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Comparison of Chemical Composition and Antioxidant Activity of Essential Oil of Gum-Resin Obtained from *Juniperus excelsa* and *Boswellia sacra*

AMANI AL-RIYAMI, NAWAL AL-MANTHARY, SALEH N. AL-BUSAFI* and SALIM H. AL-SAIDI

Department of Chemistry, College of Science, Sultan Qaboos University, Box 36, Al-Khodh 123, Oman

*Corresponding author: Fax: +968 24141469; Tel: +968 24142305; E-mail: saleh1@squ.edu.om

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Chemical composition of two essential oils extracted from *Boswellia sacra* and *Juniperus excelsa* gum-resins, respectively, were studied using infrared spectroscopy, gas chromatography-mass spectrometry (GC/MS) and GC-FID. Infrared analysis revealed the presence of C-H, O-H, C=C and C=O functionality bonds. The GC-FID and GC/MS study showed the occurrence of 25 monoterpenes in each essential oil of which 18 (56.25 %) monoterpenes were shared by the two oils. The major component, α-pinene was detected in both oils with different proportion (80.50 % in *J. excelsa* gum oil *versus* 38.47 % in *B. sacra* gum oil). In addition, limonene present as a second major component (13.36 %) in *B. sacra* oil, but it was detected in very low amount in *J. excelsa* oil (2.46 %). Sesquiterpenes exist in *B. sacra* gum-resin oil only. Essential oil of *B. sacra* gum-resin showed stronger antioxidant activity than *J. excelsa* gum-resin oil, but both oils showed lower antioxidant activity compared to ascorbic acid.

Keywords: *Boswellia sacra*, *Juniperus excelsa*, Essential oils, Monoterpenes, Antioxidant.

INTRODUCTION

Frankincense (Luban in Arabian) is an oleo-gum-resin obtained from the evergreen tree of *Boswellia sacra* (Family Burseraceae) that grows in the arid zone behind the Monsoon Mountains in Dhofar, south of Sultanate of Oman [1]. This oleo-gum-resin can also be produced by other Boswellia species such as *B. serrata* in India [2], *B. frereana* and *B. carteri* in Somalia [3], *B. dalzielii* in Nigeria [4] and *B. socotrana* in Yemen [5]. Frankincense has been used for centuries as fragrance material as well as traditional medicine to cure different kind of diseases. In Oman, crushed frankincense of *B. sacra* was used as a plaster to treat skin lesions and for healing bone fractures.The gum also made up into pills and taken to treat abdominal and chest pain [6]. In Yemen, the oleo-gum-resin of *B. socotrana* is used traditionally by the native inhabitants for relieving the pain in cavities and sweetening the breath [7]. The gum resin of *B. dalzielii* is used along with other medicines for the treatment of venereal diseases in Nigeria [8]. Frankincense extracted from the bark of *B. serrata* is still used in the traditional ayurvedic medicine in India [9].

Investigations of pharmacological activities of essential oil extracted from different type of frankincense reveal wide-ranging medicinal applications such as antibacterial, anti-fungal, anticancer, antiinflammatory and asthma medication [10-14]. In this regard, essential oil of *B. sacra* exhibits inhibition of the fungal growth and aflatoxins secretion for *Aspergillus flavus* and *A. parasiticus* by 83.7 and 83.5 %, respectively [15]. Alcoholic extract of frankincense from *B. serrata* was reported to possess antiinflammatory and anti-arthritic activities in animals, which were attributed to the presence of boswellic acid derivatives in frankincense [16].

The chemical composition of essential oils of frankincense from different species of *Boswellia* plant has been investigated in several studies. These studies displayed variable proportion of monoterpenes and sesquiterpenes from one region to another. The essential oil of oleo-gum-resin of *B. serrate* was dominated by β-eudesmene, γ-murolene, γ-cadinene and α-copaene (3.3, 3.0 , 2.9 and 2.8 %, respectively) [2]. On the other hand, high percentages of α-pinene (45.7 %), γ-terpinene (11.5 %) and *trans*-sabinene hydrate (4.6 %) were found in the essential oil of the gum of *B. dalzielii* [4]. The chemical composition of essential oil of *B. carteri* revealed the following terpenes: α-thujene (19.2 %), sabinene (9.4 %), limonene (7.8 %), α-pinene (7.2 %), octyl acetate (60.0 %), octanol (12.7 %) and *p*-cymene (8.7 %) [17]. Previous study on the essential oils of *B. sacra* revealed the following monoterpenes: α-pinene (76.0 %), limonene (2.6 %), β-selinene (1.5 %) [18]. Recently, an oxygenated sesquiterpene muskatone isolated from the essential oil of *B. sacra* was identified as a potent odorant in frankincense [19].

Juniper tree (*Juniperus excelsa*)grows in the high altitude of Jabal al Akhdar of Oman in an open dry mountain forest

where the altitude reaches about 2,300 m. In addition, *J. excelsa* can be found throughout the eastern Mediterranean from north-eastern Greece and southern Bulgaria across Turkey to Syria and Yemen [20]. Traditionally, *J. excelsa* is used in folk medicine to treat different ailments such as abdominal rigidity, asthma, fever, headache, diabetes and leucorrhoea [21-23]. In other parts of the world, the plant is considered useful as an antihypertensive, diuretic, appetizer, carminative, stimulant, anticonvulsant, flavoring agent and as a remedy for tuberculosis [24,25].

Bioactivity studies that performed on *J. excelsa* exhibited antibacterial [26], antifungal [27] and bronchodilatory activities [28]. Sandracopimaric acid, a diterpene isolated from *J. excelsa* was found to exhibit significant antibacterial activity against *Bacillus subtilis*, *Staphylococcus aureus* and *Streptococcus durans* [24]. Moreover, hexane extract of the berries of *J. excelsa* exhibited potent activity against human colon cancer cell line [29].

Chemical compositions of essential oil of *J. excelsa* leaves and fruits revealed diverse ratios of monoterpenes and sesquiterpenes from one region to another. Analysis of essential oil of the leaves of *J. excelsa* from the Crimea revealed the presence of α-pinene (56.2 %), limonene (10.4 %), δ-3-carene (3.1 %), camphene (2.9 %), β-pinene (1.2 %), α-terpinene (1.9 %) and terpinolene (0.8 %) [30]. The essential oil extracted from the leaves of *J. excelsa* from Jammu (India) was reported to contain sabinene (36.1 %) and cedrol (26.8 %) as major components [31]. Chemical analysis of the leaves oil of *J. excelsa* from Greece revealed the presence of cedrol (28.1 %), α-pinene (22.5 %) and limonene (22.7%) [32]. Fruits essential oil of *J. excelsa* from Iran showed α-pinene (89.5 %), myrcene (2.6 %), germacrene (2.2 %) and limonene (1.3 %) with other minor components [33]. Essential oil of *J. excelsa* leaves from Oman has been found to possess limonene (49.6 %), germacrene (9.6 %), δ-3-carene (5.9 %), α-pinene (4.81 %) and γ-cadinene (3.76%) [34].

In addition, juniper tree produces an oleo-gum-resin that appears on the surface of the stems. Physical examination of this resin reveals resemblance in term of colour, smell and shape with frankincense of *Boswellia sacra*. No reports were found in literature that describes the chemical contents of the essential oil extracted from oleo-gum-resin of *J. excelsa*. In this article, we are aiming to analyze the chemical compositions of essential oil of gum-resin of *J. excelsa* and compare it with that of frankincense using IR spectroscopy and GC-MS spectrometry. In addition, an antioxidant and radical scavenging activities of both oils are also provided.

EXPERIMENTAL

Oleogum resins of *J. excelsa* and *B. sacra* were collected from Jabal Al-Akhdhar (North of Oman) and Dhofar region (South of Oman), respectively. Herbarium sheets have been deposited at Sultan Qaboos University Herbarium collections (AlSaidi, Salim H, 01/Fa/15). The examined oleo-gum resins were collected from one plant of each species.

Extraction of volatile oil: The two essential oils were prepared by steam distilling freshly oleo-gum resin samples of *J. excelsa* (70.0 g) and *B. sacra* (60.5 g) using clevenger apparatus. Complete consumption of the two resin samples yielded 3.1 g (4.4 %) of *J. excelsa* gum oil and 1.4 g (2.3 %) of *B. sacra* gum oil. Infrared spectra were performed on a Magna 560 spectrometer (Nicolet model).

Gas Chromatography analysis: Gas chromatography study was performed using Shimadzu GC-2014 instrument fitted with a flame ionization detector (FID) and Restek Rtx-1 cross-linked methyl silicon capillary column (30 m × 0.25 mm I.D. × 0.25 mm film thickness). Temperature of the oven was increased from 31 ºC to 271 ºC at a rate of 3 ºC /min. The temperatures of the injector and the interface were set at 275 ºC and 300 ºC, respectively. Helium was used as a carrier gas with a linear velocity of 74.6 cm/s and total flow rate of 39.9 mL/min. The split ratio was 1:23.

GC/MS analysis: Gas chromatograph-mass spectrometry (GC-MS) studies were accomplished using Shimadzu instrument (GC-MS-QP/5050A model) fitted with a quadrupole mass spectrometer and fused silica capillary column (J&W Scientific DB-5MS model). The dimensions of the column are 0.25 mm I.D. × 30 m × 0.25 mm film thickness. Oven's temperature was controlled to increase at a rate of 3 ºC /min from 31 ºC to 271 ºC. The temperatures of the interface and injector were kept at 300 ºC and 275 ºC, respectively. Helium was used as a carrier gas with a linear velocity of 44.6 cm/s. The column flow rate was 1.5 mL/min; total flow rate was 36 mL/min and split ratio of 1:21. The ionization voltage and scan rate of the mass spectrometer were 70 eV and 500 amu/s, respectively and the mass spectra were documented continuously over mass range of 35-501 amu. The components of the two essential oils were identified by comparing their Linear Retention Indices (LRIs) with literature values. The Linear Retention Indices (LRIs) of the oils components were determined relative to the retention time (RT) of a homologous series of *n*-alkanes (C8-C30). The MS spectra were matched with the computer MS database (Wiley 229,000 library).

Antioxidant capacity: Antioxidant capacity of two essential oils was measured by applying the phosphomolybdenum protocol reported by Prieto *et al.* [35]. A 0.3 mL solution of each oil in methanol (1 mM) was mixed with 3 mL solution of antioxidant reagent (28 mM sodium phosphate, 0.6 M sulfuric acid and 4 mM ammonium molybdate) in a 4 mL capped vials. After incubation in a water bath at 95 ºC for 90 min, the vials were cooled to room temperature and the absorptions were measured at 695 nm against a blank solution. The absorption measurements were repeated three times and the antioxidant capacities were recorded as ascorbic acid equivalent by applying the following linear equation:

$$[A = 0.0013C + 0.049; R^2 = 0.974]$$

where A is the absorbance at 695 nm and C is the concentration of ascorbic acid (mg/L).

Free radical scavenging capacity: Radical scavenging capacity of the two essential oils was measured by the reported DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical method [36]. A mixture of 2.0 mL solution of DPPH in methanol (0.1 mM) and 0.1 mL solution of oil sample in methanol (0.1 mg/mL) was kept standing for 60 min. The visible absorption of the mixture was measured at 517 nm with methanol as a blank. The results were recorded as an average of three trials and the radical scavenging capacity was determined by the percentage of DPPH consumed according to the following formula:

$$\text{Reduction (\%)} = \frac{(AB - AA)}{AB} \times 100$$

where AB = absorption of blank sample and AA = absorption of tested oil solution.

RESULTS AND DISCUSSION

The essential oils of gum-resin of *J. excelsa* and *B. sacra* were obtained by conventional hydrodistillation of the crushed gums. The essential oil of gum-resin of *J. excelsa* (4.4 % w/w) was colourless oil which solidified with time to white solid while that of *B. sacra* (2.3% w/w) was light yellow oil. Both oils have nice sweetly smell.

IR analysis: IR spectra of gum-resin of *J. excelsa* revealed the presence of O-H stretch at 3438 cm^{-1}, aliphatic C-H stretch at 2965 cm^{-1}, C=O stretch at 1731 cm^{-1}, C=C stretch at 1684cm^{-1} and C-C stretch at 1447 and 1364 cm^{-1}. IR analysis of gum-resin of *B. sacra* showed the presence of O-H stretch at 3484 cm^{-1}, aliphatic C-H stretch at 2919 cm^{-1}, C=O stretch at 1734 cm^{-1}, C=C stretch at 1685 cm^{-1} and C-C stretch at 1447 and 1364 cm^{-1}.

GC-MS analysis: The chemical composition and the relative contents of the two essential oils were determined by GC-FID and GC-MS analysis and are given in Table-1. Twenty-five components were identified from *J. excelsa* gum-resin oil representing 97 % of the total oil (Table-1). The predominant compound in *J. excelsa* resin oil was α-pinene (80.50 %), other compounds that could be identified in minute proportion were *E*-pinocarveol (2.85 %), limonene (2.46 %) and *E*-verbenol (2.09 %). Among the identified compounds, 12 compounds comprising 48 % were monoterpene hydrocarbons and 13 compounds comprising 52 % were oxygenated monoterpenes. The oil is characterized by the absence of sesquiterpenes.

The GC-FID and GC/MS analysis of the oil of *B. sacra* resin revealed the identification of 39 components representing 98 % of the total oil (Table-1). The major compounds in *B. sacra* resin oil were α-pinene (38.47 %) followed by limonene (13.36 %). Other compounds like caryophyllene oxide (3.03 %), *trans*-pinocarveol (3.98 %), *cis*-piperitol (2.53 %), β-selinene (2.49 %), myrcene (2.38 %), α-phellandren-8-ol (2.37 %), δ-cadinene (2.21 %) exist in significant amounts. Among the identified compounds, 15 compounds comprising 38.5 % were monoterpene hydrocarbons and ten compounds comprising 25.6 % were oxygenated monoterpenes.The essential oil of gum-resin of *B. sacra* is distin-guished by the presence of fifteen sesquiterpenes (38.5 %).

In general, the two oils showed some similarities and differences in their monoterpene and sesquiterpenes chemical composition. Each oil contains twenty-five monoterpenes, in which the major component, α-pinene, was detected in both oils with varied proportion (80.50 % in *J. excelsa* gum oil and 38.47 % in *B. sacragum* oil). In addition, the two oils shared 18 (56.25 %) monoterpenes from a total of thirty-two different monoterpenes exist in both oils. Limonene present as a second major component (13.36%) in *B. sacra* oil, but it was detected in very low amount in the *J. excelsa* oil (2.46 %). Moreover, the fifteen sesquiterpenes characterizing the *B. sacra* oil are absent in *J. excelsa* oil. In addition, the presence of high percentage of oxygenated monoterpenes in *J. excelsa* oil (52%) compared to only 25.6 % in *B. sacra* oil may explains its solidification to a white solid with time.

TABLE-1
CHEMICAL COMPOSITION (%) OF THE GUM-RESIN OIL OF *B. sacra* AND *J. excelsa*

Compounds	LRI (exp)	LRI (lit.)*	Oil (%)	
			B. sacra	*J. excelsa*
Tricyclene	920.9	923.2	0.34	0.77
α-Thujene	924.8	927.8	1.32	0.19
α-Pinene	934.1	936.1	38.47	80.50
α-Fenchene	946.5	949.4	–	0.36
Camphene	948.0	950.3	0.99	0.57
Thuja-2,4(10)diene	951.5	955.6	0.74	0.96
Sabinene	971.0	973.0	0.88	0.22
β-Pinene	976.7	977.7	0.84	1.03
Myrcene	990.2	989.2	2.38	0.14
p-Cymene	1023.5	1024.3	3.16	2.46
Limonene	1028.2	1029.5	13.36	0.10
1,8-Cineole	1032.5	1031.8	0.23	0.1
γ-Terpinene	1056.1	1059.7	0.4	–
Linalool oxide	1084.3	1083.3	–	0.25
p-Cymene	1090.3	1087.9	–	0.33
Linalool	1098.3	1098.0	0.22	0.13
cis-Sabinene hydrate	1100.5	1101.0	0.26	–
α-Campholenal	1125.6	1127.0	0.61	1.31
E-Pinocarveol	1139.3	1141.0	3.98	2.85
cis-Verbenol	1142.0	1144.2	1.78	–
trans-Verbenol	1144.5	1144.0	–	2.09
Isoborneol	1158.0	1158.2	–	0.38
α-Phellandren-8-ol	1170.9	1170.0	2.37	–
Terpinene-4-ol	1178.8	1179.0	1.79	0.11
α-Terpineol	1185.8	1185.0	–	0.55
Myrtenal	1193.2	1192.0	–	0.47
cis-Piperitol	1194.8	1194.7	2.53	–
Verbenone	1205.5	1206.2	2.27	0.44
trans-Carveol	1217.8	1217.1	1.38	0.26
Carvone	1241.9	1242.0	0.8	–
p-Anisyl alcohol	1282.0	1282.3	0.84	0.49
α-Terpineol acetate	1344.5	1347.0	0.89	–
Carvacrol acetate	1371.5	1373	0.49	–
Geranyl acetate	1378.9	1379.9	0.33	–
β-Cubebene	1386.0	1386.6	1.67	–
β-Caryophyllene	1414.1	1420.1	1.79	–
α-Humulene	1450.0	1453.1	0.88	–
β-Selinene	1483.4	1485.0	2.49	–
cis-β-Guaiene	1490.4	1489.0	0.79	–
α-Selinene	1493.8	1493.0	0.31	–
β-Bisabolene	1507.9	1508.4	0.42	–
δ-Cadinene	1514.1	1513.1	2.21	–
Elemol	1544.3	1547.5	0.43	–
Caryophyllene oxide	1575.9	1580.6	3.03	–
δ-Cadinol	1637.3	1636.0	0.77	–
β-Eudesmol	1649.2	1650.1	1.57	–
Total identified (%)			98 %	97 %

LRI: Linear retention index [Ref. 37]

Total antioxidant activity: The antioxidant activity for the essential oils of *J. excelsa* and *B. sacra* was evaluated by using phosphomolybdenum method which is based on the reduction of Mo(VI) by the sample analyte and the subsequent formation of green phosphate Mo(V) complex with a maximum absorption at 695 nm. Total antioxidant activity of the two

essential oils, expressed as ascorbic acid (AA) equivalent (mg of AA per g of oil), was obtained from the calibration curve of ascorbic acid as shown in Fig. 1. Essential oil of *B. sacra* showed higher total antioxidant activity than *J. excelsa* oil (646 mg ascorbic acid equivalents *versus* 282 mg, respectively) (Fig. 2).

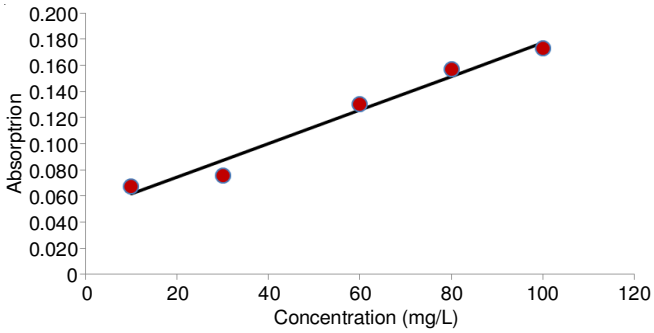

Fig. 1. Calibration curve of ascorbic acid (AA)

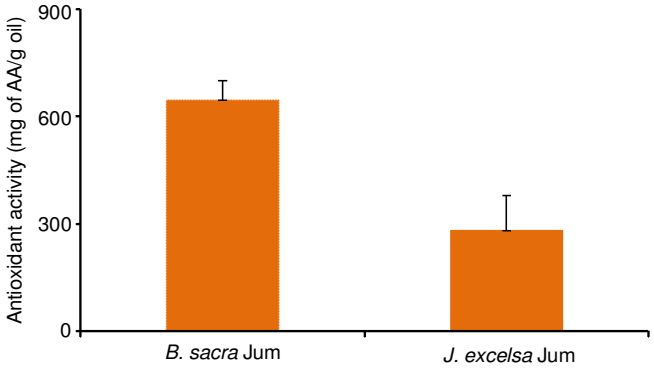

Fig. 2. Antioxidant activity of *J. excelsa* and *B. sacra* essential oils

DPPH radical scavenging activities: Another standard method to quantify antioxidant activity of essential oils is to measure their hydrogen donating ability to DPPH radical. In this study, essential oils of *J. excelsa* and *B. sacra* gum-resins were investigated for their radical scavenging activity and compared with that of ascorbic acid (Fig. 3). The scavenging activity of two essential oils as well as ascorbic acid increases as the concentration increases. Both oils, though, showed lower activity compared to that of ascorbic acid. Fig. 4 exhibited the IC_{50} values, which described the concentration of antioxidant required to inhibit 50 % of DPPH radicals. The smaller IC_{50} values, the stronger antioxidant activity. The data obtained

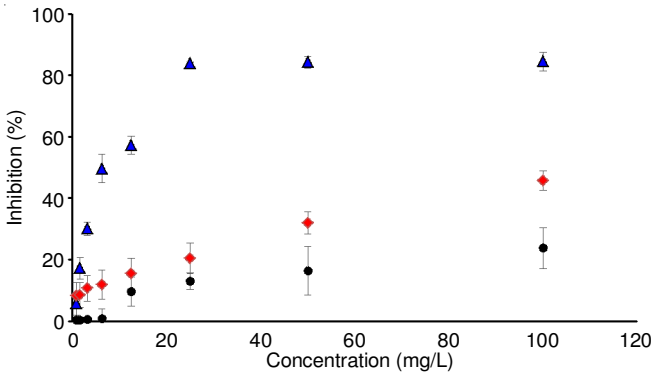

Fig. 3. DPPH radical inhibition activity of *J. excelsa* and *B. sacra* essential oils compared with ascorbic acid (AA) activity

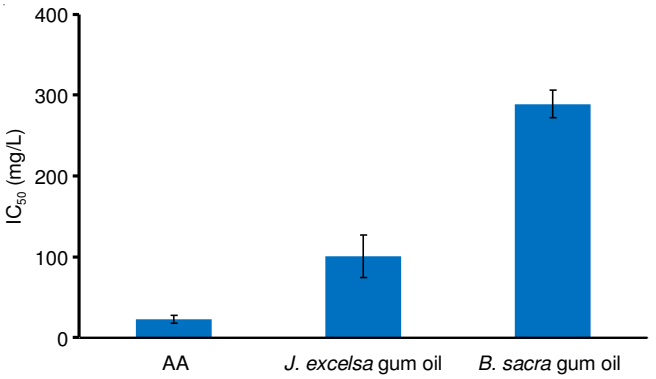

Fig. 4. IC_{50} values of ascorbic acid (AA), *J. excelsa* and *B. sacra* essential oils

indicated that the radical scavenging of the gum oil of *J. excelsa* (IC_{50} = 100.4 mg/L) was stronger than that of *B. sacra* (IC_{50} = 288.9 mg/L).

Conclusion

Although *Boswellia sacra* gum (frankincense) and *Juniper excelsa* gum have similar texture and smell, their oil chemical composition which was revealed by GC-MS analysis showed some variations. *J. excelsa* gum contains α-pinene as a major compound with 80.5% while *B. sacra* gum contains α-pinene (38.5 %) and limonene (13 %) as major constituents. Both oils contain different proportion of other minor components. Sesquiterpenes exist in *B. sacra* gum oil only. Essential oil of *J. excelsa* gum showed weaker antioxidant activity than *B. sacra* gum oil, but both oils showed lower antioxidant activity compared to ascorbic acid.

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REFERENCES

1. A.G. Miller and M. Morris, Plants of Dhofar: the Southern Region of Oman, Traditional, Economic and Medicinal Uses, Office of the Advisor for Conservation of the Environment, Diwan of Royal Court: Oman (1988).
2. A. Sharma, S. Chhikara, S.N. Ghodekar, S. Bhatia, M.D. Kharya, V. Gajbhiye, A.S. Mann, A.G. Namdeo and K.R. Mahadik, *Phcog. Rev.*, **3**, 206 (2009).
3. G. Chiavari, G.C. Galletti, R. Piccaglia and M.A. Mohamud, *J. Essent. Oil Res.*, **3**, 185 (1991); https://doi.org/10.1080/10412905.1991.9700500.
4. D. Kubmarawa, I.A. Ogunwande, D.A. Okorie, N.O. Olawore and A.A. Kasali, *J. Essent. Oil Res.*, **18**, 119 (2006); https://doi.org/10.1080/10412905.2006.9699038.
5. N.A. Ali, M. Wurster, N. Arnold, A. Teichert, J. Schmidt, U. Lindequist and L. Wessjohann, *Rec. Nat. Prod.*, **2**, 6 (2008); https://doi.org/10.3407/rpn.v2i1.17.
6. M.O. Fatope and S.N. Al-Busafi, Natural Products and their Active Compounds on Disease Prevention, In: Natural Products in the Prevention and Treatment of Invasive Human Diseases, Chap. 9, Nova Publishers (2012).
7. G.A. Miller and M. Morris, Ethnoflora of the Soqotra Archipelag, Charlesworth Group, Huddersfield, UK, pp. 457-464 (2004).
8. F.C. Nwinyi, L. Binda, G.A. Ajoku, S.O. Aniagu, N.M. Enwerem, A. Orisadipe, D. Kubmarawa and K.S. Gamaniel, *Afr. J. Biotechnol.*, **3**, 284 (2004); https://doi.org/10.5897/AJB2004.000-2052.

9. C.F. Krieglstein, C. Anthoni, E.J.M. Rijcken, M. Laukötter, H.-U. Spiegel, S.E. Boden, S. Schweizer, H. Safayhi, N. Senninger and G. Schürmann, *Int. J. Colorectal Dis.*, **16**, 88 (2001); https://doi.org/10.1007/s003840100292.
10. S. Wahab, E. Aboutabl, S. El-Zalabani, H. Fouad, H. De Pooter and B. El-Fallaha, *Planta Med.*, **53**, 382 (1987); https://doi.org/10.1055/s-2006-962745.
11. M.L. Gangwal and D.K. Vardhan, *Asian J. Chem.*, **7**, 675 (1995).
12. T. Tsukada, K. Nakashima and S. Shirakawa, *Biochem. Biophys. Res. Commun.*, **140**, 832 (1986); https://doi.org/10.1016/0006-291X(86)90709-6.
13. M.L. Sharma, S. Bani and G.B. Singh, *Int. J. Immunopharmacol.*, **11**, 647 (1989); https://doi.org/10.1016/0192-0561(89)90150-1.
14. V. Gupta, S. Gupta, A. Gupta, R. Parihar, H. Ludtke and H.P.T. Ammon, *Eur. J. Med. Res.*, **3**, 511 (1998).
15. S.A.F. El-Nagerabi, A.E. Elshafie, S.S. Al-Khanjari, S.N. Al-Bahry and M.R. Elamin, *Food Control*, **34**, 763 (2013); https://doi.org/10.1016/j.foodcont.2013.06.039.
16. G. Kesava Reddy, S.C. Dhar and G.B. Singh, *Agents Actions*, **22**, 99 (1987); https://doi.org/10.1007/BF01968824.
17. W. Wang, Y.X. Zhu, L.Z. Liy, D.K. Link, X.L. Qin and J.G. Tian, *Yaowu Fenxi Zazhi*, **13**, 170 (1993).
18. S. Al-Saidi, K.B. Rameshkumar, A. Hisham, N. Sivakumar and S. Al-Kindy, *Chem. Biodivers.*, **9**, 615 (2012); https://doi.org/10.1002/cbdv.201100189.
19. J. Niebler, K. Zhuravlova, M. Minceva and A. Buettner, *J. Nat. Prod.*, **79**, 1160 (2016); https://doi.org/10.1021/acs.jnatprod.5b00836.
20. R.P. Adams, Juniper of the World: The Genus Juniperus, Tafford Publishing, USA (2008).
21. E. Schlecht, U. Dickhoefer, E. Gumpertsberger and A. Buerkert, *J. Arid Environ.*, **73**, 355 (2009); https://doi.org/10.1016/j.jaridenv.2008.10.013.
22. K.M. Nadkarni, Indian Materia Medica, Popular Prakashan, Bombay, edn 3, p. 713 (1976).
23. S.R. Baquar, Medicinal and Poisonous Plants of Pakistan, Printas, Karachi, p. 248 (1989).
24. I. Muhammad, J.S. Mossa and F.S. El-Feraly, *Phytother. Res.*, **6**, 261 (1992); https://doi.org/10.1002/ptr.2650060508.
25. K. Usmanghani, A. Saeed and M.T. Alam, Indusyunic Medicine, University of Karachi Press, Karachi, p. 468 (1997).
26. I. Muhammad, J.S. Mossa, M.A. Al-Yahya, A.F. Ramadan and F.S. El-Feraly, *Phytother. Res.*, **9**, 584 (1995); https://doi.org/10.1002/ptr.2650090810.
27. M. Sokovic, M. Ristic and D. Grubisic, *Pharm. Biol.*, **42**, 328 (2004); https://doi.org/10.1080/13880200490511936.
28. M. Khan, A. Khan, Najeeb-ur-Rehman and A.-H. Gilani, *J. Nat. Med.*, **66**, 292 (2012); https://doi.org/10.1007/s11418-011-0605-z.
29. G. Topcu, R. Erenler, O. Cakmak, C.B. Johansson, C. Celik, H.-B. Chai and J.M. Pezzuto, *Phytochemistry*, **50**, 1195 (1999); https://doi.org/10.1016/S0031-9422(98)00675-X.
30. Y.A. Akimov, S.I. Kuznestsov, G.I. Nilov, N.N. Chirkina, A.P. Krylova and R.M. Litvinenko, *Nikitsk. Botan., Sad*, **69**, 79 (1976).
31. R.K. Thappa, S.G. Aggarwal, B.K. Kapahi and Y.K. Sarin, *J. Nat. Prod.*, **50**, 323 (1987); https://doi.org/10.1021/np50050a053.
32. R.P. Adams, *J. Essent. Oil Res.*, **2**, 45 (1990); https://doi.org/10.1080/10412905.1990.9697815.
33. E. Ehsani, K. Akbari, M. Teimouri and A. Khadem, *Afr. J. Microbiol. Res.*, **6**, 6704 (2012); https://doi.org/10.5897/AJMR12.686.
34. J. Hussain, N.U. Rehman, A. Al-Harrasi, L. Ali, A.L. Khan and M.A. Albroumi, *Asian Pac. J. Trop. Dis.*, **3**, 421 (2013); https://doi.org/10.1016/S2222-1808(13)60095-X.
35. P. Prieto, M. Pineda and M. Aguilar, *Anal. Biochem.*, **269**, 337 (1999); https://doi.org/10.1006/abio.1999.4019.
36. M.S. Blois, *Nature*, **181**, 1199 (1958); https://doi.org/10.1038/1811199a0.
37. V.I. Babushok, P.J. Linstrom and I.G. Zenkevich, *J. Phys. Chem. Ref. Data*, **40**, 043101 (2011); https://doi.org/10.1063/1.3653552.