Table 4.1 Literature sources mentioning data for lichen substances responsible for antioxidant activity of lichens

Lichen substances	References
Lecanoric acid	Jayaprakasha and Rao (2000), Lopes et al. (2008), Thadhani et al. (2011), Verma et al. (2008b), Buçukoglu et al. (2013), Ristić et al. (2016a)
Atranorin	Hidalgo et al. (1994), Jayaprakasha and Rao (2000), Melo et al. (2011), Sisodia et al. (2013). Ranković et al. (2014a, b), Kosanić et al. (2014a, b, c)
2,4-Dihydroxy-6-propyl	Sisodia et al. (2013)
Ramalin	Paudel et al. (2008)
Barbatic acid	Verma et al. (2008b)
Divaricatic acid	Hidalgo et al. (1994)
Pannarin	Hidalgo et al. (1994), Russo et al. (2008)
Zeorin	Verma et al. (2008b)
Gyrophoric acid	Buçukoglu et al. (2013), Kosanić et al. (2014c)
Umbilicaric acid	Buçukoglu et al. (2013)
Protocetraric acid	Manojlović et al. (2012)
Fumarprotocetraric acid	de Barros Alves et al. (2014), Kosanić et al. (2014a, b, c)
Stictic acid	Lohézic-Le Dévéhat et al. (2007)
Salazinic acid	Verma et al. (2012), Manojlović et al. (2012), Selvaraj et al. (2015)
Usnic acid	Odabasoglu et al. (2006), Manojlović et al. (2012), Ranković et al. (2012, 2014a, b), Verma et al. (2012), Sisodia et al. (2013), Ananthi et al. (2015)
Variolaric acid	Brisdelli et al. (2013)
2-Hydroxy-4-methoxy-6-propylbenzoic acid	Sisodia et al. (2013)
Evernic acid	Kosanić et al. (2013a, b)
Erythrin	Choudhary et al. (2009)
2,4-Dihydroxy-3,6-dimethylbenzoate	Sisodia et al. (2013)
Lobaric acid	Thadhani et al. (2011); Brisdelli et al. (2013)
Physodic acid	Kosanić et al. (2013a, b), Ranković et al. (2014a, b)
Protolichesterinic acid	Sisodia et al. (2013)
Norstictic acid	Ranković et al. (2012)
Cuculloquinone	Stepanenko et al. (2002)
Homosekikaic acid	Sisodia et al. (2013)
Sekikaic acid	Thadhani et al. (2011), Verma et al. (2012), Sisodia et al. (2013)
Benzoic acid	Sisodia et al. (2013)
Diffractaic acid	Brisdelli et al. (2013)
Vicanicin	Brisdelli et al. (2013)
Sphaerophorin	Russo et al. (2008)
Isidiophorin	Atalay et al. (2011)
Rhizonaldehyde	Atalay et al. (2011)
Rhizonyl alcohol	Atalay et al. (2011)

(continued)

Table 4.1 (continued)

Lichen substances	References
Pulmonarianin	Atalay et al. (2011)
Hypotrachynic acid	Papadopoulou et al. (2007)
Deoxystictic acid	Papadopoulou et al. (2007)
Cryptostictinolide	Papadopoulou et al. (2007)
8′-Methylconstictic acid	Papadopoulou et al. (2007)
8′-Methylstictic acid	Papadopoulou et al. (2007)
8′-Methylmenegazziaic acid	Papadopoulou et al. (2007)
Ethylstictic acid	Papadopoulou et al. (2007)
2′-O-methyl anziaic acid	Ristić et al. (2016a)
Obtusatic acid	Ristić et al. (2016b)
Methyl evernate	Ristić et al. (2016b)

Caloplaca regalis from King George Island were analysed using thin layer chromatography (TLC) followed by a DPPH (2,2-diphenyl-1-picrylhydrazyl) spray technique. The experimental data showed that 33–50% of the major constituents of the test extracts were active antioxidants (Bhattarai et al. 2008a, b).

Hidalgo et al. (1994) reported the antioxidant activity of some depsides, such as atranorin (isolated from *Placopsis* sp.) and divaricatic acid (isolated from *Protousnea malacea*), and depsidones, such as pannarin (isolated from *Psoroma pallidum*) and 1′-chloropannarin (isolated from *Erioderma chilense*). All of these secondary compounds inhibited rat brain homogenate autoxidation and β-carotene oxidation, and depsidones were found to be the most effective. Russo et al. (2008) found that both sphaerophorin (depside) and pannarin (depsidone) inhibited superoxide anion formation in vitro, pannarin being more efficient, confirming Hidalgo et al. (1994). Similarly, de Barros Alves et al. (2014) found high antioxidant power of fumarprotocetraric acid produced by the lichen *Cladonia verticillaris* evaluated using the thiobarbituric acid reactive species assay in mouse lung tissue.

Thadhani et al. (2011) assessed the antioxidant activity of several classes of lichen metabolites in the in vitro superoxide radical (SOR), nitric oxide radical and 2,2-diphenyl-1-picrylhydrazyl radical scavenging assays. The depsides sekikaic acid and lecanoric acid showed promising antioxidant activity in SOR assay with IC_{50} values of 82.0 ± 0.3 μmol and 91.5 ± 2.1 μmol, respectively, while the depsidone lobaric acid exhibited an IC_{50} value of 97.9 ± 1.6 μmol, all relative to the standard, propyl gallate ($IC_{50} = 106.0 \pm 1.7$ μmol). One of the most abundant mononuclear phenolic compounds, methyl-β-orcinol carboxylate, was found to be a potent NO scavenger ($IC_{50} = 84.7 \pm 0.1$ μmol), compared to the standard rutin ($IC_{50} = 86.8 \pm 1.9$ μmol).

Brisdelli et al. (2013) investigated the effects of six lichen metabolites (diffractaic acid, lobaric acid, usnic acid, vicanicin, variolaric acid, protolichesterinic acid) on reactive oxygen species (ROS) level towards three human cancer cell lines, MCF-7 (breast adenocarcinoma), HeLa (cervix adenocarcinoma) and HCT-116 (colon carcinoma). All tested lichen compounds did not exhibit free radical scavenging activity using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay. The lichen metabolites did