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Two new bioactive salsolanol and biphenylsalsinol from the aerial parts of *Salsola villosa* Delile. ex Schul. (Chenopodiaceae) growing in Saudi Arabia

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ABSTRACT

Objective: To isolate and characterize the bioactive secondary metabolites from aerial parts of widespread Chenopodiaceae taxa growing in Saudi Arabia: *Salsola villosa* Delile. ex Schul.

Methods: Antibacterial activities of chloroformic extract, fractions and isolate compounds was evaluated against five bacterial strains (*Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella typhimurium*, *Staphylococcus aureus* and *Staphylococcus epidermidis*), using a paper disc diffusion method. The purification of compound(s) of chloroform extract was done by chromatographic column of silica gel. The structure elucidation was determined by extensive spectroscopic analysis (^{1}H and ^{13}C nuclear magnetic resonance, correlation spectroscopy, heteronuclear multiple bond correlation, heteronuclear multiple quantum coherence and nuclear overhauser enhancement spectroscopy) and high resolution electrospray ionization mass spectroscopy analysis.

Results: Bioactivity guided fractionation of the chloroformic extract led to the isolation of two bioactive compounds: 4-(4′-hydroxy-2′-methylcyclopent-2′-enyloxy)-4-methylcyclopent-2-enol (1) named salsolanol and 4′-[3-(hydroxymethyl)oxiran-2-yl]-3-[(E)-3-hydroxyprop-1-en-1-yl]-6, 2′-dimethoxy [1, 1′-biphenyl]-2-ol (2) named biphenylsalsinol. The antibacterial effects of the chloroform extracts, fractions and isolated compounds 1 and 2 were also evaluated in this work. Results showed that the compounds 1 and 2 exhibited antibacterial activities against four strains: *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Escherichia coli* and *Pseudomonas aeruginosa* with diameter of zone of inhibition ranging between (9.33 ± 0.94) to (26.33 ± 0.94) mm.

Conclusions: Based on data presented here, two new natural compounds secondary cyclic alcohol 1 and biphenylpropanoid 2 isolated from bioactive chloroformic extract from aerial parts of *Salsola villosa* can be responsible for its antibacterial activities.

1. Introduction

Salsola is the largest genus of the family Chenopodiaceae and includes over 200 species distributed in arid and semi-arid regions of Middle East, Asia, Europe, and Africa [1–3]. A wide range of structurally diverse secondary metabolites have been identified in *Salsola* species, such as alkaloids (salsolin and salsolidine) that have been isolated from *Salsola kali* [4], flavonoids and phenolic compounds from *Salsola kali*, *Salsola soda*, *Salsola oppositifolia* and *Salsola collina* [5,6], triterpene saponins from *Salsola imbricate*, *Salsola baryosma* and *Salsola somalensis* [7,8], antioxidant bibenzyl and isoflavonoid from *Salsola tetrandra* [9]. Our previous work on the aerial parts of *Salsola tetrandra* leds to new norisoprenoids, long chain fatty hydroxyl, taxiphyllin, trans-N-feruloyltyramine, S-

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(−)-trans-N-feruloyloctopamine and coumarinolignan [10]. In our efforts to discover new and potentially bioactive secondary metabolites from *Salsola* species, we investigated the chloroformic extract of the aerial parts of *Salsola villosa* (*S. villosa*) which grows in Saudi Arabia. Here we report the isolation, the structure elucidation, and the biological activities of two new bioactive compounds. Their structures were elucidated by extensive spectroscopic methods including one-dimensional nuclear magnetic resonance (1D-NMR) and two-dimensional nuclear magnetic resonance (2D-NMR) experiments as well as high resolution electrospray ionization mass spectroscopy (HRESIMS) analysis.

2. Materials and methods

2.1. General experimental procedures

The optical rotations were recorded on a Perkin–Elmer 241-MC polarimeter. Fourier transform infrared spectroscopy (FTIR) spectra were recorded using Perkin–Elmer IR 157G infrared spectrophotometer. ^{1}H-(300 MHz), ^{13}C-(75 MHz) and 2D-NMR spectra of compounds 1 and 2 were recorded in $CDCl_3$ and CD_3OD respectively with a Bruker NMR-300 spectrometer. The residual solvent resonances were used as internal references. Chemical shifts were expressed in ppm and coupling constants were given in Hertz. HRESIMS were measured on a Shimadzu LCMS-IT-TOF mass spectrometry.

2.2. Plant material

Aerial parts of *S. villosa* Delile. ex Schul were collected from Arar, Saudi Arabia, on November 2013. The plant was identified by Dr. Ahmed Kamel Osman, College of Sciences, Department of Biology, Kingdom of Saudi Arabia. A voucher specimen was deposited at the herbarium.

2.3. Extraction and isolation

The air-dried powdered plant 1.5 kg was extracted with methanol at room temperature for 6 days. Evaporation of the solvent under reduced pressure from the crude extract yielded a residue of 164 g. The residue suspended in a H_2O solution (2 L) and then extracted successively with petroleum ether, $CHCl_3$, ethyl acetate (EtOAc) and BuOH, yielding 45, 12.4, 32.4 and 24 g sub-extracts, respectively. Bioactivity-guided fractionation of the chloroformic extract on a silica gel column (mesh 70–230, 70 × 5 cm, inner diamete, *n*-hexane, EtOAc, methanol gradients) led to eight fractions (F_1–F_8). Bioactivity was detected only in fraction F_6 and F_8. The highest antimicrobial effect of sub-fraction F_8 (m = 1.7 g) was rechromatographed by silica gel column using $CHCl_3$/EtOAc gradient as eluent to give five sub-fractions (f_1–f_5). The sub-fraction f_3 (85 mg) which was purified by silica gel column (mesh 70–230, 40 × 1 cm, inner diameter) eluted with $CHCl_3$-EtOAc (80: 20) to yield 6 mg of a bioactive compound 1 (R_f = 0.29, CH_3Cl_2/EtOAc 7:3). The sub-fraction f_5 (56 mg) was purified by preparative thin layer chromatography 85:15 ($CHCl_3$/MeOH) to yield 8 mg of a bioactive compound 2 (R_f = 0.33, $CHCl_3$/MeOH, 9/1). The structures of compounds 1 and 2 were elucidated on the basis of extensive spectroscopic procedures including infrared, high resolution mass spectrometry (HR-MS) and one-dimensional nuclear magnetic resonance (1D-NMR) and 2D-NMR [correlation spectroscopy (COSY), heteronuclear multiple bond correlation (HMBC), and nuclear overhauser enhancement spectroscopy (NOESY)] experiments.

2.4. Antibacterial activities

2.4.1. Bacterial strains

The crude extract, fractions and pure compounds were tested with five reference bacteria at the concentration 1 mg/mL against Gram positive strains represented by *Staphylococcus aureus* ATCC 25923 (*S. aureus*) and *Staphylococcus epidermidis* NCIMB 8853 (*S. epidermidis*) and Gram negative represented by *Escherichia coli* ATCC 25922 (*E. coli*), *Pseudomonas aeruginosa* ATCC 27853 (*P. aeruginosa*), *Salmonella typhimurium* ATCC 19430 (*S. typhimurium*).

2.4.2. Preparation of inoculum

Mueller-Hinton (M–H) broth was inoculated aseptically with the appropriate microorganism, 24 h before testing. This was to ensure that the bacteria was fully adapted to the broth and reached the stationary phase of growth. The inoculated bacterial strains were incubated at 37 °C during 18–24 h in Mueller-Hinton agar, the inoculums suspension contain approximately 10^5 CFU/mL colonies.

2.4.3. Disc diffusion method

The antibacterial assay of crude extract and fractions from *S. villosa* was carried out by the paper disc diffusion method [11–14]. A suspension of each tested microorganism (500 µL) was spread on Petri dishes containing specific sterile Mueller-Hinton agar (pH 7.2) cooled medium (DIFCO Muller Hinton agar, lot 1303004, code 0252-17, autoclave at 121 °C for 15 min). Paper discs (6 mm diameter) were impregnated with 20 µL of the crude extract, fractions and pure compounds kept for drying, and placed on the inoculated Petri dishes, which were, after staying at 4 °C for 2 h, incubated at 37 °C for 24 h. The levofloxacin was used as positive control at 5 µg/disc. The developing inhibition zones were measured in millimeters and compared with those of control discs. All tests were performed in triplicate.

3. Results

The antibacterial activities of the chloroformic extract of *S. villosa* aerial parts were evaluated, at the concentration of 1 mg/mL against five bacterial strains (Table 1). The chloroformic extract exhibited activity against four species *S. aureus*, *S. epidermidis*, *E. coli* and *P. aeruginosa* showed an inhibition zone ranging between (10.33 ± 0.81) to (25.33 ± 0.94) mm (Table 1). Bioactivity guided fractionation of the biologically active crude extract by silica gel chromatography led to the isolation of two new antibacterial natural compounds 1 and 2 (Figure 1). 4-(4′-hydroxy-2′-methylcyclopent-2′-enyloxy)-4-methylcyclopent-2-enol (compound 1) named salsolanol and 4′-[3-(hydroxymethyl) oxiran-2-yl]-3-[(*E*)-3-hydroxyprop-1-en-1-yl]-6, 2′-dimethoxy [1, 1′-biphenyl]-2-ol (compound 2) named biphenylsalsinol. 1D-NMR is present in Tables 2 and 3 and 2D-NMR (COSY, HMBC, and NOESY) experiments are showed in Figures 2 and 3.

According to the results given in Table 1, the chloroform extract and fractions (F_6 and F_8) were found to be active towards

Table 1
Antibacterial activities of $CHCl_3$ extract, fractions, compounds 1 and 2.

Plant fractions and antibiotics	DD values (mm)				
	S. epidermidis	*S. aureus*	*E. coli*	*P. aeruginosa*	*S. typhimurium*
$CHCl_3$ extract	25.33 ± 0.94	12.33 ± 0.57	22.66 ± 0.81	10.33 ± 0.81	na
F_6	9.33 ± 0.81	na	10.66 ± 0.81	na	na
F_8	28.66 ± 0.94	16.66 ± 0.47	22.33 ± 0.57	14.66 ± 0.57	na
Compound 1	12.66 ± 0.47	10.66 ± 0.81	9.33 ± 0.94	na	na
Compound 2	26.33 ± 0.94	16.33 ± 0.94	12.66 ± 0.94	14.33 ± 0.81	na
Negative control (chloroform)	–	–	–	–	–
Levofloxacin[a]	30.33 ± 0.47	29.00 ± 0.81	36.33 ± 0.57	28.66 ± 0.47	18.00 ± 0.81

DD: Diameter of zone of inhibition (mm) including disc diameter of 6 mm; na: Not active; –: No inhibition zone.
[a] Tested at a concentration of 5 μg/disc.

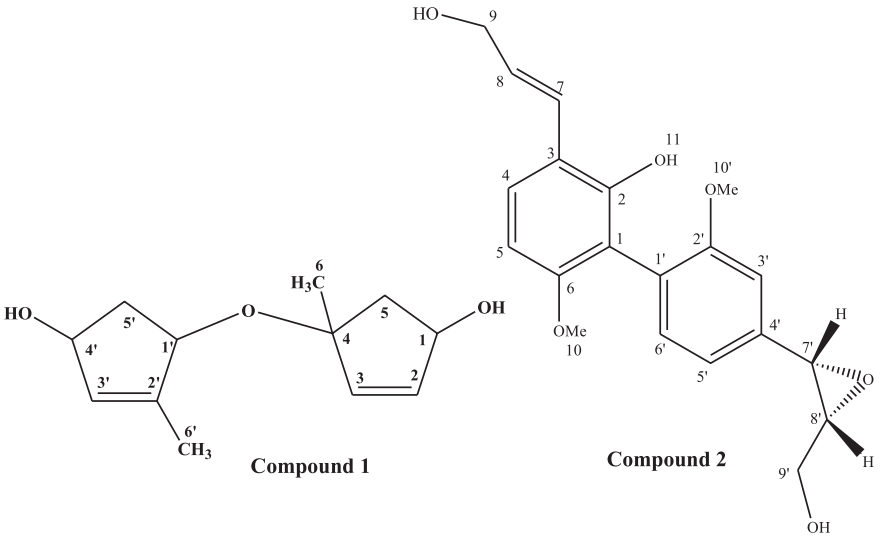

Figure 1. Structures of compounds 1 and 2.

the used bacterial strains. The chloroformic extract showed high diameter of zone of inhibition values both against Gram positive bacteria (25.33 ± 0.94 mm against *S. epidermidis*) and Gram negative bacteria (22.66 ± 0.81) against *E. coli*. However, the fraction F_8 showed the highest diameter of zone of inhibition values against *S. epidermidis*, *S. aureus*, *E. coli* and *P. aeruginosa*: (28.66 ± 0.94), (16.66 ± 0.47), (22.33 ± 0.57) and (14.66 ± 0.57) mm, respectively. Whereas all the samples exhibited no activities against *S. typhimurium*. The fraction F_6 exhibited the lowest diameter of zone of inhibition values respectively against *S. epidermidis* (9.33 ± 0.81) and *E. coli* (10.66 ± 0.81) mm. This fraction seems to be completely not active against three bacterial strains *S. aureus*, *P. aeruginosa*, and *S. typhimurium.*

Table 2
NMR spectral data of compound 1 (CD_3Cl, 300 MHz, 75 Mz *J* in Hz).

Position	^{13}C (δ)	^{1}H (δ)	COSY
1	76.6	4.64 (m)	H-2, H-5a, H-5b
2	141.8	5.80 (dd, 1.8, 5.6)	H-1, H-3
3	135.3	5.76 (dd, 1.2, 5.7)	H-2
4	81.8	–	–
5	45.3	H_{5a}; 2.40 (dd, 7.2, 13.5)	H-1
		H_{5b}; 1.73 (dd, 7.2, 13.5)	
6	28.6	1.30 (s)	–
1′	77.6	4.33 (m)	H-5a, H-5b
2′	147.0	–	–
3′	131.6	5.52 (m)	H-4′
4′	74.3	4.50 (m)	H-3′, H-5′a, H-5'b
5′	51.5	$H_{5'a}$; 2.73 (dt, 7.0, 13.5)	H-1′
		$H_{5'b}$; 1.47 (dt, 7.0, 13.5)	
6′	14.0	1.78 (s)	H-3′

Table 3
NMR spectral data of compound 2 (CD_3OD, 300 MHz, 75 Mz *J* in Hz).

Position	^{13}C (δ)	^{1}H (δ)	COSY
1	136.4	–	–
2	149.8	–	–
3	132.9	–	–
4	114.7	6.78 (1H, d, *J* = 8.1)	H-5
5	108.6	6.95 (1H, d, *J* = 8.1)	H-4
6	151.2	–	–
7	130.5	6.28 (1H, d, *J* = 15.9)	H-8
8	126.8	5.56 (1H, dt, *J* = 15.9 *J* = 6.0)	H-7, H-9
9	64.5	4.21 (2H, d, *J* = 5.7)	H-8
10 (OMe)	56.8	3.82 (3H, s)	–
1′	135.0	–	–
2′	150.4	–	–
3′	117.1	6.97 (1H, d, *J* = 1.9)	H-5′
4′	130.7	–	–
5′	120.2	6.84 (1H, dd, *J* = 8.1, *J* = 1.9)	H-3′, H-6′
6′	111.5	6.92 (1H, d, *J* = 8.1)	H-5′
7′	89.7	5.50 (1H, d, *J* = 6.3)	H-8′
8′	54.5	3.48 (1H, m)	H-7′, H-9′
9′	65.8	4.25 (2H, m)	H-8′
10’ (OMe)	57.2	3.85 (3H, s)	–

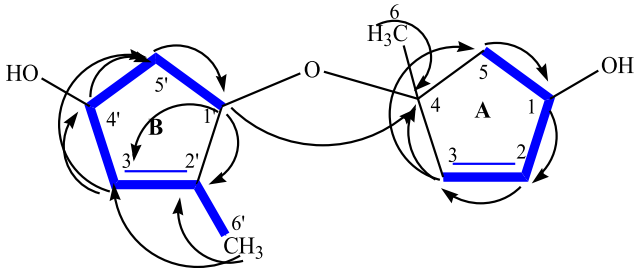

Figure 2. Relevant HMBC (H⌒C) and COSY (—) correlations.

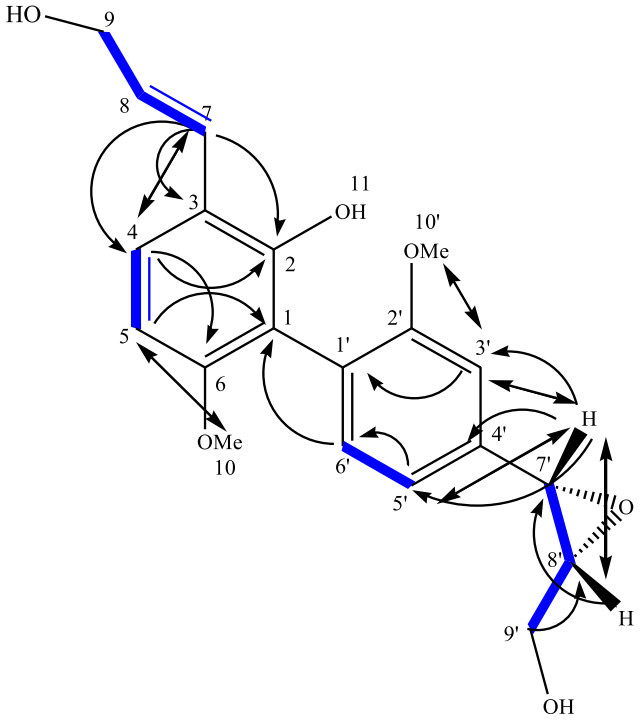

Figure 3. Relevant HMBC (H⌒C), COSY (—) and *nOes* (↔) correlations.

The highest antimicrobial effect was observed for compound 2 against *S. epidermidis*, *S. aureus*, *E. coli* and *P. aeruginosa* (Table 1). On the other hand the compound 1 is slightly active against *S. epidermidis*, *S. aureus* and *E. coli* (Table 1).

Compound 1 was obtained as a colorless oil $[\alpha]D^{25}$ = −22 (c = 0.18, $CHCl_3$) with the molecular formula $C_{12}H_{18}O_3$ calculated from the [M + Na^+] peak at *m/z* 233.1156 (calcd, 233.1153) in the HRESIMS. The IR spectrum displayed absorption bands due to hydroxyl (3432 cm^{-1}) and olefinic (1615 cm^{-1}) groups. ^1H and ^{13}C NMR data (CD_3Cl, 300 and 75 MHz), see Table 2.

Compound 2 Was obtained as a pale yellow gum $[\alpha]D^{25}$ = + 48 (c = 0.2, CH_3OH). Its molecular formula, $C_{20}H_{22}O_6$, was deduced from its HR-EI-MS data, which show [M + Na]$^+$ pseudo-molecular ion peak at *m/z* 381.1318 (calcd, 381.1314). Its UV spectrum revealed maximal absorption bands at 212, 232 and 256 its IR spectrum indicated the presence of hydroxyl group and aromatic ring at 3432 and 1624 cm^{-1}. ^1H and ^{13}C NMR data (CD_3OD, 300 and 75 MHz), see Table 3.

4. Discussion

By the end of the present study, the chloroformic extract of the aerial parts of *S. villosa* growing in Saudi Arabia were investigated. In addition, the isolation, the structure elucidation, and the biological activities of two new bioactive compounds were studied.

In compound 1, The NMR spectra 1 (Table 2) showed two methyl groups at $(\delta)_H/(\delta)_C$ 1.30 (3H, s)/28.6 and 1.78 (3H, s)/14.0 assignable to H-6/C-6 and H-6'/C-6′, a high-field two methylenic carbons at $(\delta)_C$ 45.3 and 51.5 were observed, each bearing nonequivalent protons resonating at δ_H 2.40 (1H, dd, *J* = 7.2 Hz, *J* = 13.5 Hz, H-5a), 1.73 (1H dd, *J* = 7.2 Hz, *J* = 13.5 Hz, H-5b), and δ_H 2.73 (1H, dt, *J* = 7.0 Hz; *J* = 13.5 Hz, H-5'a), and 1.47 (1H, dt, *J* = 7.0 Hz; *J* = 13.5 Hz, H-5'b), three oxymethine protons at $(\delta)_H$ 4.64 (1H, m), 4.33 (1H, m) and 4.50 (1H, m) assignable to H-1, H-1′ and H-4′ respectively, one oxygenated quaternary carbon at $(\delta)_C$ 81.8 assignable to C-4 and three olefinic protons at $(\delta)_H$ 5.80 (dd, *J* = 1.8 Hz, *J* = 5.4 Hz), 5.76 (dd, *J* = 1.2 Hz, *J* = 5.7 Hz) and 5.52 (m), attributable to H-2, H-3 and H-3′ respectively.

Analysis of the heteronuclear multiple quantum coherence and ^1H–^1H COSY spectra (Figure 2) provided evidence for the fragments CH═CH–CHOH–CH2- (A) and CH_3–C═CH–CHOH–CH_2–CHO- (B).

The long-range ^2J and ^3J correlations observed in the HMBC spectrum (Figure 2) of the olefinic proton H-3 at δ_H 5.76 with the oxygenated quaternary carbon C-4 at δ_C 81.8 and methylenic carbon C-5 at δ_C 45.3 allowed the cyclization of fragment A. On the other hand the ^2J and ^3J HMBC correlations of the oxymethine protons H-1′ at δ_H 4.33 with the ethylenic carbon quaternary C-2′ at δ_C 147.0 and ethylenic carbon C-3′ δ_C at 131.6 enabled the cyclization of fragment B. The junction between the two rings A and B was determined from the ^3J correlation through the oxygen atom of the proton of ring An H-1′ at δ_H 4,33 with the quaternary carbon ring B C-4 at δ_C 81,8 observed in HMBC spectrum (Figure 2). The position of two methyl groups is confirmed by the ^2J correlations H-6/C-4 and H-6′/C-2′ in the HBMC spectrum (Figure 2). The small amount of available sample precluded the use of chemical or enzymatic methods for determination of the absolute configuration of C-1, C-4, C-1′ and C-4′.

In compound 2, The ^{1}NMR spectrum (Table 3) exhibited two sets of an aromatic, ABX spin systems at δ_H 6.97 (1H, d, *J* = 1.9 Hz, H-3′), 6.84 (1H, dd, *J* = 8.1 Hz, *J* = 1.9 Hz, H-5′) and 6.92 (1H, d, *J* = 8.1 H-6′) assignable of the trisubstituted aromatic ring and a two ortho-coupled protons at δ_H 6.95 (1H, d, *J* = 8.1 Hz, H-5) and 6.78 (1H, d, *J* = 8.1 Hz, H-4) corresponding of the tetrasubstituted aromatic ring. The spectrum also included two trans-olefinic protons at δ_H 6.28 (1H, d, *J* = 15.9 Hz, H-7) and 5.56 (1H, dt, *J* = 15.9 Hz, *J* = 6.0 Hz, H-8), two oxymethylenes at δ_H 4.21 (2H, d, *J* = 5.7, H-9) and 4.25 (2H, m, H-9′), two oxymethines at 5.50 (1H, d, *J* = 6.3, H-7′) and 3.48 (1H, m, H-8′) and two methoxy groups at δ_H 3.82 (3H, s, H-10) and 3.85 (3H, s, H-10′).

The ^{1}H-NMR, ^{13}C-NMR and heteronuclear multiple quantum coherence spectra of compound 2 showed six quaternary aromatic carbons including three oxygenated at δ_C 149.8 (C-2), 151.2 (C-6), and 150.4 (C-2′), besides signals of seven sp^2 hydrogenated carbons where two of them, those at δ 130.5 and δ 126.8, corresponded to two olefinic carbons C-7 and C-8, respectively, and two methoxy carbons at δ_C 56.8 (C-10) and 57.2 (C-10′). In addition, a group of signals at δ_H/δ_C 5.50 (1H, d, *J* = 6.3 Hz)/89.7, 3.48 (1H, m)/54.5 and 4.25 (2H, m)/65.8 indicated an epoxy substituted propanoid moiety attached to the aromatic rings [15,16]. The ^1H–^1H COSY spectrum (Figure 3)

showed correlations H-7′/H-8′ and H-8′/H-9′ provided evidence for the epoxy propanoid moieties. HMBC cross-peaks of C-4′, C-3′, and C-5′ with H-7′ (δ_H 5.50) confirmed the attachment of this epoxy propanoid moiety to the trisubstituted aromatic rings at C-4′ (Figure 3). The correlations observed in the ^1H–^1H COSY spectrum between H-7/H-8 and H-8/H-9 provided evidence for the propenol moiety (-CH═CH–CH_2OH) (Figure 3). The long-range correlations observed in the HMBC spectrum of the olefinic proton H-7 with C-3, C-4, C-2 showed that the propenol moiety is connected to the tetrasubstituted aromatic ring at C-3 (Figure 3).

The HMBC long-range ^2J and ^3J correlations H-4/C-2, H-4/C-3, H-4/C-5, H-4/C-6, H-5/C-1, H-5/C-2, H-6′/C-1, H-6′/C-1′, H-6′/C-4, H-3′/C-1′ and H-5′/C-6′ indicated compound 2 should be processed a biphenyl skeleton [17–19]. The HMBC (Figure 3) correlations of two methoxy signals with C-6 (δ_C 151.2) and C-2′ (δ_C 150.4) indicated that the two methoxy groups were connected to C-6 and C-2′ respectively. This result was reinforced by the NOE cross peaks between H-5/H-10 (OMe) and H-3′/H-10′ (OMe) in the NOESY spectrum. The relative stereochemistry of the epoxide moiety was established on the basis of the NOESY spectrum showing a NOE between H-7′ and H-8′ indicating a *cis* epoxyde.

Two new natural compounds named salsolanol (compound 1) and biphenylsalsinol (compound 2) were isolated from the aerial parts of *S. villosa*. Their structures were elucidated by spectroscopic methods including 1D-NMR, 2D-NMR experiments and mass spectroscopic. Their antibacterial activity was evaluated by the paper disc diffusion method against *S. epidermidis*, *S. aureus*, *E. coli*, *P. aeruginosa* and *S. typhimurium*. The highest antimicrobial effect was observed for compound 2 against *S. epidermidis*, *S. aureus*, *E. coli* and *P. aeruginosa* showing an inhibitory zone diameter at (28.66 ± 0.94), (16.66 ± 0.47), (12.33 ± 0.57), (14.66 ± 0.57) mm repectively. Whereas the compound 1 is slightly active against *S. epidermidis*, *S. aureus* and *E. coli* with an inhibitory zone diameter (12.66 ± 0.47), (10.66 ± 0.81), (9.33 ± 0.94) mm respectively.

Conflict of interest statement

We declare that we have no conflict of interest.

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References

[1] Mabberley DJ. *The plant book: a portable dictionary of the vascular plants*. 2nd ed. New York: Cambridge University Press; 1997, p. 149.

[2] Botschantzev V. A synopsis of *salsola* (Chenopodiaceae) from South and South-West africa. *Kew Bull* 1974; **29**: 597-614.

[3] Pyankov VI, Voznesenskaya EV, Kuz'min AN, Ku MSB, Ganko E, Franceschi VR, et al. Occurrence of C_3 and C_4 photosynthesis in cotyledons and leaves of *Salsola* species (Chenopodiaceae). *Photosynth Res* 2000; **63**: 69-84.

[4] Tundis R, Menichini F, Conforti F, Loizzo MR, Bonesi M, Statti G, et al. A potential role of alkaloid extracts from *Salsola* species (Chenopodiaceae) in the treatment of Alzheimer's disease. *J Enzyme Inhib Med Chem* 2009; **24**: 818-24.

[5] Tundis R, Loizzo MR, Statti GA, Menichini F. Inhibitory effects on the digestive enzyme alpha-amylase of three *Salsola* species (Chenopodiaceae) *in vitro*. *Pharmazie* 2007; **62**: 473-5.

[6] Syrchina AI, Vereshchagin AL, Larin MF, Semenov A. Flavonoids of *Salsola collina*. *Chem Nat Compd* 1989; **25**: 619-20.

[7] Hamed AI, Masullo M, Sheded MG, Mahalel UA, Tawfik MM, Perrone A, et al. Triterpene saponins from *Salsola imbricate*. *Phytochem Lett* 2011; **4**: 353-6.

[8] Ahmad Z, Mehmood S, Fatima I, Malik A, Ifzal R, Afza N, et al. Structural determination of salsolins A and B, new antioxidant polyoxygenated triterpenes from *Salsola baryosma* by 1D and 2D NMR spectroscopy. *Magn Reson Chem* 2008; **46**: 94-8.

[9] Beyaoui A, Chaari A, Ghouila H, Ali Hamza M, Ben Jannet H. New antioxidant bibenzyl derivative and isoflavonoid from the Tunisia *Salsola tetrandra* Folsk. *Nat Prod Res* 2012; **26**: 235-42.

[10] Oueslati MH, Ben Jannet H, Mighri Z, Chriaa J, Abreu PM. Phytochemical constituents from *Salsola tetrandra*. *J Nat Prod* 2006; **69**: 1366-9.

[11] Efstratiou E, Hussain AI, Nigam PS, Moore JE, Ayub MA, Rao JR. Antimicrobial activity of *Calendula officinalis* petal extracts against fungi, as well as Gram-negative and Gram-positive clinical pathogens. *Complement Ther Clin Pract* 2012; **18**: 173-6.

[12] Senatore F, Oliviero F, Scandolera E, Taglialatela-Scafati O, Roscigno G, Zaccardelli M, et al. Chemical composition, antimicrobial and antioxidant activities of anethole-rich oil from leaves of selected varieties of fennel [*Foeniculum vulgare* Mill. ssp. *vulgare* var. *azoricum* (Mill.) Thell]. *Fitoterapia* 2013; **90**: 214-9.

[13] Alshawsh MA, Abdulla MA, Ismail S, Amin ZA, Qader SW, Hadi A, et al. Free radical scavenging, antimicrobial and immune modulatory activities of *Orthosiphon stamineus*. *Molecules* 2012; **17**: 5385-95.

[14] Khan AV, Ahmed QU, Shukla I, Khan AA. Antibacterial activity of leaves extracts of *Trifolium alexandrinum* Linn. against pathogenic bacteria causing tropical diseases. *Asian Pac J Trop Biomed* 2012; **2**: 189-94.

[15] Huang WZ, Zhang CF, Zhang M, Wang ZT. A new biphenylpropanoid from *Alpinia katsumadai*. *J Chin Chem Soc* 2007; **54**: 1553-6.

[16] Li J, Huang Y, Guan XL, Li J, Deng SP, Wu Q, et al. Anti-hepatitis B virus constituents from the stem bark of *Streblus asper*. *Phytochemistry* 2012; **82**: 100-9.

[17] Siridechakorn I, Maneerat W, Sripisut T, Ritthiwigrom T, Cheenpracha S, Laphookhieo S. Biphenyl and xanthone derivatives from the twigs of a *Garcinia* sp. (Clusiaceae). *Phytochem Lett* 2014; **8**: 77-80.

[18] Ribeiro PR, Ferraz CG, Guedes ML, Martins D, Cruz FG. A new biphenyl and antimicrobial activity of extracts and compounds from *Clusia burlemarxii*. *Fitoterapia* 2011; **82**: 1237-40.

[19] Shang SZ, Xu WX, Lei P, Zhao W, Tang JG, Miao MM, et al. Biphenyls from *Nicotiana tabacum* and their anti-tobacco mosaic virus. *Fitoterapia* 2014; **99**: 35-9.