Table 1.1 Literature sources mentioning data for some lichen substances with different pharmaceutical activity

Lichen compounds	Studied activities	References
Lecanoric acid	Antitumor, antioxidant, antibacterial, antifungal, antidiabetic, anticancer, anti-inflammatory	Gomes et al. (2003), Lopes et al. (2008), Ranković et al. (2008), Honda et al. (2010), Bogo et al. (2010), Choudhary et al. (2011), Ristić et al. (2016b), Studzinska-Sroka and Dubino (2018)
Atranorin	Antimicrobial, antioxidant, anti-inflammatory, anticancer, antineurodegenerative, antidiabetic	Kumar and Muller (1999), Yilmaz et al. (2004), Turk et al. (2006), Ranković et al. (2008, 2014), Melo et al. (2011), Reddy et al. (2016), Thadhani and Karunaratne (2017), Studzinska-Sroka and Dubino (2018)
Zeorin	Antioxidant, antibacterial, antifungal, antidiabetic	Behera et al. (2008), Kosanić et al. (2010), Karunaratne et al. (2014)
Gyrophoric acid	Antimicrobial, anticancer, antioxidant, antidiabetic	Candan et al. (2006), Ranković et al. (2008), Burlando et al. (2009), Choudhary et al. (2011), Kosanić et al. (2014a, b)
Protocetraric acid	Antibacterial, antifungal, antioxidant, anticancer	Tay et al. (2004), Ranković et al. (2008), Honda et al. (2010), Manojlović et al. (2012)
Fumarprotocetraric acid	Antibacterial, antifungal, antioxidant, anticancer, neuroprotective	Yilmaz et al. (2004), Ranković et al. (2008), Kosanić et al. (2014a, b), Fernández-Moriano et al. (2017)
Stictic acid	Antioxidant, antimicrobial, anticancer	Lohézic-Le Dévéhat et al. (2007), Ranković et al. (2008)
Salazinic acid	Antitumor, antibacterial, antifungal, antioxidant, antidiabetic, antiviral	Candan et al. (2007), Burlando et al. (2009), Manojlović et al. (2012), Verma et al. (2012), Odabasoglu et al. (2006)
Usnic acid	Antiviral, antitumor, antioxidant, antibacterial, antifungal, antipyretic, analgetic, anti-inflammatory, hepatotoxic, antiviral, antidiabetic	Lauterwein et al. (1995), Tay et al. (2004), Ranković et al. (2008, 2014), Paudel et al. (2010), Perry et al. (1999), Odabasoglu et al. (2006), Bazin et al. (2008), Burlando et al. (2009), Ramos and Almeida da Silva (2010), Verma et al. (2012), Thadhani and Karunaratne (2017), Vijayakumar et al. (2000), Okuyama et al. (1995)
Vulpinic acid	Antimicrobial, anticancer	Lauterwein et al. (1995), Burlando et al. (2009)
Evernic acid	Antifungal, antibacterial, antioxidant, anticancer	Halama and Van Haluwin (2004), Kosanić et al. (2013)
Lobaric acid	Antibacterial, antifungal, anticancer, antineurodegenerative	Ingolfsdottir et al. (1998), Piovano et al. (2002), Sundset et al. (2008), Thadhani et al. (2014)
Physodic acid	Antibacterial, antifungal, antioxidant, anticancer, antineurodegenerative, anti-inflammatory	Turk et al. (2006), Ranković et al. (2008, 2014), Kosanić et al. (2013), Emsen et al. (2016), Reddy et al. (2016), Studzinska-Sroka and Dubino (2018)

(continued)

Table 1.1 (continued)

Lichen compounds	Studied activities	References
Protolichesterinic acid	Antitumor, antibacterial, anticancer, anti-inflammatory	Ingolfsdottir et al. (1998), Turk et al. (2003), Bucar et al. (2004), Studzinska-Sroka and Dubino (2018)
Norstictic acid	Antimicrobial, antioxidant, anticancer	Tay et al. (2004), Honda et al. (2010), Ranković et al. (2014)
Ramalin	Antioxidant, antibacterial	Paudel et al. (2008, 2010)
Barbatic acid	Antioxidant, antimicrobial	Verma et al. (2008), Martins et al. (2010)
Divaricatic acid	Antioxidant, antimicrobial, antidiabetic	Hidalgo et al. (1994), Kosanić et al. (2010), Thadhani and Karunaratne (2017), Oh et al. (2018)
Panarin	Antioxidant, anticancer	Hidalgo et al. (1994), Russo et al. (2008)
Umbilicaric acid	Antioxidant, antimicrobial	Buçukoglu et al. (2013).
Variolaric acid	Antioxidant, anticancer	Brisdelli et al. (2013)
Homosekikaic acid	Antioxidant, antibacterial	Sisodia et al. (2013)
Sekikaic acid	Antioxidant, antibacterial, antidiabetic	Verma et al. (2012), Sisodia et al. (2013)
Benzoic acid	Antioxidant	Sisodia et al. (2013)
Diffractaic acid	Analgetic, antiproliferative, antioxidant, antipyretic, analgesic, anti-inflammatory	Brisdelli et al. (2013), Atalay et al. (2011), Kumar and Muller (1999), Okuyama et al. (1995), Studzinska-Sroka and Dubino (2018)
Vicanicin	Antioxidant, anticancer	Brisdelli et al. (2013)
2,4-Dihydroxy-6-propyl	Antioxidant	Sisodia et al. (2013)
1′-Chloropannarin	Antioxidant	Hidalgo et al. (1994)
Biruloquinone	Antineurodegenerative	Luo et al. (2013)
Olivetoric acid	Antineurodegenerative, anti-inflammatory	Emsen et al. (2016), Studzinska-Sroka and Dubino (2018)
Psoromic acid	Antineurodegenerative	Emsen et al. (2016)
Perlatolic acid	Antineurodegenerative, anti-inflammatory	Reddy et al. (2016), Studzinska-Sroka and Dubino (2018)
Methyl β-orcinolcarboxylate	Antidiabetic	Karunaratne et al. (2014)
Methylorsellinate	Antidiabetic	Karunaratne et al. (2014)
Ethyl hematommate	Antidiabetic	Choudhary et al. (2011)
Ethyl orsellinate	Antidiabetic	Choudhary et al. (2011)
Alectorialic acid	Antiviral	Odabasoglu et al. (2006)
Parietin	Antiviral, antimicrobial	Fazio et al. (2007), Basile et al. (2015)
5-Hydroxysekikaic acid	Antiviral	Lai et al. (2013)
2-Dehydro-5-oxysekikaic acid	Antiviral	Lai et al. (2013)
Sekikaic acid	Antiviral	Lai et al. (2013)
Homosekikaic acid	Antiviral	Lai et al. (2013)
4′-O-methylnorhomosekikaic acid	Antiviral	Lai et al. (2013)

(continued)

Table 1.1 (continued)

Lichen compounds	Studied activities	References
4′-O-methylnorsekikaic acid	Antiviral	Lai et al. (2013)
Divaricatinic acid	Antiviral	Lai et al. (2013)
2,3-Dihydroxy-4-methoxy-6-pentylbenzoic acid	Antiviral	Lai et al. (2013)
2,3-Dihydroxy-4-methoxy-6-propylbenzoic acid	Antiviral	Lai et al. (2013)
3,4-Methylenedioxy-3′-methoxybibenzyl	Antiviral	Lai et al. (2013)
Obtusatic acid	Antioxidant, antimicrobial, anticancer	Ristić et al. (2016a)
Methyl evernate	Antioxidant, antimicrobial, anticancer	Ristić et al. (2016a)
O-methyl anziaic acid	Antioxidant, antimicrobial, anticancer	Ristić et al. (2016b)

Erioderma chilense). All of these secondary compounds inhibited rat brain homogenate auto-oxidation 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. For other lichen compounds including protocetraric acid (from *Parmelia caperata*), salazinic acid (from *Parmelia saxatilis*), evernic acid (from *Evernia prunastri*), physodic acid (from *Pseudevernia furfuracea*), gyrophoric acid (from *Acarospora fuscata*), obtusatic acid (from *Ramalina fraxinea*), methyl evernate (from *R. fastigiata*), and O-methyl anziaic acid (from *Melanelia fuliginosa*) have been proven to have strong antioxidant activity using various in vitro assays (Manojlović et al. 2012; Kosanić et al. 2013, 2014a, b; Ristić et al. 2016a, b).

There are many studies on the antimicrobial activity of lichen secondary metabolites. For example, atranorin (from *Physcia aipolia*), fumarprotocetraric acid (from *Cladonia furcata*), gyrophoric acid (from *Umbilicaria polyphylla*), lecanoric acid (from *Ochrolechia androgyna*), physodic acid (from *Hypogymnia physodes*), protocetraric acid (from *Flavoparmelia caperata*), stictic acid (from *Xanthoparmelia conspersa*), usnic acid (from *Flavoparmelia caperata*), obtusatic acid (from *Ramalina fraxinea*), methyl evernate (from *R. fastigiata*), O-methyl anziaic acid (from *Melanelia fuliginosa*), divaricatic acid (from *Evernia mesomorpha*), and parietin (from *Xanthoria parietina*) showed relatively strong antimicrobial effects against numerous bacteria and fungi, among which were human pathogens (Ranković and Mišić 2008; Ranković et al. 2008; Basile et al. 2015; Ristić et al. 2016a, b; Oh et al. 2018).

Species of *Usnea* contains high amount of usnic acid, a very active lichen substance used as tumor inhibitor and as analgesic. (+)-Usnic acid was found to be