Asplenioideae Species as a Reservoir of Volatile Organic Compounds with Potential Therapeutic Properties
Didier Froissard, Sylvie Rapior, Jean-Marie Bessière, Bruno Buatois, Alain Fruchier, Vincent Sol, Françoise Fons

To cite this version:
Didier Froissard, Sylvie Rapior, Jean-Marie Bessière, Bruno Buatois, Alain Fruchier, et al.. Asplenioideae Species as a Reservoir of Volatile Organic Compounds with Potential Therapeutic Properties. Natural Product Communications, SAGE Publications, 2015, 10 (6), pp.1079-1083. 10.1177/1934578X1501000671. hal-01257591
This Issue is Dedicated to
Dr. Pawan K. Agrawal
On the Occasion of his 60th Birthday

ISSN 1934-578X (printed); ISSN 1555-9475 (online)
www.naturalproduct.us
INFORMATION FOR AUTHORS

Full details of how to submit a manuscript for publication in Natural Product Communications are given in Information for Authors on our Web site http://www.naturalproduct.us.

Authors may reproduce/republish portions of their published contribution without seeking permission from NPC, provided that any such republication is accompanied by an acknowledgment (original citation)-Reproduced by permission of Natural Product Communications. Any unauthorized reproduction, transmission or storage may result in either civil or criminal liability.

The publication of each of the articles contained herein is protected by copyright. Except as allowed under national “fair use” laws, copying is not permitted by any means or for any purpose, such as for distribution to any third party (whether by sale, loan, gift, or otherwise); as agent (express or implied) of any third party; for purposes of advertising or promotion; or to create collective or derivative works. Such permission requests, or other inquiries, should be addressed to the Natural Product Inc. (NPI). A photocopy license is available from the NPI for institutional subscribers that need to make multiple copies of single articles for internal study or research purposes.

To Subscribe: Natural Product Communications is a journal published monthly. 2015 subscription price: US$2,595 (Print, ISSN# 1934-578X); US$2,595 (Web edition, ISSN# 1555-9475); US$2,995 (Print + single site online); US$595 (Personal online). Orders should be addressed to Subscription Department, Natural Product Communications, Natural Product Inc., 7963 Anderson Park Lane, Westerville, Ohio 43081, USA. Subscriptions are renewed on an annual basis. Claims for nonreceipt of issues will be honored if made within three months of publication of the issue. All issues are dispatched by airmail throughout the world, excluding the USA and Canada.
Aspleniaceae Species as a Reservoir of Volatile Organic Compounds with Potential Therapeutic Properties

Didier Froissard*a, Sylvie Rapiore, Jean-Marie Bessièrec, Bruno Buotois, Alain Frucherid, Vincent Solae and Françoise Fons**

a Laboratoire de Chimie des Substances Naturelles, LCSN, EA 1069, Faculté de Pharmacie de Limoges, 2 rue du Docteur Marcland, F-87025 Limoges Cedex, France
b Laboratoire de Botanique, Phytotechnie et Mycologie, Faculté de Pharmacie, CEFE UMR 5175, CNRS - Université de Montpellier - Université Paul-Valéry Montpellier - EPHE, 15 avenue Charles Flahault, F-34093 Montpellier Cedex 5, France
c Centre d’Ecologie Fonctionnelle et Evolutive – Plate-forme d’analyses chimiques en écologie, UMR 5175 CEF, 1919 Route de Mende, F-34293 Montpellier Cedex 5, France
d ENSCM, UMR 5253, 8 Rue de l’Ecole Normale, F-34296 Montpellier Cedex 5, France.
francoise.fons@univ-montp1.fr

Received: September 17th, 2014; Accepted: November 14th, 2014

Twelve French Aspleniaceae ferns (genera Asplenium and subgenera Ceterach and Phyllitis) were investigated for the first time for volatile organic compounds (VOC) using GC-MS. Sixty-two VOC biosynthesized from the lipidic, shikimic, terpenic and carotenoid pathways were identified. Several VOC profiles can be highlighted from Asplenium jahandiezii and A. ×alternifolium with exclusively lipidic derivatives to A. onopteris with an equal ratio of lipidic/shikimic compounds. Very few terpenes as carophyllene derivatives were identified, but only in A. obovatum subsp. bilotii. The main odorous lipidic derivatives were (E)-2-decanal (waxy and fatty odor), nonenal (aldehydic and waxy odor with a fresh green nuance), (E)-2-heptenal (green odor with a fatty note) and 1-octen-3-ol (mushroom-like odor), reported for all species. A few VOC are present in several species in high content, i.e., 9-oxononanoic acid used as a precursor for biopolymers (19% in A. jahandiezii), 4-hydroxyacetophenone with a sweet and heavy floral odor (17.1% in A. onopteris), and 4-hydroxybenzoic acid used as a precursor in the synthesis of parabens (11.3% in A. forrestii). Most of the identified compounds have pharmacological activities, i.e., octanoic acid as antimicrobial, in particular against Salmonellas, with fatty and waxy odor (41.1% in A. petrarchae), tetradecanoic acid with trypanocidal activity (13.3% in A. obovatum subsp. bilotii), 4-hydroxybenzoic acid (8.7% in A. onopteris) with antimicrobial and anti-aging effects, 3,4-dihydroxybenzaldehyde as an inhibitor of growth of human cancer cells (6.7% in Ceterach officinarum), and phenylacetic acid with antifungal and antibacterial activities (5.8% in A. onopteris). Propionylfilinic acid was identified in the twelve species. The broad spectrum of odorous and bioactive VOC identified from the Asplenium, Ceterach and Phyllitis species are indeed of great interest to the cosmetic and food industries.

Keywords: Asplenium, Ceterach, Phyllitis, Volatile Organic Compounds, 9-Oxononanoic acid, 3,4-Dihydroxybenzaldehyde, Antimicrobial, Anti-aging.

Aspleniaceae Link is a great and homogeneous subfamily of Aspleniaceae Newman. Asplenium L. is the major genus with approximately seven hundred subcosmopolitan ferns distributed worldwide, and seventeen species in France. Several subgenera have been separated, such as Ceterach (Willd) Vida ex Bir, Fraser-Jenkins & Lovis and Phyllitis (Hill) Jermy & Viane [1a-1e].

The scientific name Asplenium was given by Pedanius Dioscorides (Roman physician, pharmacologist and botanist of Greek origin) to these plants that are well-known for their medicinal properties to cure the spleen; their common name “spleenwort” derives from the doctrine of signatures. Aspleniaceae includes many species reported for various traditional medicinal uses. Leaves and/or rhizomes of Asplenium adiantum-nigrum L., Ceterach officinarum Willd. (= A. ceterach L.), A. cuneatum Lam., A. falcatum Lam., A. marinanum L., A. monanthes L., A. nidus L., A. ruta-muraria L., Phyllitis scolopendrium (L.) Newman (= A. scolopendrium L.) and A. trichomanes L. are used against worms, lung affictions, cough inflammation, hypertension, jaundice, enlarged spleen, intestinal disorder, kidney stones, burns, elephantiasis and ulcers, and as an emetic, deparutive, diaphoretic and sedative in traditional medicine [2a-2g]. Recently, antioxidant, antimicrobial and antibacterial properties of A. ceterach and A. nidus were demonstrated [2h-2i]. Regarding the chemical composition of Aspleniaceae, A. adiantum nigrum, A. fontanum, A. forrestense, A. incisum, A. normale, A. obovatum, A. ruta-muraria, A. trichomanes and Ceterach officinarum were investigated for their phenolic derivatives [3a-3e].

Very few Asplenium are known to have an odor: A. auritum Sw. has pleasantly fragrant fronds and A. lamprophilum Carse smells of wintergreen [4a]. Consequently, little is known about the volatile organic compounds (VOC) of these ferns. The terpenoid constituents of A. scolopendrium were studied [4b]. In addition, A. trichomanes subsp. trichomanes was investigated for its volatile profile [4c], which showed mainly polyketides, for example octanoic acid (= caprylic acid; fatty and waxy odor), nonanoic acid (waxy, dairy note), (E)-2-decenol (waxy note), (E)-2-heptenal (green odor with a fatty note) with globally an oily or waxy odor.

In this new work, fresh aerial parts of twelve French species of Aspleniaceae were investigated for their volatile profiles using GC-MS, as reported in the literature for the twenty-three monilophytes previously studied [4c-4f]. Sixty-two components biosynthesized from the shikimic, lipidic, terpenic and carotenoid pathways were identified from the concentrated diethyl ether extracts of the twelve Aspleniaceae (Table 1).

The VOC profile of Ceterach officinarum is widely dominated by lipidic derivatives (77.4%), in particular (E)-2-decanal (10.5%), a natural plant and mushroom VOC with waxy and fatty odor type
Table 1: Percentage of volatile organic compounds in fresh aerial part of Asplenium, Ceterach and Phyllitis species.

| Compounds                  | RF | Ceterach officinarum scopolianum | Asplenium septentrionale flavum | Asplenium septentrionale foreczense | Asplenium sebulletum | Asplenium balearicum | A. rutheninum | A. ceterach | A. ceterach petrarchae | A. ceterach jahandiezii | A. ceterach officinarum | A. ceterach onopteris | A. ceterach sebullatissimo | A. ceterach septentrionale | A. ceterach septentrionale septentrionale | A. ceterach sebullatissimo alpenlilium |
|----------------------------|----|----------------------------------|---------------------------------|-------------------------------------|---------------------|---------------------|----------------|------------|------------------------|------------------------|----------------------|----------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Lipidic derivatives        |    | 1080                             | 1080                             | 1080                                | 1080                | 1080                | 1080          | 1080      | 1080                   | 1080                   | 1080                 | 1080                 | 1080                            | 1080                            | 1080                            | 1080                            | 1080                            |
| Hexanal                    | 1008 | 1.8                             | 0.4                               | 2.0                                 | 3.7                 | 1.3                 | 1.3           | 0.3       | 0.3                    | 0.3                    | 0.3                  | 0.3                  | 0.3                             | 0.3                             | 0.3                             | 0.3                             | 0.3                             |
| (E)-3-Hexenoic acid        | 1017 | 1.1                             | 0.1                               | 0.3                                 | 0.5                 | 0.7                 | 0.1           | 0.2       | 0.2                    | 0.2                    | 0.2                  | 0.2                  | 0.2                             | 0.2                             | 0.2                             | 0.2                             | 0.2                             |
| 3-Octen-2-one              | 1029 | 3.1                             | 1.0                               | 0.5                                 | 1.4                 | 2.1                 | 2.2           | 0.4       | 0.4                    | 0.4                    | 0.4                  | 0.4                  | 0.4                             | 0.4                             | 0.4                             | 0.4                             | 0.4                             |
| (E,E)-3-Hexenoic acid      | 1056 | 1.1                             | 0.3                               | 0.6                                 | 1.8                 | 2.3                 | 1.2           | 1.5       | 1.5                    | 1.5                    | 1.5                  | 1.5                  | 1.5                             | 1.5                             | 1.5                             | 1.5                             | 1.5                             |
| (E)-2-Octenal              | 1069 | 0.5                             | 1.0                               | 0.2                                 | 0.5                 | 0.5                 | 1.5           | 1.7       | 1.7                    | 1.7                    | 1.7                  | 1.7                  | 1.7                             | 1.7                             | 1.7                             | 1.7                             | 1.7                             |
| 3,4-Dihydroxybenzaldehyde  | 1077 | 2.1                             | 0.8                               | 0.4                                 | 2.4                 | 0.1                 | 4.0           | 2.0       | 1.5                    | 4.1                    | 4.1                  | 4.1                  | 4.1                             | 4.1                             | 4.1                             | 4.1                             | 4.1                             |
| Nonanal                    | 1098 | 2.3                             | 0.5                               | 3.1                                 |                     |                     |                |           |                        |                        |                      |                      |                                  |                                  |                                  |                                  |                                  |
| Decanoic acid              | 1104 | 10.0                            | 9.3                               | 2.8                                 | 2.8                 | 7.5                 | 7.2           | 5.0       | 11.2                   | 13.3                   | 14.0                 | 8.5                  | 4.4                             |                                  |                                  |                                  |                                  |
| 2-Amino-4-methoxyphenol     | 1114 | 2.9                             | 0.5                               | 0.7                                 | 3.1                 |                     |                |           |                        |                        |                      |                      |                                  |                                  |                                  |                                  |                                  |
| 2,3-Octanedione             | 1115 | 1.0                             | 1.2                               | 0.4                                 | 0.8                 | 0.5                 | 0.7           | 0.9       | 0.9                    | 1.3                    | 1.4                  | 1.6                  | 1.6                             |                                  |                                  |                                  |                                  |
| Hexanoic acid              | 1116 | 1.2                             | 1.0                               | 0.4                                 | 0.8                 | 0.5                 | 0.7           | 0.9       | 0.9                    | 1.3                    | 1.4                  | 1.6                  | 1.6                             |                                  |                                  |                                  |                                  |
| 2-Octenal                  | 1117 | 1.1                             | 2.2                               | 2.8                                 | 41.1                | 5.4                 | 1.8           | 3.2       | 7.2                    | 12.2                   | 3.3                  | 3.9                  | 3.2                             |                                  |                                  |                                  |                                  |
| 3,4-Octadienal             | 1118 | 1.0                             | 0.5                               | 0.2                                 | 1.7                 | 0.4                 | 1.2           | 0.4       | 1.1                    | 0.8                    | 0.9                  | 0.9                  | 0.9                             |                                  |                                  |                                  |                                  |
| 2,4-Nonadienal             | 1119 | 1.7                             | 1.8                               | 1.4                                 | 3.0                 | 13.3                | 3.7           | 6.5       | 3.3                    | 7.3                    | 4.2                  | 4.2                  | 4.2                             |                                  |                                  |                                  |                                  |
| 3-Octen-1-ol               | 1121 | 0.5                             | 0.3                               | 0.2                                 | 1.5                 | 1.5                 | 1.0           | 2.8       | 3.9                    | 3.2                    | 3.2                  | 3.2                  | 3.2                             |                                  |                                  |                                  |                                  |
| 9-Octanenitrile            | 1150 | 6.2                             | 2.1                               | 19.0                                | 2.2                 | 3.7                 | 3.8           | 4.4       | 4.1                    | 7.0                    | 7.0                  | 7.0                  | 7.0                             |                                  |                                  |                                  |                                  |
| Methyl laurate             | 1151 | 7.9                             | 0.5                               | 4.6                                 |                     |                     |                |           | 1.5                    | 0.2                    |                      |                      |                                  |                                  |                                  |                                  |                                  |
| Propionylfumaric acid      | 1228 | 0.5                             | 0.4                               | 0.7                                 |                     |                     |                |           |                        |                        |                      |                      |                                  |                                  |                                  |                                  |                                  |
| Lipoic acid                | 1229 | 0.3                             | 0.3                               | 0.3                                 |                     |                     |                |           |                        |                        |                      |                      |                                  |                                  |                                  |                                  |                                  |
| Nonanamide                 | 1230 | 0.3                             | 0.3                               | 0.3                                 |                     |                     |                |           |                        |                        |                      |                      |                                  |                                  |                                  |                                  |                                  |
| Methyl 2-hydroxypropanoate  | 1231 | 1.5                             | 1.5                               | 1.5                                 |                     |                     |                |           | 0.5                    | 0.5                    | 0.5                  | 0.5                  | 0.5                             |                                  |                                  |                                  |                                  |
| 2,3-Dihydrobenzenoic acid  | 1232 | 1.1                             | 0.9                               | 0.9                                 |                     |                     |                |           | 0.9                    | 0.9                    | 0.9                  | 0.9                  | 0.9                             |                                  |                                  |                                  |                                  |
| 3,4-Dihydroxybenzaldehyde  | 1233 | 1.1                             | 0.9                               | 0.9                                 |                     |                     |                |           | 0.9                    | 0.9                    | 0.9                  | 0.9                  | 0.9                             |                                  |                                  |                                  |                                  |
| 3-Octyl acetate            | 1234 | 0.5                             | 0.5                               | 0.5                                 |                     |                     |                |           | 0.5                    | 0.5                    | 0.5                  | 0.5                  | 0.5                             |                                  |                                  |                                  |                                  |
| 3-Octane                  | 1235 | 1.1                             | 0.5                               | 0.5                                 |                     |                     |                |           | 0.5                    | 0.5                    | 0.5                  | 0.5                  | 0.5                             |                                  |                                  |                                  |                                  |
| 3,4-Dihydroxybenzaldehyde  | 1236 | 0.5                             | 0.5                               | 0.5                                 |                     |                     |                |           | 0.5                    | 0.5                    | 0.5                  | 0.5                  | 0.5                             |                                  |                                  |                                  |                                  |
| 3-Octyl acetate            | 1237 | 0.5                             | 0.5                               | 0.5                                 |                     |                     |                |           | 0.5                    | 0.5                    | 0.5                  | 0.5                  | 0.5                             |                                  |                                  |                                  |                                  |
| 3-Octyl acetate            | 1238 | 0.5                             | 0.5                               | 0.5                                 |                     |                     |                |           | 0.5                    | 0.5                    | 0.5                  | 0.5                  | 0.5                             |                                  |                                  |                                  |                                  |

**Note:** Relative percentage of the VOC based on the GC-MS chromatographic area; *RI = Retention Indices on SLB**<sup>TM</sup>-5MS column (Supelco); N.I = Not identified.
Asplenium jahanidzeii is a small and protected fern only located in the canyon of Verdon (France) [1a]. Its VOC spectrum is almost exclusively dominated by twenty-nine identified lipidic compounds (98%). The major volatile is 9-oxononanoic acid (19%), an interesting VOC as a renewable resource of a precursor for biopolymers [9a]. It was recently discovered that 9-oxononanoic acid stimulates the activity of phospholipase A₂, the key enzyme of the arachidonate cascade [9b]. The other lipidic derivatives with various odorous or pharmacological properties were (E)-2-decenal (13.1%), (E)-2-heptenal (10.5%), nonanal (7.2%), octanoic acid (5.4%), 1-octen-3-ol (3.7%) and tetradecanoic acid (3%). The minor odorous and bioactive lipidic derivatives were 2,3-octanediol (2.9%), with a dill cooked broccoli butty odor [9c], and octanol (2.4%), with a sweetish odor and toxic to Colletotrichum gloeosporioides, an endophytic plant pathogen [9d], as well as (E,Z)-2,4-decadienal (2.3%), with a fatty, green and waxy odor, (E,E)-2,4-decadienal (2.2%), octanal (2.2%), with an aldehyde, fatty, orange peel, pungent and soapy flavor, (E)-2-decenol (2.1%), with a waxy, citrus and fresh note, and hexanoic acid (2%).

Asplenium obovatum subsp. bilotti has a broad spectrum of VOC with a high content of lipidic derivatives (59.4%) including 13.3% of tetradecanoic acid. This saturated fatty acid is one of the lipidic constituents of the cellular membrane of Eucaryotes. It is used as a lubricant and in the manufacture of flavors, pharmaceuticals, soaps and cosmetics, and has a trypanocidal activity, which was highlighted against *Trypanosoma evansi* two decades ago [10a]. This acid was identified in eleven of the studied ferns (Table 1). Nonanal (7.2%), (E)-2-decenal (6.1%), 1-octen-3-ol (4.5%), (E)-2-heptenal (3.9%), nonanoic acid (2.7%), hexahydrofarnesylacetone (2.7%), 9-oxononanoic acid (2.2%), and octanoic acid (1.8%) were also identified from the organic extract. Aromatic compounds represent 25.5% of the VOC content of *A. obovatum* subsp. *bilotti* with 4-hydroxybenzoic acid (7.8%), 3-methoxy-4-hydroxybenzoic acid (4.4%), 2-amino-4-methoxyphenol (2.7%) as well as 3,4-dihydroxyxystereine (1.8%), an inhibitor of phenylalanine hydroxylase used for the production of experimental phenylketonuria [10b]. Finally, the carotenoids (13.1%) are dominated by 4-hydroxy-β-ionone (1.9%), 4-hydroxy-5,6-epoxy-β-ionone (1.7%) and 4-hydroxy-7,8-dihydro-β-ionone (1.6%), which is well-known as a key odorant in yellow wines [10c]. Two sesquiterpenes, i.e., caryophyllene alcohol and caryophyllene oxide, complete the VOC composition of *A. obovatum* subsp. *bilotti*. This oxygenated terpenoid, which is a flavoring agent used in cosmetics and food, also displays biological activities (anti-inflammatory, antifungal, skin enhancing and anti-carcinogenic) [10d].

The six others *Asplenium* species also investigated for their VOC content for the first time were *A. septentrionale*, *A. foreziense*, *A. balearicum*, *A. ruta-muraria*, *A. fontanum* and *Asplenium alternifolium*.

Most of their volatile constituents were mentioned above for the six first detailed VOC fern profiles. The main VOCs identified for *A. septentrionale* were two aldehydes, i.e., (E)-2-decenal (10.9%) and nonanal (5%). In addition *A. septentrionale* contained the highest concentration of hexahydrofarnesylacetone (5.6%), hexanoic acid (3.7%), a fatty acid found in animal oils with a fatty, waxy or cheesy flavor, N-acetylpyrrolidone (3.1%) and 3-hydroxy-5,6-epoxy-β-ionone (3.1%). *A. foreziense* also produced a high level of aldehydes (nonanal, (E)-2-decenal...) and the highest proportions of 4-hydroxybenzoic acid (11.3%), (E,Z)-2,4-decadienal (5.3%), with a...
fatty, green and waxy odor, and 7,8-epoxy-β-ionone (3.8%) when compared with the other Asplenioidae (Table 1).

The highest percentages of (E)-2-decenal (20.2%), with a waxy fatty odor, and (E)-2-heptenal (13%), with a green fatty note, were found in A. balearicum, which also produced a high level of nonanal (13.5%), with an aldehydic and green scent. The volatile fraction of A. ruta-muraria contained 13.5% of shikimic compounds, i.e., phenylacetic acid (5.6%), as well as 11.4% of carotenoid derivatives, i.e., 4-hydroxy-5,6-epoxyenol (7.8%). Its major lipid derivatives (74.5%) were nonanal (14%), (E)-2-decenal (13.1%), nonanoic acid (7.8%) and (E)-2-heptenal (5.6%), already found in the other Asplenium species. The global VOC profile of this species (lipidic derivatives / shikimic derivatives ratio) can be compared with those of P. sclopetandrum and P. petrachae.

The major VOC of A. fontanum were three aldehydes, i.e., (E)-2-decenal, nonanal and (E)-2-heptenal, as well as tetradeconic acid, already found in most of the Asplenium species. The Asplenium ×alternifolium VOC profile was close to that of A. jahandizii, with uniquely lipidic derivatives (99.3%) and no shikimic compounds. The major lipid compounds of A. ×alternifolium were (E)-2-decenal (12.8%), (E)-2-heptenal (8.8%), 9-oxononanoic acid (7%), (E)-2-tridecanonic acid (6.4%) and 1-octen-3-ol (6.1%), also produced by C. officinarum and A. septentrionale. Compared with the eleven other species investigated (Table 1), A. ×alternifolium contained the highest amount of 2-pentylfuran (4.3%), 3-octen-2-one (4.2%); earthy spicy herbal with mushroom nuances), octanal (4.1%), (E,E)-2,4-decadienal (4.1%), heptanal (3.3%), and 2,3-octanedione (3.2%).

Conclusion: The twelve French ferns from the family Aspleniaceae investigated for VOC mainly contain derivatives of lipidic origin. Several VOC profiles can be highlighted from the eleven other species investigated (Table 1), A. ×alternifolium compared with those of P. sclopetandrum and P. petrachae.

References


Volatile organic compounds from twelve French Asplenioideae ferns


A New Aromatic Compound from the Stem Bark of *Terminalia catappa*
David Pertuit, Anne-Claire Mitaine-Offer, Tomofumi Miyamoto, Chiaki Tanaka, Stéphanie Delemasure, Patrick Dutartre and Marie-Aleth Lacaille-Dubois

Effect of Non-psychoactive Plant-derived Cannabinoids on Bladder Contractility: Focus on Cannabigerol
Ester Pagano, Vittorino Montanaro, Antonio di Girolamo, Antonio Pistone, Vincenzo Altieri, Jordan K. Zjawiony, Angelo A. Izzo and Raffaele Capasso

In Cell Interactome of Oleocanthal, an Extra Virgin Olive Oil Bioactive Component
Chiara Cassiano, Agostino Casapullo, Alessandra Tosco, Maria Chiara Monti and Raffaele Riccio

Synthesis of γ-Viniferin Glycosides by Glucosyltransferase from *Phylolaccia americana* and their Inhibitory Activity on Histamine Release from Rat Peritoneal Mast Cells
Hiroki Hamada, Hatsuyuki Hamada and Kei Shimoda

Stability of the Ellagitannin Fraction and Antioxidant Capacity of Varietal Pomegranate Juices
Pedro Mena and Cristina Garcia-Viguera

Phthalide Anions in Organic Synthesis. A Direct Total Synthesis of Furomollugin
George A. Kraus and Pengfei Dong

Absolute Configuration Assignment of 3',4'-di-O-acylkhellactones Using Vibrational Circular Dichroism Exciton Chirality
Abigail L. Buendia-Trujillo, J. Martin Torres-Valencia, Pedro Joseph-Nathan and Eleuterio Burgueño-Tapia

Antifouling Compounds from the Marine-Derived Fungus *Aspergillus terreus* SCSCAF0162
Xu-Hua Nong, Xiao-Yong Zhang, Xin-Ya Xu and Shu-Hua Qi

Goji Berry: Quality Assessment and Crop Adaptation of Plants Cultivated in Tuscany (Italy) by Combination of Carotenoid and DNA Analyses
Giada Capecchi, Emanuele Goti, Elena Nicolai, Maria Camilla Bergonzoni, Roberto Monnanni and Anna Rita Bilia

Activity of *Vitis vinifera* Tendrils Extract Against Phytopathogenic Fungi
Daniele Fraternale, Donata Ricci, Giancarlo Verardo, Andrea Gorassini, Vilberto Stocchi and Piero Sestili

Long-chain Glucosinolates from *Arabis turrita*: Enzymatic and Non-enzymatic Degradations
Ivica Blažević, Sabine Montaut, Gina Rosalinda De Nicola and Patrick Rollin

Aroma of Turmeric: Dependence on the Combination of Groups of Several Odor Constituents
Toshio Hasegawa, Kenta Nakatani, Takashi Fujihara and Hideo Yamada

Terpenoids Preserved in Fossils from Miocene-aged Japanese Conifer Wood
Agneszka Ludwiczuk and Yoshinori Asakawa

Can Ozone Alter the Terpenoid Composition and Membrane Integrity of *in vitro Melissa officinalis* Shoots?
Francesca D’Angioliillo, Mariagrazia Tonelli, Elisa Pellegrini, Cristina Nali, Giacomo Lorenzini, Luisa Pistelli and Laura Pistelli

Composition and Chemical Variability of *Ivoirian Xylopia staudtii* Leaf Oil
Thierry Acafou Yapi, Jean Brice Boti, Antoine Coffy Ahbio, Sylvain Sutour, Ange Bighelli, Joseph Casanova and Félix Tomi

Chemoinformatics Approach to Antibacterial Studies of Essential Oils
Dragoljub L. Miladinović, Budimir S. Ilie and Branislava D. Kocić

Chemical Composition of *Nardostachys grandiflora* Rhizome Oil from Nepal – A Contribution to the Chemotaxonomy and Bioactivity of *Nardostachys*
Prabhodh Satyal, Bhuwans K. Chhetri, Noura S. Dosoky, Amberk Poudel and William N. Setzer

Chemical Composition and Biological Activity of Essential Oils from Wild Growing Aromatic Plant Species of *Skimmia laureola* and *Juniperus macroplexa* from Western Himalaya

Comparative Chemical Composition and Antioxidant Properties of the Essential Oils of three *Sideritis libanotica* Subspecies
Carmen Formisano, Filomena Oliviero, Daniela Rigano, Nelly Apostolides Arnold and Felice Senatore

Asplenioideae Species as a Reservoir of Volatile Organic Compounds with Potential Therapeutic Properties
Didier Pertuit, Sylvie Rapior, Jean-Marie Bessière, Bruno Buatois, Alain Fruchier, Vincent Sol and Françoise Fons

Composition and Comprehensive Antioxidant Activity of Ginger (*Zingiber officinale*) Essential Oil from Ecuador
Martina Höferl, Ivanka Stoilova, Juergen Wanner, Erich Schmidt, Leopold Jirovetz, Dora Trifonova, Veselin Stanchev and Albert Krastanov

Chemical Components of Four Essential Oils in Aromatherapy Recipe
Sarin Tadtong, Narsa Kamkaen, Rith Watthanachaiyingcharoen and Nijisiri Ruangrungsi

Articles/Reviews

Recent Advances in the Synthesis of *Stemona* Alkaloids
Xiao-Yu Liu and Feng-Peng Wang

Flavonoid Properties in Plant Families Synthesizing Betalain Pigments (Review)
Tsukasa Iwashina

Phytochemistry and Pharmacology of the Genus *Tovomita*
Francesco Epifano, Maria Carmela Specchiulli, Vito Alessandro Taddeo, Serena Fiorito and Salvatore Genovese

Fungal Phytotoxins with Potential Herbicidal Activity to Control *Chenopodium album*
Alessio Cimmino, Marco Masi, Marco Evidente and Antonio Evidente

Essential Oils as “A Cry for Help”. A Review
Christine Zitzelsberger and Gerhard Buchbauer
Anti-Acetylcholinesterase Alkaloids from *Annona glabra* Leaf
Shohei-Sheng Lee, Dong-Yi Wu, Sheng-Fa Tsai, and Chien-Kuang Chen

Increased Oxidative Stress in Cultured 3T3-L1 Cells was Attenuated by Berberine Treatment
Shi-fen Dong, Naomi Yasui, Hiroko Negishi, Aya Kishimoto, Jin-ning Sun and Katsumi Ikeda

Synthesis and Antimicrobial Activities of 3-Methyl-β-carboline Derivatives
Jiwen Zhang, Longbo Li, Wen-jia Dan, Jian Li, Qianliang Zhang, Hongjin Bai and Junru Wang

A Novel One-step Synthesis of Quinoline-2(1H)-thiones and Selones by Treating 3-Aryl-3-(2-amino phenyl)-1-propyn-3-ols with a Base and Elemental Sulfur or Selenium
Kazuaki Shimada, Hironori Izumi, Koki Otashiro, Jeong-hyun Lee, Jeong-Hyung Lee, Jeong Ah Kim, Mi Hee Woo and Byung Sun Min

Computational and Investigative Study of Flavonoids Active Against *Trypanosoma cruzi* and *Leishmania* spp
Frederico F. Ribeiro, Francisco J.B.M. Junior, Marcelo S. da Silva, Marcus Tullius Scotti and Luciana Scotti

Two New Secondary Metabolites from *Tephradia purpurea*
Yin-Ning Chen, Yan Peng, Cheng-Hai Gao, Tao Yan, Zhi-Fang Xu, Samuel X. Qiu, Wen-Hao Cao, Ligao Deng and Ri-Ming Huang

Regioselective Glycosylation of 3-, 5-, 6-, and 7-Hydroxyflavones by Cultured Plant Cells
Kei Shimoda, Naoki Kubota, Dai-Suke Usugi, Yuuya Fujitaka, Shouta Okada, Masato Tanigawa and Hiroki Hamada

Unusual Flavonoid Glycosides from the Hawaiian Tree *Metroselanders polymorpha*
Benjamin R. Clark, Swapan Pramanick, Norman Arancan and Robert P. Borris

Anti-inflammatory Flavonoids Isolated from *Passiflora foetida*
Thi Yen Nguyen, Dao Cuong To, Manh Hung Tran, Joo Sang Lee, Jeong Hyung Lee, Jeong Ah Kim, Mi Hee Woo and Byung Sun Min

Clavamide and Flavonoids from Leaves of *Trifolium pratense* and *T. pratense* subsp. *nivale* Grown in Italy
Aldo Tava, Lukasz Pecio, Anna Stochem and Luciano Pecetti

Water Extract of *Mentha × villosa*: Phenolic Fingerprint and Effect on Ischemia-Reperfusion Injury
Silvia Fialova, Lucia Veizerova, Viera Nosalova, Katarina Drabikova, Daniela Tekelova, Daniel Grancai and Ruzena Sotnikova

Distribution and Taxonomic Significance of Secondary Metabolites Occurring in the Methanol Extracts of the Stonecrops (*Sedum L.*, *Crassulaceae*) from the Central Balkan Peninsula
Gordana S. Stojanovic, Snjezana Ć. Jovanovic and Bojan K. Zlatkovic

In vitro Xanthine Oxidase Inhibitory Studies of *Lippia nodiflora* and Isolated Flavonoids and Phenylethanoid Glycosides as Potential Urinary Acid-lowering Agents
Lee-Chuen Cheng, Vikneswaran Murugainay and Kit-Lam Chan

Enzymatic Synthesis of Quercetin Monoglucopyranoside and Maltoligosaccharides
Ryo Yasukawa, Natsumi Suda, Koichi Katoh, Miya-i Taxho, Koichi Matsumoto, Koichiro Kawaguchi, Sei-ichi Kawahara, Hiroshi Fujii and Hidefumi Makabe

Polymethylene Microstructures—A Good or Bad Partner for the Isoflavone Genistein?
Corina Danciu, Florin Borcan, Codruta Soica, Istvan Zipko, Erzsébet Csányi, Rita Ambrus, Delia Muntean, Camelia Sass, Diana Antal, Claudia Toma and Cristina Dehelean

Chemical Constituents of the Underground Parts of *Iris florentina* and Their Cytotoxic Activity
Akihito Yokosuka, Yoshikazu Koyama and Yoshihiro Mimaki

Synthesis of Arecatannin A1 from Dimeric Epicatechin Electrophile
Masato Suda, Koichi Katoh, Koichi Matsumoto, Koichiro Kawaguchi, Sei-ichi Kawahara, Hiroshi Fujii and Hidefumi Makabe

Anthocyanin Profile and Antioxidant Activity of Various Berries Cultivated in Korea
Hong-Sook Bae, Hyun Ju Kim, Jin Hee Kang, Rika Kudo, Takahiro Hosoya, Shigenori Kumazawa, Mira Jun, Oh-Yoen Kim and Mok-Ryeon Ahn

Metabolite Fingerprinting of *Eugenia jambolana* Fruit Pulp Extracts using NMR, HPLC-PDA-MS, GC-MS, MALDI-TOF-MS and ESI-MS/MS Spectrometry
Ram Jee Sharma, Ramesh G. Gupta, Arvind Kumar Bansal and Inder Pal Singh

Flavonoids and Phenolic Acids in Needles of *Agnieszka Arceusz*, Marek Wesolowski and Beata Ulewicz-Magulska

Flavonoids and Other Phenolic Compounds in Needles of *Eugenia jambolana* and *Passiflora foetida* and their Cytotoxic Activity
Hong-Sook Bae, Hyun Ju Kim, Jin Hee Kang, Rika Kudo, Takahiro Hosoya, Shigenori Kumazawa, Danerail Tekelova, Daniel Grancai and Ruzena Sotnikova

Anti-inflammatory, Antimicrobial Activity Characterization and Toxicity Studies of Flowers of “Jarrow”, a Medicinal Shrub from Argentina
Alejandra Moreno, Gabriela Nuño, Soledad Cuello, Jorge E. Sayago, Mar'a Rosa Alberto, Catiana Zampini and María Inés Isla

Synthesis of Resveratrol Glycosides by Plant Glucosyltransferase and Cyclodextrin Glucanotransferase and Their Neuroprotective Activity
Kei Shimoda, Naoki Kubota, Hatsuyuki Hamada and Hiroki Hamada

The Lignan-containing Extract of *Schisandra chinensis* Berries Inhibits the Growth of *Chlamydia pneumoniae*
Elina Hakala, Leena L. Hanski, Teijo Yrjönen, Heikki J. Vuorela and Pia M. Vuorela
Natural Product Communications
2015
Volume 10, Number 6
Contents

Editorial i

Preface iii

Original Paper

Chemical and Genetic Diversity of Ligularia hodgsonii in China
Chiaki Kuroda, Kou Inagaki, Xun Chao, Kyousuke Inoue, Yasuko Okamoto, Motoo Tori, Xun Gong, and Ryo Hanai

Constituents of Ligularia brassicoides Collected in China: A New Diels-Alder Adduct of Eremophilan-10β-ol and Methacrylic Acid
Mizuho Taniguchi, Katsuyuki Nakashima, Yasuko Okamoto, Xun Gong, Chiaki Kuroda and Motoo Tori

Four New Sesquiterpenoids from Ligularia subspicata Collected in China; Isolation of a Bakkane-type Lactone, an Eremophilane-type Lactone, and Two Ortho Esters
Yoshinori Saito, Takanori Osutbo, Katsuyuki Nakashima, Yasuko Okamoto, Xun Gong, Chiaki Kuroda and Motoo Tori

Natural Caryophyllane Sesquiterpenoids from Rumphella antipathies
Hsu-Ming Chung, Wei-Hsien Wang, Tsong-Long Hwang, Yang-Chang Wu and Ping-Jyun Sung

Bioactive Compounds in Wild, In vitro Obtained, Ex vitro Adapted, and Acclimated Plants of Centaurea davidovii (Asteraceae)
Antoaneta Trendafilova, Milka Jadranin, Rossen Gorgorov and Marina Stanilova

New Laurene-type Sesquiterpene from Bornean Laurencia nangii
Takashi Kamada and Charleq Santhanaraju Vairappan

New Furanone and Sesquiterpene from the Pericarp of Calocedrus formosana
Tzong-Huei Lee, Ming-Shian Lee, Horng-Huey Ko, Jih-Jung Chen, Hsun-Shuo Chang, Sheng-Yang Wang, Chien-Chih Chen and Yueh-Hsiung Kuo

The Importance of the 5-Alkyl Substituent for the Violet Smell of Ionones: Synthesis of Racemic 5-Demethyl-α-ionone
Serena Chierici, Serena Bugoni, Alessio Porta, Giuseppe Zanoni and Giovanni Vidari

Antiproliferative Activity of seco-Oxicasanes from Acacia schaffneri

Continued inside backcover