Review

Apiaceae Medicinal Plants: A Review of Traditional Uses, Phytochemistry, Bolting and Flowering, and Controlling Approaches

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Apiaceae Medicinal Plants: A Review of Traditional Uses, Phytochemistry, Bolting and Flowering, and Controlling Approaches

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Abstract: Apiaceae plants have been widely used as traditional Chinese medicines (TCMs) for the treatment of removing dampness, relieving superficies, and dispelling cold, etc. In order to exploit the potential application and improve the yield and quality of Apiaceae medicinal plants (AMPs), The traditional use, phytochemistry, modern pharmacological use, effect of bolting and flowering (BF), and approaches for controlling the BF were summarized. Currently, about 228 AMPs have been recorded as TCMs with 6 medicinal parts, 72 traditional uses, 62 modern pharmacological uses, and 5 main kinds of metabolites. Three effect degrees (*i.e.*, significantly affected, affected to some extent, and no significantly affected) could be classed based on the yield and quality. The BF of individual plants (*e.g.*, *Angelica sinensis*) could be effectively controlled by the standard cultivation techniques, while the mechanism of BF has not been systemically revealed. This review will provide useful references for the reasonable exploration and high-quality production of AMPs.

Keywords: Apiaceae plants; traditional use; phytochemistry; bolting and flowering; controlling approaches

1. Introduction

Apiaceae (syn. Umbelliferae) is one of the largest angiosperm families including 300 genera (3000 species) in the world and 100 genera (614 species) in China [1]. Apiaceae plants have been widely used as medical healthcare, nutrition, food industry, and other fields [2]. Currently, 55 genera (230 species) of Apiaceae plants have been applied in medical healthcare, and over 20 species have been widely used as traditional Chinese medicines (TCMs) [3]. Extensive studies have demonstrated that Apiaceae medicinal plants (AMPs) present a variety of pharmacological properties for the treatment of central nervous system, cardiovascular, and respiratory system diseases, amongst others [1,4]. These pharmacological activities are largely associated with bioactive metabolites such as polysaccharides, alkaloids, phenylpropanoids (simple phenylpropanoids and coumarins), flavonoids, and polyene alkynes [1,5,6].

In China, Apiaceae plants have been primarily used as traditional medicines for main treatment of removing dampness, relaxing tendons, activating blood, relieving superficies, and dispelling cold, etc. [1,2]. For example, rhizomatous and whole plants are mainly used for the treatment of common cold due to wind-cold, cough, asthma, rheumatic arthralgia, as well as ulcerative carbuncle and pyogenes infections; fruits are mainly used for the treatment of expelling pathogenic wind and regulating vital energy, harmonizing the stomach and promoting digestion, as well as relaxing abdominal pain and expelling parasite [1,2].

As known, the occurrence of bolting and flowering (BF) plays a critical role in transiting from vegetative growth to reproductive development in plant life cycle [7]. However, the BF significantly reduces the accumulation of metabolites in vegetative organs, which ultimately leads to the lignification of rhizomes and/or roots such as sugar beet [8], lettuce [9], and Chinese cabbage [10]. Particularly, it is more common that the BF significantly reduces the yield and quality for the rhizomatous AMPs [11]. Extensive studies have demonstrated that the BF is regulated by both internal factors (*e.g.*, germplasm resource, seedling size, and plant age) and external factors *(e.g.*, vernalization, photoperiodism, and environmental stresses) [12]. To date, the BF, especially in the rhizomatous AMPs, has not been effectively controlled [11,13].

In order to comprehensively learn about the current status of AMPs, herein, the progress on traditional use, phytochemistry, bolting and flowering, and controlling approaches were summarized. These reviews will provide references for efficient cultivation and quality improvement of AMPs.

2. Materials and Methods

All information involved in AMPs was searched on scientific databases (*i.e.*, PubMed, Web of science, Springer, and CNKI) using the keywords including: Apiaceae plant, traditional use, phytochemistry, bolting and flowering, and lignification. Additional information was collected from ethnobotanical literatures focusing on herb from *Flora of China* and local herbal classic literature, such as *Divine Husbandman's Classic of the Materia Medica* (*Shen Nong Ben Cao Jing*), *Compendium of Materia Medica*, *Illustrated Book on Plants*, *Collection of National Chinese Herbal Medicine*, and *Pharmacopoeia of the People's Republic of China*. The names of all the plants were corresponded to the Catalogue of Life China. Chemical structures were drawn using ChemDraw 2021 software.

3. A tour of Apiaceae Medicinal Plants (AMPs)

Apiaceae plants have been traditionally used as medicines in China for *ca.* 2400 years (Figure 1). In 390-278 BC, 3 Apiaceae plants including *Angelica dahurica*, *Ligusticum chuanxiong*, and *Cnidium monnieri* were firstly recorded as medicines in *Sorrow after Departure* [1,2]. With the progress of Chinese civilization, *ca.* 100 Apiaceae plants were historically recorded as medicines. Specifically, 12 AMPs such as *Angelica decursiva*, *Bupleurum chinense*, and *Centella asiatica* were recorded in the known herbal text of China, the *Divine Husbandman's Classic of the Materia Medica* (*Shen Nong Ben Cao Jing*) in 1st-2nd century AD [14]; In 1578 and 1848, 24 and 31 AMPs were respectively recorded in the *Compendium of Materia Medica* and *Illustrated Book on Plants* [15]. In the 21st century, the number of AMPs has been increasing up to 93 species recorded in *Flora of China* in 2002 [16], and 96 species in *Collection of National Chinese Herbal Medicine* in 2014 [17]. In recent years, 22 species are recorded in *Pharmacopoeia of the People's Republic of China* [18]; specifically, 18 species are used with rhizomes and/or roots (Table 1).

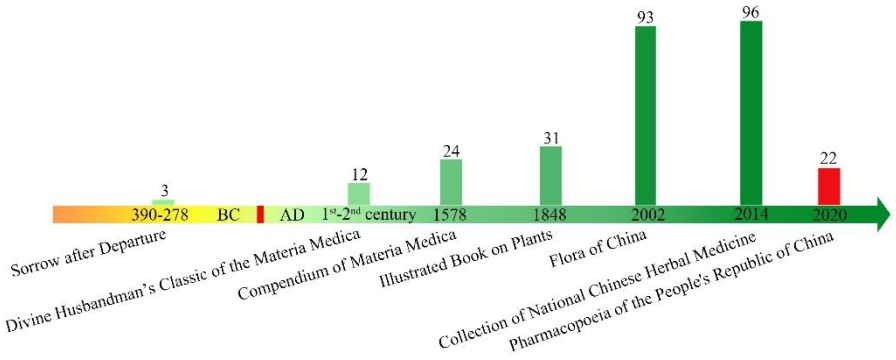

Figure 1. A tour of Apiaceae medicinal plants (AMPs).

Table 1. The list of the 228 AMPs.

No.	Plant species	Parts of plant used	Traditional use	Modern pharmacological use	Main chemical constituents	References
1	*Aegopodium alpestre* Ledeb.	Stems and leaves	Dispelling wind, relieving pain, and treatment of influenza	Treatment of rheumatic diseases, obesity and hypotensive	Apiole, undecane, and limonene	[19–21]
2	*Ammi majus* L.	Fruits	Treatment of vitiligo	\	Furanocoumarins	[16]
3	*Anethum graveolens* L.	Fruits, leaves or whole plant	Treatment of bladder inflammation, liver diseases, and insomnia	Antibacterial, antifungal, antioxidant	Alkaloid, terpenoids, and flavonoids	[22]
4	*Angelica acutiloba* (Siebold & Zucc.) Kitag.	Roots	Treatment of menoxenia and anemia	Hemogenic, analgesic, and sedative activities	Ferulic acid, ligustilide, and angelicide	[23]
5	*Angelica amurensis* Schischk.	Roots	\	\	α-pinene, limonene, and sabinene	[1,24]
6	*Angelica anomala* Avé-Lall.	Roots	Dispelling wind, eliminating dampness, and relieving pain	Antioxidant, anti-inflammatory, and antitumor	Isoimperatorin, umbelliferone, and adenosine	[16,25–27]
7	*Angelica apaensis* R. H. Shan & C. C. Yuan	Roots	Relieving pain, relieving cough and asthma	Bacteriostat, anti-inflammatory	Oxypeucedanin, isoimperatorin, and oxypeucedanin hydrate	[19,28]
8	***Angelica biserrata* (R. H. Shan & C. C. Yuan) C. C. Yuan & R. H. Shan	Roots	Dispelling wind, eliminating dampness, and relieving pain	Antitumor, anti-inflammatory, and antioxidant	Coumarins osthole, columbianadin, and volatile oils	[29]
9	*Angelica cartilaginomarginata var. Foliosa* C. C. Yuan & R. H. Shan	Roots	\	\	\	[17]
10	***Angelica dahurica* (Fisch. Ex Hoffm.) Benth. & Hook. F. Ex Franch. & Sav.	Roots	Treatment of acne, erythema, and headache	Antiinflammatory, anti-mutagenic, and antitumor	Scopoletin, and psoralen	[18,30–33]
11	***Angelica dahurica* cv. Hangbaizhi	Roots	Treatment of headache, toothache, abscess, and furunculosis	Estrogenic, cytotoxic, and anti-inflammatory	isoimperatorin, imperatorin, and phellopterin	[18,34,35]
12	*Angelica dahurica var. Formosana* (H. Boissieu) Yen	Roots	\	Anti-staphylococca	Falcarindiol	[33,34]
13	***Angelica decursiva* (Miq.) Franch. & Sav.	Roots	A remedy for thick phlegm, asthma, and upper respiratory tract infections	Antioxidant and anti-inflammatory potential	Decursin, decursidin, and nodakenetin	[36]
14	*Angelica gigas* Nakai	Roots	Treatment of dysmenorrhea, amenorrhea, and menopausal	Anti-platelet effects	Decursin, and decursinol angelate	[37,38]
15	*Angelica laxifoliata* Diels	Roots	Dispelling wind, Dispelling wind, and relieving pain	Treatment of wind-damp pain, aching lumbus and knees	Angelicin, β-sitosterol, and laxifolin	[16,26,39]
16	*Angelica megaphylla* Diels	Roots	Same as *Angelica sinensis*	Same as *A. Sinensis*	Ferulic acid, ligustilide, and angelol	[40,41]
17	*Angelica morii* Hayata	Roots and leaves	Treatment of deficiency-cold in spleen and stomach, cold cough, and toothache	Used for diarrhea caused by deficiency of spleen and for cough caused by weak-ness and chill	Imperatorin, isoimperatorin, and phellopterin	[42–44]

18	*Angelica nitida* H. Wolff	Roots	Nourishing the blood, regulating menstrual disorder, and relieving pain	\	Isoimperatorin, imperatorin, and cnidilin	[45]
19	*Angelica polymorpha* Maxim.	Roots	Dispelling wind and relieving pain	Treatment of stomachache	Coumarins, sesquiterpenoids, and alkaloid	[19,46,47]
20	***Angelica sinensis* (Oliv.) Diels	Roots	Nourishing the blood, regulating menstrual disorder, and relieving pain	Cardio-cerebrovascular, anti-inflammatory, and antioxidant	Ferulic acid, alkylphthalides, and polysaccharides	[18,48,49]
21	*Angelica sinensis* var. Wilsonii	Roots	Same as *Angelica sinensis*, relieving pain	Same as *Angelica sinensis*	Isoimperatorin, coumarin, and oxypeucedanin	[50]
22	*Angelica sylvestris* L.	Roots	Relieves rheumatism, sweating, and detoxification	\	Cnidilide, sedanenolide, and ligustilide	[19]
23	*Angelica tsinlingensis* K. T. Fu	Roots	\	\	\	[1]
24	*Angelica valida* Diels	Roots	\	\	\	[1]
25	*Anthriscus nemorosa* (M. Bieb.) Spreng.	Roots, whole plant, and leaves	Same as *Peucedanum praeruptorum*	Same as *Peucedanum praeruptorum*	\	[51]
26	*Anthriscus sylvestris* (L.) Hoffm.	Roots and leaves	Invigorating spleen and replenishing qi and expelling phlegm	Antitumor, antioxidation, and antisenity	Phenylpropanoids, flavonoids, and steroidal	[19,52]
27	*Apium graveolens* L.	Whole plant, roots, and rhizome	Dispelling wind, eliminating dampness, and detoxification	Hypertension, hyperlipidemia, and dysuria	Organic acids, apigenin, and volatile oils	[19,53,54]
28	*Archangelica brevicaulisf*	Roots	Same as *Angelica biserrata*	Same as *Angelica biserrata*	Osthol, imperatorin, and archangelicin	[16,55]
29	*Bupleurum angustissimum* (Franch.) Kitag.	Roots	\	\	Saikosaponins (a, c, and d), β -terpinene, and β -thujene	[56]
30	*Bupleurum aureum* Fisch.	Roots	\	\	Saikosaponins (a, c, and d)	[1,57]
31	*Bupleurum bicaule* Helm	Roots	Same as *Bupleurum scorzonerifolium*	Same as *Bupleurum scorzonerifolium*	Saikosaponin d, prosaikogenin G, and prosaikogenin F	[16,58,59]
32	*Bupleurum candollei* Wall. Ex DC.	Whole plant	Diminish inflammati and detoxify, dispelling wind, and relieving convulsion	\	Saikosaponin and flavonoids	[16,56]
33	*Bupleurum chaishoui* R. H. Shan & M. L. Sheh	Roots and rhizome	Same as *Bupleurum*	Same as *Bupleurum*	Saikosaponins (a, c, and d)	[60]
34	***Bupleurum chinense* DC.	Roots	Treatment of chronic hepatitis, kidney syndrome, and inflammatory diseases	Anti-allergic, analgesic, and anti-inflammation	Saikosaponins (a, c, and d)	[18,61,62]
35	*Bupleurum chinense* DC. F. Octoradiatum (Bunge) Shan et Sheh	Roots	Same as *Bupleurum*	Anti-allergic, analgesic, and anti-inflammation	Saikosaponins (a, c, and d)	[63,64]

36	*Bupleurum chinense* DC. F. Vanheurckii (Muell. -Arg.) Shan et Y. Li	Roots	Same as *Bupleurum*	Anti-allergic, analgesic, and anti-inflammation	Saikosaponins (a, c, and d)	[63,64]
37	*Bupleurum commelynoideum var. Flaviflorum* R. H. Shan & Yin Li	Roots, rhizome and whole plant	Antipyretic-analgesic effect, choleretic, and hepatoprotection	Treating or relieving inflammatory bowel disease	Saikosaponins (a, c, and d), β-pinene, and perillen	[65,66]
38	*Bupleurum densiflorum* Rupr.	Roots	\	\	\	[63]
39	*Bupleurum dielsianum* H. Wolff	Roots	\	\	\	[63]
40	*Bupleurum euphorbioides* Nakai	Roots	\	\	Saikosaponins, perillen, and undecanal	[56]
41	*Bupleurum exaltatum M.* Bieb.	Roots	\	\	\	[64]
42	*Bupleurum falcatum* L.	Roots	\	Treatment of colds and upper respiratory tract infections	Saikosaponins (a, c, and d)	[64,67,68]
43	*Bupleurum gansuense* S. L. Pan et Hsu	Roots	\	\	\	[56]
44	*Bupleurum hamiltonii* N. P. Balakr.	Roots or whole plant	Antipyretic-analgesic effect, treatment of chill, and fever alternation	Treatment of stomach pain, dysuria, and cough	Kaerophyllin, isokaerophyllin, and ethyl caffeic acid	[69]
45	*Bupleurum hamiltonii var. Hamiltonii* / *Bupleurum tenue*	Roots or whole plant	Same as *Bupleurum hamiltonii* N. P. Balakr.	Same as *Bupleurum hamiltonii* N. P. Balakr.	Same as *Bupleurum hamiltonii* N. P. Balakr.	[70]
46	*Bupleurum hamiltonii var. Humile* (Franch.) R. H. Shan & M. L. Sheh	Roots	\	\	\	[64]
47	*Bupleurum huizei* S. L. Pan sp. Nov.	Roots	\	\	\	[64]
48	*Bupleurum kaoi* T. S. Liu, C. Y. Chao & T. I. Chuang	Roots	\	Treatment of influenza and fever	Saikosaponin a and saikosaponin c	[64]
49	*Bupleurum komarovianum* Lincz.	Roots	Same as *Bupleurum chinense*	Same as *Bupleurum chinense*	Saikosaponins (a, c, and d) and volatile oils (1-caprylene, limonene, and thymol)	[71,72]
50	*Bupleurum krylovianum Schischk. Ex* Krylov	Roots	\	\	Saikosaponins (a, c, and d)	[56,57]
51	*Bupleurum kunmingense* Yin Li & S. L. Pan	Roots	\	Immunomodulatory	Saikosaponins (a, c, and d), cyclohexanone, and 2- methyldodecane	[56]
52	*Bupleurum longicaule var. Amplexicaule* C. Y. Wu	Roots	\	\	Saikosaponins (a, c, and d)	[64]
53	*Bupleurum longicaule var. Franchetii* H. Boissieu	Roots or whole plant	\	\	Saikosaponins (a, c, and d), cyclohexanone, and myrcene	[56]
54	*Bupleurum longicaule var. Giraldii* H. Wolff	Roots	\	\	Saikosaponins (a, c, and d), narcissin, and rutin	[56]

55	*Bupleurum longiradiatum* Turcz.	Roots	Treatment of gout and inflammatory illness	Anti-inflammatory and/or antimicrobial	Thymol, butylidene phthalide and 5-indolol	[73]
56	*Bupleurum luxiense* Yin Li & S. L. Pan	Roots	\	\	Saikosaponins (a, c, and d), n-heptaldehyde, and octanal	[56]
57	*Bupleurum malconense* R. H. Shan & Yin Li	Whole plant	Hepatoprotection and antipyretic effect	Acute toxicity	Saikosaponins (a, c, and d), rutin, and quercetin	[74–76]
58	*Bupleurum marginatum var. Marginatum*	Whole plant	Hepatoprotection and antipyretic effect	Anti-allergic, analgesic, and anti-inflammatory	Saikosaponins (a, c, and d), rutin, and quercetin	[74,75,77]
59	*Bupleurum marginatum var. Stenophyllum* (H. Wolff) R. H. Shan & Yin Li	Whole plant	\	\	Saikosaponins (a, c, and d), chikusaikoside I, II, and 2-methylcyclopentanone	[56]
60	*Bupleurum marginatum* Wall. Ex DC.	Whole plant and roots	Hepatoprotection and antipyretic effect	Anti-allergic, analgesic, and anti-inflammatory	Saikosaponins (a, c, and d), rutin, and quercetin	[74,75,77]
61	*Bupleurum microcephalum* Diels	Whole plant and roots	Hepatoprotection and antipyretic effect	Anti-allergic, analgesic, and anti-inflammatory	Saikosaponins (a, c, and d), rutin, and quercetin	[74,75]
62	*Bupleurum petiolulatum var. tenerum* R. H. Shan & Yin Li	Whole plant	Antipyretic-analgesic effect	Anti-inflammatory	\	[63,78]
63	*Bupleurum polyclonum* Yin Li & S. L. Pan	Roots	\	Anticancer	Saikosaponins (a, c, and d), 4′-O-saikosaponin-a, and fenchane	[56]
64	*Bupleurum rockii* H. Wolff	Roots	\	\	Saikosaponins (a, c, and d), thymol, and β-guaiene	[56]
65	*Bupleurum scorzonerifolium* f. Longiradiatum	Roots	Same as *Bupleurum*	Same as *Bupleurum*	Same as *Bupleurum*	[19]
66	*Bupleurum scorzonerifolium* f. Pauciflorum	Roots	Same as *Bupleurum*	Same as *Bupleurum*	Same as *Bupleurum*	[19]
67	***Bupleurum scorzonerifolium* Willd.	Roots	Antipyresis, relieve liver depression and menstrual disorder	Same as *Bupleurum chinense*	Rutin, quercetin, and kaempferol	[18,19]
68	*Bupleurum sibiricum var. Jeholense* (Nakai) Y. C. Chu ex R. H. Shan & Yin Li	Roots	\	\	\	[1]
69	*Bupleurum sibiricum* Vest	Roots	Same as *Bupleurum*	Same as *Bupleurum*	Saikosaponin a, rutin, and quercetin	[16,79,80]
70	*Bupleurum sichuanense* S. L. Pan et Hsu.	Roots	\	\	Saikosaponins (a, c, and d)	[56]
71	*Bupleurum smithii* H. Wolff	Roots	Antipyretic-analgesic effect	Anti-inflammatory, immunomodulatory, and anti-hepatic injury	Saponins, volatile oils, and lignans	[81]
72	*Bupleurum smithii var. Parvifolium* R. H. Shan & Yin Li	Roots	Relieve liver depression and activate the yang-energy	Anti-inflammatory, immunomodulatory, and antitumor	falcarinol, saponins, and flavonoids	[82]
73	*Bupleurum thianschanicum* Freyn	Roots	\	\	Saikosaponins (a, c, and d)	[57]
74	*Bupleurum triradiatum* Adams ex Hoffm.	Roots	\	\	\	[1]

75	*Bupleurum wenchuanense* R. H. Shan & Yin Li	Roots	Same as *Bupleurum*	Same as *Bupleurum*	Quercetin-3-*O*-α-*L*-rhamnoside, quercetin, and rutin	[16,75]
76	*Bupleurum yinchowense* R. H. Shan & Yin Li	Roots	Antipyresis, relieve liver depression, and activate the yang-energy	Same as *Bupleurum*	Saikosaponins (a, c, and d)	[16,65,83,84]
77	*Carum buriaticum* Turcz.	Roots and fruits	\	\	\	[5]
78	*Carum carvi* L.	Roots, fruits, and leaves	Dispelling wind and eliminating dampness, invigorate the stomach, and treatment of heart disease	Anti-bacterial, antioxidant, and antitumor	Carvone, limonene, and dihydrocarvone	[19,85,86]
79	**Centella asiatica* (L.) Urb.	Whole plant	Clearing heat, promoting diuresis, and toxicity	Anti-bacterial, anti-depression and neuroprotection	Asiaticoside, madecassoside, and elemene	[18,87]
80	***Changium smyrnioides* H. Wolff	Roots	Strengthening with tonics, moistening lung melt phlegm, and calm the liver	Immunomodulatory, relieve fatigue, and enhance adaptability	Cetylic acid, succinic acid, and imperatorin	[18,88]
81	*Chuanminshen violaceum* M. L. Sheh & R. H. Shan	Roots	Moistening lung melt phlegm, harmonize the stomach, and engender liquid	Antioxidant, enhancing immunity, and antimutation	Polysaccharides, coumarins, and flavonoids	[89–91]
82	*Cicuta virosa* L.	Roots and rhizome	Expelling phlegm and detoxification	Treatment of osteomyelitis, gout, and rheumatism	P-cymene, cicutoxine, and L-limonene	[17,92]
83	**Cnidium monnieri* (L.) Spreng.	Fruits	Dispelling wind, relieving convulsion, and Impotence	Antibacterial, antiviral, and antimutagenesis	Osthole, limonene, and cnidimoside A	[18,93]
84	*Cnidium officinale*	Roots	Same as *Cnidium monnieri*	Same as *Cnidium monnieri*	\	[1]
85	*Conioselinum acuminatum* (Franch.) Lavrova	Roots	\	\	Sabinene, α-pinene, and aromadendrene	[11]
86	*Conioselinum anthriscoides* '*Fuxiong*'	Roots	\	\	β-bergamotene	[11]
87	*Conioselinum tenuisectum* (H. Boissieu) Pimenov & Kljuykov	Roots	\	\	\	[94]
88	*Conioselinum vaginatum* (Spreng.) Thell.	Roots	Dispelling wind, eliminating dampness, and relieving pain	Treatment of common cold due to wind-cold and gastro spasm	Diligustilide, daucosterol, and palmitic acid	[19,95]
89	*Conium maculatum* L.	Whole plant	Relieving pain and relieving muscular spasm	Treatment of cancer	Coniine, N-methyl-coniine, conhydrine 2-(1-hydroxypropyl)-piperidine	[16,96,97]
90	*Coriandrum sativum* L.	Whole plant, fruits, and stems	Invigorate the stomach and promoting eruption	Antibacterial, antifungal, and antioxidant	Petroselinic acid, linoleic acid, and oleic acid	[19,98]
91	*Cryptotaenia japonica* Hassk.	Whole plant	Treatment of weakness, urinary closure, and swelling	Antioxidant, protect liver, and anticancer	Friedelin, stigmasterol, and apigenin	[19,99,100]
92	*Cuminum cyminum* L.	Fruits	Treatment of indigestion and	Antibacterial, antioxidant, and	α-pinene, 1,8-cineole, and linalool	[19,101]

			stomach cold abdominal pain	radical-scavenging properties		
93	*Cyclorhiza peucedanifolia* (Franch.) Constance	Fruits	Enriching the blood, activating blood, and regulating menstrual disorder	\	\	[102]
94	*Daucus carota* L.	Fruits	Treatment of ascariasis, enterobiasis, and tapeworm disease	Insecticide, anti-bacterial, and anticancer	α-pinene, isophorone oxide, and and quercetrin	[18,103]
95	*Daucus carota var. Carota*	Fruits	Treatment of ascariasis, enterobiasis, and tapeworm disease	Insecticide, anti-bacterial, and anticancer	α-pinene, β-bisabolene , and luteolin	[18,103]
96	*Daucus carota var. Sativus* Hoffm.	Roots and basal leaves	Strengthening spleen, treatment of dyspepsia, and chronic dysentery	Enhancing immunity, anticancer, and prevents aging	Carotene, (1R)-α-pinene, and β-carotene	[19,104]
97	*Eriocycla albescens* (Franch.) H. Wolff	Roots	\	\	\	[1]
98	*Eryngium foetidum* L.	Whole plant	Diuresis, treatment of dropsy, and snakebite	Bacteriostat, diminish inflammati, and detumescence	Lanolin alcohol, carotene, and *n*-nonyl aldehyde	[19,105]
99	*Ferula bungeana* Kitag.	Whole plant and seeds	Heat-clearing and detoxifying, relieving pain and expelling phlegm, and arresting coughing	Treatment of cold, bronchopneumonia, and pulmonary tuberculosis	Anisole, *d*-fenchone, and limonen	[19,106]
100	*Ferula caspica* M. Bieb.	Roots and resin	Eliminating stagnated food, relieving dyspepsia, and insecticide	Toxicity effect	Umbelliprenin, farnesyl alcohol, and umbelliferone	[107]
101	*Ferula conocaula* Korovin	Resin, roots, and rhizome	Eliminating stagnated food, insecticide, treatment of abdominal mass, and a lump in the abdomen	Anticancer and treatment of influenza	Umbelliprenin, fezelol, and feterin	[107]
102	*Ferula feruloides* (Steud.) Korovin	Roots and resin	Treatment of chilliness, and pain of the heart and abdomen	Insecticidal, bacteriostat and antitumor	α-pinene, farnesene and toluene	[108,109]
103	**Ferula fukanensis* K. M. Shen	Resin	Eliminating stagnated food, relieving dyspepsia and insecticide	Treatment of stomach disease, rheumatism and joint pain	Ferulic acid, guaiol and ethyl-p-hydroxybenzoate	[18,19,110–112]
104	*Ferula jaeschkeana* Vatke	Resin of overground part	Eliminating stagnated food, insecticide, treatment of tumour, wound, and peptic ulcer	Antifertility	Jaeschkeanadiol, α-pinene and β-pinene	[107]
105	*Ferula krylovii* Korovin	Resin	Eliminating stagnated food and insecticide	\	fekrynol, ferukrin and fekrynol acetate	[107]
106	*Ferula lehmannii* Boiss.	Resin	Detoxification, deodorize, and insecticide	Treatment of gastropathy,	Lehmannolone, sinkianone, and lehmannolone A	[16,113]

				rheumatism and arthralgia		
107	*Ferula moschata* (Reinsch) Koso-Pol.	Roots	Sedative, spasmolysis, and treatment of hysteria	Suppress the replication of human immunodeficiency virus in H9 lymphocytes and suppress the production of cytokine	fezelol, fesumtuorin A and fesumtuorin B	[107]
108	*Ferula olivacea* (Diels) H. Wolff ex Hand.-Mazz.	Resin	Wind-heat dispersing, expelling phlegm, and arresting coughing	\	\	[16]
109	***Ferula sinkiangensis* K. M. Shen	Resin	Eliminating stagnated food, detoxification, and insecticide	Antioxidant, antitumor, and antiviral	Ferulic acid, fekrynol, and lehmannolone	[16,18,114,115]
110	*Ferula songarica* Pall. Ex Schult.	Resin and whole plant	Eliminating stagnated food and insecticide	\	2, 4-dihydroxylacetophenone, 3, 3', 4, 4'-biphenyltetracarboxylic acid, and Δ^3-carene	[116]
111	*Ferula teterrima* Kar. & Kir.	Resin	Eliminating stagnated food, and insecticide	Treatment of malaria and dysentery	Feterin, badrakemin, and badrakemin acetate	[116]
112	**Foeniculum vulgare* Mill.	Fruits, roots, stems, leaves, and whole plant	Dispelling wind, relieving pain, and harmonize the stomach	Bacteriostat, anti-inflammatory, and antianxiety	Trans-anethole, estragole, and anisaldehyde	[18,19,117]
113	***Glehnia littoralis* F. Schmidt ex Miq.	Roots	Heat-clearing and detoxifying, diminish inflammation, and expelling phlegm and arresting coughing	Anti-inflammatory, bacteriostat, and antitumor	Phenyllactic acid, catechol, and quercetin	[18,118]
114	*Hansenia oviformis* (R. H. Shan) Pimenov & Kljuykov	Rhizome, roots, and leaves	Treatment of rheumatic arthralgia, cold due to wind-cold, and headache	\	\	[16,102]
115	*Heracleum barmanicum* Kurz	Roots	Treatment of cold abdominalgia	\	\	[16]
116	*Heracleum candicans* Wall. Ex DC.	Roots	Dispelling wind, eliminating dampness, and relieving pain	Treatment of cold headache	Bergapten, heraclenin, and imperatorin	[19,119]
117	*Heracleum dissectifolium* K. T. Fu	Roots	Dispelling wind, eliminating dampness, and relieving pain	\	\	[16]
118	*Heracleum fargesii* H. Boissieu	Roots	\	\	\	[17]
119	*Heracleum franchetii* M. Hiroe	Roots and rhizome	\	\	\	[120,121]
120	*Heracleum hemsleyanum*	Roots and rhizome	Dispelling wind, eliminating dampness, and relieving pain	Antioxidant, anti-inflammatory, and antitumor	β-pinene, α-pinene, and (1S)-6,6-dimethyl-2-methylene-bicyclo[3.1.1] heptane	[26,27,122,123]

121	*Heracleum hemsleyanum* Diels	Roots and rhizome	Dispelling wind, eliminating dampness, and relieving pain	Antioxidant, anti-inflammatory, and antitumor	Osthole, columbianadin, and columbianetin	[26,27]
122	*Heracleum henryi* H. Wolff	Roots	Clearing and activating the channels and collaterals, relieving pain, and scattered stasis	\	Turgeniifolin B, turgeniifolin C, and bergapten	[124]
123	*Heracleum millefolium var. Millefolium*	Roots and rhizome	Detumescence, disintegrate masse, and treatment of leprosy	\	\	[102,120,121]
124	*Heracleum moellendorffii* Hance	Roots and rhizome	Clearing and activating the channels and collaterals, relieving pain, and scattered stasis	Bacteriostat	β-pinene, α-pinene, and pentadecane	[122,124–126]
125	*Heracleum oreocharis* H. Wolff	Roots	\	\	\	[121]
126	*Heracleum rapula* Franch.	Roots	Clearing and activating the channels and collaterals, relieving pain, and scattered stasis	Bacteriostat, treatment of asthma, and chronic bronchitis	Ostholce, marmesin, and imperatorin	[19,124,127]
127	*Heracleum scabridum* Franch.	Roots, rhizome, and fruits	Treatment of common cold due to wind-cold, headache, and cough asthma	\	Heraclenol, oxypeucedanin-hydrate, and byakangelicin	[128–130]
128	*Heracleum souliei* H. Boissieu	Roots	\	\	Bergapten	[119,121]
129	*Heracleum stenopterum* Diels	Roots	Treatment of cold and rheumatism	\	Bergapten, isopimpinellin, and sphondin	[16,131]
130	*Heracleum tiliifolium* H. Wolff	Roots	Dispelling wind, eliminating dampness, and relieving pain	\	\	[16]
131	*Heracleum vicinum* H. Boissieu	Roots	Same as *Notopterygium incisum*	\	\	[120,121]
132	*Heracleum wenchuanense* F. T. Pu & X. J. He	Roots	\	\	\	[121]
133	*Heracleum wolongense* F. T. Pu & X. J. He	Roots	\	\	\	[1,121]
134	*Heracleum yungningense* Hand.-Mazz.	Roots and rhizome	Treatment of waist and knee pain, limb spasm, and leucoderma	\	Pimpinellin, angelicin, and isobergapten	[26,132]
135	*Hydrocotyle himalaica* P. K. Mukh.	Whole plant	Heat-clearing, detoxifying, and eliminating dampness	\	Asiaticoside, madecassoside, and quercetin	[133,134]
136	*Hydrocotyle hookeri subsp. Chinensis* (Dunn ex R. H. Shan & S. L. Liou)	Whole plant	Relieving pain, diuresis, and removing dampness	Antiviral, antitumor, and anti-bacterial	Flavonoids, triterpenes, and volatile oils	[16,128,134]

	M. F. Watson & M. L. Sheh					
137	*Hydrocotyle nepalensis* Hook.	Whole plant	Clearing heat and promoting diuresis, dissolving stasis, and hemostasis and detoxicate	Antiviral, antitumor, and anti-bacterial	Flavonoids, triterpenes, and volatile oils	[16,134]
138	*Hydrocotyle sibthorpioides* Lam.	Whole plant	Heat-clearing, diuresis, and detumescence	Anti-ulcer, antilipemic, and antiviral	Quercetin, isorhamnetin, and asiaticoside	[134,135]
139	*Hydrocotyle sibthorpioides var. batrachium* (Hance) Hand.-Mazz. Ex R. H. Shan	Whole plant	Heat-clearing and detoxifying, eliminating dampness, and diuresis	Anti-ulcer, spasmolysis, and anti-inflammatory	Benzene propane nitrile, phytol, and caryophyllene oxide	[16,136,137]
140	*Hydrocotyle wilfordii* Maxim.	Whole plant	As *Hydrocotyle nepalensis* Hook.	As *Hydrocotyle nepalensis* Hook.	Asiaticoside, madecassoside, and quercetin	[133,134]
141	*Hymenidium chloroleucum* (Diels) Pimenov & Kljuykov	Roots or whole plant	Regulating flow of qi, invigorating stomach, and activating blood	Anti-inflammatory, analgesia, and nutritious function	Nobiletin, falcarindiol, and isoliquiritingenin	[19,138,139]
142	*Hymenidium davidii* (Franch.) Pimenov & Kljuykov	Roots	\	\	\	[140]
143	*Hymenidium delavayi* (Franch.) Pimenov & Kljuykov	Roots	\	\	\	[1,6]
144	*Hymenidium lindleyanum* (Klotzsch) Pimenov & Kljuykov	Roots	Treatment of hypertensive, coronary heart disease, and altitude stress	\	Bergapten, isoimperatorin, and oxypeucedanin	[141]
145	*Kitagawia formosana* (Hayata) Pimenov	Roots	\	\	\	[1]
146	*Kitagawia macilenta* (Franch.) Pimenov	Roots	Expelling phlegm	\	\	[142]
147	*Kitagawia terebinthacea* (Fisch. Ex Trevir.) Pimenov	Roots	Cleaning heat and dispelling wind, alm the adverse-rising energy, and expelling phlegm	Treatment of cold and cough, bronchitis, and cough during pregnancy	Isoepoxybuterixin	[19]
148	*Levisticum officinale* W. D. J. Koch	Roots	Diuresis, invigorate the stomach, and expelling phlegm	Inhibition of rhythmic uterine contractions, Scavenging oxygen free radicals, and anti- lipid peroxidation	Ligustilide, α-phellandrene, and β-phellandrene	[19,143]
149	*Libanotis buchtormensis* (Fisch.) DC.	Roots	Divergent wind chill, dispel wind-damp, and relieving pain	Bacteriostat, treatment of common cold due to wind-cold, generalized pain, and cough	Falcarinone, isoimperatorin, and xanthotoxin	[19,144]
150	*Libanotis iliensis* (Lipsky) Korovin	Roots	Expel wind-cold pathogens, thermolysis, and relieving pain	Treatment of common cold due to wind-cold and rheumatic arthritis	Archangelin and iliensin	[19]

151	*Libanotis lancifolia* K. T. Fu	Roots	Divergent wind chill, dispel wind-damp, and relieving pain	Bacteriostat, treatment of common cold due to wind-cold, generalized pain, and cough	Falcarinone, isoimperatorin, and xanthotoxin	[19,144]
152	*Libanotis laticalycina* R. H. Shan & M. L. Sheh	Roots	Dispelling wind, antispasmodic, and relieving pain	Analgesia, sedation, and anti-inflammatory	Octanal, hexanal, and 2-pentylfuran	[16,145,146]
153	*Libanotis seseloides* (Fisch. & C. A. Mey. Ex Turcz.) Turcz.	Roots	Eliminating dampness, activating spleen, and promote blood circulation	Treatment of damobstruction, dysentery, and sore	Edultin	[19]
154	*Libanotis sibirica* (L.) C. A. Mey.	Roots	\	\	\	[1]
155	*Libanotis spodotrichoma* K. T. Fu	Roots	Divergent wind chill, dispel wind-damp, and relieving pain	Bacteriostat, treatment of common cold due to wind-cold, generalized pain, and cough	Falcarinone, isoimperatorin, and xanthotoxin	[19,144]
156	*Ligusticopsis brachyloba* (Franch.) Leute	Roots	Sudation, relieving pain, and dispelling wind	Treatment of headache dizziness, arthralgia, and tetanus	α-pinene, β-pinene, and sabinene	[147–149]
157	*Ligusticopsis daucoides* (Franch.) Lavrova & Kljuykov	Roots	\	\	\	[1,94]
158	*Ligusticopsis likiangensis* (H. Wolff) Lavrova & Kljuykov	Roots	\	\	\	[1,94]
159	***Ligusticum chuanxiong* Hort.	Roots, rhizome, stems, and leaves	Activating blood, relieving pain, and Dispelling wind	Anti-inflammatory, antioxidant, and antitumor	Abietene, tetramethylpyrazine, and glucose	[18,19,150]
160	***Ligusticum jeholense* Nakai et Kitag.	Roots and rhizome	Dispelling wind, dispersing cold, and eliminating dampness	Anti-inflammatory, sedation, and anti-ulcer	Ferulic acid, isoferulic acid, and daucosterol	[18,19,151,152]
161	*Ligusticum pteridophyllum* Franch.	Roots	Dispelling wind, relieving pain, and eliminating dampness	Treatment of cold due to wind-cold and migraine	Asaricin, β-sitosterol, and daucosterol	[26,153]
162	***Ligusticum sinense* Oliv.	Roots, rhizome, and tuber	Expel wind-cold pathogens, eliminating dampness, and relieving pain	Anti-inflammatory, central inhibitory, and anti-thrombotic effect	3-butylphthalide, opthalonide, and neopthalonide	[18,154]
163	*Ligusticum tenuissimum* (Nakai) Kitagawa	Roots and rhizome	Same as *ligusticum sinense* Oliv. Divergent wind chill, treatment of wind-cold headache, and diarrhoea.	Analgesia and sedation	Ferulic acid	[19,94,155]
164	*Meeboldia delavayi* (Franch.) W. Gou & X. J. He	Roots	Treatment of cold, fever, headache	\	\	[16]
165	*Nothosmyrnium japonicum var. Japonicum*	Roots	\	Sedation and analgesia	\	[16]
166	*Nothosmyrnium japonicum var.*	Roots	\	Sedation and analgesia	\	[16]

	Sutchuensis H. Boissieu					
167	***Notopterygium franchetii* H. De Boiss.	Roots and rhizome	Divergent wind chill, dispelling wind, and eliminating dampness	Anti-inflammatory, analgesia, and antiviral	Nodakenin, ferulic acid, and bergamot lactone	[18,156,157]
168	***Notopterygium incisum* Ting ex H. T. Chang	Roots and rhizome	Divergent wind chill, dispelling wind, and eliminating dampness	Anti-inflammatory, analgesia, and antiviral	Nodakenin, notopterol, and isoimperatorin	[18,157]
169	*Oenanthe benghalensis* Benth. & Hook.	Roots and whole plant	Same as *Oenanthe javanica* (Blume) DC.	Same as *Oenanthe javanica* (Blume) DC.	\	[17,158]
170	*Oenanthe javanica* (Blume) DC.	Roots, stems and whole plant	Heat-clearing, detoxification, and removing liver-fire	Enhancing immunity, antiarrhythmic, and hypoglycemic	Phytic acid, γ-terpinene, and caryophyllene	[19,159]
171	*Oenanthe linearis subsp. Rivularis* (Dunn) C. Y. Wu & F. T. Pu	Roots and whole plant	Same as *Oenanthe javanica* (Blume) DC.	Same as *Oenanthe javanica* (Blume) DC.	\	[17]
172	*Osmorhiza aristata var. Laxa* (Royle) Constance & R. H. Shan	Roots	Divergent wind chill, sudation, and relieving pain	\	\	[16]
173	*Ostericum citriodorum* (Hance) C. C. Yuan & R. H. Shan	Roots and whole plant	Activating blood, dissolving stasis, and dispelling wind	Expectorant, anti-inflammatory, and bacteriostat	Isoapiole, panaxynol, and myristicin	[19,160–162]
174	*Ostericum grosseserratum* (Maxim.) Kitag.	Roots	Activating spleen, dispersing cold, and invigorating spleen and replenishing qi	\	Octanal, β-pinene, and myristic acid	[16,163,164]
175	*Ostericum sieboldii* (Miq.) Nakai	Roots	\	\	\	[165–167]
176	*Peucedanum dielsianum* Fedde ex H. Wolff	Roots and rhizome	Relieving pain, dispelling wind, and eliminating dampness	\	Isoimperatorin, Phellopterin, and 9-octadecenoic acid	[19,168,169]
177	*Peucedanum dissolutum* (Diels) H. Wolff	Roots	\	\	\	[1]
178	*Peucedanum harry-smithii var. Subglabrum*	Roots	Same as *Peucedanum praeruptorum*, alleviate asthma, reducing phlegm, and heatelimination	Treatment of bronchitis, hypertensive, and coronary heart disease	Psoralen, bergapten, and xanthotoxin	[170–173]
179	*Peucedanum japonicum* Thunb.	Roots	Clearing heat, relieving cough, and diuresis	Antipyresis, analgesia, and anti-inflammatory	Peucedanol, umbelliferone, and β-pinene	[19,174,175]
180	*Peucedanum ledebourielloides* K. T. Fu	Roots	\	\	\	[1,167]
181	*Peucedanum longshengense* R. H. Shan & M. L. Sheh	Roots	\	\	\	[1]
182	*Peucedanum mashanense* R. H. Shan & M. L. Sheh	Roots	Expelling phlegm	\	\	[142]
183	*Peucedanum medicum* Dunn	Roots	*Expelling phlegm, alleviating asthma and cough, and*	Anticoagulation, antioxidant, and antibacterial	2-methoxy-4-vinylphenol, *p*-menthan-	[19,176,177]

			arresting convulsion		1-ol, and *cis*-α-bisabolene	
184	*Peucedanum medicum var. Gracile* Dunn ex R. H. Shan & M. L. Sheh	Roots and rhizome	*Expelling phlegm, alleviating asthma and cough, and arresting convulsion*	Anticoagulation, antioxidant, and antibacterial	Isoimperatorin, phellorerin, and bergapten	[19,176,178]
185	*Peucedanum medicum var. Medicum*	Roots and rhizome	*Expelling phlegm, alleviating asthma and cough, and arresting convulsion*	Anticoagulation, antioxidant, and antibacterial	2-methoxy-4-vinylphenol, *p*-menthan-1-ol, and *cis*-α-bisabolene	[19,176,177]
186	***Peucedanum praeruptorum* Dunn	Roots	Divergent wind, clearing heat, and reducing phlegm	Anticoagulation, antioxidant, and anticancer	Praeruptorin A, praeruptorin B, and scopoletin	[18,179]
187	*Peucedanum shanianum* F. L. Chen & Y. F. Deng	Roots	Relieving asthma, expelling phlegm, and spasmolysis	Anti-inflammatory, antiallergic, and anti-ulcer	Sinodielides A, deltoin, and (+)-pareruptorin A	[180–183]
188	*Peucedanum turgeniifolium* H. Wolff / *Peucedanum pulchrum*	Roots and whole plant	Expelling phlegm, antibechic, and dispersing wind-heat	Smooth muscle spasmolysis	Turgenifolin A, turgenifolin B, and bergapten	[19,183,184]
189	*Peucedanum wawrae* (H. Wolff) S. W. Su ex M. L. Sheh	Roots	Antibechic and expelling phlegm	Analgesia, sedation, and anti-inflammatory	Peucedanocoumarin, d-laserpitin, and bergapten	[16,167,185]
190	*Peucedanum wulongense* R. H. Shan & M. L. Sheh	Roots	\	\	\	[1]
191	*Phlojodicarpus sibiricus* (Steph. Ex Spreng.) Koso-Pol.	Roots	\	\	\	[1]
192	*Physospermopsis alepidioides* (H. Wolff & Hand.-Mazz.) R. H. Shan	Roots	\	\	\	[1]
193	*Physospermopsis delavayi* (Franch.) H. Wolff	Roots	\	\	\	[1]
194	*Pimpinella anisum* L.	Fruits	Warming meridian and diuresis	Treatment of paralysis, facial paralysis, and migraine	Anisaldehyde, anisole, and (E)-anethole	[186–190]
195	*Pimpinella candolleana* Wight & Arn.	Roots or whole plant	Warming spleen and stomach for dispelling cold, relieving pain, and dispelling wind	Relieving muscular spasm, antiviral, and antibacterial	α-zingiberene, pregeijerene, and β-elemene	[19,191–193]
196	*Pimpinella coriacea* (Franch.) H. Boissieu	Whole plant	Warming spleen and stomach for dispelling cold, dispelling wind and eliminating dampness, and activating blood	\	\	[194]
197	*Pimpinella diversifolia* DC.	Whole plant	Expelling phlegm, activating blood, relieving pain, and removing toxicity for detumescence	Anti-inflammatory, antitumor, and antituberculous	1H-benzocycloheptene, sesquiphellandrene, and β-chamigrene	[195–197]
198	*Pimpinella diversifolia var. Diversifolia*	Roots or whole plant	Invigorating stomach, dispersing	Anti-inflammatory, antitumor, and antituberculous	1H-benzocycloheptene, sesquiphellandrene, and β-chamigrene	[19,195–197]

			accumulations, and antidiarrheic			
199	*Pimpinella thellungiana* H. Wolff	Roots or whole plant	Warming spleen and stomach for dispelling cold, benefiting qi and nourishing blood, and coordinating yin and yang	Hypotensive, hypolipidemic, and modulates, and improves cellular immunity	Protocatechuic acid, gallic acid and neochlorogenic acid	[198–202]
200	*Pleurospermopsis bicolor* (Franch.) Jing Zhou & J. Wei	Whole plant	Warming spleen and stomach for dispelling cold, benefiting qi and nourishing blood, and coordinating yin and yang	Hypotensive, antilipemic, and modulates and improves cellular immun antimicrobial ity	Chlorogenic acid, isochlorogenic acid A, and apigenin-7-*O*-β-D-glucuronopyranoside	[198,200,201]
201	*Pleurospermum aromaticum* W. W. Sm.	Whole plant	\	\	\	[1]
202	*Pleurospermum giraldii* Diels	Whole plant and seeds	Warming spleen, digesting food, and checking vaginal discharge	Inhibition of smooth muscle contraction and release intestinal smooth muscle spasm	Carvone, n-triactanol, and γ-sitosterol	[19,203–205]
203	*Pleurospermum rivulorum* (Diels) K. T. Fu & Y. C. Ho	Roots or whole plant	Tonifying the kidney	\	\	[1,102]
204	*Pternopetalum leptophyllum* (Dunn) Hand.-Mazz.	Whole plant	\	\	\	[16]
205	*Pternopetalum vulgare var. Vulgare*	Roots or whole plant	Treatment of lumbago	\	\	[19]
206	*Sanicula astrantiifolia* H. Wolff ex Kretschmer	Whole plant	Tonifying the kidney and lung, treating tuberculosis, and kidney vacuity lumbar pain	Antioxidant, antibacterial, and bacteriostat	Total flavonoids, rutin, and polysaccharides	[206–208]
207	*Sanicula caerulescens* Franch.	Whole plant	Dispelling wind, melting phlegm, and promoting blood circulation for regulating menstruation	Expectorant, antibechic, and anti-inflammatory	Angelicin, isoferulaldehyde, and 12-hydroxybakuchiol	[19,209,210]
208	*Sanicula chinensis* Bunge	Whole plant	Detoxification, hemostasis, and treatment of throat pain	Antiviral	\	[128,211–213]
209	*Sanicula elata* Buch.-Ham. Ex D. Don	Whole plant	Same as *Sanicula lamelligera*	Antiviral	Oleanane saponins, saponins, and microelement	[211–216]
210	*Sanicula lamelligera* Hance	Whole plant	Dispelling wind, melting phlegm, and promoting blood circulation for regulating menstruation	Expectorant, antibechic, and anti-inflammatory	Angelicin, isoferulaldehyde, and 12-hydroxybakuchiol	[19,209,210]
211	*Sanicula orthacantha* S. Moore	Roots or whole plant	Heat-clearing and detoxifying, treatment of traumatic injury	\	\	[16]
212	*Sanicula orthacantha var. Brevispina* H. Boissieu	Whole plant	Heat-clearing and detoxifying, treatment of traumatic injury	\	\	[16]

213	***Saposhnikovia divaricata* (Turcz.) Schischk.	Roots	Dispelling wind to relieve superficies, removing dampness to relieve pain, and arrest convulsio	Analgesia, sedation, and anti-inflammatory	Prim-*o*-glucosylcimifugin, 5-*O*-methylvisamitol glycoside, and cimifugin	[18,217,218]
214	*Selinum cryptotaenium* H. Boissieu	Roots	\	\	\	[1]
215	*Semenovia montana* Kamelin & V. M. Vinogr.	Roots	\	\	\	[121]
216	*Seseli delavayi* Franch.	Roots	Dispelling wind, removing dampness, and relieving pain	\	\	[19]
217	*Seseli mairei var. Mairei*	Roots and rhizome	Dispelling wind, removing dampness, and relieving pain	Antipyretic, analgesia, and anti-inflammatory	Sphondin, bergapten and isopimpinellin	[19,219–221]
218	*Seseli yunnanense* Franch.	Roots and rhizome	Dispelling wind, removing dampness, and relieving pain	Antipyretic, analgesia, and anti-inflammatory	Falcarindiol, falcarinol, and glycerol monolinoleate	[19,219,220,222]
219	*Seselopsis tianschanica* Schischk.	Roots	Treatment of fall injury, anemia, and other diseases	Treatment of nasopharynx cancer	\	[16]
220	*Sium suave* Walter	Whole plant	Dispersing cold, relieving headache, and decreasing blood pressure	\	\	[16,223]
221	*Spuriopimpinella arguta* (Diels) X. J. He & Z. X. Wang	Roots and whole plant	\	\	\	[194]
222	*Tongoloa silaifolia* (H. Boissieu) H. Wolff	Roots	Stopping bleeding, relieving pain, and activating blood	Treatment of traumatic injury, trauma bleeding, and rheumatic pain	Suberosin, crenulatin, and isoimperatorin	[19,224,225]
223	*Tongoloa stewardii* H. Wolff	Roots	\	\	\	[1]
224	*Torilis japonica* (Houtt.) DC.	Fruits and roots	Lumbricide ascaricide, and external antiphlogistic agent	\	Essential oil	[19]
225	*Torilis scabra* (Thunb.) DC.	Fruits or whole plant	Activating blood, insecticide, and antidiarrheal	Bacteriostat	Cyclohexene, 6,6-dimethyl-bicyclo [3.1.1] heptane-2-carboxaldehyde, and endo-borneol	[19,194,226]
226	*Trachyspermum ammi* (L.) Sprague.	Fruits	Dispersing cold, relieving pain, and treatment of indigestion	Antibacterial, antimicrobial, and antifungal	thymol, ϱ-cymene, and β-pinene	[19,187,227] [228–230]
227	*Vicatia thibetica* H. Boissieu	Roots	Dispelling wind, eliminating dampness, and dispelling cold	Anti-fatigue, antioxidant, and enhancing immunity	Umbelliferone, bergapten, and ferulic acid	[231–233]
228	*Visnaga daucoides* Gaertn.	Fruits	Treatment of coronary artery disease, such as panhandling coronary thrombosis	Treatment of renal colic, angina pectoris, and urinary calculi	Khellin, visnagin, and khellol glycoside	[16,234]

Note: "*" means the plant reported in Pharmacopoeia of the People's Republic of China (2020), "**" means the plant roots used as medicine reported in Pharmacopoeia of the People's Republic of China (2020), the same below.

4. Classification of AMPs Species

To our best knowledge, a total of 228 AMPs used as TCMs are collected from previously published literatures and books (Table 1). Based on the traditionally used medicinal parts, the 228 AMPs are categorized into 6 classes including: 51 species (21 genera) used with the whole plants (*i.e.*, rhizome and/or root, stem, and leaf), 184 species (44 genera) used with rhizomes and/or roots, 5 species (5 genera) used with stems, 9 species (8 genera) used with leaves, 17 species (14 genera) used with fruits, and single species (single genus) used with seeds.

Specifically, the 51 species (21 genera) used with whole plants include: Anethum, Anthriscus, Apium, Bupleurum, Centella, Conium, Coriandrum, Cryptotaenia, Eryngium, Ferula, Foeniculum, Hydrocotyle, Oenanthe, Peucedanum, Pimpinella, Pleurospermum, Pternopetalum, Sanicula, Sium, Spuriopimpinella, and Torilis genera. Specially, Sanicula (e.g., S. astrantiifolia, S. caerulescens, S. chinensis), Hydrocotyle (e.g., H. himalaica, H. hookeri, and H. nepalensis), and Pimpinella (e.g., P. candolleana, P. coriacea, and P. diversifolia) genera plants are usually used with whole plants.

The 184 species (44 genera) used with rhizomes and/or roots, which are mainly used in AMPs, include: *Angelica*, *Anthriscus*, *Apium*, *Archangelica*, *Bupleurum*, *Carum*, *Changium*, *Chuanminshen*, *Cicuta*, *Cnidium*, *Conioselinum*, *Daucus*, *Eriocycla*, *Ferula*, *Foeniculum*, *Glehnia*, *Heracleum*, *Hymenidium*, *Kitagawia*, *Levisticum*, *Libanotis*, *Ligusticopsis*, *Ligusticum*, *Meeboldia*, *Nothosmyrnium*, *Oenanthe*, *Osmorhiza*, *Ostericum*, *Peucedanum*, *Phlojodicarpus*, *Physospermopsis*, *Pimpinella*, *Pleurospermum*, *Pternopetalum*, *Sanicula*, *Saposhnikovia*, *Selinum*, *Semenovia*, *Seseli*, *Seselopsis*, *Spuriopimpinella*, *Tongoloa*, *Torilis*, and *Vicatia* genera. Specially, *Angelica* (*e.g.*, *A. biserrata*, *A. dahurica*, and *A. sinensis*), *Bupleurum* (*e.g.*, *B. bicaule*, *B. chinense*, and *B. scorzonerifolium*), and *Ligusticum* (*L. chuanxiong*, *L. jeholense*, and *L. sinense*) genera plants are usually used with whole plants.

The 5 species (5 genera) used with stems include: Aegopodium (A. alpestre), Coriandrum (C. sativum), Foeniculum (F. vulgare), Ligusticum (L. chuanxiong), and Oenanthe (O. javanica); the 9 species (8 genera) used with leaves include: Aegopodium (A. alpestre), Anethum (A. graveolens), Angelica (A. morii), Anthriscus (A. nemorosa and A. sylvestris), Carum (C. carvi), Daucus (D. carota), Foeniculum (F. vulgare), and Ligusticum (L. chuanxiong); the 17 species (14 genera) used with fruits include: Ammi (A. majus), Carum (C. buriaticum and C. carvi), Cnidium (C. monnieri), Coriandrum (C. sativum), Cuminum (C. cyminum), Cyclorhiza (C. peucedanifolia), Daucus (D. carota L. and D. carota var. Carota), Pimpinella (P. anisum), Trachyspermum (T. ammi), and Visnaga (V. daucoides) genera; as well as the single genera used with seeds is Ferula (F. bungeana) (Table 1).

5. Traditional Uses

As shown in Table 1, distinct traditional uses of the 228 AMPs were recorded. Based on their clinical agents, a total of 79 traditional uses are enriched, with 40 species (*e.g.*, *Angelica apaensis*, *Conium maculatum*, and *Hydrocotyle hookeri*) contributing to the treatment of relieving pain, 36 species (*e.g.*, *Aegopodium alpestre*, *Apium graveolens*, and *Carum carvi*) to the treatment of dispelling wind; and 21 species (*e.g.*, *Conioselinum vaginatum*, *Hydrocotyle sibthorpioides* var. *batrachium*, and *Ligusticum sinense*) to the treatment of eliminating dampness (Figure 2).

What's more, AMPs were also widely used as ethnodrug in ethnic minority of China. For example, *Carum carvi* was used as Tibetan medicine for the treatment of dispelling wind and eliminating dampness, treating cat fever and joint pain [86], *Trachyspermum ammi* [235] was used as Uygur medicine for the treatment of eliminating cold damp, dispelling coldness, and promoting digestion; *Angelica acutiloba* was used as Korean nationalities medicine for the treatment of strengthening spleen, enriching blood, stopping bleeding, and promoting coronary circulation [236]; *Angelica sinensis* was used as Tujia minority medicine for the treatment of enriching the blood, treating dysmenorrheal, and relaxing bowel [237]; and *Chuanminshen violaceum* was used as geo-

authentic medicine of Sichuan province for the treatment of moistening lung melt phlegm, as well as nourishing spleen and stomach [89].

Meanwhile, AMPs combined with other herbs have also been applied in many prescriptions for thousands of years [238]. For example, Decoction of Notopterygium for Rheumatism, a famous Chinese prescription, composed of *Notopterygium incisum*, *Angelica biserrata*, *Ligusticum sinense*, *Eryngium foetidum*, and *Ligusticum chuanxiong*, etc., has been widely used for the treatment of exopathogenic wind-cold, rheumatism, headache, and pantalgia [94]. Xinyisan composed of *Yulania liliiflora*, *Actaea cimicifuga*, *Angelica dahurica*, *Eryngium foetidum*, and *Ligusticum sinense*, etc., has been widely used for the treatment of deficiency of pulmonary qi and nasal obstruction due to wind-cold pathogens and damp-heat in lung channel [94,167]. Shiquan Dabu Wan of *Angelica sinensis*, recorded in *Pharmacopoeia of the People's Republic of China*, has been mainly used for treatment of pallor, fatigability, and palpitations [239]; and Juanbi Tang of *Notopterygium incisum* and *Angelica biserrata*, recorded in Medical Words (Qing dynasty), has been mainly used for treatment of arthralgia due to wind cold-dampness [120].

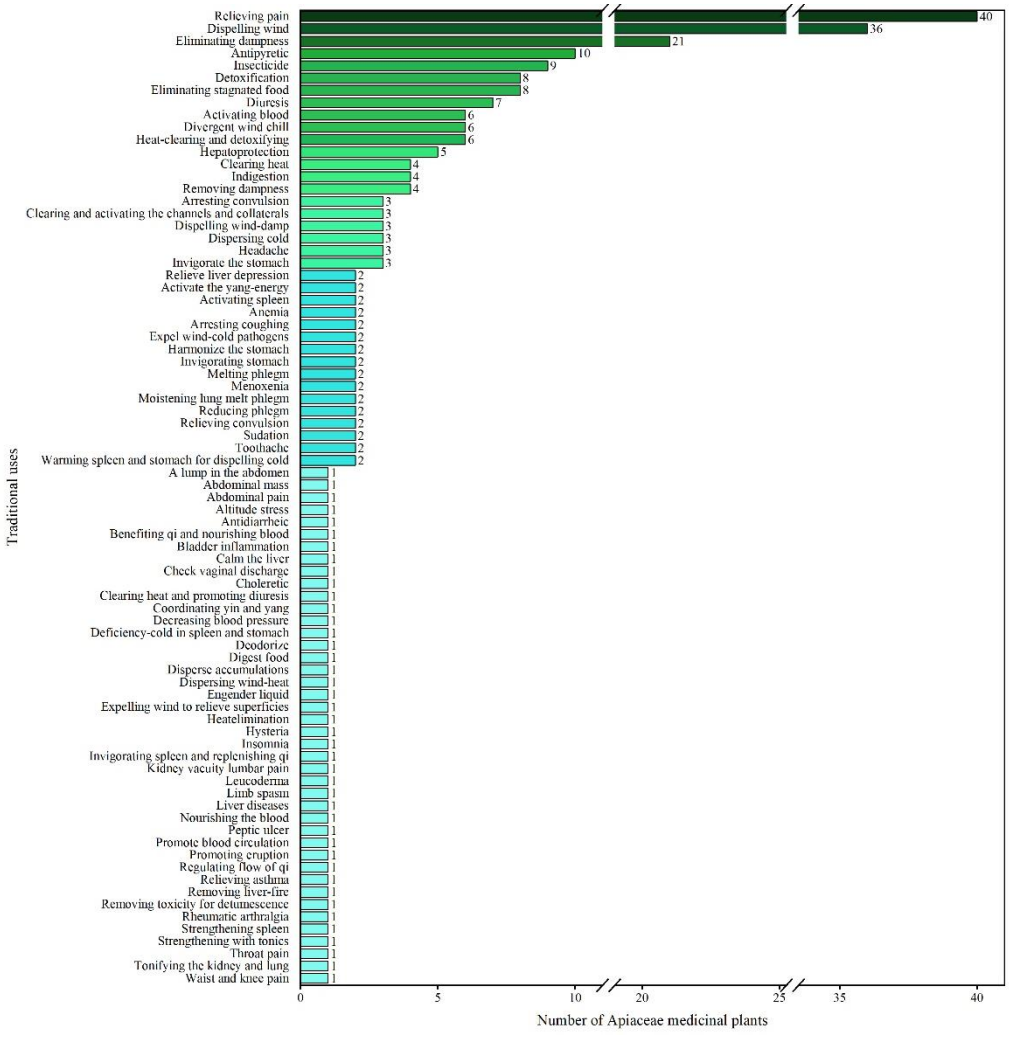

Figure 2. Traditional use of the 228 AMPs.

6. Modern Pharmacological Uses

Modern pharmacological researches of the 228 AMPs were recorded (Table 1). Based on their pharmacological effects, a total of 62 modern uses are enriched (Figure 3), with 36 species (*e.g.*, *Angelica biserrata*, *Bupleurum. marginatum*, and *Foeniculum vulgare*) showing anti-inflammatory activity, 20 species (*e.g.*, *Chuanminshen violaceum*, *Cryptotaenia japonica*, and *Ferula songarica*) showing

antioxidant activity, and 16 species (*e.g.*, *Anethum graveolens*, *Centella asiatica*, and *Changium smyrnioides*) showing antitumor activity.

Specifically, the sesquiterpene-coumarin, such as (3'S, 5'S, 8'R, 9'S, 10'R)-kellerin, gummosin, galbanic acid, and methyl galbanate in *Ferula sinkiangensis* resin, showed the anti-neuroinflammatory effect and might be a potential natural therapeutic agent for Alzheimer's disease [240]. The ferulin B and C in *Ferula ferulaeoides* rhizomes could restrain the multiplication of HepG2 stomach cancer cell lines, and 2,3-dihydro-7-hydroxyl-2R*, 3R*-dimethyl-2-[4,8-dimethyl-3(E),7-nonadienyl]-furo[3,2-c] coumarin could restrain the proliferation of HepG2, MCF-7, and C6 cancer cell lines [107,241]. The osthole in *Angelica biserrata* could restrain the multiplication of human gastric cancer cell lines MKN-45 and BGC-823, human lung adenocarcinoma cell line A549, human mammary carcinoma cell line MCF-7, and human colon carcinoma cell line LOVO [242]. The phthalides (*i.e.*, sedanolide and 3-n-butylphthalide) in *Apium graveolens* showed the anticarcinogenic and neuroprotective properties [243,244].

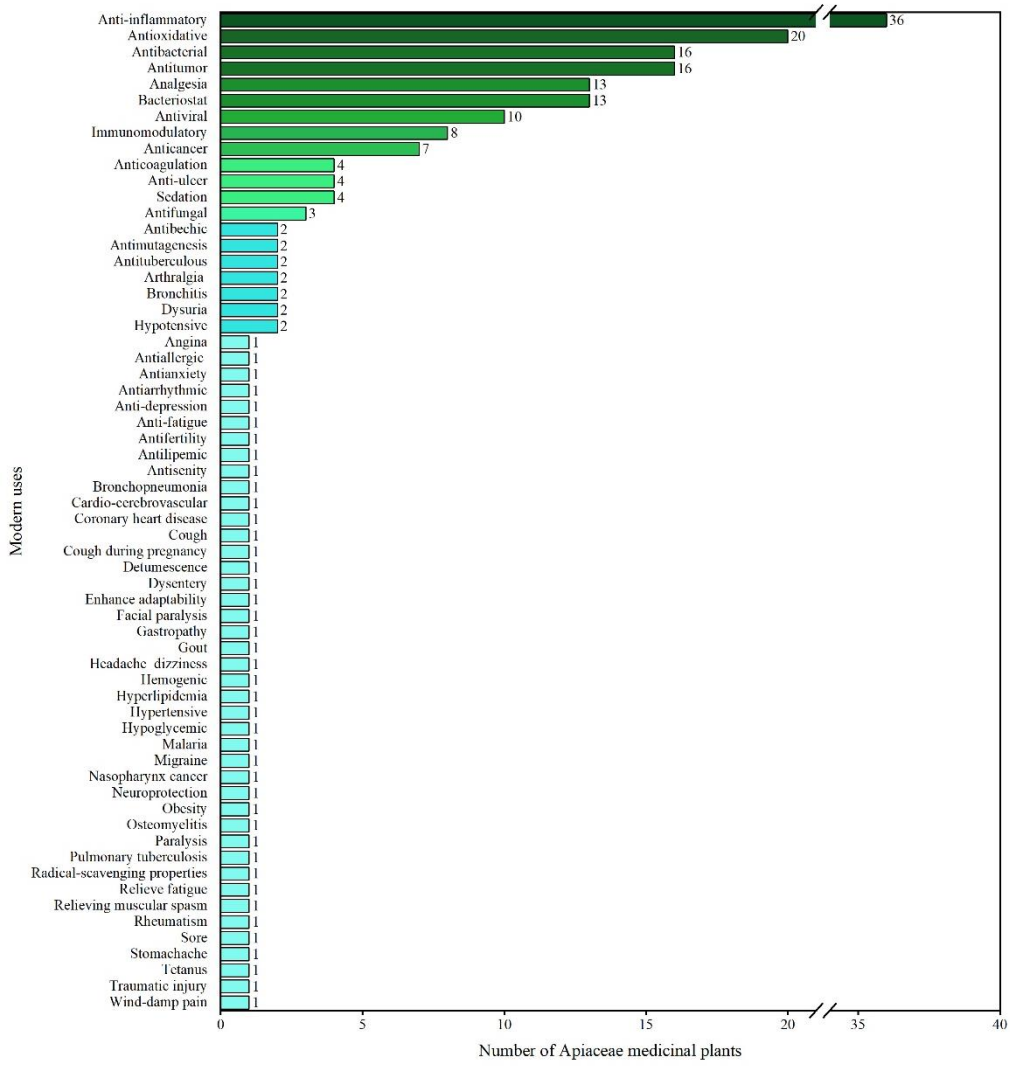

Figure 3. Modern pharmacological uses of the 228 AMPs.

7. Phytochemistry

As shown in Table 1, hundreds of bioactive metabolites have been identified from the 228 AMPs [1,245]. Based on their chemical structures, these metabolites can be categorized into 5 main classes including: (1) polysaccharides, (2) alkaloids, (3) phenylpropanoids, (4) flavonoids, and (5) terpenoids (Figure 4).

Among the 22 AMPs recorded in the *Pharmacopoeia of the People's Republic of China* [18], 18 bioactive metabolites in the 17 AMPs (*e.g.*, *Angelica biserrata*, *Bupleurum chinense DC.*, and *Centella asiatica*) (Figure 5) were described as quality control indicators, which include: 10 phenylpropanoids (*i.e.*, osthole, columbianadin, imperatorin, isoimperatorin, nodakenin, ferulic acid, ttrans-anethole, notopterol, praeruptorin A, and praeruptorin B), 4 terpenoids (*i.e.*, saikosaponin a, saikosaponin d, asiaticoside, and madecassoside), 2 chromones (*i.e.*, prim-O-glucosylcimifugin and 5-O-methylvisammioside), and 2 phthalides (*i.e.*, ligustilide and levistilide A,); and there is no specific quality marker mentioned for the other 5 AMPs (*e.g.*, *Changium smyrnioides*, *Daucus carota* L., and *Glehnia littoralis*) (Table 2).

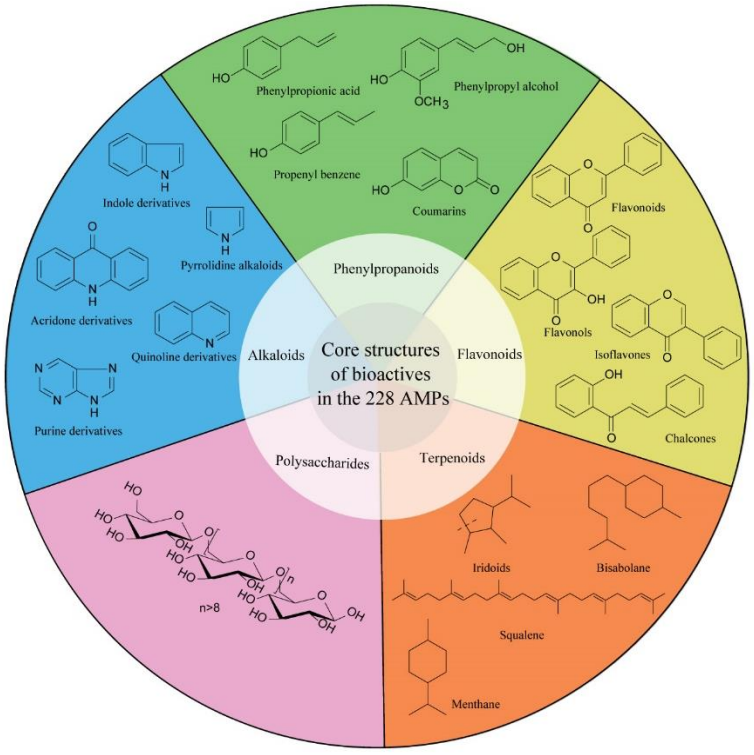

Figure 4. Core structures of five different bioactive compounds identified from the 228 AMPs.

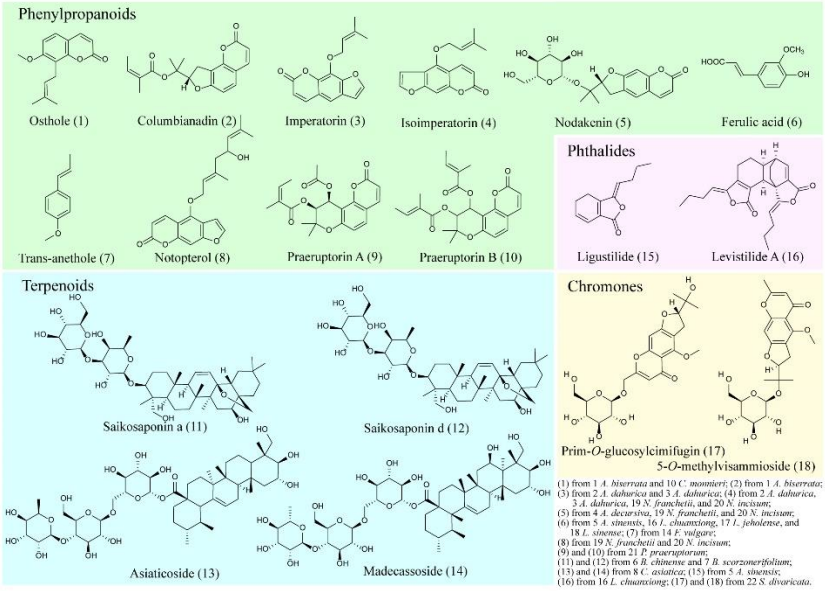

Figure 5. Structures of 18 quality markers from the 22 AMPs in *Pharmacopoeia of the People's Republic of China* (2020).

Table 2. Quality markers in the 22 AMPs recorded in the *Pharmacopoeia of the People's Republic of China* (2020).

No. /No. in Table 1	Plant species	Quality markers	Classification	Biosynthetic pathway
1/8	*Angelica biserrata*	Osthole (1) and columbianadin (2)	Coumarins	Phenylpropanoids
2/10	*Angelica dahurica*	Imperatorin (3) and isoimperatorin (4)	Coumarins	Phenylpropanoids
3/11	*Angelica dahurica* cv. Hangbaizhi	(3) and (4)	Coumarins	Phenylpropanoids
4/13	*Angelica decursiva*	Nodakenin (5)	Coumarins	Phenylpropanoids
5/20	*Angelica sinensis*	Ferulic acid (6) and ligustilide (15)	Propenyl benzenes and phthalides	Phenylpropanoids and phthalides
6/34	*Bupleurum chinense*	Saikosaponin a (11) and saikosaponin d (12)	Triterpenes	Terpenes
7/67	*Bupleurum scorzonerifolium*	(11) and (12)	Triterpenes	Terpenes
8/79	*Changium asiatica*	Asiaticoside (13) and madecassoside (14)	Triterpenes	Terpenes
9/80	*Changium smyrnioides*	–	–	–
10/83	*Changium monnieri*	(1)	Coumarins	Phenylpropanoids
11/94	*Daucus carota*	–	–	–
12/102	*Ferula fukanensis*	–	–	–
13/109	*Ferula sinkiangensis*	–	–	–
14/112	*Foeniculum vulgare*	Trans-anethole (7)	Phenylpropene	Phenylpropanoids
15/113	*Glehnia littoralis*	–	–	–
16/159	*Ligusticum chuanxiong*	(6) and levistilide A (16)	Phenylpropanoids and phthalide	Phenylpropanoids and phthalides
17/160	*Ligusticum jeholense*	(6)	Phenylpropanoids	Phenylpropanoids
18/162	*Ligusticum sinense*	(6)	Phenylpropanoids	Phenylpropanoids
19/167	*Notopterygium franchetii*	(4), (5), and notopterol (8)	Coumarins	Phenylpropanoids
20/168	*Notopterygium incisum*	(4), (5), and (8)	Coumarins	Phenylpropanoids
21/186	*Peucedanum praeruptorum*	Praeruptorin A (9) and praeruptorin B (10)	Coumarins	Phenylpropanoids
22/213	*Saposhnikovia divaricata*	Prim-*O*-glucosylcimifugin (17) and 5-*O*-methylvisammioside (18)	Chromones	Chromones

Note: The "–" indicates there are no specific quality markers recorded in the *Pharmacopoeia of the People's Republic of China* (2020).

7.1. Polysaccharides

Polysaccharides are the largest component of biomass and account for *ca.* 90% of the carbohydrates in plants [246]. Studies have demonstrated that polysaccharides in medicinal plants are the indispensable bioactive compounds presenting uniquely pharmacological effects such as immunomodulatory, hypoglycemic, antitumor, anti-diabetic, and antioxidant, amongst others, with almost no side effect or adverse drug reaction [247,248]. To date, polysaccharides in the 228 AMPs have also been identified to show multiple pharmacological effects. For example, polysaccharides in *Angelica sinensis* present the effect of hematopoietic, antitumor, and liver protection, etc., [238,249]; polysaccharides in *Angelica dahurica* protect the effect of spleen lymphocytes, natural killer cells, and procoagulant, etc., [250,251]; as well as polysaccharides in *Bupleurum chinense* and *Bupleurum smithii* present the effect of macrophage modulation, kidney protection, and inflammatory alleviation, etc., [252–254].

7.2. Alkaloids

About 27 000 alkaloids presenting as water-soluble salts of organic acids, esters, and combined with tannins or sugars have been found in plants [255]. Many alkaloids are valuable medicinal agents that can be utilized to treat various diseases including malaria, diabetes, cancer, cardiac dysfunction, and blood clotting related diseases, etc., [256–258]. While alkaloids in the 228 AMPs mainly exist in the *Ligusticum*, *Apium*, *Conium*, and *Cuminum* genera [245]. Pharmacological studies demonstrated that alkaloids in *Ligusticum chuanxiong* show the activity of inhibiting myocardial fibrosis, protecting ischemic myocardium, and relieving cerebral ischemia-reperfusion injury [150,259,260]; and a novel alkaloid 2-pentylpiperidine named as conmaculatin in *Conium maculatum* shows strong peripheral and central antinociceptive activity [261]. While some alkaloids have been verified to show antidepressant activity, such as berberine in *Berberis aristata*, strictosidine acid in *Psychotria myriantha*, and Anonaine in *Annona cherimolia*, which could be explored as an emerging therapeutic alternative for the treatment of depression of AMPs.

7.3. Phenylpropanoids

Phenylpropanoids are a large class of secondary metabolites biosynthesized from the amino acids, phenylalanine, and tyrosine [262]. Over 8000 aromatic metabolites of the phenylpropanoids that have been identified in plants include simple phenylpropanoids (propenyl benzene, phenylpropionic acid, and phenylpropyl alcohol), coumarins, lignins, lignans, and flavonoids [263].

7.3.1. Simple Phenylpropanoids

To date, limited simple phenylpropanoids have been identified from the AMPs, such as 3 phenylpropanoids (*e.g.*, trans-isoelemicin, sarisan, and trans-isomyristicin) existed in roots of *Ligusticum mutellina* [264]; and ferulic acid, one of the phenylpropionic acids, as an important bioactive metabolite of AMPs had many activities, mainly existed in the *Angelica*, *Ligusticum*, *Ferula*, and *Pleurospermum* genera [238,265,266]. Pharmacological studies demonstrated that ferulic acid in *Angelica sinensis* shows strong properties in inhibiting platelet aggregation, increasing coronary blood flow, and stimulating smooth muscle [267,268]; ferulic acid in *Angelica acutiloba* shows antidiabetic effects, immunostimulant properties, antiinfammatory, antimicrobial, anti-arrhythmic, and antithrombotic activity [269]; and ferulic acid in *Ligusticum tenuissimum* shows anti-melanogenic and anti-oxidative effects [270].

7.3.2. Coumarins

Coumarins are the most widespread in 20 genera of AMPs (*e.g.*, *Angelica*, *Bupleurum*, and *Peucedanum*) and mainly include simple coumarins, pyranocoumarins, and furocoumarins [56,271,272]. In recent years, distinct coumarins have been identified from the AMPs, such as 99 coumarins in *Ferula* [273], 116 coumarins in *Angelica decursiva* and *Peucedanum praeruptorum* [179], as well as 9 coumarins in *Angelica dahurica* [274]. Furthermore, 8 coumarins have been selected as quality markers including cnidiadin (1) in *Angelica biserrata* and *Cnidium monnieri*, zosimin (2) in *Angelica biserrata*, imperatorin (3) in *Angelica dahurica* and *Angelica dahurica* cv. Hangbaizhi, isoimperatorin (4) in *Angelica dahurica*, *Angelica dahurica* cv. Hangbaizhi, *Notopterygium franchetii*, and *Notopterygium incisum*, nodakenin (5) in *Angelica decursiva*, *Notopterygium franchetii*, and *Notopterygium incisum*, notopterol (14) in *Notopterygium franchetii* and *Notopterygium incisum*, as well as praeruptorin A (15) and praeruptorin B (16) in *Peucedanum praeruptorum* (Table 2 and Figure 5) [18].

To date, various biological activities of coumarins have been demonstrated including antifungal, antimicrobial, antiviral, anti-cancerous, antitumor, anti-inflammatory, anti-filarial, enzyme inhibitors, antiaflatoxigenic, analgesics, antioxidant, and oestrogenic [275–278]. For example, coumarins are recognized as the main bioactive constituents in *Peucedani* genus and play critical roles in relieving cough and asthma, strengthening heart function, as well as preventing and treating cardiovascular diseases such as nodakenin, (+)-praeruptorin B, and praeruptorin C [279]; imperatorin oxypeucedanin hydrate, xanthotoxol, bergaptol, 5-methoxy-8-hydroxypsoralen, isoimperatorin, phelloptorin, and pabularinone in *Angelica dahurica* exhibited moderate DPPH•scavenging activity,

strong $ABTS^{+}$ scavenging activity, and significant inhibition on HepG2 cells, which could be explored as new and potential natural antioxidants and cancer prevention agents [30]; pabulenol and osthol extract in *Angelica genuflexa* show anti-platelet and anti-coagulant components [38]; decursinol angelate in *Angelica gigas* shows platelet aggregation and blood coagulation activity [38].

7.4. Flavonoids

Flavonoids are a group of the most abundant secondary metabolites in plants [262]. Generally, flavonoids can be further categorized into 8 subgroups including: flavones (*e.g.*, apigenin, luteolin, and baicalein), flavonols (*e.g.*, kaempferol, quercetin, and myricetin), flavanones (*e.g.*, naringenin, hesperitin, and liquiritigenin), flavanonols (*e.g.*, dihydrokaempferol, dihydromyricetin, and dihydroquercetin), isoflavones (*e.g.*, daidzein, pururarin, and peterocarpin), aurones, anthocyanidins, and proanthocyanidins [280–282]. In recent years, flavonoids have been identified from the AMPs, such as 6 flavonoids (*e.g.*, luteolin, isoquercitrin, and rutin) in *Ferula* [107], 12 flavonoids (*e.g.*, quercetin-3-*O*-rutinoside, kaempferol-3,7-di-*O*-rhamnoside, quercetin-3-*O*-arabinoside) in Bupleurum [283], and 18 flavonoids (*e.g.*, rutin, quercetin, and quercitrin) in Hydrocotyle [134].

To date, various biological activities of flavonoids have been demonstrated including antioxidant, antiinflammatory, antidiabetic, anticancer, antiobesity, and cardioprotective [280,284]. For example, apigenin in *Apium graveolens* shows anticancer property [21], and flavonoids in *Pimpinella diversifolia* DC., *Anthriscus sylvestris*, and *Sanicula astrantiifolia* show antioxidant effect [196,285]; as well as quercetin and its metabolites show vasodilator effects with selectivity toward the resistance vessels [286].

7.5. Terpenoids

About 25 000 terpenoids have been reported in plants and they are most diverse secondary metabolites containing three subgroups including: monoterpenoids, sesquiterpenes, and triterpenoids [287]. Actually, terpenoids have been also identified from the AMPs, such as 4 terpenoids (*e.g.*, angelicoidenol, pregnenolone, and β-sitosterol) in *Pleurospermum* [141], 75 terpenoids (*e.g.*, myrcene, farnesene, and xiongterpene) in *Ligusticum* [140], 109 terpenoids (*e.g.*, nerolidol, guaiol, and ferulactone A) in *Ferula* [273], and 13 triterpenoids (*e.g.*, ranuncoside, oleanane, and barrigenol) in *Hydrocotyle sibthorpioides* Lam. [135].

Studies have found that terpenoids possess various biological activities such as anti-inflammatory, anti-oxidation, and anti-fibrosis activities, antitumor, anti-Alzheimer's disease, and anti-depression [288,289]. For example, xiongterpene in *Ligusticum chuanxiong* shows insecticide effect [150], asiaticoside in *Centella asiatica* shows antitumor property [290], as well as saikosaponin d in *Bupleurum chinense* DC. and *Bupleurum scorzonerifolium* show the effect of reducing blood glucose, inhibiting inflammation, and reducing insulin resistance [291].

7.6. Other Compounds

Chromones and phthalides also exist in the AMPs and show pharmacological properties. Specifically, phthalides (*e.g.*, ligustilide, *n*-butylidenephthalide, and *Z*-ligustilide) in the *Angelica sinensis* show the effect of inhibiting vasodilation, decreasing platelet aggregation, as well as exerting analgesic, anti-inflammatory, and anti-proliferative [238]; butylphthalide in *Ligusticum sinense* shows the effect of anti-inflammatory, antithrombus, dilate blood vessels, improve brain microcirculation, and anti-myocardial ischemia [154].

For the chromones, 3 chromones [*i.e.*, 5 thydroxy 2 [(angebyloxy) mehyI] fuan [3, 2': 6, 7] chrmone, angeliticin A, and noreugenin)] in *Angelica polymorpha* [292], 10 chromones (*e.g.*, cnidimoside A, cnidimol B, and peucenin) in *Cnidiummonnieri* (L.) Cuss. [93], and 22 chromones [*e.g.*, edebouriellol, hamaudol, and 3'(R)-(+)-hamaudol] in *Saposhnikovia divaricate* [217] have been identified. Studies have found that 2 chromones 3'S-(-)-*O*-acetylhamaudol and (±)-hamaudol in *Angelica morii* show the effect of inhibiting Ca^{2+} influx of vascular smooth muscle [293], prim-*O*-

glucosylcimifugin and 5-*O*-methylvisammioside show the effect of antipyretic, analgesic, and anti-inflammatory [294], and chromones in *Bupleurum multinerve* shows the analgesic effect [295].

8. Effect of Bolting and Flowering (BF) on Yield and Quality

Previous literatures have repeatedly emphasized that the BF reduces the yield and quality of plants, especially in rhizomatous medicinal plants [11]. Here, a total of 38 rhizomatous plants reported in the 228 AMPs are associated with the BF (Table 3). Based on the effect degree of the BF on the yield and quality, the 38 rhizomatous AMPs belonging to 17 genera can be categorized into 3 classes including: (1) the BF significantly affects the yield and quality of 14 AMPs (*i.e.*, *Angelica acutiloba*, *Angelica biserrata*, *Angelica dahurica*, *Angelica dahurica* cv. Hangbaizhi, *Angelica decursiva*, *Angelica polymorpha*, *Angelica sinensis*, *Daucus carota*, *Heracleum hemsleyanum*, *Heracleum rapula*, *Libanotis iliensis*, *Libanotis seseloides*, *Peucedanum praeruptorum*, and *Saposhnikovia divaricata*), and their rhizomes and/or roots are wholly lignified and absolutely useless for clinical effects; (2) the BF affects the yield of 11 AMPs (*i.e.*, *Angelica gigas*, *Bupleurum chinense*, *Bupleurum scorzonerifolium*, *Changium smyrnioides*, *Chuanminshen violaceum*, *Glehnia littoralis*, *Ligusticum chuanxiong*, *Ligusticum jeholense*, *Ligusticum sinense*, *Notopterygium franchetii*, and *Notopterygium incisum*), while their rhizomes or roots can be used as medicine to some extent; as well as (3) the BF has no significant effect on the yield and quality of 13 AMPs (*i.e.*, *Angelica sylvestris*, *Cicuta virosa*, *Ferula ferulaeoides*, *Ferula fukanensis*, *Ferula lehmannii*, *Ferula olivacea*, *Ferula sinkiangensis*, *Ferula teterrima*, *Levisticum officinale*, *Libanotis buchtormensis*, *Libanotis lancifolia*, *Libanotis spodotrichoma*, and *Pimpinella candolleana*), and their rhizomes or roots are still used as medicine (Figure 6).

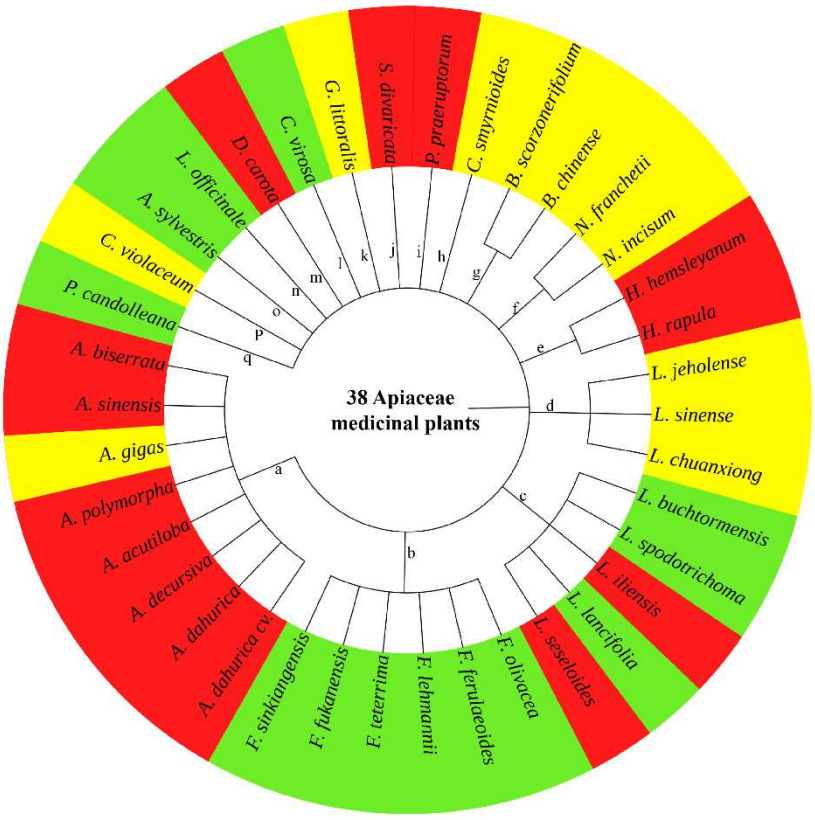

Figure 6. Cluster of the 38 rhizomatous AMPs affected by the bolting and flowering. The red color shows that the BF significantly affects the yield and quality; the yellow color shows that the BF differently affects the yield while the rhizomes or roots can be used as medicine to some extent; and the green color shows that the BF has no significant effect on the yield and quality. Different lower case letters a: *Angelica*, b: *Ferula*, c: *Libanotis*, d: *Ligusticum*, e: *Heracleum*, f: *Notopterygium*, g: *Bupleurum*, h: *Changium*, i: *Peucedanum*, j: *Saposhnikovia*, k: *Glehnia*, l: *Cicuta*, m: *Daucus*, n: *Levisticum*, o: *Anthriscus*, p: *Chuanminshen*, and q: *Pimpinella*.

For the class (1), bolting and flowering reduce the yield and contents of bioactive compounds of plants with none or almost no medicinal value, representatively, a 8.3- and 16.1-fold reduction of dry weight and quality marker ferulic acid content in *Angelica sinensis* [296]; and a 1.5- and 1.5-fold reduction of dry weight and quality marker isoimperatorin content in *Angelica dahurica* [297] have been observed after the BF. For the class (2), bolting and flowering reduce the yield and contents of bioactive compounds of plants with little medicinal value, representatively, a 1.34-fold reduction of saikosaponinsands, while no significant change of dry weight in *Bupleurum chinense* [298,299]; and a 2.0- and 1.7-fold reduction of dry weigh and polysaccharides content in *Changium smyrnioides* [300] have been observed after the BF. For the class (3), the yield and quality of the 13 AMPs are not affected after bolting and flowering by the harvest stages [19].

Table 3. Classification of the 38 rhizomatousAMPs affected by the BF.

No. /No. in Table 1	Plant species	Classes	References	No. /No. in Table 1	Plant species	Classes	References
1/4	*Angelica acutiloba* (Siebold & Zucc.) Kitag.	(1)	[301]	20/109	**Ferula sinkiangensis* K. M. Shen	(3)	[19]
2/8	***Angelica biserrata* (R. H. Shan & C. C. Yuan) C. C. Yuan & R. H. Shan	(1)	[302]	21/111	*Ferula teterrima* Kar. & Kir.	(3)	[19]
3/10	***Angelica dahurica* (Fisch. ex Hoffm.) Benth. & Hook. f. ex Franch. & Sav.	(1)	[303]	22/113	***Glehnia littoralis* F. Schmidt ex Miq.	(2)	[304]
4/11	***Angelica dahurica cv. Hangbaizhi*	(1)	[303]	23/121	*Heracleum hemsleyanum* Diels	(1)	[302]
5/13	***Angelica decursiva* (Miq.) Franch. & Sav.	(1)	[305]	24/126	*Heracleum rapula* Franch.	(1)	[19]
6/14	*Angelica gigas* Nakai	(2)	[306]	25/148	*Levisticum officinale* W. D. J. Koch	(3)	[19]
7/19	*Angelica polymorpha* Maxim.	(1)	[19]	26/149	*Libanotis buchtormensis* (Fisch.) DC	(3)	[307]
8/20	***Angelica sinensis* (Oliv.) Diels	(1)	[308]	27/150	*Libanotis iliensis* (Lipsky) Korovin	(1)	[19]
9/26	*Anthriscus sylvestris* (L.) Hoffm.	(3)	[309]	28/151	*Libanotis lancifolia* K. T. Fu	(3)	[19,307]
10/34	***Bupleurum chinense* DC.	(2)	[310]	29/153	*Libanotis seseloides* (Fisch. & C. A. Mey. ex Turcz.) Turcz.	(1)	[19]
11/67	***Bupleurum scorzonerifolium* Willd.	(2)	[310]	30/155	*Libanotis spodotrichoma* K. T. Fu	(3)	[19,307]
12/80	***Changium smyrnioides* H. Wolff	(2)	[311]	31/159	***Ligusticum chuanxiong* Hort.	(2)	[312]
13/81	*Chuanminshen violaceum* M. L. Sheh & R. H. Shan	(2)	[313]	32/160	***Ligusticum jeholense* Nakai et Kitag.	(2)	[314]
14/82	*Cicuta virosa* L.	(3)	[19]	33/162	***Ligusticum sinense* Oliv.	(2)	[314]
15/96	*Daucus carota var. sativus* Hoffm.	(1)	[315]	34/167	***Notopterygium franchetii* H. de Boiss.	(2)	[316]
16/102	*Ferula feruloides* (Steud.) Korovin	(3)	[19]	35/168	***Notopterygium incisum* Ting ex H. T. Chang	(2)	[316]
17/103	*Ferula fukanensis* K. M. Shen	(3)	[19]	36/186	***Peucedanum praeruptorum* Dunn	(1)	[317]
18/106	*Ferula lehmannii* Boiss.	(3)	[19]	37/195	*Pimpinella candolleana* Wight & Arn.	(3)	[19]
19/108	*Ferula olivacea* (Diels) H. Wolff ex Hand.-Mazz.	(3)	[19]	38/213	***Saposhnikovia divaricata* (Turcz.) Schischk.	(1)	[318,319]

Note: (1) the BF significantly affects the yield and quality, and the rhizomes or roots are absolutely useless for clinical effects; (2) the BF differently affects the yield, while the rhizomes or roots can be used as medicine to

some extent; and (3) the BF has no significant effect on the yield and quality, and their rhizomes or roots are used as medicine without doubtedly, the same below.

9. Approaches to Control the BF

Generally, Most Apiaceae plants are "low-temperature and long-day" perennial herbs, in other words, the plants must experience vernalization (*i.e.*, an extended period of cool weather at 0 to 10℃) and long days (> 12 h daylight) to induce the BF, such as *Angelica sinensis* [320], *Daucus carota* [321], and *Coriandrum sativum* [322].

As shown in Table 4, approaches to inhibit the BF of 24 AMPs have been listed. For example, the bolting rate of *Angelica sinensis* can be significantly decreased through planting the green stem cultivar (Mingui 2) instead of the purple stem cultivar (Mingui 1) [323], selecting smaller seedlings (*i.e.*, root-shoulder diameter <0.55 cm) instead of larger seedlings [324,325], storing the seedlings at freezing temperature (*i.e.*, <0℃) during overwinter stage [320], shading the plants under sunshade (*i.e.*, >40%) during growth stage [326], and providing the plants with good growth conditions (*e.g.*, plant intensity, nutrient and water balance) [327]. The bolting rate of *Angelica dahurica* can be significantly decreased through planting the purebreeds [328], selecting the immature seeds for seeding [303], increasing the potassic fertilizer while decreasing the nitrogen and phosphorus fertilizers [329], and planting with standard techniques [330]. The bolting rate of *Saposhnikovia divaricata* can also be significantly decreased through controlling the sunshade [331], sowing date [332], planting density [333], and preventing the excessive growth [331].

To inhibit the occurrence of BF of AMPs, plenty of measures that can be used include: breeding new cultivars to reduce the BF, controlling the seedling age and size to delay the transition from vegetative growth to flowering, storing seedlings at freezing temperatures to avoid vernalization, growing the plants under sunshade to avoid long-day photoperiodism, and planting with standard techniques to reduce pests and diseases (Figure 7).

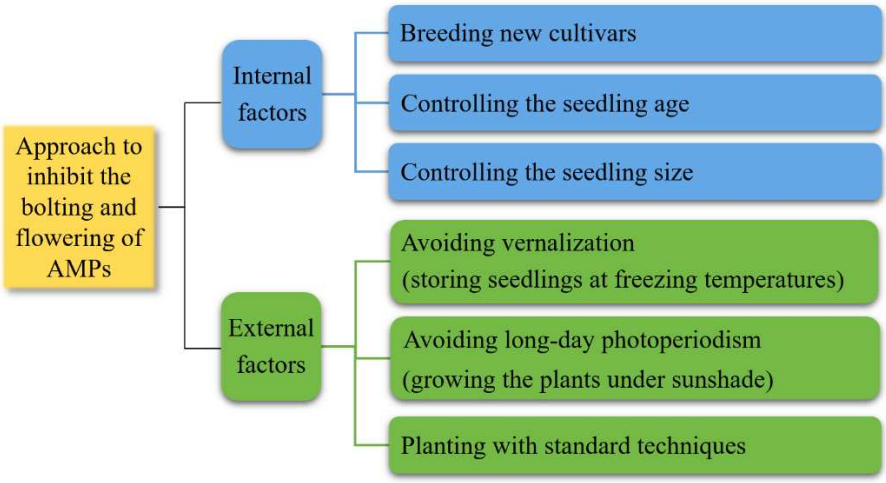

Figure 7. Approach to control the BF of AMPs.

Table 4. Approach to inhibit BF of 25 AMPs have been reported.

Classes	No. /No. in Table 1	Plant species	Measure I (Seeding)	Measure II (Cultivation)	Measure III (Abiotic)	Measure IV (Molecular biology)
(1)	1/4	*Angelica acutiloba* (Siebold & Zucc.) Kitag.	Seedling diameter [334]	Density of planted seedlings [334]	Paclobutrazol concentration [334]	\
(1)	2/8	***Angelica biserrate* (R. H. Shan & C. C. Yuan) C. C. Yuan & R. H. Shan	Seedling size and root length [302]	\	\	\

(1)	3/10	**_Angelica dahurica_ (Fisch. ex Hoffm.) Benth. & Hook. f. ex Franch. & Sav.	Seed quality and seed maturity degree [303,328]	Soil selection should avoid continuous cropping and fertile sticky soil, density of planted seedlings, and seeding time [328,330,335]	Rational application of fertilizer, and appropriate N, P, and K fertilizer [303,328,336]	Seven types of reproductive conversion genes, and adconstans-like gene [337,338]
(1)	4/11	**_Angelica dahurica_ cv. Hangbaizhi	Seed quality and seed maturity degree [303,328]	Soil selection should avoid continuous cropping and fertile sticky soil, density of planted seedlings, and seeding time [328,330,335]	Rational application of fertilizer, and appropriate N, P, and K fertilizer [303,328,336]	Seven types of reproductive conversion gene, and adconstans-like gene [337,338]
(1)	5/13	**_Angelica decursiva_ (Miq.) Franch. & Sav.	\	\	\	\
(1)	6/19	_Angelica polymorpha_ Maxim.	\	\	\	\
(1)	7/20	**_Angelica sinensis_ (Oliv.) Diels	Seed maturity degree, seeding age, seeding weight, root diameter, and excellent variety [323,325,339–341]	Short-day, storage temperature, and reasonable planting and cultivation [308,339,342]	Plant growth retardant [343]	Four pathways of genes for regulating early bolting and flowering [344,345]
(1)	8/96	_Daucus carota var. Sativus_ Hoffm.	Endogenous hormone content and different cultivars [346,347]	Temperature, short-day, and seeding time [346,348–350]	\	Two major genes: _Bol1-1_ and _Bol1-2_ [351]
(1)	9/121	_Heracleum hemsleyanum_ Diels	\	\	\	\
(1)	10/126	_Heracleum rapula_ Franch.	\	\	\	\
(1)	11/150	_Libanotis iliensis_ (Lipsky) Korovin	\	\	\	\
(1)	12/153	_Libanotis seseloides_ (Fisch. & C. A. Mey. ex Turcz.) Turcz.	\	\	\	\
(1)	13/186	**_Peucedanum praeruptorum_ Dunn	\	Compact planting and seeding time [352,353]	\	\
(1)	14/213	**_Saposhnikovia divaricata_ (Turcz.) Schischk.	\	Density of planted seedlings [333]	\	Differentially expressed genes associated with bolting and flowering during early flowering, flower bud differentiation, and late flowering [354]
(2)	15/14	_Angelica gigas_ Nakai	\	\	\	\
(2)	16/34	**_Bupleurum chinense_ DC.	\	Cut the flowers [310]	Temperature [355]	Flowering gene (bcsvp, bcpaf1, bcco and bcft) [356]
(2)	17/67	**_Bupleurum scorzonerifolium_ Willd.	\	\	\	\

(2)	18/80	*Changium smyrnioides* H. Wolff	\	Cut the flowers [311]	\	\
(2)	19/81	*Chuanminshen violaceum* M. L. Sheh & R. H. Shan	\	\	\	\
(2)	20/113	***Glehnia littoralis* F. Schmidt ex Miq.	\	Cut the flowers [304]	\	\
(2)	21/159	***Ligusticum chuanxiong* Hort.	Asexual reproduction and tissue cultur [312,357]	Cut the bolted stem [358]	\	Transcriptome original data by Illumina sequencing technology [359]
(2)	22/160	***Ligusticum jeholense* Nakai et Kitag.	\	Cut the flower [360,361]	\	\
(2)	23/162	***Ligusticum sinense* Oliv.	\	Cut the flower [360,361]	\	\
(2)	24/167	***Notopterygium franchetii* H. de Boiss.	\	Cut the flower [362]	\	\
(2)	25/168	***Notopterygium incisum* Ting ex H. T. Chang	\	Cut the flower [316]	\	\

10. The Mechanism of BF Inducing the Rhizome Lignification

Extensive experiments have demonstrated that the BF induces the lignification of fleshy rhizomes, meanwhile, enhances the degradation of bioactive metabolites [11,13,323]. Studies on anatomical structures reveal that the ratio of secondary phloem to secondary xylem respectively changes from 2:1 to 1:10 and 2/5-1/2 to 1/2-3/4 for the rhizomes of *Angelica sinensis* and *Angelica dahurica* before and after BF, meanwhile, the number of secretory cells producing essential oils significantly decreased [363,364]. Studies have been found that EARLY BOLTING IN SHORT DAY (EBS) acts as a negative transcriptional regulator preventing premature flowering of *Arabidopsis thaliana* and have been observed as co-enrichment of a subset of EBS-associated genes with H3K4me3, H3K27me3, and Polycomb repressor complex 2 [365]; a potential genetic resource for radish late-bolting breeding with introgression of the RsVRN1In-536 insertion allele into early-bolting genotype could contribute to delay bolting time of *Raphanus sativus* [366]; and *peroxidases* (*PRXs*) involved in lignin monomers biosynthesis were downregulated in *Peucedanum praeruptorum* at the bolting stage [367].

As known, lignin biosynthesis belongs to the general phenylpropanoid pathway, which starts from phenylalanine and is catalyzed by a serial of enzymes [13,368]. Specifically, phenylalanine is catalyzed to form *p*-Coumaroyl CoA sequentially through the 3 enzymes phenylalanine ammonia lyase (PAL), cinnamate 4-hydroxylase (C4H), and 4-coumarate-CoA ligase (4CL); lignin biosynthesis is synthesized via 3 sub-pathways including: (1) lignins are catalyzed to from *p*-Coumaroyl CoA sequentially through the three enzymes cinnamoyl-CoA reductases (CCR), cinnamyl alcohol dehydrogenases (CAD), and laccases (LACs); and then coniferyl aldehyde is catalyzed to from *p*-Coumaroyl CoA sequentially through the 4 enzymes hydroxycinnamoyl shikimate/quinate transferase (HCT), *p*-coumarate 3-hydroxylase (C3H), caffeoyl-CoA 3-*O*-methyltransferase (CCOMT), and CCR; (2) lignins are catalyzed to from coniferyl aldehyde sequentially through the 2 enzymes CAD and LACs; as well as (3) lignins are catalyzed to from coniferyl aldehyde sequentially through the 3 enzymes ferulate 5-hydroxylase (F5H), caffeic acid 3-*O*-methyltransferase (COMT), and LACs (Figure 8).

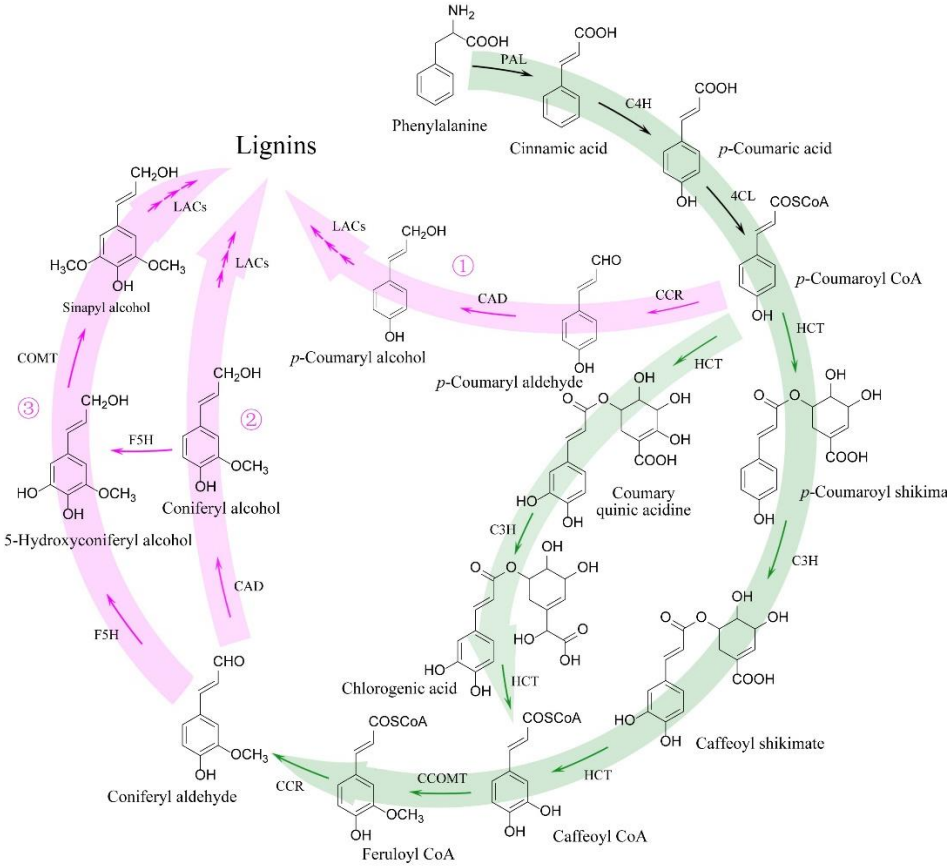

Figure 8. Schematic representation of biosynthetic pathways of lignins. Abbreviations: PAL, phenylalanine ammonia lyase; C4H, cinnamate 4-hydroxylase; 4CL, 4-coumarate-CoA ligase; HCT, hydroxycinnamoyl shikimate/quinate transferase; C3H, *p*-coumarate 3-hydroxylase; CCOMT, caffeoyl-CoA 3-O-methyltransferase; CCR, cinnamoyl-CoA reductases; CAD, cinnamyl alcohol dehydrogenases; LACs, laccases; F5H, ferulate 5-hydroxylase; COMT, caffeic acid 3-O-methyltransferase. The green color shows the common phenylpropanoid pathway of phenylpropanoids, and the red color shows the lignin biosynthetic sub-pathway.

Although lignin biosynthesis has been depicted, studies on the mechanism of BF inducing rhizome lignification are still limited. To our knowledge, only the mechanism of BF affecting *Angelica sinensis* has been conducted, with the expression level of genes (*e.g.*, *PAL1*, *4CLs*, *HCT*, *CAD1*, and *LACs*) significantly upregulated at the stem-node forming and elongating stage compared with stem-node pre-differentiation stage, leading to the reduction of accumulation of bioactive metabolites (*i.e.*, ferulic acid and flavonoids) [13].

11. Conclusions and Future Aspect

In this review, we summarized the tour of AMPs, classification of AMPs species, traditional use, modern pharmacological use, phytochemistry, effect of BF on yield and quality, approach to control the BF, and the mechanism of BF inducing the rhizome lignification. Although *ca.* 228 AMPs, 72 traditional uses, 62 modern uses, and 5 main kinds of metabolites have been recorded, the potential properties still need to be exploited. Although the urgent problems in the BF significantly reducing the yield and quality of AMPs have been found and several approaches have been applied in controlling the BF, the effective measures to inhibit the BF and its mechanism have not been systemically revealed. Thus, in order to effectively control the BF of AMPs, on one hand, standard cultivation techniques of AMPs should be applied; on the other hand, new cultivars should be innovated by the modern biotechnology such as the CRISPR/Cas9 system.

Author Contributions: collected and analyzed the references, drew the chemical structures, and wrote the manuscript, M.L.L.; checked the classification and traditional use of Apiaceae medicinal plants, M.L.; checked the language and modern pharmacological use, L.W.; Conceptualization, Methodology, Supervision, Writing-review and editing, M.F.L.; Conceptualization and Project administration, J.W.

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