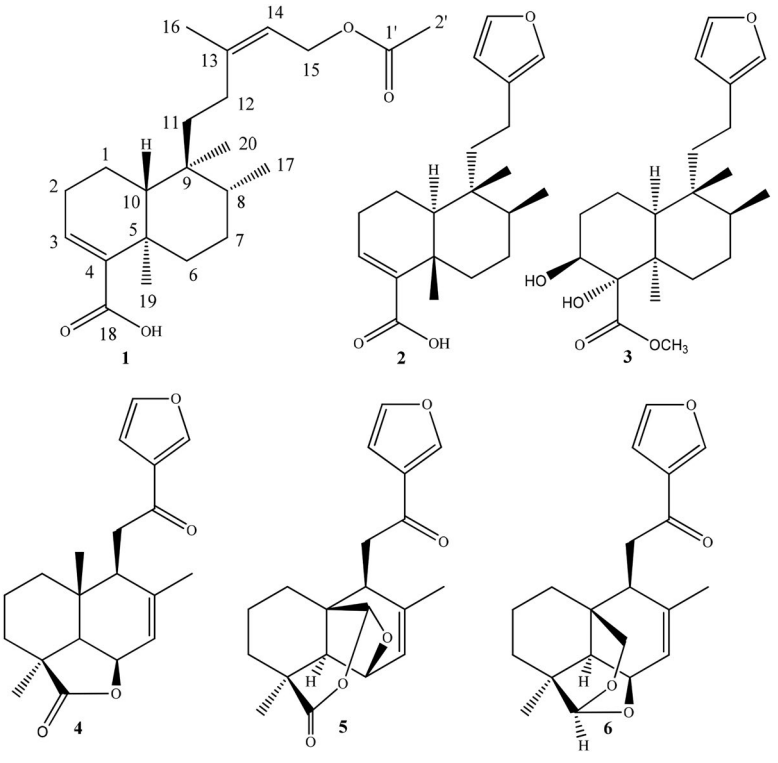


Figure 1. Structures of compounds (**1–6**) isolated from *B. enneandra* tubers.

(Tchinda et al. 2007). This is further supported by the presence of five angular methyl groups, among which four are attributable to a clerodane skeleton at δ_H 1.63 (d, $J = 1.3$ Hz, Me-16), 0.67 (s, Me-19), 0.74 (d, $J = 6.2$ Hz, Me-17) and 1.25 (s, Me-20), together with a methyl at δ_H 2.00 (s, Me-2′) attributable to an acetate group. In addition, the signal of *O*-methylene protons is noticed at δ_H 4.59 (d, $J = 7.1$ Hz, 2H). Moreover, the position of this oxygen-bearing methylene was supported through homonuclear correlation revealed by the COSY spectrum (Figures S1 and S6) between protons at δ_H 4.59 (H-15) with one of the olefinic proton at δ_H 5.32–5.35 (H-14) (Tchinda et al. 2007). The homonuclear correlation between protons at δ_H 6.68 (H-3) with 2.21/2.23 (H-2a/2b) and between 0.74 (Me-17) and 1.36–1.38 (H-8) led to positioning the second double bond and to assuming the clerodane skeleton (Heymann et al. 1994). The HMBC spectrum (Figure S1 and S8) reveals the heteronuclear correlation between the proton at δ_H 6.68 (H-3) with carbons at δ_C 169.7 (C-18), 143.1 (C-4) and 17.9 (C-1) and δ_H 0.67 (Me-19) with carbons at δ_C 143.1 (C-3) and 47.4 (C-10), leading to the easy positioning the acid group and the first double bond, while the correlation δ_H 1.25 (Me-20) with carbons at δ_C 47.4 (C-10) and 36.8 (C-8) and δ_H 1.63 (Me-16) with carbons at δ_C 143.5 (C-13), 118.9 (C-14) and 33.4 (C-12) unambiguously assumes the clerodane skeleton as well as the position of the second double bond (Tchinda et al. 2007; Tang et al. 2011). In addition, the heteronuclear correlations of δ_H 4.59 (H-15) with carbons at δ_C 171.9 (C-1′), 143.5 (C-13) and 118.9 (C-14) led to support for the connection of the acetate group at the position C-15, which had not been reported so far. The relative stoichiometric configuration of

compound **1** was based on its NOESY spectrum (Figures S1 and S9) and supported by Tang et al. (2011). Therefore, protons at δ_H 1.25 (Me-20), 0.74 (H-17) and 0.67 (H-19) reveal their *β*-orientations. Then, compound **1** was characterised as a new clerodane derivative trivially named 13-(*Z*)-kolavenic acid 15-acetate or Guiskreoic acid.

The structures of the known compounds were based on the interpretation of their spectroscopic and spectrometric spectra compared to the previous reports as two clerodane diterpenoids, i.e., hardwickiic acid or 1-naphthalenecarboxylic acid (**2**) (Heymann et al. 1994; Zhao et al. 2021), methyl(1α, 4αa, 5α, 6β, 8aα)-5-[−2-(3-furan-3-ene-2-one)ethyl]-1,2,3,4, 4a, 5,6,7,8, 8a-decahydro-1,2-dihydroxy -1-naphthalenecarboxylate and three furanolabdane diterpenoids, hypopurin A **(4),** hypopurin B**(5)** and hypopurin E**(6)** (Shen et al. 2004; Metiefeng et al. 2023).

The antibacterial activity of the **EA.E** and isolated compounds is summarised in Tables S3–S4. The disc diffusion test showed that the **EA.E** and compounds **1**, **3, 4, 5**, **6** are more active on the strains studied than compound **2**. Indeed, the latter has only a moderate effect (10.0 mm) on the negative-Gram bacterial strains at the concentration of 0.2 mg/mL. On the other hand, at the same concentration, *E. coli* (ATCC-25922) showed a very significant sensitivity towards the **EA.E** (14.0 mm) and isolated compounds **1** (14.0 mm) and **5** (14.0 mm). *Salmonella typhi* (ATCC-14028) (Table S3) presented a high sensitivity towards the **EA.E** and isolated compounds at 0.2 mg/mL, with the exception of isolated compound **2**, which showed only weak inhibitory activity (8.0 mm). Isolated compounds **1** and **5** exhibit interesting antibacterial activity on *S. typhi* (ATCC-14028) with an inhibition diameter of 16.0 mm each at a concentration of 0.2 mg/mL. **EA.E** and isolated compounds showed a significant variation of inhibitory activity against positive-Gram strains of the tested bacteria as summarised in Table S4. *B.subtilis* (ATCC-19659) strain was the most sensitive against compound 1 (14 mm) and compound 5 (14 mm) at 0.2 mg/mL among isolated compounds. However, other ethyl acetate extracts have inhibition diameter zones at 0.2 mg/mL up to 16 mm. At the same concentration, isolated compounds named compound **1, 5** and **EA.E** showed the same value of inhibition zone (16 mm) against the bacterial strain *S. aureus* (ATCC-25923). Results of antimicrobial activity of the **EA.E** and isolated compounds suggest that positive-Gram strains were the most resistant. The antibacterial activity of **EA.E** and isolated compounds were qualitatively determined by the inhibition diameter zone, Ceftazidim, Ampicillin, Nalidixic acid, Streptomycin and Gentamicin, which were used as positive references, and DMSO was used as a negative control.

The **EA.E** and compounds **1, 3, 4, 5 and 6** were therefore selected to determine the MIC and CMB. Table S1 shows that the **EA.E** isolated compounds **1** and **5** had the best bacteriostatic effect on *E. coli* (ATCC-25922) and *S. typhi* (ATCC-14028) with the lowest MIC value of 15.625 µg/mL, 0.04 µmol/mL and 0.05 µmol/mL respectively, followed by isolated compounds **3, 4** and **6**. **EA.E** and isolated compound **1** exhibited high bactericidal activity against *B. subtilis* (ATCC-19659) with a minimal bactericidal concentration of 0.09 µmol/mL. The inhibitory power of compound 1 and 5 towards negative-Gram bacteria (*E. coli* (ATCC-25922) and *S. typhi* (ATCC-14028)) could be due to the presence in these molecules of the carboxylic acid function, the trans double bond and the acetate group. According to Gan et al. (2017), negative-Gram bacteria contain a lipid layer in the wall, making them less permeable and therefore more

resistant than positive-Gram bacteria. Negative-Gram bacteria tend to be more hydrophilic as compared to positive-Gram because of the lower predominance of peptidoglycan in the cell wall (Abhyankar et al. 2021; Liu et al. 2021). The sensitivity of the two bacterial strains towards EA.E and compound **1** is of great interest for future use as antibiotics.

3. Experimental

3.1. General experimental procedures

The NMR spectra (^{1}H,^{13}C, DEPT, HSQC, COSY, HMBC and NOESY) were recorded on a Bruker AVANCEII 500 spectrometer machine at different frequencies, with TMS (TetraMethylSilane) as an internal standard. The HRESIMS spectra were measured with a spectrometer type QTOF Bruker equipped with a high-sensitivity ESI source operating in positive ion mode with Na formate as an internal calibrant. IR spectra were recorded on an Alpha spectrometer. *B. subtilus* (ATCC 19659), *S. aureus* (ATCC25923) *S. typhimurium* (ATCC14028), and *E. coli* (ATCC25922) were obtained from the Microbiology and Food Products of Montreal, Canada.

3.2. Plant material

B. enneandra tubers were collected during the dry season at Moulvoudaye, Mayo-Kani Division, from the Far North Region (10°54′0.0″ North latitude and 14°12′0.0″ East longitude) of Cameroon. The plant was identified at the National Herbarium of Cameroon. 61845HNC is the voucher of the specimen used for the identification by comparison at the national herbarium.

3.3. Extraction and isolation

The powder (2.5 kg) of *B. enneandra* tubers was extracted for 72h with EtOAc. The macerate was filtered using Whatman filters, and the filtrate was concentrated under reduced pressure at about 68 °C to obtain the EtOAc crude extract (180.4 g). 25 g of EtOAc extract was fractionated on a silica gel (60–120 mesh type analysis) column using a system of *n*-hexane/EtOAc gradient and EtOAc/MeOH isocratic (v:v, 9:1), which led to the isolation of six (**6**) compounds: **2** (385 mg, v:v, 2:8, *n*-hexane/EtOAc), **1** (128 mg, v:v, 4:6, *n*-hexane/EtOAc), **3** (326 mg, 9:1, *n*-hexane/EtOAc), **5** (458 mg, v:v, 7:3, EtOAc/MeOH), **4** (512 mg, v:v, 4:6, EtOAc/MeOH) and **6** (231 mg, v:v, 3:7, EtOAc/MeOH).

3.4. Spectroscopic data of compound 1

Guiskreoic acid (**1**): Formula $C_{22}H_{34}O_4$, white powder; IR ν_{max} 2980 (C-H), 1710-1644 (C = O) and 1146 (C-O) cm^{-1}; ^{1}H-NMR (CD_3OD, 500 MHz): 1.55–1.57 (m, 2H-1), 2.21–2.23 (m, 2H-2), 6.68 (dd, J = 4.8, 2.8, 1H-3), 1.39–1.42 (m, 2H-6), 2.25 (dt, J = 13.1, 4.3, 1H-7), 1.36–1.38 (m, 1H-8), 1.30–1.32 (m, 1H-10), 2.00–2.02 (m, 2H-11), 2.05 (dt, J = 12.9, 4.7, 1H-12), 5.32–5.35 (m, 1H-14), 4.59 (d, J = 7.1, 1H-15), 1.63 (d, J = 1.3, 3H-16), 0.74

(d, $J = 6.2$, 3H-17), 0.67 (s, 3H-19), 1.25 (s, 3H-20), 2.00 (s, 3H-2′); ^{13}C-NMR (CD_3OD, 125 MHz): 17.9(C-1), 36.5(C-2), 137.5(C-3), 143.1(C-4), 38.1(C-5), 37.4(C-6), 27.8(C-7), 36.8(C-8), 39.3(C-9), 47.4(C-10), 27.5(C-11), 33.4(C-12), 143.5(C-13), 118.5(C-14), 61.6(C-15), 16.1(C-16), 15.8(C-17), 169.7(C-18), 20.6(C-19), 18.4(C-20), 171.9(C-1′), 20.4(C-2′); HR-ESI-MS *m/z*: 385.2343 $[M + Na]^+$ (*m/z* calcd. 385.2355 for $C_{22}H_{34}O_4Na^+$).

3.5. Antibacterial activity of extract and isolated compounds

3.5.1. Microbial tests and condition of growth

The **EA.E**, compounds (**1–6**) were evaluated for their antibacterial activity against four bacterial strains that included both positive-Gram (*B. subtilis* (ATCC 19659), *S. aureus* (ATCC25923)) and negative-Gram (*S. typhimurium* (ATCC14028), *E. coli* (ATCC25922)) provided by the Laboratory of Microbiology and Food Products of Montreal (University of Alberta, Canada). All bacterial cultures were maintained in Mueller-Hinton agar broth mixed with 20% glycerol and stored at −20 °C until usage. All different cultures were grown at 37 °C in test tubes containing 10 mL of BHI broth for 24 h. Then, the microbial strain was diluted (2:1) in fresh Mueller-Hinton agar medium in order to obtain a final cell concentration of approximately 10^8 CFU/mL, equivalent to the McFarland 0.5 standard.

3.5.2. Determination of antibacterial effect of extract and isolated compounds

The evaluation of the antibacterial activity of the extract and isolated compounds was carried out by the disc diffusion method on the gelled medium Muller-Hinton Agar (Cos et al. 2006; Zhang et al. 2016) in order to identify the active compounds and anticipate future studies. The test solutions were prepared in five different concentrations (0.1, 0.2, 0.4, 0.8, 1.6 and 3.2 mg/mL). Briefly **EA.E**, compounds (**1–6**) were dissolved in 5 mL of DMSO. The microbial suspensions in the exponential growth phase (0.5 on the McFarland scale, approximately 10^8 cell/mL) were inoculated into sterile Muller-Hinton Agar. Commercially available antibacterial susceptibility discs containing gentamycin (30 µg/disc), ceftazidime (25 µg/disc), ampicillin (25 µg/disc), nalidixic acid (25 µg/disc) and streptomycin (30 µg/disc) were used as reference antibacterial drugs. After a pre-diffusion of 30 min at room temperature, the Petri dishes were incubated for 18–24 h at 37 °C. The diameters of the inhibition zones were measured.

3.5.3. Determination of minimal inhibitory concentrations (MIC) and minimal bactericidal concentrations (MBC) of extract and compounds

The determination of the MIC and the MBC was done according to the microdilution method using 96-well microplates as described by Feng et al. (2021) and Cos et al. (2006) with some slight modifications. A stock solution of extract and isolated compound at 10 mg/mL was diluted (500, 250, 125, 62.5, 31.25 and 15.625 µg/mL) and then mixed with Mueller-Hinton Broth and microbial broth suspension at 10^8cells/mL. The crude extract and isolated compounds diluted in Muller-Hinton broth are taken as negative controls, and the microbial suspension with Muller-Hinton as a positive control. The inoculated microplates are incubated for 24 h at 37 °C. The well

corresponding to the smallest concentration of crude extract or isolated compounds for which no turbidity is observed is taken as being the Minimum Inhibitory Concentration (MIC). From this MIC, the wells that have shown no microbial growth visible to the naked eye are re-isolated on Muller-Hinton Agar. The lowest concentration for which no microbial colony is observed (99.99% destruction) is the Minimum Bactericidal Concentration (MBC). The antibiotic potential of the strain is determined by calculating the MBC/MIC (Kalenga et al. 2021).

3.6. Statistical analysis

All the experiments were performed in triplicate, and the results were given as mean ± standard deviation (SD). The obtained data were analysed using Statgraphics software (version. 16). One-way variation analysis (ANOVA) on the statistical significance level 0.01 was performed. Significance of the differences between mean values was examined using Tukey's test ($p < 0.01$).

4. Conclusion

This study shows that *B. enneandra* is a good natural source of diterpenes like clerodane, having interesting antibacterial activity, which could be used for further pharmaceutical purposes. In addition, the results of this investigation are in agreement with the local use of *B. enneandra* in traditional medicine in ancient times. The present results may justify the local use of *B. enneandra* in the treatment of several diseases.

Acknowledgements

The authors gratefully acknowledge the Laboratory of NMR and molecular Imaging, General, Organic and Biomedical Chemistry Unit, University of MONS, Belgium, for the NMR facilities. The bioprofiling platform supported by the European Regional Development Fund and the Walloon Region, Belgium is also acknowledged.

Author contributions

CRediT: **Honoré Wangso**: Conceptualization, Methodology, Visualization, Writing – original draft, Writing – review & editing; **Gaetan Bayiha Ba Njock**: Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing; **Alphonse Laya**: Formal analysis, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing; **Bosco Peron Leutcha**: Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing; **Isaac Silvère Gade**: Investigation, Supervision, Visualization, Writing – original draft, Writing – review & editing; **Albert Atangana Fouda**: Data curation, Methodology, Validation, Writing – original draft, Writing – review & editing; **Benoît Koubala Bargui**: Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing; **Celine Henoumont**: Data curation, Formal analysis, Methodology, Software, Validation, Visualization, Writing – review & editing; **Sophie Laurent**: Data curation, Formal analysis, Methodology, Software, Validation, Visualization, Writing – review & editing; **Emmanuel Talla**: Formal analysis, Methodology, Supervision, Visualization.

Disclosure statement

There is not potential conflict of interest among authors.

Funding

Not applicable.

References

Abhyankar I, Sevi G, Prabhune AA, Nisal A, Bayatigeri S. 2021. Myristic acid derived sophorolipid: efficient synthesis and enhanced antibacterial activity. ACS Omega. 6(2):1273–1279. https://doi.org/10.1021/04683

Ciavatta ML, Trivellone E, Cimino G, Uriz MJ. 1994. Chemical diversity in the Mediterranean sponge *Raspaciona aculeata:* structure and absolute stereochemistry of blanesin. Tetrahedron Letters. 35(41):7871–7874. https://doi.org/10.1016/0040-4039(94)80140-1

Cos P, Vlietinck AJ, Vanden BD, Maes L. 2006. Anti-infective potential of natural products: how to develop a stronger in vitro 'proof-of-concept. J Ethnopharmacol. 106(3):290–302. https://doi.org/10.1016/j.jep.2006.04.003

Delazar A et al. 2008. Furanolabdane diterpene glycosides from *Eremostachys Laciniata*. Nat Prod Commun. 3(6). https://doi.org/10.1177/1934578X0800300609

Feng L et al. 2021. Alisma genus: phytochemical constituents, biosynthesis, and biological activities. Phytother Res. 35(4):1872–1886. https://doi.org/10.1002/ptr.6933

Gan J, Feng Y, He Z, Li X, Zhang K. 2017. Ccorrelations between antioxidant activity and alkaloids and phenols of Maca (*Lepidium meyenii*). J Food Qual. 2017:1–10. https://doi.org/10.1155/2017/3185945

García A, Ramírez-Apan T, Cogordan JA, Delgado G. 2006. Absolute configuration assignments by experimental and theoretical approaches of ent -labdane- and cis - ent -clerodane-type diterpenes isolated from *Croton glabellus*. Can J Chem. 84(12):1593–1602. https://doi.org/10.1139/v06-164

Heymann H, Tezuka Y, Kikuchi T, Supriyatna S. 1994. Constituents of *Sindora sumatrana* MIQ. III. New trans-clerodane diterpenoids from the dried pods. Chem Pharm Bull. 42(6):1202–1207. https://doi.org/10.1248/cpb.42.1202

Kalenga TM et al. 2021. Biflavanones, chalconoids, and flavonoid analogues from the stem bark of *Ochna holstii*. J Nat Prod. 84(2):364–372. https://doi.org/10.1021/acs.jnatprod.0c01017

Klang MJ, Talamond P, Djidimbele N, Tavea F, Ndjouenkeu R. 2014. Partial purification and characterization of α -amylases from *Abrus precatorius*, *Burnatia enneandra* and *Cadaba farinosa*. J Enzyme Res. 5(1):66–71.

Lin YC et al. 2020. Clerodane diterpenoids from *Callicarpa hypoleucophylla* and their anti-inflammatory. Molecules. 25(10):2288.

Liu M et al. 2021. Antimicrobial benzyltetrahydroisoquinoline-derived alkaloids from the leaves *of Doryphora aromatica*. J Nat Prod. 84(3):676–682. https://doi.org/10.1021/acs.jnatprod.0c01093

Metiefeng TN et al. 2023. In vitro and in silico evaluation of anticholinesterase and antidiabetic effect of furanolabdanes and other constituents from *Graptophyllum pictum* (Linn.) Griffith. Molecules. 28(12):4802. https://doi.org/10.3390/28124802

Misra R, Pandey RC, Dev S. 1964. The chemistry of the oleo resin from hardwickia pinnata: a series of new diterpenoids. Tetrahedron Lett. 5(49):3751–3759. https://doi.org/10.1016/S0040-4039(01)89373-4

Morobe ICM, Oyedeji O, Vasaikar DS, Obi LC. 2023. Chemical components of the volatile and non-volatile extractives of *Croton* species and their antibacterial activities. Afr J Biotechnol. https://doi.org/10.5897/AJB2020.17182

Negash L. 2021. A selection African native trees: biology, uses, propagation and restoration techniques. Self p. 621.

Possi DLF et al. 2025. Two new neo-clerodane furanoditerpenoids and other bioactive constituents from the stem bark of the Cameroonian *Croton macrostachyus* (Euphorbiaceae). Phytochem Lett. 68:103004. https://doi.org/10.1016/j.phytol.2025.103004

Shen C, Ni C, Huang Y, Huang R, Chen C. 2004. Furanolabdane diterpenes from hypoestes purpurea. J Nat Prod. 15(5):1947–1949.

Taira A, Desobgo ZC, Nso JE. 2019. Use of aqueous two-phase system for partial purification and characterization of α-Amylase from *Burnatia enneandra* Micheli. J Food Stab. 10(2):26–41.

Tang W, Harada K, Kubo M, Hioki H, Fukuyama Y. 2011. Eight new clerodane diterpenoids from the bark of *Ptychopetalum olacoides*. Nat Prod Commun. 6(3):327–332.

Tchinda AT, Fuendjiep V, Mekonnen Y, Ngo BB, Dagne E. 2007. A bioactive diterpene from *Entada abyssinica*. Nat Prod Commun. 2(1):1–9. 12. https://doi.org/10.1177/1934578X0700200103

Tefere EM et al. 2022. *In vitro* anti-HIV and cytitoxic effects of pure compounds isolated from *Croton macrostachyus* Hochst. Ex Delile. BMC Complement Med Ther. https://doi.org/10.1186/s12906-022-03638-6

Wangso H et al. 2022. Antibacterial and antioxidant activities and phytochemical composition of Stereospermum kunthianum root bark Antibacterial and antioxidant activities and kunthianum root bark. Nat Prod Res. 36(22):5665–5675. https://doi.org/10.1080/14786419.2021.2019730

Zhang L et al. 2016. Antioxidants and a -glucosidase inhibitors from *Ipomoea batatas* leaves identified by bioassay-guided approach and structure-activity relationships. Food Chem. 208:61–67. https://doi.org/10.1016/j.foodchem.2016.03.079

Zhao XT et al. 2021. Dimeric clerodane diterpenoids and antiviral constituents o*f Dodonaea viscosa*. Bioorg Chem. 112:104916. https://doi.org/10.1016/j.bioorg.2021.104916