New oleanane-type saponins: Leptocarposide B-D, from Ludwigia leptocarpa (Onagraceae)

Florence Déclaire Mabou, David Ngnokam, Dominique Harakat, Laurence Voutquenne-Nazabadioko

New oleanane-type saponins: Leptocarposides B-D from *Ludwigia leptocarpa* (Onagraceae)

Florence Déclaire MABOU[a], David NGNOKAM[a*], Dominique HARAKAT[b] and Laurence VOUTQUENNE-NAZABADIOKO[c]

[a]Faculty of Science, Department of Chemistry, University of Dschang, P.O. Box 67. Dschang, Cameroon

[b]Service Commun d'Analyses, Institut de Chimie Moléculaire de Reims (ICMR), CNRS UMR 7312, Bat. 18 B.P. 1039, 51687 Reims Cedex 2, France

[c]Groupe Isolement et Structure, Institut de Chimie Moléculaire de Reims (ICMR), CNRS UMR 7312, Bat. 18 B.P. 1039, 51687 Reims Cedex 2, France

Abstract

Three new oleanane saponins, leptocarposides B-D (**1-3**), were isolated from the whole plant of *Ludwigia leptocarpa* (Nutt) Hara, together with ten known compounds **4-13**. The structures of the compounds were determined by interpretation of their spectral data, mainly HR-TOFESIMS, 1D-NMR (^{1}H, ^{13}C) and 2D-NMR (^{1}H-^{1}H COSY, HSQC, HMBC, and NOESY), and by comparison with literature data. The structures of the new compounds were established as 28-*O*-*β*-D-xylopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→2)-[*α*-L-arabinopyranosyl-(1→3)]-4-*O*-(3′-hydroxybutanoyloxy-3-hydroxybutanoyloxy)-*β*-D-fucopyranosylzanhic acid (**1**); 3-*O*-*β*-D-glucopyranosyl-28-*O*-*β*-D-xylopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→2)-4-*O*-(3′-hydroxybutanoyloxy-3-hydroxybutanoyloxy)-*β*-D-fucopyranosylmedicagenic acid (**2**); 3-*O*-*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl-28-*O*-*β*-D-xylopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→2)-[*α*-L-arabinopyranosyl-(1→3)]-4-*O*-(3′-hydroxybutanoyloxy-3-hydroxybutanoyloxy)-*β*-D-fucopyranosylzanhic acid (**3**).

Keywords: Ludwigia leptocarpa; Onagraceae; Triterpenoid glycoside; Bidesmoside; Leptocarposide; Structure elucidation.

1. Introduction

Ludwigia leptocarpa (Nutt) Hara (Onagraceae or Oenotheraceae) is a pantropical genus that is also well represented in North America and in tropical Africa (Oziegbe and Faluyi, 2012). It is used in Nigerian folk medicine for the treatment of rheumatism and dysentery (Burkill, 1997). Previous work on this genus revealed the presence of flavonoids (Averett et al., 1990; Mabou et al., 2014), cerebrosides and triterpenoids (Mabou et al., 2014). Further investigation of the whole plant of *L. leptocarpa*, as part of an ongoing effort to discover new secondary metabolites of biological importance from Cameroonian medicinal plants, resulted in the isolation and characterization of three new oleanane saponins, together with ten known compounds (**4-13**). This paper deals with the isolation and structure elucidation of the three new saponins.

2. Results and discussion

Chromatography of the *n*-BuOH soluble fraction of the crude MeOH extract of the whole plant of *L. leptocarpa* afforded leptocarposides B-D (**1**-3) and ten known compounds (**4**-**13**) which were identified as 3-*O*-*β*-D-glucopyranosyl-28-*O*-*β*-D-xylopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→2)-[*α*-L-arabinopyranosyl-(1→3)]-4-*O*-(3′-hydroxybutanoyloxy-3-hydroxybutanoyloxy)-*β*-D-fucopyranosylzanhic acid (**4**) (leptocarposide A) (Mabou et al., 2014), *β*-D-altro-2-heptulofuranose (**5**) (Begbie et al., 1966; Okuda et al., 1969), 3-*O*-*α*-D-galactopyranosyl-(1→6)-*O*-*β*-D-galactopyranosyl-glycerol (**6**) (Son et al., 1990), (*Z*)-3-hexenyl *O*-*α*-L-arabinopyranosyl-(1→6)-*β*-D-glucopyranosyl (**7**) (Noiarsa et al., 2007), phenylethyl *O*-*α*-L-arabinopyranosyl-(1→6)-*β*-D-glucopyranoside (**8**) (Ali et al., 2008), phenylmethyl *O*-*α*-L-arabinopyranosyl-(1→6)-*β*-D-glucopyranoside (**9**) (Rosa et al., 1996; Ali et al., 2008), *α*-D-glucopyranose (**10**) (Gorin and Mazurek, 1975), *β*-D-glucopyranose (**11**) (Gorin and Mazurek, 1975), *β*-D-fructofuranose (**12**) (Okada et al., 2010) and *β*-D-psicopyranose (**13**) (Penhoat and Perlin, 1974; Valentine et al., 1981) by comparison of their spectroscopic data with literature values.

Compound **1** was obtained as a white amorphous solid which reacted positively with Liebermann-Burchard reagent. Its molecular formula was determined as $C_{60}H_{94}O_{27}$ on the basis of its HR-TOFESIMS spectrum which showed a pseudo-molecular ion peak at *m/z* 1269.5870 $[M+Na]^+$ (calcd. for $C_{60}H_{94}O_{27}Na$ 1269.5880). Its proton and carbon NMR data were similar to those of leptocarposide A (Mabou et al., 2014). Its ^{1}H-NMR spectrum (Table 1) indicated the presence of six tertiary methyl groups at δ_H 0.81 (s, Me-26); 0.90 (s, Me-29); 0.98 (s, Me-30); 1.30 (s, Me-25); 1.34 (s, Me-24) and 1.41 (s, Me-27), an olefinic proton at δ_H 5.36 (t, *J* = 3.1 Hz, H-12) and three oxygenated methine protons at δ_H 4.00 (d, *J* = 3.3 Hz, H-

3), 4.11 (q, J = 3.3 Hz, H-2) and 4.48 (t, J = 2.9 Hz, H-16). Its ^{13}C-NMR spectrum (Table 2) exhibited signals for six methyl groups at δ_C 13.2 (C-24), 16.2 (C-25), 16.5 (C-26), 23.6 (C-30), 25.8 (C-27) and 31.9 (C-29) and two olefinic carbons at δ_C 121.9 (C-12) and 143.5 (C-13), attributable to an olean-12-ene skeleton (Mahato and Kundu, 1994; Lavaud et al.,1998; Inoue et al., 2009), in which three hydroxy groups were located at C-2 (δ_C 71.1), C-3 (75.2) and C-16 (73.4), together with two carboxylic groups at C-23 (182.1) and C-28 (175.8). The ^{1}H-^{1}H COSY showed correlations between H-2 (δ_H 4.11) and H-3 (δ_H 4.00) and between H-15α (δ_H 1.67), H-15β (δ_H 1.48), and H-16 (δ_H 4.48), indicating the sites of hydroxylation. The HMBC correlations between the C-23 carboxyl carbon (δ_C 181.1) and H-3 (δ_H 4.00), H-5 (1.62) and Me-24 (1.34), and between the ester carbonyl at C-28 (δ_C 175.8) and the oxymethine H-16 (δ_H 4.48) confirmed the substitution pattern (Mahato and Kundu, 1994; Lavaud et al., 1998; Inoue et al., 2009). The 2β,3β,16α configurations of the hydroxyl groups, and the α-orientation of the C-23 COOH at C-4 was confirmed from the ROESY experiments. The coupling constant (J = 3.3 Hz) between H-2 and H-3 is in accordance with the literature (Lavaud et al., 1998; Inoue et al., 2009). On this basis, the aglycone moiety of compound **1** was established as zanhic acid (2β,3β,16α-trihydroxyolean-12-ene-23,28-dioic acid. The shielded nature of C-28 (δ_C 175.8) and C-3 (75.2) suggested a monodesmosidic saponin with an ester glycosidic linkage at C-28 (Lavaud et al., 1998; Inoue et al., 2009).

The ^{1}H and ^{13}C-NMR spectra revealed the presence of four sugar units with anomeric protons at δ_H 5.41 (d, J = 7.8 Hz, H-1’’’), 5.38 (d, J = 1.5 Hz, H-1’’’’), 4.51 (d, J = 7.6 Hz, H-1’’’’’), and 4.41 (d, J = 6.8 Hz, H-1’’’’’’) and the corresponding carbons at δ_C 105.5 (C-1’’’’’), 104.4 (C-1’’’’’’), 100.0 (C-1’’’’), and 93.7 (C-1’’’) (Agrawal, 1992). Two methyl carbons at δ_C 15.5 (C-6’’’) and 17.0 (C-6’’’’) indicated the presence of two 6-desoxyhexoses, and two oxymethylene carbons at δ_C 65.6 (C-5’’’’’), and 65.9 (C-5’’’’’’) suggested two pentoses. Analysis of COSY, TOCSY, and ROESY spectra allowed complete assignment of the spin systems of a rhamnopyranose, a fucopyranose, a xylopyranose and an arabinopyranose (Table 1). The anomeric configurations of the fucose and xylose were determined to be beta, and those of arabinose and rhamnose to be alpha from the $^3J_{H1\text{-}H2}$ values of the anomeric protons and the chemical shifts of the anomeric carbons (Agrawal, 1992). The sugar composition was confirmed by thin layer chromatography (TLC) after hydrolysis, and the D or L-configurations were proved by gas chromatography-mass spectrometry (GC-MS) after derivatization (Mabou et al., 2014). The carbons of each monosaccharide were attributed by analysis of HSQC spectra and indicated the presence of a terminal β-D-xylopyranose, a terminal α-L-arabinopyranose, a 4-substitued α-L-

rhamnopyranose (δ_C 82.5 (C-4’’’’)), and a 2,3,4-trisubstitued β-D-fucopyranose (δ_C 72.8 (C-2’’’), δ_C 80.8 (C-3’’’), and δ_C 73.7 (C-4’’’)) (Table 2). The downfield shift of H-4’’’ (δ_H 5.30 (d, J = 3.5 Hz)) suggested an esterification of the fucose at this position.

The ^{1}H-NMR spectrum (Table 1) also showed two oxymethine groups at δ_H 5.31 (m, H-3’’’’’’’) and 4.18 (m, H-3’’’’’’’’) and two methyl groups at δ_H 1.35 (d, J = 6.4 Hz, H-4’’’’’’’) and 1.23 (d, J = 6.2 Hz, H-4’’’’’’’’), suggesting the presence of two 3-hydroxybutanoic acid (HBA) (Li and Doi, 1998; Mabou et al., 2014). In the ^{13}C-NMR spectrum (Table 2), resonances of two other ester carbonyls at δ_C 171.1 and 170.3, corresponding respectively to C-1’’’’’’’ of HBA and to C-1’’’’’’’’ of HBA′, two methyl carbons at δ_C 21.9 (HBA-C-4’’’’’’’) and 18.6 (HBA′-C-4’’’’’’’’), and two oxymethine carbons at δ_C 67.3 (HBA-C-3’’’’’’’) and 64.2 (HBA′-C-3’’’’’’’’) confirmed the presence of two HBA units (Li and Doi, 1998; Inose et al., 1992 ; Laurençon et al., 2013; Mabou et al., 2014). The HMBC correlations observed between the ester carbonyl at δ_C 170.3 (HBA-C-1’’’’’’’) and the methylene protons at δ_H 2.81 (HBA-H-2’’’’’’’a) and 2.73 (HBA-H-2’’’’’’’b) and the oxymethine proton at δ_H 5.31 (HBA-H-3’’’’’’’); and between the carbonyl at δ_C 171.1 (HBA′-C-1’’’’’’’’) and the two oxymethine protons at δ_H 5.31 (HBA-H-3’’’’’’’) and 4.18 (HBA′-H-3’’’’’’’’), and the methylene protons at δ_H 2.49 (HBA′-H-2’’’’’’’’a) and 2.44 (HBA′-H-2’’’’’’’’b) suggested that the two HBA were attached together (Inose et al., 1992 ; Laurençon et al., 2013; Mabou et al., 2014). The sequences and linkage sites of the different monosaccharide units were determined with the aid of key HMBC correlations. A correlation between the ester carbonyl at δ_C 175.8 (C-28) and the fucose anomeric proton (δ_H 5.41) revealed the attachment of the fucose. Correlations between the Fuc-C-2’’’ (δ_C 74.1) and the rhamnose anomeric proton (δ_H 5.38), the Fuc-C-3’’’ (δ_C 80.8) and the arabinose anomeric proton (δ_H 4.41), between Rha-C-4’’’’ (δ_C 82.5) and the xylose anomeric proton (δ_H 4.51), and between the ester carbonyl at δ_C 170.3 (HBA-C-1’’’’’’’) and Fuc-H-4’’’ (δ_H 5.30) revealed the remaining connectivity. Thus the sugar unit is 28-*O*-β-D-xylopyranosyl-(1→4)-α-L-rhamnopyranosyl-(1→2)-[α-L-arabinopyranosyl-(1→3)]-4-*O*-(3′-hydroxybutanoyloxy-3-hydroxylbutanoyloxy)-β-D-fucopyranoside. The structure of compound **1** was also supported by the ^{1}H-^{1}H ROESY spectrum, which revealed correlations between Rha-H-1’’’’ and Fuc-H-2’’’, Fuc-H-3’’’ and Ara-H-1’’’’’’ and Xyl-H-1’’’’’ and Rha-H-4’’’’. Thus compound **1**, leptocarposide B, is 28-*O*-β-D-xylopyranosyl-(1→4)-α-L-rhamnopyranosyl-(1→2)-[α-L-arabinopyranosyl-(1→3)]-4-*O*-(3′-hydroxybutanoyloxy-3-hydroxybutanoyloxy)-β-D-fucopyranosylzanhic acid (Fig. 1).

Compound **2** was obtained as a white amorphous solid which reacted positively with Liebermann-Burchard reagent. Its positive HR-TOFESIMS exhibited a pseudo-molecular ion peak at *m/z* 1283.6044 $[M+Na]^+$ (calcd. for $C_{61}H_{96}O_{27}Na$ 1283.6037), indicating a molecular formula $C_{61}H_{96}O_{27}$. The ^{1}H- and ^{13}C-NMR spectra were very similar to those of compound **1**, except for the presence of a glucopyranose unit and the absence of the arabinopyranose unit and the hydroxyl group at C-16 (δ_C 28.8 (C-16); δ_H 2.07 (m, H-16α), 1.65 (m, H-16β)). Thus the aglycone moiety of compound **2** was established as medicagenic acid, 2β,3β-dihydroxyolean-12-ene-23,28-dioic acid (Mahato and Kundu, 1994; Lavaud et al., 1998; Inoue et al., 2009, Mabou et al., 2014). The loss of the arabinopyranose unit was apparent from the shielded chemical shift of Fuc-C-3''' (δ_C 73.2). The anomeric proton at δ_H 4.41 (d, *J* = 7.9 Hz, H-1') and the corresponding anomeric carbon at δ_C 103.2 (C-1') suggested the presence of a glucopyranose moiety. Analysis of COSY, TOCSY and ROESY spectra allowed the full identification of the spin systems of all the sugars, a glucopyranose, a fucopyranose, a rhamnopyranose and a xylopyranose (Table 2). The linkage of the glucopyranosyl unit to C-3 of the aglycone was determined by the HMBC correlation between Glc-C-1' and H-3. The chemical shifts of C-3 (δ_C 85.2) and C-28 (δ_C 176.7) confirmed the attachment of the sugar units to the aglycone and showed that compound **2** was a bidesmosidic saponin (Lavaud et al., 1998; Inoue et al., 2009). The sugar units were confirmed by thin layer chromatography (TLC) after hydrolysis, and the D or L-configurations were established as for compound **1** (Mabou et al., 2014). Thus, compound **2,** leptocarposide C, is 3-*O*-β-D-glucopyranosyl-28-*O*-β-D-xylopyranosyl-(1→4)-α-L-rhamnopyranosyl-(1→2)-4-*O*-(3′-hydroxybutanoyloxy-3-hydroxybutanoyloxy)-β-D-fucopyranosylmedicagenic acid (Fig. 1).

Compound **3**, a white amorphous solid, had a molecular formula $C_{72}H_{114}O_{37}$, deduced from the pseudo-molecular ion peak at *m/z* 1593.6927 $[M+Na]^+$ (calcd. for $C_{72}H_{114}O_{37}Na$ 1593.6937) in its positive HR-TOFESIMS, suggesting two additional hexopyranose units relative to compound **1**. The ^{1}H- and ^{13}C-NMR spectral data for the aglycone part were very similar to those of compound **1,** indicating that it was zanhic acid. Its ^{1}H-NMR spectrum**,** showed signals corresponding to two additional anomeric protons at δ_H 4.47 (d, *J* = 7.8 Hz, H-1') and 4.43 (d, *J* = 7.8 Hz, H-1''), correlating to the corresponding anomeric carbons at δ_C 102.9 (C-1') and 103.1 (C-1'') in the HSQC spectrum. Analysis of the COSY, TOCSY and ROESY spectra revealed the spin systems of the two new glucopyranoses, in addition to a fucopyranose, a rhamnopyranose, a xylopyranose and a arabinopyranose. An HMBC correlation between Glc'-C-1'' (δ_C 103.1) and Glc-H-4' (δ_H 3.63) showed that the two

glucopyranose units were attached together. The site of linkage of this bisaccharide moiety was determined by the HMBC correlation between Glc-C-1' (δ_C 102.9) and H-3 (δ_H 4.15). The chemical shifts of C-28 (δ_C 175.8) and C-3 (δ_C 85.5) confirmed that compound **3** was a bidesmosidic saponin (Lavaud et al., 1998; Inoue et al., 2009; Mabou et al., 2014). The sugar units were confirmed by thin layer chromatography (TLC) after hydrolysis, and the D or L-configurations were determined as for compounds **1** and **2** (Mabou et al., 2014). Thus compound **3.** leptocarposide D, is 3-*O*-*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl-28-*O*-*β*-D-xylopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→2)-4-*O*-(3′-hydroxybutanoyloxy-3-hydroxybutanoyloxy)-*β*-D-fucopyranosylzanhic acid (Fig. 1).

3. Experimental

3.1. General experimental procedures

The melting points were recorded with a Reichert microscope (Reichert Technologies, Depew, New York USA) and are uncorrected. IR spectra were recorded with a Shimadzu FT-IR-8400S (Shimadzu, France) spectrophotometer. ^{1}H (500 MHz) and ^{13}C (125 MHz) NMR spectra were recorded on a BRUKER Avance DRX-500 spectrometer (Bruker, Wissembourg, France) equipped with a BBFO+5 mm sonde. ^{1}H (600 MHz) and ^{13}C (150 MHz) NMR spectra were recorded on a BRUKER Avance III-600 spectrometer (Bruker, Wissembourg, France) equipped with a cryoplatform using CD_3OD with TMS as the internal standard. TOF-ESIMS and HR-TOFESIMS experiments were performed using a Micromass Q-TOF micro instrument (Manchester, UK) with an electrospray source. The samples were introduced by direct infusion in a solution of MeOH at a rate of 5μL min^{-1}. The optical rotations were measured on a Bellingham & Stanley ADP 220 polarimeter (Bellingham + Stanley Ltd, United-Kingdom). Column chromatography was run on Merck silica gel (VWR, France) 60 (70-230 mesh) and gel permeation on Sephadex LH-20 (VWR, France), while TLC was carried out on silica gel GF_{254} pre-coated plates with detection accomplished by spraying with 50% H_2SO_4 followed by heating at 100 °C or by visualizing with a UV lamp at 254 and 365 nm.

3.2. Plant material

The whole plant of *Ludwigia leptocarpa* was collected in Foto village (Menoua Division, Western region of Cameroon), in April 2011. Authentication was performed by Victor Nana, a botanist of the Cameroon National Herbarium, Yaoundé, where a voucher specimen (N° 38782/HNC) has been deposited.

3.3. Extraction and isolation

The dried whole plant of *L. leptocarpa* (4 kg) was extracted with MeOH at room temperature for 3 days, and the extract was concentrated to dryness under reduced pressure. Part of residue obtained (102 g) was suspended in water and successively extracted with ethyl acetate and *n*-butanol to obtain, after evaporation of solvent, 20 g and 40 g, respectively. Part of the *n*-butanol-solute extract (30 g) was purified by silica gel column chromatography, eluting with EtOAc containing increasing MeOH (10 %, 20 %, 30 %, 40 %, and 50 %). Five sub-fractions (G_1-G_5) were obtained. Fraction G_2 (3.1 g) was purified by silica gel column chromatography eluting with EtOAc-MeOH (8.5:1.5) to give compound **5** (white amorphous powder, 41 mg) and a mixture of compounds **7**, **8** and **9** (25 mg). Fractions G_3 and G_4 were combined and purified by silica gel column chromatography eluting with the mixture of EtOAc-MeOH-H_2O (8:1:1) to give the compounds **6** (white amorphous powder, 30 mg), **1** (white amorphous solid, 38 mg) and **2** (white amorphous solid, 24 mg). Fraction G_5 (2.5 g) was purified by silica gel column chromatography eluting with EtOAc-MeOH-H_2O (7:2:1) to give compounds **3** (white amorphous solid, 40 mg), **4** (white amorphous solid, 66 mg) and the mixture of compounds **10**, **11**, **12** and **13** (white amorphous solid, 15 mg).

3.4. New compound information

Leptocarpside B (**1**): white amorphous powder; ^{1}H- and ^{13}C-NMR data, see Tables 1 and 2; $[\alpha]_D^{20}$ -9° (*c* 0.15, MeOH); IR (KBr) ν_{max} (cm^{-1}): 3500-3300 (OH), 1750, (COOR), 1710 (COOH), 1635 (C=C), 1670 (C-O); HRESIMS (positive-ion mode) *m/z*: 1269.5870 $[M+Na]^+$ (calcd. for $C_{60}H_{94}O_{27}Na$ 1269.5880).

Leptocarpside C (**2**): white amorphous powder; ^{1}H- and ^{13}C-NMR data, see Tables 1 and 2; $[\alpha]_D^{20}$ +5° (*c* 0.68, MeOH); IR (KBr) ν_{max} (cm^{-1}): 3500-3300 (OH), 1760, (COOR), 1710 (COOH), 1640 (C=C), 1656 (C-O); HRESIMS (positive-ion mode) *m/z*: 1283.6044 $[M+Na]^+$ (calcd. for $C_{61}H_{96}O_{27}Na$ 1283.6037).

Leptocarpside D (**3**): white amorphous powder; ^{1}H- and ^{13}C-NMR data, see Tables 1 and 2; $[\alpha]_D^{20}$ -2 (*c* 0.18, MeOH); IR (KBr) ν_{max} (cm^{-1}): 3500-3300 (OH), 1750, (COOR), 1710 (COOH), 1630 (C=C), 1650 (C-O); HRESIMS (positive-ion mode) *m/z*: 1593.6927 $[M+Na]^+$ (calcd. for $C_{72}H_{114}O_{37}Na$ 1593.6937).

3.5. Acid hydrolysis and determination of the absolute configurations of the monosaccharide

Compounds **1-3** (each, 10 mg) were heated individually in 1 M HCl (dioxane-H_2O, 1:1, 2 mL) at 100 °C for 2 h. After removal of the dioxane, the solutions were extracted with EtOAc (2 mL x 3). The remaining aqueous layers, containing the monosaccharides, were concentrated under reduced pressure to dryness. The residues were dissolved in pyridine (0.1 mL), to which

0.1 M L-cysteine methyl ester hydrochloride in pyridine (0.20 mL) was added, and heated at 60 °C for 2 h, dried in *vacuo*, and trimethylsilylated with hexamethyldisilazane-trimethylchlorosilane (0.2 mL) at 60 °C for 2 h. Each mixture was partitioned between *n*-hexane and H_2O (0.4 mL) and the *n*-hexane was subjected to GC-MS analysis. The absolute configurations of the monosoccharides were identified as D-fucose, D-xylose, L-arabinose and L-rhamnose in compound **1**; D-glucose, D-fucose, D-xylose and L-rhamnose in compound **2** and D-glucose, D-fucose, D-xylose, L-arabinose and L-rhamnose in compound **3**, by comparison of the derivative retention times with literature values (Zheng, et al., 2007) and with authentic samples (10.31, 7.75, 6.32, 6.36 and 7.52, respectively).

References

Agrawal, P.K., 1992. NMR spectroscopy in the structural elucidation of oligosaccharides and glycosides. *Phytochemistry* 31, 3307-3330.

Ali, Z., Fronczek, R.F., Khan, A.I., 2008. Phenylalkanoids and monoterpene analogues from the Roots of *Rhodiola rosea*. *Planta Med.* 74, 178-181.

Averett, J.E., Zardini, E.M. Hoch, P.C., 1990. Flavonoid systematic of ten sections of *Ludwigia* (Onagraceae). *Biochem. Syst. Ecol.* 18, 529-532.

Begbie, R. and Richtmyer K.A., 1966. The isolation of some heptoses, heptuloses, octuloses, and nonuloses from *Primula officinalis* Jacq. *Carbohydr. Res.* 2, 272-288.

Brundish, D.E. and Baddiley, J. 1968. Synthesis of glucosylglycerols and diglucosylglycerols and their identification in small amounts. *Carbohydr. Res.* 8, 308-316.

Burkill, H.M., 1997. The useful plants of West Tropical Africa. *Roy. Bot. Gard*. p 969.

Cateni, F., Zilic, J., Zacchigna, M., 2008. Isolation and structure elucidation of cerebrosides from *Euphorbia platyphyllos* L. *Sci. Pharm.* 76, 451-469.

Gorin, P.A.J and Mazurek, M., 1975. Further studies on the assignment of signals in ^{13}C magnetic resonance spectra of aldoses and derivatives methyl glycosides. Can. *J. Chem.* 53, 1212-1223.

Herve du Penhoat, P.C.M. and Perlin, A.S. 1974. A carbon-13 N.M.R. Spectral study of D-psicose: Anomeric and ring-form equilibria of solutions of 2-hexuloses. *Carbohydr. Res.* 36, 111-120.

Inose, Y., Miyase, T., Ueno, A., 1992. Studies on the constituents of *Solidago virgaurea* L. II. Structures of solidago-saponins X-XX. *Chem. Pharm. Bull*. 40, 946-953.

Inoue, M., Ohtani, K., Kasai, R., Okukubo, M., Andriantsiferana, M., Yamasaki, K., Koike. T., 2009. Cytotoxic 16-ß-[(D-xylopyranosyl)oxy]oxohexadecanyl triterpene glycosides from a Malagasy plant, *Physena sessiliflora*. *Phytochemistry* 70, 1195-1202.

Laurençon, L., Sarrazin, E., Chevalier, M., Prêcheur, I., Herbette, G., Fernandez, X., 2013. Triterpenoid saponins from the aerial parts of *Solidago virgaurea alpestris* with inhibiting activity of *Candida albicans* yeast-hyphal conversion. *Phytochemistry* 86, 103-111.

Lavaud, C., Voutquenne, L., Massiot, G., Le Men-Olivier, L., Das, B.C., Laprevote, O., Serani, L., Delaude, C., Bechi, M., 1998. Saponins from the stem bark of *Filicium decipiens*. *Phytochemistry* 47,441-449.

Li, J., Uzawa, J., Doi, Y., 1998. Conformational analysis of oligomers of (*R*)-3-hydroxy butanoic acid in solutions by ^{1}H NMR spectroscopy. *Bull. Chem. Soc. Jpn*. 71, 1683-1689.

Mabou, F.D., Foning, T.P.L., Ngnokam, D., Harakat, D., Voutquenne-Nazabadioko, L., 2014. Leptocarposide: a new triterpenoid glycoside from *Ludwigia leptocarpa* (Onagraceae). *Magn. Reson. Chem.* 52, 32-36.

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

Noiarsa, P., Yu, Q., Matsunami, K., Otsuka, H., Ruchirawat, S., Kanchanapoom, T., 2007. (*Z*)-3-Hexenyl diglycosides from *Spermacoce laevis* Roxb. *J. Nat. Med.* 61, 406-409.

Okada, H., Fukushi, E., Yamamori, A., Kawazoe, N., Onodera, S., Kawabata, J. and Shiomi, N. 2010. Novel fructopyranose ologosacharides isolated from fermented beverage of plant extract. *Carbohydr. Res*. 345, 414-418.

Okuda, T., Osaki, K. and Taga, T. 1969. α-coriofuranose: conformationally unfavoured structure in the crystalline state and rapid mutarotation of coriose. *J. Chem. Soc. Chem. Comm.* 15, 851-852.

Oziegbe, M., Faluyi, J.L., 2012. Reproductive biology of *Ludwigia leptocarpa* and *L. adscendans* subsp. Diffusa in Ile Ife, Nigeria. *Turk J. Bot.* 36, 162-173.

Rosa, D.S., Giulio, D.A., Tommonaro, G., 1996. Aliphatic and aromatic glycosides from the cell cultures of *Lycopersicon esculentum*. *Phytochemistry*, 42, 1031-1034.

Son, B.W., 1990. Glycolipids from *Gracilaria verrucosa*. *Phytochemistry*, 29, 307-309.

Sridhar, R.A., Merugu, R., Atthapu, T., 2013. A New Triterpene from *ludwigia hyssopifolia* (G.Don) Exell. *Int. J. Chem. Tech. Res.* 5, 342-346.

Tiejun, L., Tao, X., Xiaochun, W., Daxiang, L., Xiaoyi, W., 2006. Cerebrosides from the roots of *Serratula chinensis*. *Molecules* **11**, 677-683.

Valentine, K.M., Doner, L.W. and Pfeffer P.E. 1981. ^{13}C-NMR resonance assignment of psicose by the differential isotope-shift technique. *Carbohydr. Res.* 96, 293-298.

Zheng, Q., Li, W., Han, L., Koike, K., 2007. Pancreatic lipase-inhibiting triterpenoid saponins from *Gypsophila oldhamiana*. *Chem. Pharm. Bull.* 55, 646-650.

Table 1

^{1}H NMR spectral data of compounds **1-3** (MeOD, 600 MHz)

N°	Saponins			N°	Saponins		
	1	**2**	**3**		**1**	**2**	**3**
1	1.27 (m)	1.28 (m)	1.30 (m)	Fuc			
	2.14 (dt, 14.4, 2.5)	2.13 (t, 6.1)	2.15 (dm, 13.2)	1’’’	5.41 (d, 7.8)	5.41 (d, 7.9)	5.41 (d, 7.9)
2	4.11 (q, 3.3)	4.32 (m)	4.31 (q, 3.4)	2’’’	3.94 (dd, 9.4, 7.8)	3.79 (m)	3.94 (dd, 9.2, 7.9)
3	4.00 (d, 3.3)	4.12 (m)	4.15 (d, 3.4)	3’’’	4.03 (dd, 9.4, 3.5)	3.92 (m)	4.03 (dd, 9.2, 3.6)
4	-	-	-	4’’’	5.30 (d, 3.5)	5.12 (d, 3.7)	5.30 (d, 3.6)
5	1.62 (m)	1.64 (m)	1.64 (m)	5’’’	3.87 (m)	3.87 (m)	3.88 (m)
6	1.25 (m)	1.22 (m)	1.28 (m)	6’’’	1.08 (d, 6.5)	1.09 (d, 6.3)	1.08 (d, 6.4)
	1.62 (m)	1.63 (m)	1.60 (m)				
7	1.40 (m)	1.39 (m)	1.39 (m)	Rha			
	1.59 (dd, 11.6, 4.2)	1.55 (m)	1.61 (m)	1’’’’	5.38 (d, 1.5)	5.40 (brs)	5.38 (d, 1.6)
8	-	-	-	2’’’’	3.97 (dd, 8.1, 1.5)	3.96 (m)	3.98 (dd, 8.9, 1.6)
9	1.67 (m)	1.61 (m)	1.69 (m)	3’’’’	3.83 (dd, 9.1, 8.1)	3.84 (m)	3.83(m)
10	-	-	-	4’’’’	3.57 (t, 9.1)	3.50 (t, 9.3)	3.55 (t, 9.4)
11	1.97 (m)	1.63 (m)	1.95 (m)	5’’’’	3.82 (m)	3.83 (m)	3.81 (m)
	2.04 (m)	2.07 (m)	2.03 (m)				
12	5.36 (t, 3.1)	5.30 (t, 3.5)	5.36 (t, 4.9)	6’’’’	1.35 (d, 6.4)	1.35 (d, 6.4)	1.35 (d, 6.3)
13	-	-	-	Xyl			
				1’’’’’	4.51 (d, 7.6)	4.43 (d, 7.5)	4.49 (d, 7.4)
14	-	-	-	2’’’’’	3.21 (dd, 8.9, 7.6)	3.22 (m)	3.26 (dd, 9.5, 6.3)
15	1.48 (dd, 11.8, 2.8)	1.37 (m)	1.47 (dd, 11.3, 4.1)	3’’’’’	3.25 (m)	3.30 (m)	3.30 (t, 9.5)
	1.67 (dm, 11.8)	1.63 (m)	1.68 (dm, 11.3)				
16	4.48 (t, 2.9)	1.65 (m)	4.49 (t, 2.5)	4’’’’’	3.52 (m)	3.50 (m)	3.52 (m)
		2.07 (m)					
17	-	-	-	5’’’’’	3.20 (t, 10.6)	3.19 (t, 10.8)	3.21 (t, 11.5)
					3.88 (dd, 11.4, 5.2)	3.85 (m)	3.86 (m)
18	2.95 (dd, 14.2, 3.9)	2.84 (m)	2.95 (dd, 13.8, 3.9)	Ara			
				1’’’’’’	4.41 (d, 6.8)	-	4.42 (d, 6.6)
19	1.23 (m)	1.16 (m)	1.09 (dd, 13.8, 3.9)	2’’’’’’	3.56 (dd, 8.7, 6.8)	-	3.55 (m)
	2.32 (t, 13.8)	1.76 (m)	2.31 (t, 13.8)				
20	-	-	-	3’’’’’’	3.53 (m)	-	3.52 (t, 2.1)
21	1.21 (m)	1.27 (m)	1.20 (m)	4’’’’’’	3.80 (m)	-	3.80 (m)
	1.97 (m)	1.42 (m)	1.96 (m)				
22	1.82 (dd, 14.4, 4.5)	1.63 (m)	1.80 (m)	5’’’’’’	3.53 (dd, 11.6, 1.4)	-	3.53 (m)
	1.97 (m)	1.74 (m)	1.96 (m)				3.85 (m)

					3.84 (dd, 11.6, 3.5)		
23	-	-	-	Glc			
				1’	-	4.41 (d, 7.9)	4.47 (d, 7.8)
24	1.34 (s)	1.39 (s)	1.37 (s)	2’	-	3.23 (dd, 8.7, 7.9)	3.30 (t, 8.0)
25	1.30 (s)	1.30 (s)	1.30 (s)	3’	-	3.27 (m)	3.53 (m)
26	0.81 (s)	0.81 (s)	0.80 (s)	4’	-	3.36 (m)	3.63 (m)
27	1.41 (s)	1.40 (s)	1.40 (s)	5’	-	3.36 (m)	3.42 (t, 9.5)
28	-	-	-	6’	-	3.70 (m)	3.83 (dd, 11.6, 1.8)
						3.81 (m)	3.90 (dm, 11.6)
29	0.90 (s)	0.90 (s)	0.90 (s)	Glc			
				1’’	-	-	4.43 (d, 7.8)
30	0.98 (s)	0.96 (s)	0.98 (s)	2’’	-	-	3.24 (dd, 9.0, 7.8)
				3’’	-	-	3.39 (t, 9.0)
				4’’	-	-	3.34 (m)
				5’’	-	-	3.34 (m)
				6’’	-	-	3.69 (dd, 11.8, 5.0)
							3.88 (dm, 11.8)
				HBA			
				1’’’’’’’	-	-	-
				2’’’’’’’	2.73 (dd, 16.1, 5.7)	2.74 (dd, 16.1, 5.6)	2.73 (dd, 16.0, 5.8)
							2.82 (dd, 16.0, 7.4)
					2.81 (dd, 16.1, 7.3)	2.84 (dd, 16.1, 7.3)	
				3’’’’’’’	5.31 (m)	5.30 (m)	5.31 (m)
				4’’’’’’’	1.35 (d, 6.2)	1.30 (m)	1.35 (t, 6.2)
				HBA’			
				1’’’’’’’’	-	-	-
				2’’’’’’’’	2.44 (dd, 15.0, 5.1)	2.38 (dd, 15.0, 5.3)	2.5 (dd, 14.8, 5.7)
							2.61 (dd, 14.8, 7.8)
					2.49 (dd, 15.0, 7.3)	2.44 (dd, 15.0, 7.5)	
				3’’’’’’’’	4.18 (m)	4.16 (m)	4.18 (m)
				4’’’’’’’’	1.23 (d, 6.1)	1.22 (d, 6.1)	1.23 (d, 6.2)

Table 2

^{13}C NMR spectral data of compounds **1-3** (MeOD, 150 MHz)

N°	Saponins			N°	Saponins		
	1	**2**	**3**		**1**	**2**	**3**
1	44.4	43.6	43.5	Fuc 1’’’	93.7	93.7	93.6
2	71.1	69.8	70.0	2’’’	72.1	73.2	72.9
3	75.2	85.2	85.6	3’’’	80.8	73.2	80.8
4	53.1	52.5	52.7	4’’’	73.7	73.1	73.7
5	51.5	51.8	51.8	5’’’	69.8	69.7	69.8
6	20.7	20.4	20.5	6’’’	15.5	15.2	15.4
7	32.6	32.4	32.5	Rha 1’’’’	100.0	100.1	100.2
8	39.8	39.8	39.9	2’’’’	70.4	70.4	70.4
9	47.1	47.1	47.1	3’’’’	70.7	70.8	70.8
10	36.1	36.0	36.0	4’’’’	82.5	83.7	82.9
11	23.3	22.8	23.3	5’’’’	67.6	67.5	67.7
12	121.9	122.2	122.0	6’’’’	17.0	16.9	17.0
13	143.5	143.6	143.5	Xyl 1’’’’’	105.5	106.1	105.6
14	41.5	41.4	41.6	2’’’’’	74.7	74.9	74.8
15	35.0	24.6	35.1	3’’’’’	76.9	77.0	77.0
16	73.4	28.8	73.4	4’’’’’	69.5	69.7	69.5
17	48.9	46.7	48.9	5’’’’’	65.6	65.9	65.9
18	40.9	41.8	40.9	Ara 1’’’’’’	104.4	-	104.4
19	46.8	46.8	46.8	2’’’’’’	70.9	-	71.1
20	29.4	29.1	29.1	3’’’’’’	73.7	-	73.0
21	35.2	35.1	35.1	4’’’’’’	68.2	-	68.2
22	30.5	30.1	29.9	5’’’’’’	65.9	-	65.6
23	182.1	183.2	183.6	Glc 1’	-	103.2	102.9
24	13.2	13.0	13.4	2’	-	73.9	73.7
25	16.2	15.9	16.1	3’	-	76.3	74.7
26	16.5	16.7	16.5	4’	-	69.9	78.4
27	25.8	24.9	25.9	5’	-	76.3	74.9
28	175.8	176.7	175.8	6’	-	60.9	60.9
29	31.9	32.1	31.9	Glc 1’’	-	-	103.1
30	23.6	23.3	23.6	2’’	-	-	73.5
				3’’	-	-	76.4
				4’’	-	-	69.9
				5’’	-	-	76.7
				6’’	-	-	60.1
				HBA 1’’’’’’’	170.3	169.9	170.1
				2’’’’’’’	40.0	39.9	39.8
				3’’’’’’’	67.3	67.4	67.5
				4’’’’’’’	18.6	18.7	18.6
				HBA’ 1’’’’’’’’	171.1	170.4	171.4
				2’’’’’’’’	43.7	43.6	43.6

	3’’’’’’’’	64.2	64.1	64.3
	4’’’’’’’’	21.9	21.9	21.9

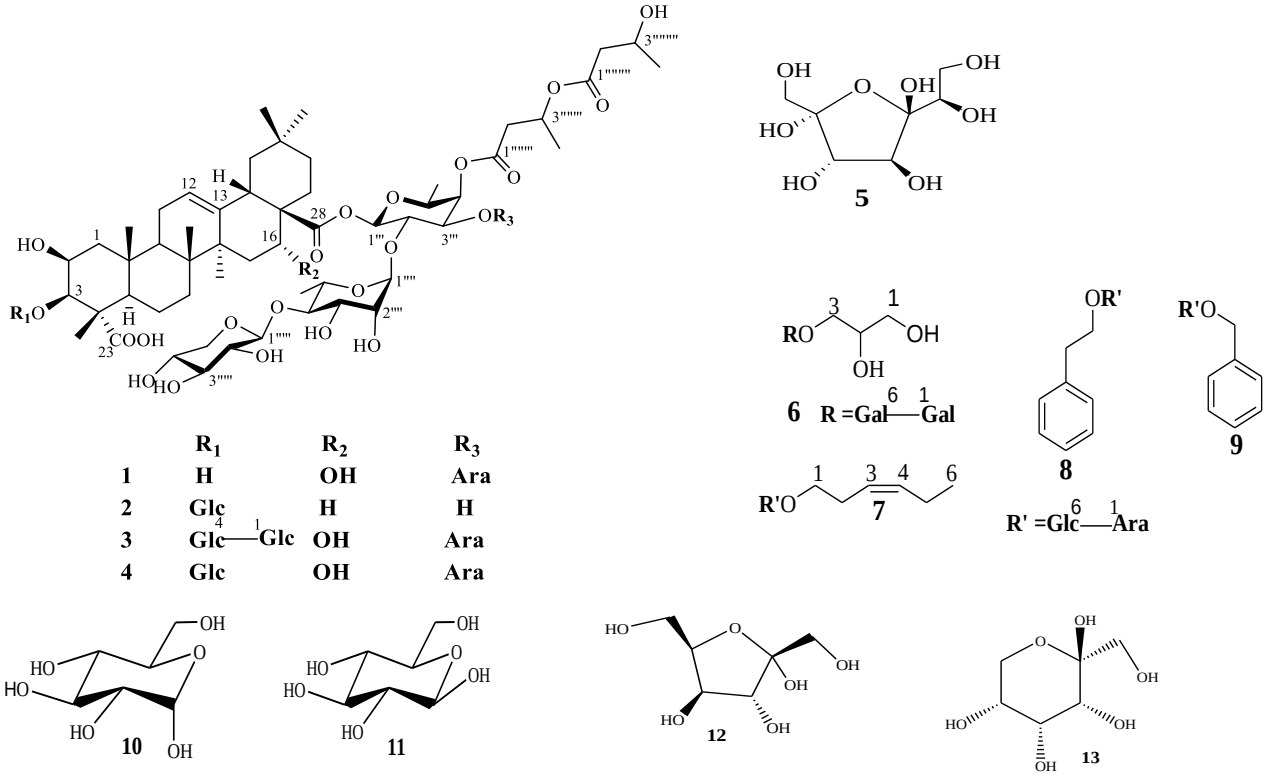

Fig. 1. Structures of compounds 1-13 isolated from *n*-BuOH soluble extract of *L. leptocarpa*.