Screening of phytoconstituents and antibacterial activity of leaves and bark of *Quercus leucotrichophora* A. Camus from Uttarakhand Himalaya

Prabhakar Semwal1*, Sakshi Painuli1, Himani Badoni1 and Rakesh K. Bacheti2

**Abstract**

**Background:** *Quercus leucotrichophora* A. Camus (QL) belongs to the family Fagaceae, commonly known as Banj oak in the Garhwal region of Himalaya, where it is the principal source of fuel, fodder, and medicine.

**Methods:** In the present study, GC-MS analysis has been performed for profiling the chemical composition of methanolic extracts of leaves and bark of QL. The antibacterial activity was evaluated by using the disk diffusion method against five bacterial strains.

**Results:** Total 23 components in bark and 62 components in leaves extracts of QL were identified. The major components identified in the bark extracts were Linoleic acid (19.77%), Lupeol (17.91%), Epi-psi-Taraxastanonol (14.20), and cis-Vaccenic acid (13.10%), while others were present in relatively small amounts. For the leaves extract, the major components were Linoleic acid (17.09%), Simiarene (15.29%), Flavone 4′-oh, 5-oh,7-di-o-glucoside (15.26%), and D-Quinic acid (9.29%), respectively. As far as antibacterial assays are concerned, it was observed that both the extracts are active against most of the tested bacterial strains with the zone of inhibition ranging between 8.53 ± 0.50 to 19.07 ± 0.31 mm, respectively.

**Conclusion:** The GC-MS results revealed the presence of several phytochemical compounds in leaves and bark of QL extract and are recommended as a plant of pharmaceutical importance. The antibacterial analysis showed that both the extracts (leaves and bark) of QL have antibacterial activity against all gram positive (*S. aureus, B. subtilis and S. pyogenes*) and gram negative (*E. coli, P. aeruginosa*) bacterial strains.

**Keywords:** Antibacterial activity, Chemical composition, Himalaya, *Quercus leucotrichophora*

**Background**

Use of plants and plant extracts as a source of medicine has been inherited and is an important component of the health care system in the world. India is the largest producer of medicinal herbs and is known as the botanical garden of the world [1]. The Himalayan region is well known for its huge diversity of flora with more than 10,000 natural plant species, especially medicinal plants. Banj oak (*Quercus leucotrichophora* A. Camus) belonging to the family Fagaceae is an evergreen tree of approximately 40 m height and commonly found throughout the Himalayan region with a latitudinal range from 800 to 2300 m [2]. Several species of *Quercus* genus possess immense medicinal properties and therapeutic applications [3–6]. Banj oak is the principal source of fuel supply as well as the main fodder tree in the Himalayan region [7]. The leaves, seeds and bark of QL are used in human health care system as well as for livestock health care [8, 9]. Gum of the tree is traditionally used for the treatment of gonorrhoeal and digestive disorders, especially in children [10, 11]. The seeds act as astringent and diuretic agents and are also used in the treatment of indigestion, diarrhoea and asthma in humans [12]. Previously, active compounds like, quercetin and kaempferol were
isolated from the ethanolic stem bark extract of QL, whereas the antimicrobial activity of the extract showed highest activity against *E. coli* followed by *S. aureus, P. aeruginosa* and *B. subtilis*, respectively [13]. Further, the presence of twenty-three phytoconstituents (major phyto-component: monoterpenoids) in the volatile extract of bark of QL were analyzed by GC-MS analysis [14]. The fruit extract of QL revealed the presence of higher amount of saturated fatty acid compared to unsaturated fatty acid. The bark and fruit extract of QL possess antimicrobial activity [14, 15]. The QL is used in traditional system of medicine, but still there are not many scientific reports to confirm its phytochemical activity and medicinal properties [16]. Thus, the present study was aimed to investigate the chemical composition and antibacterial activity of methanolic leaves and bark extracts of QL.

**Methods**

**Plant collection and preparation of crude extracts**

Leaves and bark of QL were collected from the Uttarakhand Himalaya (Tehri district), India and voucher specimens (BSI/NRC-115222) have been kept in the herbarium of Botanical Survey of India (BSI/NRC–Dehradun), Uttarakhand, India. Plant samples (leaves and bark) of QL were cleansed, shade dried and coarsely powdered. Crude powdered material (500 g) was extracted with methanol (80%) using a Soxhlet extractor. The extracts obtained were filtered and concentrated using a rotary vacuum evaporator (Strike-12, Steroglass, Italy) and used for further analysis (GC-MS and antibacterial analysis).

**GC-MS analysis**

GC-MS analysis was performed at University Science Instrumentation Centre, Jawaharlal Nehru University (JNU), Delhi (India). The analyses of the methanolic extracts were carried out on a GCMS-QP2010 Plus (Shimadzu, Kyoto, Japan). The system was equipped with an auto injector (AOC-20i), head space sampler (AOC-20s), a mass selective detector with an ion source (220 °C) and an interface (260 °C). Rtx-5 MS capillary column (Restek Company, Bellefonte, USA) having 30 m (length) × 0.25 mm (diameter) × 0.25 μm (film thickness) was used for GC-MS analyses. The mass range of 40–650 m/z with 1000 ev of threshold was used. The injector was set in the split injection mode having 250 °C of temperature. The starting temperature was adjusted to 80 °C (3 min), which afterwards increased to 280 °C with a ramp rate of 10 °C/min. Helium (> 99.99%) with 40.5 cm/s of linear velocity was employed as a carrier gas. The system was programmed with 16.3 ml/min of total flow rate and 1.21 ml/min of column flow according to stranded methods [17, 18]. The bark and leaves extract components were identified on the basis of retention time (RT) by gas chromatography and interpretation of mass spectrum was performed by comparing spectral fragmentation obtained, to the database provided by NIST11.LIB and Wiley8.LIB [17, 18].

**Antibacterial activity**

Five pathogenic bacterial strains were used in this study for assessing the antibacterial activity of QL, including the Gram-negative and Gram-positive strains namely; *Escherichia coli* (MTCC-582); *Pseudomonas aeruginosa* (MTCC-2295); *Staphylococcus aureus* (MTCC-3160); *Bacillus subtilis* (MTCC-441); and *Streptococcus pyogenes* (MTCC-1924). The reference bacterial strains were obtained from the Institute of Microbial Technology (IMTECH), Chandigarh (India) and were maintained at 4 °C on slants of nutrient agar (NA) (Merck, Germany). The antibacterial activity of plant extracts was carried out using the disk diffusion method [19]. The methanolic bark and leaves extracts were dissolved in 10% of dimethyl sulfoxide (DMSO). The concentration and

| SN | Retention time | Area per cent | Name of compounds             |
|----|----------------|---------------|--------------------------------|
| 1  | 10.086         | 0.19          | Beta-Himachalene               |
| 2  | 11.992         | 0.14          | Alpha-Eudesmol                 |
| 3  | 12.152         | 0.62          | Myristyl acrylate              |
| 4  | 13.239         | 0.08          | 1-Octadecene                   |
| 5  | 14.150         | 0.10          | Phthalychloride                 |
| 6  | 14.643         | 0.14          | Methyl Palmitate               |
| 7  | 15.067         | 4.53          | Pentadecanoic acid             |
| 8  | 16.030         | 0.11          | Heptadecanoic acid             |
| 9  | 16.318         | 0.24          | Linoleic acid methyl ester     |
| 10 | 16.772         | 19.77         | Linoleic acid                  |
| 11 | 16.803         | 13.10         | cis-Vaccenic acid              |
| 12 | 16.860         | 4.13          | Ambrettolide                   |
| 13 | 16.974         | 2.92          | Octadecanoic acid              |
| 14 | 17.566         | 0.67          | 10,12-Hexadecadien-1-ol        |
| 15 | 20.814         | 0.41          | Lignoceric alcohol             |
| 16 | 24.147         | 0.28          | Nonadecyl pentafluoropropionate |
| 17 | 26.641         | 0.31          | 2,3-Oxidosqualene              |
| 18 | 36.274         | 2.59          | Taxerone                       |
| 19 | 36.631         | 1.45          | Clionasterol                   |
| 20 | 37.952         | 6.21          | Simiarene                      |
| 21 | 38.517         | 14.20         | Epi-psi-Taraxastanonol         |
| 22 | 39.357         | 17.91         | Lupeol                         |
| 23 | 41.461         | 1.81          | Sitostenone                    |

Total 91.91

Unidentified 0.34
| SN | Retention time | Area percent | Name of compounds |
|----|----------------|--------------|-------------------|
| 1  | 5.184          | 0.23         | 2,3-Dihydro-3,5-dihydroxy-6-methyl-4-h-pyran-4-one |
| 2  | 8.397          | 0.26         | 4-Propylphenol    |
| 3  | 10.625         | 0.07         | Lauric acid      |
| 4  | 11.354         | 0.36         | .beta.-Methylglucoside |
| 5  | 11.750         | 9.29         | D-Quinic acid    |
| 6  | 11.924         | 0.14         | 2H-Indeno[1,2-b]furan-2-one, 3,3a,4,5,6,7,8,8b-octahydro-8,8-dimethyl |
| 7  | 12.111         | 0.87         | Tetradecyl acrylate |
| 8  | 12.367         | 0.12         | Methoxyeugenol   |
| 9  | 12.533         | 0.08         | 2-Hydroxy-S-isopropyl-2,4,6-cycloheptatrienone |
| 10 | 12.733         | 0.25         | Methyl-(4-hydroxy-3-methoxyphenyl) acetat |
| 11 | 12.856         | 1.44         | Coniferol        |
| 12 | 13.200         | 0.07         | Cyclopentadecane |
| 13 | 13.283         | 0.26         | (-)-Loliolide    |
| 14 | 13.453         | 0.84         | 2-Cyclohexen-1-one, 4-hydroxy-3,5,6-trimethyl-4-(3-oxo-1-butenyl)- |
| 15 | 13.711         | 0.67         | Oleic acid       |
| 16 | 13.970         | 0.15         | Neophytadiene    |
| 17 | 14.093         | 0.05         | Caprylone        |
| 18 | 14.164         | 0.25         | E-2-Tetradecen-1-ol |
| 19 | 14.458         | 0.20         | 3,5-Dimethoxy-4-hydroxyphenylamine |
| 20 | 14.596         | 0.27         | Methyl palmitate |
| 21 | 15.020         | 5.04         | Pentadecanoic acid |
| 22 | 15.254         | 0.18         | 5,9-Dimethyl-2-(1-methylethyl)cyclodecane-1,4-dione |
| 23 | 15.405         | 0.11         | 2,4,4-Trimethyl-3-(3-oxobutyl)cyclohex-2-enone |
| 24 | 15.490         | 0.20         | Benzenepropanoic acid, 2,5-dimethoxy- |
| 25 | 15.996         | 0.37         | 4-Oxazolecarboxylic acid, 4,5-dihydro-2-phenyl-, 1-methylethyl ester |
| 26 | 16.270         | 0.17         | Methyl linoleate |
| 27 | 16.317         | 0.14         | Methyl oleate    |
| 28 | 16.456         | 1.21         | Phytol           |
| 29 | 16.726         | 17.09        | Linoleic acid    |
| 30 | 16.919         | 1.43         | Octadecanoic acid |
| 31 | 18.527         | 0.42         | Methyl hexadecadienoate |
| 32 | 18.718         | 0.11         | 11-Eicosenoic acid |
| 33 | 18.978         | 0.62         | Arachidic acid   |
| 34 | 19.279         | 0.12         | cis-9-Hexadecenal |
| 35 | 20.133         | 0.13         | Methyl tetrahydroionol |
| 36 | 21.618         | 0.50         | cis-Vaccenic acid |
| 37 | 23.680         | 0.11         | Ethyl linoleate (JAN) |
| 38 | 23.807         | 0.09         | 1,1',Biphenyl, 2-formyl-4',5',6'-trimethoxy- |
| 39 | 24.061         | 2.93         | 1-Heptacosanol |
| 40 | 25.631         | 0.10         | S-Hydroxymethyl-1,1,4a-trimethyl-6-methylenedecahydronaphthalen-2-ol |
| 41 | 25.889         | 0.56         | Octadecanal      |
| 42 | 26.567         | 0.41         | 2,8-Dimethyl-2-(4,8,12-trimethyltridecyl)-6-chromanol |
| 43 | 26.915         | 0.44         | Butanedioic acid, di-9-dodecyn-1-yl ester |
| 44 | 27.372         | 0.49         | 2,6,6-Trimethylcyclohex-1-enylmethanesulfonylethene |
volume of the extracts used for the analysis of antibacterial activity were 5 mg/ml and 20 μl (extract soaked by each disc), respectively. The antibacterial activity was assessed by measuring the zone of inhibition surrounding the disks and each experiment was carried out in triplicate. In the present study, DMSO (10%) and ampicillin (1 mg/ml) were used as negative and positive controls, respectively.

Results and discussion
This study focused on the chemical composition and antibacterial screening of QL extracts. The yield of bark and leaves extracts were found to be 9.7% and 13.6%, respectively. A range of volatile phytoconstituents have been identified by GC-MS in different Quercus species other than QL [20, 21]. In the present study, the percentages (area per cent) and the retention time (RT) of the components are listed in Tables 1 and 2. In leaves extract of QL, 62 components were identified, representing 94.54% of the total plant extract, in which Linoleic acid (17.09%), Simiarene (15.29%), and Flavone 4’-OH,5-OH,7-di-O-glucoside (15.26%) were the major components, however, in bark extract of QL, 23 components were identified, representing 91.91% of the total plant extract, in which Linoleic acid (19.77%), Lupeol (17.91%), Epi-psi-Taraxastanonol (14.20%), and cis-Vaccenic acid (13.00%) were the major compounds. Linoleic acid is an omega-6-fatty acid and is enormously used in cosmetic industries, whereas the conjugated linoleic acid was accounted to have anticarcinogenic, fat reducing, antiatherogenic and immune enhancing activity [22]. Lupeol is a triterpenoid which possess

| SN | Retention time | Area percent | Name of compounds                        |
|----|----------------|--------------|------------------------------------------|
| 45 | 27.673         | 0.45         | Tocopherol                                |
| 46 | 28.406         | 0.56         | 3-Hydroxycholest-4-en-6-one              |
| 47 | 29.332         | 0.47         | beta-Tocopherol                          |
| 48 | 29.583         | 0.24         | gamma-Tocopherol                         |
| 49 | 30.461         | 1.17         | Baccharane                                |
| 50 | 31.294         | 2.78         | Vitamin E                                 |
| 51 | 32.319         | 1.25         | (+)-gamma-Tocopherol, O-methyl-           |
| 52 | 33.809         | 0.47         | 1H-indole                                |
| 53 | 36.231         | 15.29        | Simiarene                                |
| 54 | 36.396         | 0.74         | Clionasterol                             |
| 55 | 36.793         | 0.82         | Verticil                                 |
| 56 | 37.508         | 0.49         | beta-Amyrin                              |
| 57 | 37.714         | 0.45         | Methyl ursolate                          |
| 58 | 39.351         | 0.67         | D-C-Friedo-8’A’-neogammacer-9(11)-en-3-one|
| 59 | 40.473         | 0.62         | 9,19-Cyclolanost-23-en-3-ol, 25-methoxy-, acetate, (3.beta.,23e)-|
| 60 | 40.807         | 0.16         | -Heptadecyloxirane                      |
| 61 | 41.130         | 3.81         | Statigmast-4-en-3-one                     |
| 62 | 44.451         | 15.26        | Flavone 4’-OH,5-OH,7-di-o-glucoside      |
| Total | 94.54          |              |                                          |
| Unidentified | 1.10 |              |                                          |

Table 3 Antibacterial profile of QL extracts

| Bacterial strains | QLB (ZOI) | QLL (ZOI) | DMSO (ZOI) |
|-------------------|-----------|-----------|------------|
|                   | QLB (Ave ± SD) mm | Amp (Ave ± SD) mm | QLL (Ave ± SD) mm | Amp (Ave ± SD) mm | DMSO (Ave ± SD) mm |
| E. coli           | 9.37 ± 0.65     | 22.7 ± 0.65     | 8.53 ± 0.50     | 21.3 ± 0.62     | 0.00                 |
| P. aeruginosa     | 13.97 ± 0.42    | 23.2 ± 0.74     | 13.27 ± 0.25    | 23.3 ± 0.70     | 0.00                 |
| S. aureus         | 16.97 ± 0.25    | 22.6 ± 0.62     | 13.80 ± 1.51    | 20.7 ± 0.56     | 0.00                 |
| S. pyogenes       | 15.97 ± 0.65    | 21.2 ± 0.46     | 15.83 ± 0.29    | 22.4 ± 0.52     | 0.00                 |
| B. subtilis       | 19.07 ± 0.31    | 22.2 ± 0.51     | 17.03 ± 0.55    | 20.6 ± 0.57     | 0.00                 |

Note: QLB Quercus leucotrichophora bark, QLL Quercus leucotrichophora Leaves, ZOI Zone of inhibition, Ampi Ampicillin, DMSO Dimethyl sulfoxide
and solvent system [27]. Developmental stage, time of collection, extraction method of the plant used for the study, even agronomic conditions, and seasonal variation, geographical origin, and the part of the plant used for the study, even agronomic conditions, developmental stage, time of collection, extraction method and solvent system [27].

The quantification of antibacterial activity for methanolic extracts of QL has been evaluated against five bacterial species by means of the agar disk diffusion method. The results of antibacterial activity of QL extracts are expressed as the diameter of the inhibition zone in millimetre (shown in Table 3). QLB and QLL extracts showed zone of inhibition (ZOI) from a range of 9.37 ± 0.65 to 19.07 ± 0.31 mm and 8.53 ± 0.50 to 17.03 ± 0.55 mm, respectively. Both the extracts showed the maximum and minimum zone of inhibition (ZOI) against B. subtilis and E. coli, respectively. Ampicillin showed ZOI from a range of 21.2 ± 0.46 to 23.3 ± 0.70 mm for all the bacterial strains, and DMSO was used as a negative control, which showed no zone of inhibition. Previously, the antimicrobial profile of the volatile extract of QLB was recorded against three microbial cultures, namely; Streptococcus pyogenes, Streptococcus aureus, and Escherichia coli. The volatile extract of QLB exhibited a potential antimicrobial activity against Streptococcus pyogenes, compared to Streptococcus aureus, and Escherichia coli [14]. The antibacterial activity of the fatty acid methyl ester (FAME) extract of QL fruits was recorded against four bacterial stains namely; Bacillus subtilis, Staphylococcus aureus, Pseudomonas aeruginosa and Escherichia coli from a range of 7.8 to 15.9 mm [15]. The extract of FAME showed dissimilar activity against different bacterial strains due to the chemical nature, antimicrobial agents, and their mode of action on different microorganism [28]. In the present study, both the extracts of QL demonstrated better antibacterial activity compared to previous studies.

Conclusion

The GC-MS analysis of methanolic extract of bark and leaves of QL revealed the presence of highly composite profiles of medicinally important bioactive components. This study also revealed the antibacterial activity of QLB and QLL against pathogenic microbes. Therefore, it can be concluded that the methanolic leaf and bark extracts of QL have shown the presence of active compounds having pharmacological and industrial importance.

Abbreviations

Amp; Ampicillin; B. subtilis; Bacillus subtilis; DMSO; Dimethyl sulfoxide; E. coli; Escherichia coli; GC-MS; Gas Chromatography- Mass spectrometry; P. aeruginosa; Pseudomonas aeruginosa; QL; Quercus leucotrichophora; QLB; Quercus leucotrichophora bark; QLL; Quercus leucotrichophora leaves; RT; Retention time; S. aureus; Staphylococcus aureus; S. pyogenes; Streptococcus pyogenes; ZOI; Zone of inhibition

Acknowledgements

Help and support received from the Graphic Era University, Dehradun, India and Jawaharlal Nehru University (JNU), Delhi, India are gratefully acknowledged.

Availability of data and materials

All data generated or analysed during this study are included in this article.

Authors’ contributions

PS, SP and HB reviewed the literature, collected the samples, performed all the experiments, and drafting the manuscript with RKB. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Publisher’s Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Author details

1Department of Biotechnology, Graphic Era University, 566/6 Bell Road, Clement Town, Dehradun, Uttarakhand 248002, India. 2Department of Industrial Chemistry, College of Applied Science, Addis Ababa Science and Technology University, Akaky Kaliti subcity, Addis Ababa, Ethiopia.

Received: 15 June 2018 Accepted: 9 October 2018

Published online: 28 November 2018

References

1. Ahmedulla M, Nayar MP. Red data book for Indian plants. Calcutta: Botanical Survey of India; 1999.
2. Singh JS. Forests of the Himalaya: structure, functioning and impact of man. India: Gyanodaya Prakashan; 1992.
3. Hayouni EA, Abedrabba M, Bouix M, Hamdi M. The effects of solvents and extraction method on the phenolic contents and biological activities in vitro of Tunisian Quercus coccifera L. and Juniperus phoenicea L. fruit extracts. Food Chem. 2007;105:1126–34.
4. Berahou A, Auhmani A, Fdil N, Benharref A, Jana M, et al. Antibacterial activity of Quercus ilex bark’s extracts. J Ethnopharmacol. 2007;112:426–9.
5. Sánchez-Burgos JA, Ramirez-Mares MV, Larrosa MM, Gallegos-Infiarte JA, González-Laredo RF, et al. Antioxidant, antimicrobial, antitopoisomerase and gastroprotective effect of herbal infusions from four Quercus species. Ind Crop Prod. 2013;42:57–62.
6. Jamil M, Ul Haq I, Mirza B, Qayyum M. Isolation of antibacterial compounds from Quercus dilatata L. through bioassay guided fractionation. Ann Clin Microbiol Antimicrob. 2012;11:11.

7. Singh SP, Singh JS. Structure and function of the central Himalayan oak forests. Proc Indian Acad Sci. 1986;96:159–89.

8. Pande PC, Tiwari L, Pande HC. Folk-medicine and aromatic plants of Uttarakhal Dehradun. India: Bishen Singh Mahendra Pal Singh; 2006.

9. Al-Rousan WM, Ajo RY, Al-Ismail KM, Attlee A, Shaker RR, Osaili TM. Characterization of acorn fruit oils extracted from selected Mediterranean Quercus species. Grasas Aceites. 2013;64:554–60. https://doi.org/10.3989/gya.023313.

10. Gaur RD. Flora of the district Garhwal north west Himalaya. Srinagar: trans media, media house. New Delhi: Council of Scientific and Industrial Research, India; 1999.

11. Soni PL, Sharma H, Gharia MM. Physicochemical properties of Quercus leucotrichophora (oak) starch. Starch-Stärke. 1993;45:127–30.

12. Chopra RN, Nayar SL, Chopra IC. Glossary of Indian medicinal plants (including the supplement). 1986.

13. Sati SC, Sati N, Sati OP. Chemical investigation and screening of antimicrobial activity of stem bark of Quercus leucotrichophora. Int J Pharm Pharm Sci. 2011;3:89–91.

14. Sati SC, Sati N, Sati OP. Chemical composition and antimicrobial activity of fatty acid methyl ester of Quercus leucotrichophora fruits. Nat Prod Res. 2016. https://doi.org/10.1080/14786419.2016.1217202.

15. Joshi AK, Juyal D. Traditional and ethnobotanical uses of Quercus leucotrichophora a. Camus (Quercus oblongata D. Don) in Kumaun and Garhwal regions of Uttarakhand, India: a review. Int. J Herb Med. 2017;5:06–8.

16. Hameed IH, Jasim H, Kareem MA, Hussein AO. Alkaloid constitution of Nerium oleander using gas chromatography-mass spectroscopy (GC-MS). J Med Plants Res. 2015;9:326–34. https://doi.org/10.5897/JMPR2015.5746.

17. Hussein AO, Mohammed GJ, Hadli MY, Hameed IH. Phytochemical screening of methanolic dried galls extract of Quercus infectoria using gas chromatography-mass spectrometry (GC-MS) and Fourier transform-infrared (FT-IR). J Pharmacognosy Phytother. 2016;8:49–59. https://doi.org/10.5897/JPP2015.0368.

18. Aydin R. Conjugated linoleic acid: chemical structure sources and biological properties. Turk J Vet Anim Sci. 2005;29:889–95.

19. Ansarali S, Manikandan S, Lakshmanan GMA. Identification of biological components from potential bone healer medicinal plants. J Drug Deliv Ther. 2018;8:32–41. https://doi.org/10.22270/jddt.v8i3.83.1762.

20. Tejerina D, García-Torres S, Cabeza de Vaca M, Marqués J, Cava R. Acorns (Quercus rotundifolia Lam.) and grass as natural sources of antioxidants and fatty acids in the montanera feeding of Iberian pigs: intra- and inter-annual variations. Food Chem. 2011;124:997–1004. https://doi.org/10.1016/j.foodchem.2010.07.058.

21. Barbouer E, Al Sharif M, Sahgerian V, Habre AN, Talhouk RS, et al. Screening of selected indigenous plants of Lebanon for antimicrobial activity. J Ethnopharmacol. 2004;93:1–7.