Arctium lappa: A Review on Its Phytochemistry and Pharmacology

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Suhail Ahmad Mir, Lateef Ahmad Dar, Tabassum Ali, Ozaifa Kareem, Rumaisa Rashid, Nisar Ahmad Khan, I. A. Chashoo, and G. N. Bader

Abstract

Arctium lappa (family, *Asteraceae*), commonly called Burdock, owing to its diverse volatile and nonvolatile metabolites is known for a variety of therapeutic and pharmacological effects. These secondary metabolites consist of phytosterols, terpenes/terpenoids, hydrocarbons, flavonoids, fatty acids, carboxylic derivatives, lignans, fatty acids, acetylenic compounds, polysaccharides, aldehydes, methoxypyrazines, carboxylic and fatty acids, monoterpenes, and sesquiterpenes. Burdock has also shown multifaceted pharmacological actions that include antidiabetic, antioxidant, hepatoprotective, anticancer, gastroprotective, antibacterial, antiallergic, antimicrobial, antiviral, and anti-inflammatory. This chapter aims to provide a comprehensive overview of the chemistry and biological activities of the secondary metabolites found in *A. lappa* and its species.

Keywords

Arctium lappa · Pharmacological properties · Phytochemistry · *Asteraceae*

S. A. Mir · L. A. Dar · T. Ali · O. Kareem · R. Rashid · N. A. Khan · I. A. Chashoo · G. N. Bader (✉)
Department of Pharmaceutical Sciences, School of Applied Science and Technology, University of Kashmir, Hazratbal, Srinagar, Jammu and Kashmir, India
e-mail: suhailmir.scholar@kashmiruniversity.net; darlateef.scholar@kashmiruniversity.net; ozaifa.scholar@kashmiruniversity.net; gnbader@kashmiruniversity.ac.in

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10.1 Introduction

Arctium lappa, commonly known as greater "burdock," "gobo," "edible burdock," or "beggar's button," is an Eurasian species belonging to family *Asteraceae*. The plant has been originally cultivated in Asia and Europe, but now it is being cultivated in different climates and countries as well. It has become an invasive weed of high-nitrogen-content soils that are mostly found in countries and regions like North America, Australia, and others regions. The plant is regarded as a nutritive and healthy food in Chinese societies. It has been used for its therapeutic value in countries of Europe, North America, and Asia for hundreds of years (Tabassum et al. 2018). The genus name has been derived from a Greek word "*arcteion*" which means "bear," alluding to the plant habitus which is characterized by marked hairiness. Among various species, *A. lappa* is most common and widespread, besides other species as *A. minus* and *A. tomentosum*. This shrub grows nearly up to 1 m in height and its young roots usually develop branches that can reach nearly 45–50 and 3–6 cm in depth and diameter, respectively. The shape of the roots is cylindrical, with slightly thin brown skin. The interior of the plant varies from white to yellowish-white that usually depends on the age of the plant (Barceloux 2008). The period from planting to reap varies from 8 to 12 months with a per hectare yield of 8–40 tons. Burdock roots, leaves, and seeds are used as therapeutic elements in traditional medicine, predominantly in the form of tea. Because of presence of a significant content of chlorogenic acid, the parts of plant have bitter and astringent taste (Chan et al. 2010; Burgmans et al. 1992).

In Chinese traditional medicine system, *A. lappa* is commonly known as "Niu Bang Zi" and is believed to be a healthy and nutritious food in Chinese societies. In folk medicine, seeds of *A. lappa* are crushed to form a combination that provides relief against common cold, tonsillitis, throat pain, measles, and arthritis. Burdock root is also used to treat ulcers, eczema, rheumatism, gout, psoriasis, and acne. In Chinese traditional system, dried burdock is used as a diaphoretic, diuretic, and blood-purifying agent. It is believed to purify blood by removing dangerous toxins. The extract from different parts of *A. lappa* has been considered beneficial for health, as it helps to improve the body's defense system and improves metabolic activities (Liu et al. 2012).

A. lappa and its species are characterized by hemicryptophyte plants that have erect taproot system and stout stems. The leaves are held sporadically as dentate, tomentose, alternate and cordate. The stem is usually strong, upright, grooved, usually branched, and reddish in color. Inflorescences (a cluster of flowers) is formed by corymbose or solitary conical-ovoid to orbicular capitula armed with involucres that are made up of bracts ending with curved apices. Receptacles are made up of many hard scales. Florets are hermaphrodite, white or purple in color. Pollination is mainly carried out by insects, generally belonging to Lepidoptera (The Scientific Foundation for Herbal Medicinal Products 2003). Figure 10.1 shows the photographic images of some species of Arctium at flowering stage, and Fig. 10.2 shows the photographic image of Arctium root.

Fig. 10.1 *A. lappa* species (Wang et al. 2019)

10.2 Phytochemistry of *A. lappa*

A. lappa has shown diverse pharmacological effects owing to the presence of diverse volatile and nonvolatile secondary metabolites like fatty acids, terpenes, flavonoids, lignans, acetylenic compounds, hydrocarbons, polysaccharides, phytosterols, terpenoids, aldehydes, carboxylic acids, fatty acids, monoterpenes, and sesquiterpenes (Swamy 2019). So far, over 200 nonvolatile compounds have been isolated and identified from this genus. With the advancement of technology different modern analytical techniques like high-performance liquid chromatograph (HPLC), thin layer chromatography (TLC), nuclear magnetic resonance (NMR),

Fig. 10.2 Burdock root (with copy right permission license number: 499428779638) (Chan et al. 2010)

mass spectrometry (MS), infrared (IR) spectrometry, etc., more active ingredients of this plant have been isolated over the last 10 years (Park et al. 2007). The details of chemical constituents, occurrence in different plant parts, viz. seeds, leaves, fruits, or roots, and the modern qualitative analytical techniques used for their determinations are briefly summarized in Table 10.1, whereas their detailed description is given in below section. The chemical structures of some of the nonvolatile compounds from *Arctium* and its species are shown in Fig. 10.3.

10.2.1 Lignans

Main bioactive lignans that are found in *A. lappa* include arctigenin (a dietary phytoestrogen) and its glycoside arctiin, which are mostly present in seeds, fruits, roots, and leaves (An et al. 2003; Ming et al. 2004; Liu et al. 2012). Apart from lignans, these plant parts are also rich in low levels of sesquilignans and dilignans. Lappaol A and B were the first sesquilignans isolated and characterized from the seeds of *A. lappa* (Ichihara et al. 1976). In the subsequent years more sesquilignans, namely Lappaol C, D, and E, and two dilignans, namely Lappaol F and H were structurally determined from the seeds of *A. lappa*. Boldizsár and colleagues in 2010 used simple high performance liquid chromatography analytical technique to

Table 10.1 Some of the nonvolatile compounds reported from *A. lappa*

S. no.	Compound name	Formula	Species	Plant origin/ part	Analytical method	References
Lignans						
1	Diarctigenin	$C_{42}H_{46}O_{12}$	*A. lappa*	Fruits, roots, seeds	IR/NMR/MS/TLC	
2	Arctin	$C_{27}H_{34}O_{11}$	*A. lappa, A. tomentosum*	Leaves fruits, roots, seeds	UV/IR/MS/NMR/HPLC/ LCMS/MALDI-QIT-TOF MS	Ferracane et al. (2010)
3	Arctigenin	$C_{12}H_{24}O_7$	*A. lappa, A. tomentosum*	Leaves fruits, roots, seeds	UV/MS/NMR/HPLC/LCMS/ MALDI-QIT-TOF MS/HRESI-MS	Boldizsár et al. (2010)
4	Arctigenin-4-O-α-D galactopranosyl-(1→6)-O-β-D-glucopyranoside	$C_{18}H_{32}O_{16}$	*A. lappa*	Fruits	NMR/UV/IR/ORD/HRESI-MS	
5	Arctigenin-4-O- β -Dapiofuranosyl-(1→6)-O-β-D-glucopyranoside	$C_{32}H_{42}O_{15}$	*A. lappa*	Fruits	NMR/UV/IR/ORD/HRESIMS	
6	7,8-Didehydroarctigenin	$C_{21}H_{22}O_5$	*A. lappa*	Fruits	HRFAB/EIMS/NMR	
7	Arctiidilactone	$C_{20}H_{20}O_8$	*A. lappa*	Fruits	NMR/UV/IR/ORD/HRESIMS	
8	Arctiiapolignan A	$C_{20}H_{28}O_{10}$	*A. lappa*	Fruits	NMR/UV/IR/ORD/HRESIMS	
9	Arctiisesquineolignan A	$C_{42}H_{52}O_{19}$	*A. lappa*	Fruits	NMR/UV/IR/ORD/HRESIMS	
10	Arctiisesquineolignan B	$C_{36}H_{46}O_{16}$	*A. lappa*	Fruits	UV/IR/HRESIMS/NMR	
11	Arctiiphenolglycoside A	$C_{19}H_{28}O_{13}$	*A. lappa*	Fruits	UV/IR/HRESIMS/NMR	
12	Arctignan A	$C_{30}H_{34}O_{10}$	*A. lappa*	Seeds	UV/MS/NMR/HPLC	
13	Arctignan B	$C_{30}H_{34}O_{10}$	*A. lappa*	Seeds	UV/MS/NMR/HPLC	
14	Arctignan C	$C_{30}H_{34}O_{10}$	*A. lappa*	Seeds	UV/MS/NMR/HPLC	
15	Arctignan D	$C_{30}H_{34}O_{10}$	*A. lappa*	Seeds	UV/MS/NMR/HPLC/LCMS/ MALDI-QIT-TOF MS	
16	Arctignan E	$C_{40}H_{44}O_{13}$	*A. lappa*	Seeds	UV/IR/MS/NMR/HPLC	Ferracane et al. (2010)

(continued)

Table 10.1 (continued)

S. no.	Compound name	Formula	Species	Plant origin/ part	Analytical method	References
17	Lappaol A	$C_{30}H_{32}O_9$	*A. lappa*, *A. tomentosum*	Seeds/fruits	TLC/UV/IR/MS/NMR/HPLC	Ferracane et al. (2010)
18	Syringaresinol	$C_{22}H_{26}O_8$	*A. lappa*	Roots	UV/IR/ESIMS/NMR	
19	(7S,8R)4,7,9,90-tetrahydroxy-3,30-dimethoxyl-70-oxo-8-40-oxyneolignan-4-O-β-D-glucopyranoside	$C_{26}H_{34}O_{13}$	*A. lappa*	Roots	IR/HR-ESIMS/NMR/CD	Yang et al. (2012)
20	(70S,80R,8S)-4,40,90-trihydroxy-3,30-dimethoxy-70,9-epoxylignan-7-oxo-4-O-b-D-glucopyranosyl-40-O-b-D-glucopyranoside	$C_{32}H_{42}O_{17}$	*A. lappa*	Roots	IR/HR-ESIMS/NMR/CD	Yang et al. (2012)
21	Arctiopicrin	$C_{19}H_{26}O_6$	*A. lappa*, *A. minus*	Leaves	TLC/NMR	Savina et al. (2006)
22	Dehydrovomifoliol	$C_{13}H_{18}O_3$	*A. lappa*	Leaves	NMR/HR-ESI-TOF-MS	Machado et al. (2012)
23	Loliolide	$C_{11}H_{16}O_3$	*A. lappa*	Leaves	NMR/HR-ESI-TOF-MS	Machado et al. (2012)
24	Dehydromelitensin-8-(4'-hydroxymethacrylate	$C_{15}H_{24}O_6$	*A. lappa*	Leaves	NMR/HR-ESI-TOF-MS	Machado et al. (2012)
25	Dehydromelitensin	$C_{15}H_{20}O_4$	*A. lappa*	Leaves	NMR/HR-ESI-TOF-MS	Machado et al. (2012)
26	Melitensin	$C_{15}H_{22}O_4$	*A. lappa*	Leaves	NMR/HR-ESI-TOF-MS	Machado et al. (2012)
27	3-α-Acetoxyhop-22(29)-ene	$C_{30}H_{49}O_2$	*A. lappa*	Leaves	NMR, IR and MS	Jeelani and Khuroo (2012)
28	3-α-Hydroxylanosta-5,15-diene	$C_{30}H_{50}O$	*A. lappa*	Leaves	NMR, IR and MS	Jeelani and Khuroo (2012)

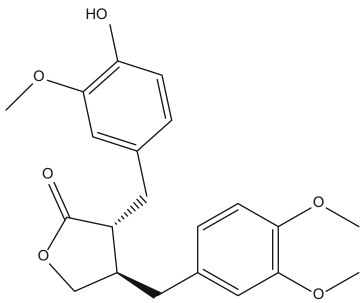
Flavonoids						
1	Luteolin	$C_{25}H_{24}O_{12}$	*A. lappa*	Leaves roots	UPLC/LC-MS	Ferracane et al. (2010)
2	Rutin	$C_{27}H_{30}O_{16}$	*A. lappa*	Leaves	TLC/UPLC/LC-MS	Lou et al. (2010)
3	Quercitrin	$C_{21}H_{20}O_{11}$	*A. lappa*	Leaves roots	UPLC/LC-MS	Lou et al. (2010)
4	Quercetin	$C_{15}H_{10}O_{7}$	*A. lappa*	Leaves Roots	UPLC/LC/MS/MS/HRESIMS	Lou et al. (2010)
5	Quercetin 3-O-glucuronide	$C_{21}H_{18}O_{13}$	*A. lappa*	Roots	HPTLC/LC/ESI–MS/MS	Rajasekharan et al. (2015)
6	Quercetin 3-vicianoside	$C_{26}H_{28}O_{16}$	*A. lappa*	Roots	HPTLC/LC/ESI–MS/MS	Rajasekharan et al. (2015)
7	Quercetin rhamnoside	$C_{21}H_{20}O_{11}$	*A. lappa*	Roots	HPLC/LC/MS/MS	Ferracane et al. (2010)
Sterols						
1	β-Sitosterol	$C_{29}H_{50}O$	*A. lappa*	Seeds roots fruits	UV/IR/MS/NMR/HPLC	
2	Sitosterol-beta-D-glucopyranoside	$C_{35}H_{60}O_{6}$	*A. lappa*	Roots	IR/NMR/EI-MS	Miyazawa et al. (2005)
Fatty acids						
1	Methyl linolenate	$C_{19}H_{32}O_{2}$	*A. lappa*	Roots	IR/NMR/EI-MS/GCMS	Miyazawa et al. (2005)
2	Methyl oleate	$C_{19}H_{36}O_{2}$	*A. lappa*	Roots	IR/NMR/EI-MS/GCMS	Arctium et al. (2005)
3	Linolenic acid	$C_{18}H_{30}O_{2}$	*A. lappa*	Fruits	IR/NMR/EI-MS/GCMS	Kuo et al. (2012)

(continued)

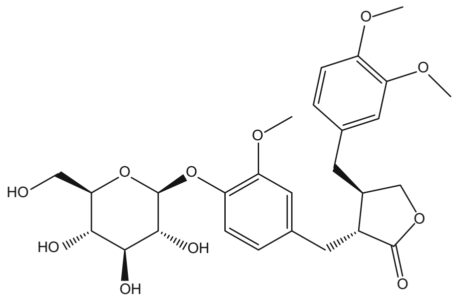
Table 10.1 (continued)

S. no.	Compound name	Formula	Species	Plant origin/part	Analytical method	References
4	Stearic acid	$C_{17}H_{35}CO_2H$	*A. lappa*	Fruits	IR/NMR/EI-MS	Arctium et al. (2005)
5	Arctinone-a	$C_{13}H_{10}O_2S_2$	*A. lappa*	Roots	UV/TLC/IR/NMR/MS	Washino et al. (1986)
6	Arctinone-b	$C_{13}H_{10}OS_2$	*A. lappa*	Roots	UV/TLC/IR/NMR/MS	Washino et al. (1986)
7	Arctinol-a	$C_{13}H_{12}O_2S_2$	*A. lappa*	Roots	UV/TLC/IR/NMR/MS	Washino et al. (1986)
8	Arctinol-b	$C_{13}H_{12}O_2S_2$	*A. lappa*	Roots	UV/TLC/IR/NMR/MS	Washino et al. (1986)
Carboxylic acids/quinic acids and derivatives						
1	Caffeic acid	$C_9H_8O_4$	*A. lappa*	Seeds leaves roots	TLC/HPLC/UPLC//LC/MC/HRESI-MS	Ferracane et al. (2010)
2	Chlorogenic acid	$C_{16}H_{18}O_9$	*A. lappa*	Seeds leaves roots	TLC/HPLC/UPLC//LC/MC/HRESI-MS	Liu et al. (2012)
3	p-Coumaric acid	$C_9H_8O_3$	*A. lappa*	Seeds leaves roots	UPLC/EI-MS	Lou et al. (2010)
4	Cynarin	$C_{25}H_{24}O_{12}$	*A. lappa*	Seeds leaves roots	UPLC/LC/MS	Ferracane et al. (2010)
Saccharides/polysaccharides						
1	Rhamnogalacturonan	$C_{117}H_{178}O_{101}$	*A. lappa*	Leaves roots	Chromatography/NMR/sugar analysis	Kato and Watanabe (1993)

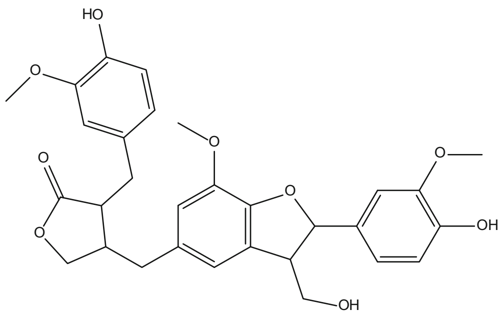
2	Xylan	$(C_5H_8O_4)_n$	*A. lappa*	Leaves roots	Chromatography/NMR/sugar analysis	Kato and Watanabe (1993)
3	Galactose	$C_6H_{12}O_6$	*A. lappa*	Leaves roots fruits	Chromatography/NMR	Boldizsár et al. (2010)
4	Mannose	$C_6H_{12}O_6$	*A. lappa*	Roots leaves	NMR	Carlotto et al. (2016)
5	Arabinose	$C_5H_{10}O_5$	*A. lappa*	Roots leaves fruits	UV/NMR//HPLC/GCMS	Carlotto et al. (2016)
6	Fructose	$C_6H_{12}O_6$	*A. lappa*	Roots	HPLC-ELSD	
7	Sorbitol	$C_6H_{14}O_8$	*A. lappa*	Fruits	UV/NMR/HPLC/GCMS	Carlotto et al. (2016)
8	Mannitol	$C_6H_{14}O_8$	*A. lappa*	Fruits	UV/NMR/HPLC/GCMS	Boldizsár et al. (2010))
Others						
1	Crocin	$C_{44}H_{64}O_{24}$	*A. lappa*	Leaves	UPLC	Lou et al. (2010)



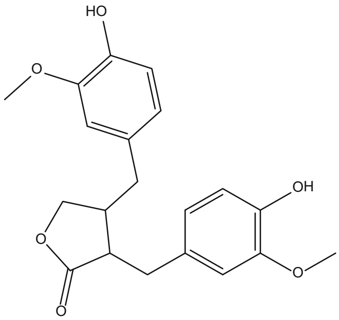
Arctigenin



Arctinn



Lappoal A



Matairesinol

Fig. 10.3 Some volatile compounds reported in *A. lappa*

identify the presence of active constituent arctiin from the fruits of plant (Boldizsár et al. 2010). Using bioactivity-guided isolation and fractionation, Lappaol A, Lappaol C, Lappaol F, arctiin, and arctigenin E were isolated and later characterized from the ethanolic extract of *A. lappa* seeds (Ming et al. 2004). High-performance liquid chromatography (HPLC), mass spectrometry (MS), liquid chromatography (LC), and ultra-performance liquid chromatography (UPLC) quantitative analytical tools have been used to isolate and characterize arctigenin and arctiin in the roots, leaves, and seeds (Ferracane et al. 2010). A high-speed counter-current chromatography (HSCCC) was used to find the pure compound arctiin from the fruit extract of the plant. More than 49% of arctiin has been obtained by modern analytical techniques based on NMR and LC-MS (Wang et al. 2005).

10.2.2 Fatty Acids and Esters

Miyazawa and colleagues found 11 compounds in the methanolic extract of *A. lappa*. Among these, 10 belonged to fatty acid (Arctium et al. 2005). The compounds were identified as stearic acid, methyl stearate, methyl palmitate, palmitic acid, oleic acid, methyl linolenate, methyl oleate, linoleic acid, methyl linoleate, and linolenic acid. Iyazawa and colleagues in 2005 (Iyazawa et al. 2005) reported methyl palmitate, methyl linoleate, sitosterol-β-D-glucopyranoside, and methyl linolenate that showed an inhibitory effect against α-glucosidase. Later, Kuo et al. (2012) isolated and characterized methyl oleate, linolenic acid, and methyl-α-linolenate as the chief constituents from the *n*-hexane fraction of roots of the plant. The presence of palmitic acid, stearic acid, linoleic acid, and oleic acid has also been reported from the fruits of the plant (Boldizsár et al. 2010).

10.2.3 Acetylenic Compounds

Washino and colleagues in 1986 (Washino et al. 1986), identified and characterized 9 sulfur-containing acetylenic compounds, namely, arctinone-a & b, arctinol-a & b, arctinal, arctic acid-b & c, arctinone-a acetate, and methyl arctate-b from the plant**.** On spectral and chemical analysis, these compounds were found to be the products of 5′-(1-propynyl)-2′,2-bimethyl-5-yl. Later, presence of few guaianolides linked with sulfur-containing acetylenic compounds, viz. lappaphen-a & b, lactone, dehydrocostus, and dehydrodihydrocostus lactone, were isolated and characterized from the acetone extracts of the plant root (Washino et al. 1986). The plant possesses several bioactive constituents having acetylenic linkages that have demonstrated antibacterial, antifungal, and anti-edematogenic activities (Maria et al. 2016).

10.2.4 Phytosterols

A study carried out by Ahangarpour and colleagues on *A. lappa,* reported a natural phytosterol, daucosterol from its seeds (Ahangarpour et al. 2017). Other species of the plant, viz. *A. tomentosum* was found to contain two steroids (β-sitosterol and daucosterol). Ming et al. (2004), using bioactivity guided fractionation technique isolated β-sitosterol and daucosterol from ethanolic seed extracts of *A. lappa*. Later in 2005, sitosterol-β-D-glucopyranoside was also isolated from the ethanolic extract of the plant (Miyazawa et al. 2005).

10.2.5 Polysaccharides

Ferracane et al. (2010) for the first time reported the presence of pectic polysaccharides in edible roots of *A. lappa*. After that Watanabe in 1993, and more recently Carlotto and colleagues in 2016, isolated several polysaccharides like pectic substances; rhamnogalacturonan with neutral sugars; hemicellulose (xyloglucan, xylan, galactan, arabinan, and arabinogalactan); cellulose, arabinose, and galactose from cell walls and roots of *A. lappa*; and leaves and roots of *A. minus* (Kato and Watanabe 1993). Biologically active inulin type fructofuranans and other fructo-oligosaccharides were isolated from the roots of *A. lappa* but in small quantity (Kardošová et al. 2003). It has been observed that these water-soluble polysaccharides obtained from the plant significantly increase the dysregulation of pro-inflammatory cytokines TNF-α, IL-6 and IL1β, and anti-inflammatory cytokines IL-10 (Wang et al. 2019).

10.2.6 Derivatives of Caffeoylquinic Acid (Carboxylic Acids)

They are the main bioactive phenolic constituents of *Arctium* species and the high antioxidant potential is thought to be due to these compounds. The roots of *A. lappa* have been found to contain derivatives of caffeoylquinic acid, viz. 1-0-,5-O-dicaffeoylquinic acid (Yang et al. 2012). Both chlorogenic acid and caffeic acid are present in the skin of roots of the plant; however, the quantity of former is more (Chen et al. 2004). HPTLC technique has been used as qualitative chemical profiling tool to estimate chlorogenic acid in roots. It has been reported that caffeoylquinic acid and its derivatives exhibit diverse biological activities like reduction in diet-induced obesity through modulation of peroxisome proliferator-activated receptor alpha (PPARα) and liver X receptors alpha (LXRα) transcription (Huang et al. 2015) and anti-ulcerogenic activity (Lee et al. 2010).

10.2.7 Flavonoids

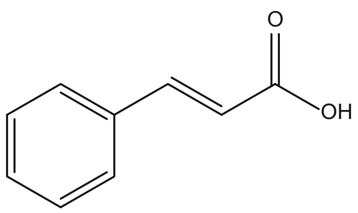
Flavanols and flavones are the two main flavonoids reported from *A. lappa*. Quercetin-3-O-rhamnoside has been reported from the leaves of the plant. Later in the year 1971 Saleh and colleagues reported more phenolic compounds such as luteolin, quercetin, quercetin and rutin from the roots, leaves, fruits, and seeds of *A. lappa* in their work (Saleh and Bohm 1971).

10.3 Volatile Compounds

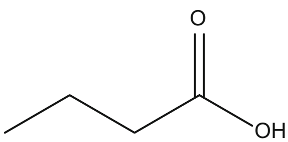
Until most recently, almost 100 volatile compounds have been reported from *A. lappa*. Details about these compounds (name, species, part, and the analytical techniques employed for isolation and identification) are described in Table 10.2**.** Some of the chemical structures of volatile compounds have also been given Fig. 10.4.

Table 10.2 Some of the volatile compounds reported in *A. lappa*

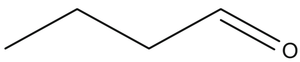
S. No	Compound name	Formula	Species	Plant origin/part	Analytical method	References
Hydrocarbons						
1	Aplotaxene	$C_{17}H_{28}$	*A. lappa*	Roots	GCMS	Washino et al. (1986)
2	Clovene	$C_{15}H_{24}$	*A. lappa*	Roots	GCMS	Washino et al. (1986)
3	Docosane	$C_{22}H_{46}$	*A. lappa*	Leaves	GCMS	Aboutabl et al. (2013)
4	Eicosane	$C_{20}H_{42}$	*A. lappa*	Roots Seeds Leaves	GCMS	Aboutabl et al. (2013)
5	Hexacosane	$C_{26}H_{54}$	*A. lappa*	Roots Leaves	GCMS	Aboutabl et al. (2013)
Aldehydes						
1	Benzaldehyde	C_7H_6O	*A. lappa*	Roots	GCMS	Washino et al. (1986)
2	Butanal	C_4H_8O	*A. lappa*	Roots	GCMS	Washino et al. (1986)
3	Decanal	$C_{10}H_{20}O$	*A. lappa*	Roots	GCMS	Washino et al. (1986)
4	Heptanal	$C_7H_{14}O$	*A. lappa*	Roots	GCMS	Washino et al. (1986)
5	Octanal	$C_8H_{16}O$	*A. lappa*	Roots	GCMS	Washino et al. (1986)



Cinnamic Acid



Butyric Acid



Butanal

Fig. 10.4 Some nonvolatile compounds reported from *A. lappa*

10.3.1 Hydrocarbons

Washino and colleagues in their studies on the plant isolated 14 hydrocarbon compounds from the seeds, leaves, and roots of the plant. These include tetradecane, tetracosane, pentadecane, pentacosane, 1-pentadecene, 2-nepthalenemethanol, nonadecane, hexacosane, heptacosane, 1-heptadecene, eicosane, dihydroaplotaxene, cloven, and aplotaxene (Washino et al. 1986).

10.3.2 Aldehydes

Work performed by Wang as well as Washino and colleagues in the year 1986 and 2004, respectively, reported 19 aldehydes namely 4-methoxybenzaldehyde, tridecanal, propanal, pentanal, phenylacetaldehyde, (E)-2-octanal, nonanal, 3-methylpropanal, (E)-2-hexenal, (Z)-3-hexenal, hexanal, heptanal, dodecanal, decanal, butanal, benzaldehyde, octanal, and undecanal from the roots of the plant (Washino et al. 1986; Wang et al. 2005). In literature, there is only one reported aldehyde, alkyl aldehyde nonanal that has been found in all parts of plant, viz. leaves, roots, and seeds (Tables 10.3 and 10.4).

Table 10.3 Some phenolic and flavonoids present in *A. lappa*

Phenolic compounds			Flavonoids		
Compound	R_{time}	ppm	Compound	R_{time}	ppm
Gallic acid	7.627	1.67	Narengin	12.287	142.12
Pyrogallol	7.725	218.35	Hisperidin	12.420	4063.70
4-Aminobenzioc acid	8.793	2.17	Rutin	12.507	633.74
Cataehein	9.220	93.76	Quercetrin	13.373	89.77
Chlorogenic	9.628	124.64	Apeginin-7-glucose	13.600	55.07
Catechol	9.929	59.82	Naringengin	–	
Caffeine	10.248	20.35	Querceitin	14.554	51.73
Vallinic	10.841	9.06	Hispirtin	14.721	72.83
P-hydroxy-benzoic acid	10.393	93.41	Kampferol		
P-coumaric	11.820	24.35	Rhamentin	15.433	54.69
Ferulic	12.013	15.48	Apegnin	154.633	25.95
Iso-ferulic	12.353	4.07			
Alpha-coumaric	13.200	7.83			
Ellagic	13.300	46.20			
Benzoic	13.417	256.99			
3,4,5-methoxy-cinnamic acid	13.953	55.92			

R_{Time} *retention time, ppm* parts per million

Table 10.4 Major nutritional ingredients present in the *A. lappa* (roots)

Types	Nutrient ingredients
Amino acids	Aspartic acid (25–28%) Arginine (18–20%)
Metal elements	Potassium, calcium, iron, magnesium, Sodium, zinc, copper
Vitamins	B1, B2, C, A
Others	Crude fiber, phosphorus, carotene

10.4 Pharmcological Profile of *A. lappa*

In traditional system of medicine *A. lappa* has been extensively used as an ethnomedicinal plant mostly in Europe, Asia, and North America and has been commonly used to treat numerous illnesses like rheumatoid arthritis, gout, Type 1 and 2 diabetes, and dermatological complications (Azizov et al. 2012). The plant has been used for the treatment of various diseases ranging from acute and chronic inflammation, arthritis, and various skin-related problems, namely, rough skin conditions such as eczema and psoriasis to cancer treatments as well (Kolacz et al. 2014b). Its roots have been employed as an antidote to mercury poisoning (Maghsoumi-Norouzabad et al. 2016). *A. lappa* has also been used to treat alopecia (loss of hair) among adults (Kolacz et al. 2014a, b). *It* has shown wide range of pharmacological activities like, anticancer, antidiabetic, antioxidative, anti-inflammatory, antimicrobial, hepatoprotective, gastroprotective, antifertility, antiallergic, and anti ulcerative colitis, etc. Table 10.5 shows the individual compounds possessing biological activity with possible mechanism of actions.

10.4.1 Anticancer Potential

Cancer therapy is very difficult because it is a complex and curatively challenging disease owing to its intra- and inter-tumor heterogeneity, which makes it difficult to target. Since anticancer therapy resistance is increasing day by day, research is being carried out to overcome this resistance. An important approach in this regard is the interdisciplinary approach, wherein research is being carried out to isolate and characterize new bioactive molecules from natural products having significant medical outcome and minimum off-target effects. Bioactive molecules that have been reported from the plant have significant anticancer activities in different cancer cell lines and cancer models.

Arctigenin, a natural lignan, that has been isolated from the seeds of *A. lappa* possesses antitumor activity. Its effect is shown by modulating the tumor cells that are susceptible to the effects of the nutrient-poor environment (Awale et al. 2006). In lung adenocarcinoma, arctigenin is found to increases the proportion of cells in the cell cycle (G0/G1) phase in A549 cell line (Susanti et al. 2013). It also decreases levels of proteins that are involved in GI/S phase checkpoint signaling, including

Table 10.5 General compounds and their effects of burdock (*A. lappa*)

Classification	Compound	Molecular formula	Part of the plant	Reported activity	Reference
Lignans	Arctigenin	$C_{12}H_{24}O_7$	Leaves, fruits, roots, and seeds	• Suppressor of heart shock • Antitumor • Anti-influenza virus	Chan et al. (2010)
	Arctin	$C_{27}H_{34}O_{11}$	Leaves, fruits, roots	• Antitumor promoting activity • Chemo-preventive activity • Antiproliferative activity against B cell hybridoma cell, MH60	
	Trachelogenin	$C_{21}H_{24}O_7$	Fruits	• Ca^{2+} antagonist activity • Anti-HIV properties	
	Lappoal F	$C_{40}H_{42}O_{12}$	Fruits, seeds	• Inhibiting NO production	
	Diarctigenin	$C_{40}H_{42}O_{12}$	Fruits, roots, seeds	• Inhibiting NO production	
Terpenoids	Beta-eudesmol	$C_{15}H_{26}O$	Fruits	• Antibacterial • Antiangiogenic	
Polyphenols	Caffeic acid	$C_9H_8O_4$	Stems, leaves, skin of roots	• Antioxidative. • Free radical scavenging activity	
	Chlorogenic acid	$C_{16}H_{18}O_9$	Leaves, skin of roots	• Neuroprotective. • Antioxidative • Antianaphylaxis • Anti-HIV	
	Tannin	$C_{76}H_{52}O_{46}$	Roots	• Antitumor • Immunomodulator • Hyaluronidase inhibition	
Fructose	Inulin	$(C_6H_{10}O_{5})_n$	Roots	• Prebiotic effectiveness • Antihypertensive • Antidiabetic	

cyclin-dependent kinases CDK2, CDK7, cyclin E & H, nuclear protein mapped to the AT locus (NPAT), and protein cyclin-dependent kinases (p-CDK) (Susanti et al. 2013). In Canadian population, *A. lappa* has been shown to improve health-related quality of life (HRQOL) and check cancer development, and is one the active ingredients present in herbal products, viz. “*Flor-Essence*” and “*Essiac*” recommended for prolonging of survival and enhancement of health-related quality of life (HRQOL) among cancer patients (Tamayo et al. 2000).

10.4.2 Inhibition of JAK-STAT Signaling

In a study conducted on mice-bearing gain- or loss-of-function gene mutations which encode Janus kinases signal transducer and activator of transcription proteins (JAK-STAT) signaling pathway, it was observed that this pathway emerged as a central means of communication node for the immune system. Work performed by Yao et al. (2011) revealed that arctigenin from *A. lappa* inhibited IL-6 and exerted inhibitory effects on STAT3 tyrosine phosphorylation through suppression of JAK1 & 2 and Schmidt-Ruppin A-2 (Src), a proto-oncogene tyrosine-protein kinase.

10.4.3 Antidiabetic Activity

In traditional system of medicine, roots of *A. lappa* have been used as first choice treatment for diabetes. A study conducted by Ahangarpour and colleagues reported that ethanolic extract of burdock roots administered orally to streptozocin-induced diabetic rats lowered levels of glucose and increased levels of insulin in blood significantly (Ahangarpour et al. 2017). *A. lappa* markedly decreased very low-density lipoproteins (VLDL), serum total cholesterol (TC), and triglycerides (TG) in diabetic mice (Ahangarpour et al. 2017).

10.4.4 Antimicrobial Activity

Roots and leaves of *A. lappa* are eaten in salad in folk medicine. In vitro studies have shown potential prebiotic effect (Moro et al. 2018). Lyophilized leaf extract of the plant exhibited antimicrobial activity, especially against bacteria that are related to endodontic pathogens such *as pseudomonas aeruginosa*, *lactobacillus acidophilus*, *candida albicans*, *and bacillus subtilis* (Pereira et al. 2005). Chlorogenic acid obtained from its root extract has shown antibacterial activity against *Klebsiella pneumoniae* and has also been found to possess anti-β-lactamase activity (Rajasekharan et al. 2017). Besides it also inhibits the formation of biofilm by *Escherichia coli* and *candida* (Chan et al. 2011).

10.4.5 Ulcerative Colitis

T cells (T helper 1 & 17 cells) and other related cytokines are said to be involved in the pathogenesis of ulcerative colitis. *A. lappa* has been shown to give relief against ulcerative colitis. Arctigenin from *A. lappa* inhibited proliferation of T cells in a dose-dependent manner that was induced by concanavalin A. It actually downregulates RORγt (Wu et al. 2015). There is enough evidence that *A. lappa*, more particularly arctigenin, significantly reduces subarachnoid hemorrhage–induced vasospasm in animal models (Tabassum et al. 2018).

10.4.6 Dermatological Effects of *A. lappa*

People from North America, Asia, and Europe have been using leaves of *A. lappa* and related species for various kinds of dermatological conditions, viz. psoriasis, abscesses, acne, ichthyosis, eczema, boils, and rashes. These actions might be due to the occurrence of phenolic compounds in the plant. Chan and colleagues reported that the antioxidant and anti-inflammatory potential of these compounds assist in detoxifying and mediate healing action of the plant (Chan et al. 2011). Burdock is used as an ingredient in various commercial cosmetic products because of the presence of various hydroxycinnamic acid derivatives which contribute in antimicrobial, anti-inflammatory, anti-collagenase, and anti-tyrosinase activities as well protection against ultraviolet radiations (Ahangarpour et al. 2017).

10.4.7 Hepatoprotective and Gastroprotective Activity

In vivo and in vitro antioxidant potential of the plant has been reported by Duh, Lin, and their colleagues in their work, which also showed that the plant possesses excellent hepatoprotective activity (Duh 1998; Lin et al. 2000). In 2018, Fierascu et al. (2018) reported antioxidant potential of *A. lappa* using phosphomolybdate and 2,2-diphenyl-1-picrylhydrazyl (DPPH) assays and reported that entire extract of burdock exhibits very high antioxidant potential because of the presence of very large quantity of polyphenols. *A. lappa* is also found to possess gastroprotective activity due to presence of 1,3-dicaffeoylquinic acid that has been isolated and characterized from the ethanolic fraction of the plant (Carlotto et al. 2015).

10.4.8 Clinical Trials

In a cohort study conducted in Japan in 2013 on safety and toxicity effects of "GBS-01," an orally administered drug containing arctigenin as one of the ingredient on gemcitabine-resistant pancreatic cancer, patients were given GBS-1. Blood toxicity, dose-limited toxicities, and non-blood of grade 3–4 toxicities were taken as main endpoints after first 4 weeks of the trial. Increase in gamma-glutamyl transferase (GGT), total serum levels of glucose, and bilirubin were some of the adverse effects noted on the oral administration of GBS-01 (Tabassum et al. 2018).

10.5 Conclusion

A. lappa (burdock) seeds, leaves, roots, and fruits contain many phytoconstituents including volatile and nonvolatile compounds that have therapeutic potential against various kinds of diseases. Though roots are more frequently used, other parts of the plant have also shown a good amount of phytoconstituents, and hence promise. A survey into the literature shows that burdock and its isolated compounds possess a wide range of therapeutic uses, viz. anti-inflammatory, anticancer, antidiabetic, anti-obesity, hepatoprotective, and gastroprotective. The promising medicinal uses of the plant, however, necessitate to have an understanding about its adverse effects, while using it for various ailments. Therefore, further studies are important for better understanding of the role of the plant in preventing and treating any disease as well as any associated off-target effects of the plant.

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