Mimonoside D: A new triterpenoid saponin from *Mimosa diplotricha* Sauvalle (Fabaceae)

Miss, Claudie Fokou Kenmogne,

Research Unit of Environmental and Applied Chemistry, Department of Chemistry, Faculty of Science, University of Dschang, Box 67, Dschang, Cameroon.

Dr, Beaudelaire Kemvoufo Ponou,

Research Unit of Environmental and Applied Chemistry, Department of Chemistry, Faculty of Science, University of Dschang, Box 67, Dschang, Cameroon.

Miss, Blondelle Matio Kemkuignou,

Department of Microbial Drugs, Helmholtz Centre for Infection Research GmbH, Inhoffenstrasse 7, 38124 Braunschweig, Germany

Dr, Jonas Kühlborn,

Johannes Gutenberg University Mainz, Department of Chemistry, Duesbergweg 10-14, D-55128 Mainz, Germany.

Dr, Roland T. Tchuenguem,

Department of Biochemistry, Faculty of Science, University of Dschang, Box 67, Dschang, Cameroon

Prof, Rémy Bertrand Teponno,

Research Unit of Environmental and Applied Chemistry, Department of Chemistry, Faculty of Science, University of Dschang, Box 67, Dschang, Cameroon.

Prof, Jean Paul Dzoyem,

Department of Biochemistry, Faculty of Science, University of Dschang, Box 67, Dschang, Cameroon

Prof, Till Opatz,

Johannes Gutenberg University Mainz, Department of Chemistry, Duesbergweg 10-14, D-55128 Mainz, Germany.

Prof, Léon Azefack Tapondjou

Research Unit of Environmental and Applied Chemistry, Department of Chemistry, Faculty of Science, University of Dschang, Box 67, Dschang, Cameroon.

Léon Azefack Tapondjou: tapondjou2001@yahoo.fr,
Beaudelaire Kemvoufo Ponou: beaudelaireponou@yahoo.fr

Mimonoside D: A new triterpenoid saponin from *Mimosa diplotricha* Sauvalle (Fabaceae)

Abstract

A new triterpenoid saponin (Mimonoside D: 3-*O*-*α*-L-arabinopyranosyl-3*β*-hydroxyolean-12-en-28-oic acid 28-*O*-*β*-D-xylopyranosyl-(1→2)-*β*-D- glucopyranoside ester (**1**)) was isolated from the aerial parts of *Mimosa diplotricha* Sauvalle together with nine known compounds: 7,4′-dihydroxyflavone (**2**), kaempferol (**3**), lupeol (**4**), betulinic acid (**5**), *β*-sitosterol (**6**), *β*-sitosterol-3-*O*-*β*-D-glucopyranoside (**7**), lutein (**8**), 5,2′-dihydroxy-7,4′,5′-trimethoxyflavone (**9**) and vitexin (**10**). Their structures were elucidated on the basis of spectroscopic (1D and 2D nuclear magnetic resonance) and high-resolution mass spectrometric data as well as by comparison of their spectral data with those of related compounds. Compounds **2**, **7** and **8** had already been isolated from *M. diplotricha*, while compounds **3**, **4**, **5** and **6** have been isolated from other *Mimosa* species. Compound **2** moderately inhibited *Proteus mirabilis* (MIC = 32 µg/mL), weakly inhibited *Pseudomonas aeruginosa* (MIC = 64 µg/mL) and very weakly inhibited *Staphylococcus aureus* (MIC = 128 µg/mL) and *Enterococus faecalis* (MIC = 128 µg/mL).

Key words: Fabaceae, *Mimosa diplotricha*, Triterpenoid saponin, antimicrobial activity.

1. Introduction

Infectious diseases remain responsible for about one quarter of deaths worldwide, causing at least 10 million deaths per year, mainly in the tropical countries (Dye 2014). Many of them are associated with known microorganisms such as bacteria (*Staphylococcus aureus, Enterococcus faecalis*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Proteus mirabilis*) and fungi (*Candida albicans*, *Candida parapsilopsis*, *Candida krusei*, *Candida glabrata* and *Candida dubiniensis*). Ketoconazole and ciprofloxacin-based combinations are the most commonly used against fungi and bacteria, respectively. But the high cost and the low availability in rural areas is still an important health problem. Therefore, there is a need to develop alternative drugs to fight against infectious diseases. Medicinal plants including some *Mimosa* species (Meckes-Lozoya et al. 1990; Ighodaro et al. 2015, Oliveira et al. 2017), are known as promising sources of potential antimicrobial compounds. *Mimosa diplotricha* Sauvalle (Fabaceae) is an erect shrub or a scrambling climber. It is native to Mexico and Central America and also present in tropical Africa. The whole plant of *M. diplotricha* is used in Formosan folk medicine as an analgesic, anticancer remedy, antidote, hemostatic agent, and tranquilizer (Chiu et al. 1998). Previous phytochemical studies of *M. diplotricha* led to the isolation of chalcone-lignoids, meroterpenoids (Chiou et al. 2016), flavonoids (Lin et al. 2011), and a carotenoid (Largo et al. 1997). In our continuous search for potentially interesting new and bioactive secondary metabolites from Cameroonian medicinal plants,

we undertook a phytochemical investigation of the MeOH extract of this plant. We herein describe the isolation and structure elucidation of a new tritepenoid saponin trivially named mimonoside D (1) together with nine known compounds. Triterpenoids saponins are naturally occurring sugar conjugates of triterpenes. The major isolated compounds were investigated for their antimicrobial activity.

2. Results and discussion

2.1. Isolation and structure elucidation

The methanolic extract of *M. diplotricha* aerial part was subjected to column chromatography on silica gel and Sephadex LH-20 to afford one previously undescribed compound (**1**) together with nine known metabolites: 7,4′-dihydroxyflavone (**2**) (Yoo et al. 2004), kaempferol (**3**) (Li et al. 2008), lupeol (**4**) (Kaundal et al. 2017) betulinic acid (**5**) (Bisoli et al. 2008), *β*-sitosterol (**6**) (Chaturvedula and Prakash 2012; Hoet et al. 2007), *β*-sitosterol-3-*O*-*β*-D-glucopyranoside (**7**) (Kowa et al. 2016; Nadella et al. 2012), lutein (**8**) (Largo et al. 1997; Šivel et al. 2014), 5,2′-dihydroxy-7,4′,5′-trimethoxyflavone (**9**) (Zidorn 2015), and vitexin (**10**) (Vázquez et al. 2001).

Compound **1** was isolated as a colorless amorphous powder. Its molecular formula $C_{44}H_{74}O_{16}$ was deduced from its HR-ESI-MS spectrum which showed pseudo molecular ion peak at *m/z* 905.4870 $[M+Na]^+$ (calcd for $C_{46}H_{74}O_{16}Na^+$, 905.4869) and *m/z* 883.5051 $[M+H]^+$ (calcd for $C_{46}H_{75}O_{16}^+$, 883.5050). The ^{1}H NMR spectrum of **1** showed signals of seven tertiary methyl groups δ_H 0.68 (H-26), 0.76 (H-24), 0.87 (H-25/H-30), 0.88 (H-29), 0.96 (H-23) and 1.08 (H-27). It also exhibited one olefinic proton signal at δ_H 5.16 (br s, H-12), one oxygen-bearing methine proton at δ_H 3.01 (H-3). The ^{13}C NMR spectrum of **1** showed one signal of a carboxylic ester group at δ_C 175.1 (C-28), as well as two olefinic carbon atom signals at δ_C 121.5 (C-12) and 143.4 (C-13). The ^{1}H and ^{13}C NMR spectral data of **1** in comparison with those reported in the literature (Mahato and Kundu 1994) revealed that **1** was an olean-12-ene derivative. Taken together, the ^{1}H and ^{13}C NMR data allowed to identify the aglycone of **1** as oleanolic acid (Ponou et al. 2014). Signals of three anomeric protons at δ_H 4.12 (d, J = 6.5, H-1'), 5.33 (d, J = 8.0, H-1") and 4.49 (overlapping, H-1'") were also observed, giving HSQC correlations with three anomeric carbons at δ_C 105.8, 91.8 and 103.9, respectively. The identification of protons belonging to each sugar unit and their assignment to the respective carbon atoms were deduced from ^{1}H,^{1}H COSY and HSQC experiments starting from anomeric protons. Extensive 2D NMR analysis and evaluation of the spin-spin coupling constants and chemical shifts of the sugar part allowed the identification of one *β*-glucopyranosyl (Glc), one *β*-xylopyranosyl (Xyl) and one *α*-arabinopyranosyl (Ara) units (Bock and Pedersen 1983; Zhou et al. 2013). The presence of these sugars was further evidenced through acid

hydrolysis followed by comparative thin layer chromatography with standard sugar samples (See the experimental part). Literature survey of bidesmosidic pentacyclic triterpenoid saponins from Fabaceae species showed that, the sugar chains are preferably attached at C-3 and C-28 (Jiang et al. 1991; Nzowa et al. 2010; Noté et al. 2009). In the case of triterpenoid saponins possessing betulinic, oleanolic or ursolic acid as aglycone, C-3 of the aglycone resonates at about 88.8 ppm (Harinantenaina et al. 2002; Huan et al. 1998; Nguyen et al. 2009). The downfield shift observed for C-3 (δ_C 87.6) and the upfield shift for C-28 (δ_C 175.1) reflected the bidesmosidic nature of compound **1**. Furthermore, the HMBC correlations observed between the anomeric proton atoms at δ_H 4.12 (H-1') and 5.33 (H-1") and the carbon atoms at δ_C 87.6 (C-3) and 175.1 (C-28), respectively evidenced the linkage positions of the sugar chains. The interglycosidic linkage site of the sugar chain at C-28 was deduced from the additional HMBC correlation depicted between the anomeric protons at δ_H 4.49 (H-1'") and the carbon at δ_C 78.6 (C-2'). The absolute configuration D (for glucose and xylose) and L (for arabinose) were tentatively assigned based on the fact that D-glucose, D-xylose and L-arabinose are widely distributed in Fabaceae species (Jiang et al. 1991; Nzowa et al. 2010; Noté et al. 2009). Thus, the structure of compound **1** was elucidated as 3-*O*-*α*-L-arabinopyranosyl-3*β*-hydroxyolean-12-en-28-oic acid 28-*O*-*β*-D-xylopyranosyl-(1→2)-*β*-D- glucopyranoside ester, a new triterpenoid saponin trivially named mimonoside D. Compounds **2-8** have been previously described from other *Mimosa* species. Compounds **2**, **7** and **8** have been isolated from *M. diplotricha* (Chiou et al. 2016; Largo et al. 1997), **3** was reported from *M. pigra* (Yusuf et al. 2003), **4** from *M. artemisiana* (Nascimento et al. 2012), **5** and **6** from *M. ceasalpiniifolia* (Monção et al. 2015) (Figure 1).

2.2. Antimicrobial activity

Since saponins (Dinda et al. 2010) and flavonoids (Xie et al. 2015; Farhadi et al. 2019) have been shown to possess a wide range of pharmacological properties including antimicrobial activity and considering the antimicrobial results previously obtained with extracts from other *Mimosa* species (Meckes-Lozoya et al. 1990; Ighodaro et al. 2015), the major isolated compounds were investigated for their antifungal activity on a selection of five isolates of *Candida*. They were also tested for their antibacterial capacity against five bacterial strains. Among the tested compounds, only 7,4′-dihydroxyflavone (**2**) moderately inhibited *Proteus mirabilis* (MIC = 32 µg/mL), weakly inhibited *Pseudomonas aeruginosa* (MIC = 64 µg/mL) and very weakly inhibited *Staphylococcus aureus* (MIC = 128 µg/mL) and *Enterococus faecalis* (MIC = 128 µg/mL). Compound **9** was weakly active against *Proteus mirabilis* with an MIC of 64 µg/mL. Compound **2** was more active against *Proteus mirabilis* compared to **9**. These data are in agreement with the antibacterial activities reported for flavones which showed that the presence of the hydroxy group at C-7 is vital for the antibacterial activity (Farhadi et al.

2019). Nevertheless, the activity can be increased by the presence of a hydroxy group at C-5 and considerably decreased through methylation of O-7 (Farhadi et al. 2019). The reducing effect of *O*-methylation on the antioxidant activity of flavonoids was previously reported and attributed to the difference in the hydrophobicity and planarity of the molecule (Musialik et al. 2009). Compound **1** was inactive against all the microbial strains. To the best of our knowledge, this is the first report on the antibacterial activity of a 7,4′-dihydroxyflavone. All the tested compounds were inactive against *Candida* isolates (Table 1).

3. Materials and methods

3.1. General experimental procedures and instrumentation

Optical rotations were determined with a Perkin Elmer (Überlingen, Germany) 241 MC polarimeter (using the sodium D line and a quartz cuvette with a 10 cm path length and 0.5 mL volume). HR-ESI-MS were carried out on an Agilent 6210 ESI-TOF mass spectrometer. ^{1}H and ^{13}C NMR spectra were performed in deuterated solvents on a Bruker AVANCE III 600 MHz spectrometer (Bruker, Germany) (600 MHz for ^{1}H and 150 MHz for ^{13}C). All chemical shifts (δ) are given in ppm with reference to tetramethylsilane (TMS) as internal standard, and the coupling constants (J) are in Hz. Column chromatography was performed using 63-200 µm and 32-63 µm mesh silica gel 60 (Merck), and Sephadex LH-20. Fractions were monitored by TLC using Merck precoated silica gel sheets (60 F254), and spots were visualized under UV light (254 and 365 nm) and by spraying with 50% H_2SO_4 and heating at 110 °C. TLC plates were developed with *n*-hexane-EtOAc, EtOAc-MeOH and EtOAc-MeOH-H_2O mixtures.

3.2 Plant material

The aerial parts of *M. diplotricha* were collected in Dschang (West Region of Cameroon) in October 2017. The plant was identified by Mr. E. Ngansop of the National Herbarium of Cameroon, Yaounde, where a voucher specimen (N°34031/HNC) was deposited.

3.3 Extraction and isolation

Air dried and pulverized aerial parts of *M. diplotricha* (3 kg) were macerated three times, each with 10 L of 95 % MeOH for 24 hours. After filtration and evaporation of the filtrate under reduced pressure, 109.4 g of residue was obtained. A part (104.4 g) of this residue was fractionated on silica gel (63-200 µm) column chromatography eluted with the mixture *n*-hexane-EtOAc with increasing polarity (from 100:0 to 0:100) then, with EtOAc-MeOH (from 100:0 to 50:50), to afford eight fractions (A-H).

Compounds **4** (10.3 mg), **6** (50.5 mg) and **7** (15.3 mg) crystallized in fractions B, C, and F, respectively, and were isolated by filtration. Sephadex LH-20 column chromatography of fraction D (3.92 g) using MeOH as eluent led to two sub-fractions, D1 and D2. The purification of sub-fraction D1 (1.47 g) on silica gel (32-63 µm) by column chromatography with isocratic elution using *n*-hexane-EtOAc (70:30) yielded compounds **8** (11.5 mg) and **5** (40.6 mg) while compound **3** (3 mg) crystallized from sub-fraction D2. Fraction E was repeatedly chromatographed on silica gel (32-63 µm) column using *n*-hexane-EtOAc (30:70) leading to the isolation of compounds **2** (27.6 mg) and **9** (6 mg). Sephadex LH-20 separation of fraction G (14.1 g) using MeOH as eluent gave two main sub-fractions, G1 and G2. The isocratic elution of the sub-fraction G**1** on silica gel column chromatography with a mixture EtOAc-MeOH-H_2O (95:5:2) afforded compound **1** (5 mg) while silica gel column chromatography of G2 using EtOAc-MeOH (98:2) allowed to obtain compound **10** (5 mg).

3.3.1. Mimonoside D (1)

White amorphous powder (MeOH); $[a]_D^{20}$ = +11.6 (c = 3.13 mg/mL, DMSO); ^{1}H NMR (600 MHz, DMSO-d_6): δ_H (ppm) **Aglycone**: 5.16 (brs, H-12), 3.01 (o, H-3), 2.73 (dd, *J* = 13.7 and 4.1 Hz, H-18), 1.79 (H-11), 1.74 (o, H-15), 1.70 (o, H_1-2), 1.63 (o, H_1-19), 1.62 (o, H_1-16), 1.58 (o, H_1-21),1.55 (o, H_2-2), 1.50 (o, H_1-1), 1.47 (o, H_2-21, H_1-6 and H-9), 1.36 (o, H_1-7), 1.29 (o, H_2-6), 1.26 (o, H_2-7), 1.23 (o, H_1-22), 1.08 (s, H-27), 1.07 (o, H_2-16), 1.06 (o, H_2-19), 0.96 (s, H-23), 0.88 (s, H-29 and H_2-22), 0.87 (s, H-25 and H-30), 0.76 (s, H-24), 0.71 (H-5), 0.68 (s, H-26); **Glucose:** 5.33 (d, *J* = 8.0 Hz, H-1′), 3.60 (o, H_1-6′), 3.46 (o, H-3′), 3.42 (o, H_2-6′ and H-2′), 3.18 (o, H-5′), 3.17 (o, H-4′); **Arabinose:** 4.12 (d, *J* = 6.5 Hz, H-1″), 3.64 (o, H_1-5″), 3.63 (o, H-3″), 3.59 (o, H-4″), 3.34 (o, H_2-5″), 3.32 (o, H-2″); **Xylose:** 4.49 (overlapping, H-1‴), 3.58 (o, H_1-5‴), 3.50 (ddd, *J* = 9.3, 6.5 and 2.5 Hz, H-4‴), 3.08 (dd, *J* = 9.3 and 8.6 Hz, H-3‴), 2.99 (o, H_2-5 ‴), 2.93 (dd, *J* = 8.6 and 7.5 Hz, H-2‴) and ^{13}C-NMR (150 MHz, DMSO-d_6): δ_C (ppm) **Aglycone**: C-1 (38.0), C-2 (25.4), C-3 (87.6), C-4 (38.7), C-5 (54.9), C-6 (17.7), C-7 (32.7), C-8 (38.9), C-9 (47.0), C-10 (36.2), C-11 (22.9), C-12 (121.5), C-13 (143.4), C-14 (41.1), C-15 (27.5), C-16 (22.0), C-17 (45.9), C-18 (40.4), C-19 (45.5), C-20 (30.2), C-21 (33.2), C-22 (31.4), C-23 (27.6), C-24 (16.4), C-25 (15.1), C-26 (16.6), C-27 (25.4), C-28 (175.2), C-29 (32.2), C-30 (23.3); **Glucose:** C-1′ (91.8), C-2′ (78.6), C-3′ (76.8), C-4′ (69.4), C-5′ (77.5), C-6′ (60.5); **Arabinose:** C-1″ (105.8), C-2″ (72.6), C-3″ (71.9), C-4″ (70.9), C-5″(65.0); **Xylose:** C-1‴(103.9), C-2‴ (74.1) , C-3‴ (76.4), C-4‴ (70.0), C-5‴ (65.7); HR-ESI-MS *m/z* 905.4870 $[M+Na]^+$ (calcd for $C_{46}H_{74}O_{16}Na^+$, 905.4869).

3.4. Acid Hydrolysis of compound 1

Compound **1** (0.3 mg) was heated in 1 M HCl (0.1 mL) at 90°C for 3 hours. After neutralization with NH_4OH followed by extraction with $CHCl_3$, the aqueous layer was evaporated in vacuo to give a crude sugar residue. The resulting residue was analysed by TLC using EtOAc-MeOH-H_2O-AcOH (70-20-10-0.5) in comparison with standard sugars (Sigma, Germany). The spots of the product on TLC were identical to those of D-glucose (Rf 0.36), D-xylose (Rf 0.62) and L-arabinose (Rf 0.46)

3.5 Antimicrobial assay

The antimicrobial activity of the major isolated compounds was determined by broth microdilution assay method as previously described (Dzoyem et al. 2018). Four strains of bacteria obtained from the American Type Culture Collection and one isolate from the *Centre Pasteur de Yaounde* (Cameroon) were used. They included: *Staphylococcus aureus* ATCC 1026, *Enterococcus faecalis* ATCC 29212, *Escherichia coli* ATCC25922, *Pseudomonas aeruginosa* ATCC74117 and *Proteus mirabilis*. Five clinical isolate of fungal were also used: *Candida albicans*, *Candida parapsilopsis*, *Candida krusei*, *Candida glabrata* and *Candida dubiniensis*. They were isolated and identified from clinical samples at the Research Unit of Microbiology and Antimicrobial Substances of the University of Dschang. Ketoconazole and ciprofloxacin (Sigma, Germany) were used as standard drug references.

4. Conclusion

A new triterpenoid saponin namely mimonoside D was isolated from the aerial parts of *Mimosa diplotricha* together with nine known secondary metabolites. The structures of the isolated compounds were determined on the basis of extensive NMR, mass spectroscopic data, and by comparison of their NMR data with those reported in the literature. The isolation of a triterpenoid saponin from *M. diplotricha* is in perfect agreement with the results previously reported from Fabaceae species. They are well known to be a rich source of triterpenoid saponins having an oleanane-type skeleton as aglycone (Jiang et al. 1991; Nzowa et al. 2010; Noté et al. 2009). The major isolated compounds were investigated for their antimicrobial activity on a selection of five fungal and five bacterial strains. 7,4′-dihydroxyflavone (**2**) moderately inhibited *Proteus mirabilis* (MIC = 32 µg/mL), weakly inhibited *Pseudomonas aeruginosa* (MIC = 64 µg/mL) and very weakly inhibited *Staphylococcus aureus* (MIC = 128 µg/mL) and *Enterococus faecalis* (MIC = 128 µg/mL). From the above results, 7,4′-dihydroxyflavone seems to be the main antibacterial constituent of the aerial parts of *Mimosa diplotricha.*

Acknowledgements

The authors are grateful to the Alexander von Humboldt Foundation (AvH), Bonn, Germany for the financial support of this work. We thank the Rhineland Palatinate Center of Natural Products Research, Mainz, Germany for funding part of the analytical chemistry involved.

Conflicts of Interest

The authors confirm that this article content has no conflict of interest.

References

Bisoli E, Garcez WS, Hamerski L, Tieppo C, Garcez FR. 2008. Bioactive pentacyclic triterpenes from the stems of *Combretum laxum*. Molecules 13:2717-2728.

Bock K, Pedersen C. 1983. Carbon-13 nuclear magnetic resonance spectroscopy of monosaccharides. Adv Carbohyd Chem Bi. 41:27-66.

Chaturvedula VSP, Prakash I. 2012. Isolation of stigmasterol and β-sitosterol from the dichloromethane extract of *Rubus suavissimus*. Int Curr Pharmaceut J. 1:239-242.

Chiou CT, Shen CC, Tsai TH, Chen YJ, Lin LC. 2016. Meroterpenoids and chalcone-lignoids from the roots of *Mimosa diplotricha.* J Nat Prod. 79:2439-2445.

Chiu NY, Change KH. 1998. The illustrated medicinal plants of Taiwan; Southern Materials Center Inc Taipei.1:5-99.

Dinda B, Debnath S, Mohanta B C, Harigaya Y. 2010. Naturally occurring triterpenoid saponins. Chem Biodivers. 7:2327-2580.

Dye C. 2014. After 2015: Infectious diseases in a new era of health and development. Philos Trans R Soc Lond B Biol Sci. 369, 20130426. https://doi.org/10.1098/rstb.2013.0426

Dzoyem JP, Tchamgoue J, Tchouankeu JC, Kouam SF, Choudhary MI, Bakowsky U. 2018. Antibacterial activity and cytotoxicity of flavonoids compounds isolated from *Pseudarthria hookeri* Wight & Arn. (Fabaceae). South Afr J Bot. 114:100-103.

Farhadi F, Khameneh B, Iranshahi M, Iranshahy M. 2019. Antibacterial activity of flavonoids and their structure-activity relationship: An update review. Phytother Res. 33:13-40.

Harinantenaina L, Kasai R, Yamasaki K, 2002. Cussosaponins A-E, triterpene saponins from the leaves of *Cussonia racemosa*, a Malagasy endemic plant. Chem Pharm Bull. 501290-1293.

Hoet S, Pieters L, Muccioli GG, Habib-Jiwan J-L, Opperdoes FR, Quetin-Leclercq J. 2007. Antitrypanosomal activity of triterpenoids and sterols from the leaves of *Strychnos spinosa* and related compounds. J Nat Prod 70:1360-1363.

Huan VD, Yamamura S, Ohtani K, Kasai R, Yamasaki K, Nham NT, Chau HM. 1998. Oleanane saponins from *Polyscias fruticosa*. Phytochemistry 47:451–457.

Ighodaro A, Anegbe B, Ogbeide OK, Onaiwu EG. 2015. The phytochemical and chemotherapeutic effect of three indigenous Africa plant used in asthma therapy. J Pharmacogn Phytochem 3:244-247.

Jiang Y, Massiot G, Lavaud C, Teulon J-M, Gufichot C, Haag-Berrurier M, Antons R. 1991. Triterpenoid glycosides from the bark of *Mimosa tenuiflora*. Phytochemistry 30:2357-2360.

Kaundal M, Akhtar M, Deshmukh R. 2017. Lupeol isolated from *Betula alnoides* ameliorates amyloid beta induced neuronal damage via targeting various pathological events and alteration in neurotransmitter levels in rat's brain. J Neurol Neurosci. 8:1-8.

Kowa TK, Zofou D, Mbouangoure R, Tala MF, Wabo HK, Tan N-H, Titanji VPK, Tane P. 2016. Antiplasmodial activity and cytotoxicity of isolated compound from the stem bark of *Anthocleista liebrechtsiana*. Rec Nat Prod. 10:287-293.

Largo GJR, Rideout JA, Ragasa CY. 1997. Bioactive carotenoid from *Mimosa invisa*. Philipp J Sci. 126:107-115.

Li YL, Li J, Wang NL, Yao XS. 2008. Flavonoids and a new polyacetylene from *Bidens parviflora* Willd. Molecules 13:1931-1941.

Lin LC, Chiou CT, Cheng JJ. 2011. 5-Deoxyflavones with cytotoxic activity from *Mimosa diplotricha*. J Nat Prod 74:2001-2004.

Mahato S, Kundu PA. 1994. ^{13}C NMR spectra of pentacyclic triterpenoids, A compilation and some salient features. Phytochemistry 37:1517-1575.

Meckes-Lozoya M, Lozoya X, González JL. 1990. Pharmacological properties *in vitro* of various extracts of *Mimosa tenuiflora* (tepescohuite). Arch Invest Med. 21:163-169.

Monção NBN, Araújo BQ, Silva JDN, Lima DJB, Ferreira PMP, Airoldi FPDS, Cláudia P, Citó AMDGL. 2015. Assessing chemical constituents of *Mimosa caesalpiniifolia* stem bark: possible bioactive components accountable for the cytotoxic effect of *M. caesalpiniifolia* on human tumour cell lines. Molecules 20:4204-4224.

Musialik M, Kuzmicz R, Pawłowski TS, Litwinienko G. 2009. Acidity of hydroxyl groups: an overlooked influence on antiradical properties of flavonoids. J Org Chem. 74:2699-2709.

Nadella D, Paarakh PM, Vedamurthy AB. 2012. Isolation of phytoconstituents from the stem bark of *Holoptelea integrifolia* (Roxb) Planch. J Pharm Res. 5:532-533.

Nascimento IAD, Braz-Filho R, Carvalho MGD, Mathias L, Fonseca FDA. 2012. Flavonolignoids and other compounds isolated from *Mimosa artemisiana* Heringer. Quím Nova 35:2159-2164.

Nguyen T, Nguyen T, Nguyen H, Nguyen S, Nguyen P. 2009. Oleanane saponins from *Polyscias guilfoylei* BAIL. (Araliaceae). Sci Technol Dev J. 12:21–28.

Noté OP, Mitaine-Offer A-C, Miyamoto T, Paululat T, Pegnyemb DE, Lacaille-Dubois M-A. 2009. Tetrapterosides A and B, two new oleanane-type saponins from *Tetrapleura tetraptera*. Magn Res Chem. 47:277-282.

Nzowa LK, Barboni L, Teponno RB, Ricciutelli M, Lupidi G, Quassinti L, Bramucci M, Tapondjou AL. 2010. Rheediinosides A and B, two antiproliferative and antioxidant triterpenesaponins from *Entada rheedii*. Phytochemistry 71:254-261.

Oliveira JFS, Rocha JDS, Lessa LO, Albiquerque JM, Bastos MLA, Verissimo RCSS, Barbosa CV, Alvino V, Bernardo THL. 2017. Antimicrobial and antiseptic activity of genus *Mimosa* spp.: A literature review. J Chem Pharm Res. 9:218-222.

Ponou BK, Nono RN, Teponno RB, Tapondjou AL, Lacaille-Dubois M-A, Quassinti L, Bramucci M, Barboni L. 2014. Bafouoside C, a new triterpenoid saponin from the roots of *Cussonia bancoensis* Aubrev. & Pellegr. Phytochem Lett. 10:255-259.

Šivel M, Kráčmar S, Fišera M, Klejdus B, Kubáň V. 2014. Lutein content in Marigold flower (*Tagetes erecta* L.) concentrates used for production of food supplements. Czech J Food Sci. 32:521-525.

Vázquez E, Martínez EM, Cogordán JA, Delgado G. 2001. Triterpenes, phenols, and other constituents from the leaves of *Ochroma pyramidale* (Balsa Wood, Bombacaceae). Preferred conformations of 8-C-*β*-D-Glucopyranosyl-apigenin (vitexin). Rev Soc Quím Méx. 45:254-258.

Xie Y, Yang W, Tang F, Chen X, Ren L. 2015. Antibacterial activities of flavonoids: structure-activity relationship and mechanism. Curr Med Chem. 22:132-149.

Yoo HS, Lee JS, Kim CY, Kim J. 2004. Flavonoids of *Crotalaria sessiliflora*. Arch Pharm Res. 27:544-546.

Yusuf UK, Abdullah N, Bakar B, Itan K, Abdullah F, Sukari MA. 2003. Flavonoid glycosides in the leaves of *Mimosa species*. Biochem Syst Ecol. 31:443-445.

Zidorn C, 2015. Isoetin and its derivatives: Analytics, chemosystematics, and bioactivities. Biochem Syst Ecol. 61:402-412.

Zhou Z, Wei X, Fu H, Luo Y. 2013. Chemical constituents of *Callicarpa nudiflora* and their anti-platelet aggregation activity. Fitoterapia 88:91-95.