A Review of the Composition of the Essential Oils and Biological Activities of Angelica Species

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Abstract: A number of Angelica species have been used in traditional systems of medicine to treat many ailments. Especially, essential oils (EOs) from the Angelica species have been used for the treatment of various health problems, including malaria, gynecological diseases, fever, anemia, and arthritis. EOs are complex mixtures of low molecular weight compounds, especially terpenoids and their oxygenated compounds. These components deliver specific fragrance and biological properties to essential oils. In this review, we summarized the chemical composition and biological activities of EOs from different species of Angelica. For this purpose, a literature search was carried out to obtain information about the EOs of Angelica species and their bioactivities from electronic databases such as PubMed, Science Direct, Wiley, Springer, ACS, Google, and other journal publications. There has been a lot of variation in the EO composition among different Angelica species. EOs from Angelica species were reported for different kinds of biological activities, such as antioxidant, anti-inflammatory, antimicrobial, immunotoxic, and insecticidal activities. The present review is an attempt to consolidate the available data for different Angelica species on the basis of major constituents in the EOs and their biological activities.

Keywords: Angelica; bioactivity; essential oil; hydrodistillation; steam distillation

1. Introduction

In traditional systems of medicine, a number of plants have been widely used for the treatment of various disorders since ancient times. Plants are a versatile source of bioactive metabolites, including polysaccharides, phenolics, alkaloids, essential oils (EOs), steroids, lignins, resins, tannins, etc. [1]. Among them, EOs obtained from plants have various applications, especially in the health, agriculture, food, and cosmetic industries. So far, more than 3000 EOs have been isolated from about 2000 plant species, out of which 300 have been commercially used for various purposes [2]. Previous scientific studies clearly revealed that EOs possess various pharmacological properties such as antioxidant, antimicrobial, antiviral, antimutagenic, anticancer, anti-inflammatory, and immunomodulatory activities [3].

EOs are mainly stored in the oil ducts, resin ducts, glands, or trichomes of the plants [2]. They are a complex mixture of low molecular weight volatile compounds, mainly monoterpenes and sesquiterpenes, and their oxygenated derivatives. Each type of EO contains about 20–100 different components from a variety of chemical classes [4]. In general, the bioactivities of a particular EO are decided by its major components [3]. However, the presence of minor components also plays an essential role in the bioactivities of EOs. They can be obtained from different organs of various medicinal and aromatic plant materials using classical and advanced techniques. Hydrodistillation and steam distillation
are the most important conventional techniques to isolate EOs. The gas chromatography and mass spectrometry (GC-MS) is a widely used method to determine the chemical composition of EOs [5,6]. The compositions of EOs are highly influenced by various parameters, such as harvesting season, plant organs, plant maturity, genetic diversity, nutritional status, environmental conditions, drying methods, and extraction and analysis techniques [7,8].

The genus Angelica L. belongs to the family of Apiaceae (Umbelliferae), comprises about 90 species of biennial perennial herbs that are widely distributed in Asia, Europe, and North America. In these, a total of 45 Angelica species (32 endemic species) are distributed in China [9]. Various species of Angelica have been used in the traditional systems of medicine for several centuries. Previously, several authors reported the volatile composition of different Angelica species using various extraction techniques such as steam distillation, hydrodistillation, solvent-free solid injector, and supercritical fluid extraction. EOs of Angelica species exhibit several pharmacological activities, such as antioxidant, antibacterial, antifungal, antimicrobial, and insecticidal activities. The present paper summarizes the compositions and biological activities of EOs from different Angelica species (Tables 1 and 2).

2. Traditional Uses of Angelica Species

Traditionally, Angelica sinensis, Angelica gigas, and Angelica acutiloba are the most important Angelica species, which are mainly found in Korea, China, and Japan, respectively. In China, A. sinensis has been used for the treatment of various ailments such as gynecological diseases, apoplexia, constipation, malaria, chills, fever, and hemorrhoids. The plant has also been used as a hematonic for nourishing blood, regulating menstruation, and relaxing bowels [10–12]. In the Korean traditional medicine, the root part of A. gigas has been to treat anemia, gynecological diseases, circulatory diseases, and arthritis. It has also been used as sedative, analgesic, and tonic agents [13,14]. A. acutiloba is traditionally used to treat gynecological diseases and anemia [15]. Angelica archangelica is commonly used in traditional medicine to cure nervousness, insomnia, stomach and intestinal disturbances, skin diseases, respiratory problems, and arthritis [16,17]. Angelica glauca has been used to treat bilious complaints, infantile atrophy, and constipation [18]. Angelica dahurica has been mainly used to treat headaches, rhinitis, toothaches, rheumatism, and sore throat [19]. Angelica pubescents has been used to cure rheumatoid arthritis, headache, paralysis, and insomnia [20].

3. The Chemical Composition of Essential Oils of Angelica Species

The main aim of this review is to offer an overview on the chemical composition of EOs from different species of Angelica growing in various countries. Table 1 shows the plant name, plant parts, extraction methods, yield, and the major components of EOs in relation to different species of Angelica. The published reports revealed that the EOs of the genus Angelica isolated by steam distillation or the hydrodistillation method mainly consist of monoterpene hydrocarbons. Figure 1 depicts the chemical structure of some of the major components of EOs from Angelica species.

In A. archangelica seed EOs, β-phellandrene (33.6–63.4%) and α-pinene (4.2–12.8%) were detected as the most abundant components [21]. On the other hand, α-pinene (21.3%), δ-3-carene (16.5%), limonene (16.4%), and α-phellandrene (8.7%) were the most abundant components in the EO of A. archangelica roots growing in Italy [22]. Nivinskiene et al. [23] studied the EO composition of A. archangelica roots collected from three habitats (Svencionys, Prienai, and Vilnus districts in Lithuania) between 1995–2002. α-Pinene (15.7–20.8%) was the major EO component in two localities, whereas β-phellandrene (13.8–18.5%) and α-pinene (11.4–15.0%) were registered as the major EO components in the third locality. The EOs contained 67.3–79.9% of monoterpenes, 9.6–19.4% of sesquiterpenes, and 3.9–6.3% of macrocyclic lactones. Chauhan et al. [17] found that the EOs of A. archangelica rhizomes obtained from three different altitudes of western Himalaya mainly contained dillapiol (35.93–91.55%) and nothoapiole (0.1–62.8%). Further, the authors reported that the composition of EOs varied greatly with the altitude of collection. Pasqua et al. [16] investigated the accumulation of EOs in the roots of
*A. archangelica* subsp. *archangelica* at different developmental stages. A high concentration of α- and β-phellandrene was found only in taproots exceeding 5 mm in diameter.

The EO of the *A. glauca* whole plant collected from Jammu and Kashmir mainly contains α-phellandrene (18.0%), trans-carveol (16.4%), β-pinene (14.0%), β-caryophyllene (8.6%), and β-caryophyllene oxide (8.0%) [24]. Agnihotri et al. [18] investigated the composition of EO from fresh aerial parts of *A. glauca* growing in Kashmir valley in higher Himalaya (India), and found that α-phellandrene (13.5%), trans-carveol (12.0%), and β-pinene (11.7%) were the major components. The EOs from the roots of *A. glauca* collected from two alpine Himalayan locations in Uttarakhand (India) highly contain (Z)-ligustilide (40.6–53.0%) and (Z)-butylidene phthalide (20.7–32.8%) [25].

![Chemical structures of major essential oil components from Angelica species.](image)

*Figure 1.* The chemical structure of some major essential oil components from *Angelica* species.
Table 1. The isolation of essential oils and extracts from different *Angelica* species, and their major components.

| S. No. | Species | Parts | Extraction Method; Extraction Time; Yield | Place of Collection | Major Components | References |
|--------|---------|-------|------------------------------------------|---------------------|------------------|------------|
| 1      | *Angelica archangelica* L. | Seeds (fruits) from three habitats | Hydrodistillation; 2 h; 0.8-1.4% | Svencionys, Prienai and Vilnius districts in Lithuania | β-phellandrene (33.6–63.4%) and α-pinene (4.2–12.8%) | [21] |
|        |         | Fruit of two chemotypes | Steam distillation; 5 h; 0.17–0.51% | Reykjavik, Iceland | α-pinene (41.4%, 28.9%, 14.4%), bicyclogermacrene (10.1%), and β-phellandrene (37.8% and 55.2%) | [26] |
| 2      | *Angelica acutiloba* (Siebold & Zucc.) Kitag. | Root (1–2, 3–4 and >5 mm) | Hydrodistillation; 30 min | Rome, Italy | α-pinene (23.89–32.69%) and δ-3-carene (3.41–17.07%) | [16] |
|        |         | Root (3 habitats) | Hydrodistillation; 2 h; 0.2–0.5% | Svencionys, Prienai and Vilnius districts in Lithuania | α-pinene (15.7–20.8%), δ-3-carene (15.4–16.9%), limonene (8.0–9.2%), β-phellandrene (13.5–15.4%), α-phellandrene (6.0–9.1%), and p-cymene (6.8–10.6%) | [23] |
|        |         | Root (3 different altitudes) | Hydrodistillation; 3 h; 0.28–0.35% | Uttarakashi, Rudraprayag and Pothiwasa in Uttarakhand, India | dillapiole (35.93–91.55%) and nothoapiole (0.14–62.81%) | [17] |
| 3      | *Angelica glauca* Edgew | Leaves, petiole and root | Hydrodistillation; 3 h; 0.44% | Rutgers University, New Brunswick, NJ, USA | leaves: ligustilide (11.61%) and butylidene phthalide (7.29%); petiole: butylidene phthalide (10.76%); root: nonane (24.85%) and α-pinene (31.59%) | [28] |
|        |         | Root | Solvent free solid injector; injection time—5 min and pre-heating time—7 min | Yeosu Province, Republic of Korea | butylidene phthalide (17.82%), furfural (13.67%), 2-furanmethanol (11.99%), 3-methyl furfural (8.50%), maltol (7.28%), and butylidene dhydro-phthalide (5.79%) | [29] |
|        |         | Root, stem and leaves | Steam distillation; 5 h; 0.05 (root), 0.06 (stem), and 0.12 (leaves) | Nantou, Taiwan | 3n-butyl phthalide (30.8–37.9%), γ-terpinene (21.1–27.2%), p-cymene (3.6–11.6%), and cis-β-ocimene (7.0–7.4%) | [30] |
|        |         | Headspace-solid phase microextraction; 20 min | Nantou, Taiwan | γ-terpinene (41.2–52.1%), p-cymene (10.6–17.0%), β-myrcene (6.7–8.6%), cis-β-ocimene (4.9–7.8%), and alloocimene (4.2–5.3%) | [30] |
| 4      | *Angelica glauca* | Whole plant | Hydrodistillation; 3 h; 0.17% | Jammu and Kashmir, Pakistan | α-phellandrene (18.0%), β-pinene (14.0%), trans-carveol (16.4%), β-caryophyllene (9.6%), and β-caryophyllene oxide (8.0%) | [24] |
|        |         | Aerial parts | Hydrodistillation; 3 h; 0.12% | Khillanmarg areas of Kashmir, India | α-phellandrene (13.5%), trans-carveol (12.0%), β-pinene (11.7%), thujene (7.5%), β-caryophyllene oxide (7.2%), β-caryophyllene (7.0%), γ-terpinene (6.7%), nerolidol (6.5%), and β-bisabolene (5.2%) | [18] |
|        |         | Root | Hydrodistillation; 5 h; 0.3% and 1.8% | Himalayan locations of Uttarakhand, India | (Z)-ligustilide (40.6–53.0%), (Z)-butylidene phthalide (20.7–32.8%), and (E)-butylidene phthalide (2.5–5.9%) | [25] |
Table 1. Cont.

| S. No. | Species                  | Parts                      | Extraction Method; Extraction Time; Yield | Place of Collection                      | Major Components                                                                 | References |
|--------|--------------------------|----------------------------|-------------------------------------------|------------------------------------------|----------------------------------------------------------------------------------|------------|
| 4      | *Angelica gigas* Nakai   | Root                       | Hydrodistillation; 4 h                     | Yeosu Province, Republic of Korea        | nonane (19.97%), a-pinene (44.31%), camphene (6.66%), and l-limonene (6.26%)     | [29]       |
|        |                          |                            | Solvent-free solid injector; injection time—5 min and pre-heating time—7 min | Yeosu Province, Republic of Korea        | decursin (29.34%), decursinol angelate (16.83%), lomatol (10.23%), and marmesin (9.32%) | [29]       |
|        |                          |                            | Simultaneous steam distillation (n-pentane/diethyl ether); 2 h; 0.31% | Gwangju, Republic of Korea               | a-pinene (30.89%), 2,4,6-trimethyl heptane (13.39%), a-limonene (4.29%), and camphene (4.10%) | [31]       |
|        |                          |                            | Steam distillation; 1 h 30 min; 0.31%     | Pyeongchang, Republic of Korea           | decursin (40.13%), decursinol angelate (28.44%), and l-limonene (7.84%)            | [14]       |
|        |                          |                            | Supercritical CO₂ extraction; 1 h; 1.67%  | Pyeongchang, Republic of Korea           | decursin (40.13%), decursinol angelate (28.44%), and l-limonene (7.84%)            | [14]       |
| 5      | *Angelica sinensis* (Oliv.) Diels | Root                        | Hydrodistillation; 8 h; 0.3%              | Gansu Province, China                    | (Z)-ligustilide 78.61% and (Z)-butyldieneephthalide 7.99%                       | [32-34]   |
|        |                          |                            | Solvent free solid injector; injection time—5 min and pre-heating time—7 min | Yeosu Province, Republic of Korea        | butyldiene dihydro-phthalide, (15.22%), butyldiene phthalide (14.27%), furfural (16%), camphene (10.66%), and 4-pyridinol (7.17%) | [29]       |
|        |                          |                            | Steam distillation, 3 h; 0.02%            | Chiang Mai province, Thailand            | 3-N-butylphthalide, butyldieneephthalide, ligustilide and di-iso-octyl phthalate | [35]       |
| 6      | *Angelica koreana* Maxim. | Root                       | Steam distillation; 0.28%                 | Jinsu, Gangwon-do, Republic of Korea     | sabinen (31.85%), m-cresol (4.46%), a-pinene (4.80%), and α-bisabolol (3.63%)      | [36]       |
| 7      | *Angelica dahurica* (Fisch. Ex Hoffm.) Benth. & Hook. | Root                        | Supercritical CO₂ extraction; 2 h; 1.8%   | Jilin, China                            | dodecyl alcohol (13.71%), elemene (7.54%), hexadecanoic acid, ethyl ester (7.32%), l-pertedecanol (6.08%), and α-pinene (6.25%), | [19]       |
|        |                          |                            | Hydrodistillation; 3 h; 0.45%             | Beijing, China                          | α-pinene (46.5%), sabine (9.5%), myrcene (3.5%), 1-dodecanol (5.2%), and terpinen-4-ol (4.9%) | [20]       |
| 8      | *Angelica pancicii* Vandus ex Velen. | Root                        | Hydrodistillation; 2 h                    | Balkan mountains, Serbia                | Liquid and headspace injection modes: β-phellandrene (54.9% and 60.1%), α-pinene (14.5% and 20.1%), and α-phellandrene (4.5% and 4.3%) | [37]       |
| 9      | *Angelica pubescens* Maxim. | Root                       | Hydrodistillation; 3 h; 0.65%             | Beijing, China                          | α-pinene (37.6%), p-cymene (11.6%), limonene (8.7%), and cryptone (6.7%)         | [20]       |
| 10     | *Angelica arumiiensis* (Mozaffarian) | Stem                      | Hydrodistillation; 3 h; 0.2%              | Uremia, Province West Azerbaijan, Iran   | Stem: α-cadinol (9.24%), (epi)-α-cadinol (5.76%), and β-cadinol (6.11%)         | [38]       |
### Table 1. Cont.

| S. No. | Species                      | Parts          | Extraction Method; Extraction Time; Yield | Place of Collection                  | Major Components                                                                 | References |
|--------|------------------------------|----------------|-------------------------------------------|--------------------------------------|--------------------------------------------------------------------------------|------------|
| 11     | *Angelica urumiensis*        | Leaves         | Hydrodistillation; 3 h; 0.18%             | Uremia, Province West Azerbaijan, Iran | Leaves: α-cadinol (20.2%), hexahydrofarnesyl acetone (10.03%), 1-dodecanol (7.55%), linoleic acid (6.37%) and oleic acid (5.34%) | [38]       |
| 12     | *Angelica viridiflora*       | Aerial parts   | Steam distillation; 2 h; 0.2%             | Shkotovskii District, Primorsky Krai, Russia | Caryophyllene oxide (61.7%) and 3,4-dimethyl-3-cyclohexan-1-carboxaldehyde (5.8%)       | [39]       |
| 13     | *Angelica cincta* Baissieu   | Aerial parts   | Steam distillation; 2 h; 0.2%             | Shkotovskii District, Primorsky Krai, Russia | α-pinene (67.2%), sabinene (5.8%) and β-pinene (4.9%)                             | [39]       |

### Table 2. Biological activities of essential oils from different *Angelica* species.

| S. No. | Species                      | Parts          | Biological activity                          | Model                                                                                     | References |
|--------|------------------------------|----------------|----------------------------------------------|------------------------------------------------------------------------------------------|------------|
| 1      | *Angelica archangelica* L.   | Seeds          | Antioxidant                                  | Aldehyde/Carboxylic Acid Assay, DPPH radical scavenging assay, and Malonaldehyde/Gas Chromatography Assay | [40]       |
| 2      | *Angelica gigas* Nakai       | Root           | Anti-seizure                                 | Maximal electroshock and pentylentetrazol-induced seizures in mice                         | [41]       |
| 3      | *Angelica glauca* Edgew      | Whole plant    | Antioxidant, antimicrobial, and phytotoxic  | Repeated nicotine-induced locomotor activity and extracellular dopamine levels in the nucleus accumbers of rats | [42]       |
|        |                              |                |                                              | Bacteria: *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, and *Pasteurella multocida* | [22,27]    |
|        |                              |                |                                              | Fungi: *Candida albicans*, *Microsporum canis*, *Aspergillus flavus*, and *Fusarium solani*. |            |
|        |                              |                |                                              | DPPH radical scavenging assay                                                             |            |
|        |                              |                |                                              | Phytotoxic activity against *Lemna minor*                                                | [24]       |
|        |                              | Leaves         | Immunotoxicity                               | Larvae of *Aedes aegypti*                                                                  | [44]       |
|        |                              |                |                                              | Broncho-relaxant                                                                          | [45]       |
Table 2. Cont.

| S. No. | Species                          | Parts                  | Biological activity                                      | Model                                                                 | References |
|--------|----------------------------------|------------------------|---------------------------------------------------------|----------------------------------------------------------------------|------------|
| 4      | *Angelica sinensis* (Olive) Diels | Root                   | Anti-inflammatory                                       | Carrageenan-induced rats                                              | [32]       |
|        |                                  |                        | Anti-inflammatory                                       | DPPH, ABTS scavenging, and β-carotene bleaching assays.               | [46]       |
|        |                                  |                        | Anti-inflammatory                                       | Carrageenan-induced rats and mechanism by plasma metabolomics approach | [34]       |
|        |                                  |                        | Antibacterial                                            | Staphylococcus aureus, Staphylococcus chromogenes, and Streptococcus uberis | [47]       |
|        |                                  |                        | Anti-inflammatory                                       | Carrageenan-induced acute inflammation model rats                     | [48]       |
|        |                                  |                        | Anti-inflammatory                                       | Lipopolysaccharide-induced inflammation rat model                     | [33,49]    |
|        |                                  |                        | Anxiolytic                                               | Elevated plus-maze, light/dark and stress-induced hyperthermia tests | [50]       |
|        |                                  |                        | Social interaction test of anxiety and the hole-board test |                                                                      | [51]       |
|        |                                  |                        | Repellent                                                | Against *Aedes aegypti*                                               | [35]       |
| 5      | *Angelica koreana* Maxim.         | Root                   | Antifungal and antioxidant                              | *Aspergillus* (*A. flavus, A. fumigaus, A. niger, A. terreus and A. versicolor*) and *Trichophyton* (*T. mentagrophytes, T. rubrum and T. tonsurans*) species | [36]       |
|        |                                  |                        | Anti-inflammatory and immunomodulating properties        | Xylene-induced acute ear swelling and carrageenan-induced acute paw edema in mice; anti-inflammatory and immunomodulating properties in Freund’s complete adjuvant (FCA)-induced arthritis in rats. | [19]       |
|        |                                  |                        | Enhance sensitivity of MCF-7/ADR breast cancer cells to doxorubicin | MDR human breast cancer MCF-7/ADR cells                              | [52]       |
|        |                                  |                        | Insecticidal                                             | Yellow fever mosquito, *Aedes aegypti*, and azalea lace bugs, *Stephanitis pyrioides* | [20]       |
|        |                                  |                        | Antibacterial                                            | Staphylococcus aureus, Staphylococcus chromogenes, and Streptococcus uberis | [47]       |
| 6      | *Angelica dahurica* (Fisch. Ex Hoffm.) Benth. & Hook. | Root                   | Antifungal and Insecticidal                             | *Colletotrichum acutatum, Colletotrichum fragariae, and Colletotrichum gloeosporioides*, Yellow fever mosquito, *Aedes aegypti*, and azalea lace bugs, *Stephanitis pyrioides* | [20]       |
| 7      | *Angelica pubescentis* Maxim.     | Root                   | Antifungal and Insecticidal                             | *Colletotrichum acutatum, Colletotrichum fragariae, and Colletotrichum gloeosporioides*, Yellow fever mosquito, *Aedes aegypti*, and azalea lace bugs, *Stephanitis pyrioides* | [20]       |
| 8      | *Angelica anomala* Avé-Lall., *Angelica cartilagino-magnata* var. distans, *Angelica czerniewia*, *Angelica decursiva* (Miq.) Franch. & Sax., *Angelica fallax* H. Boissieu , *Angelica japonica* A. Gray | Leaves                 | Immunotoxicity                                           | Larvae of *Aedes aegypti*                                             | [44]       |
|        |                                  |                        | Penetration Enhancers for Transdermal Administration of Ibuprofen | Therapeutic efficacy of ibuprofen with essential oil was evaluated using dysmenorrheal model mice | [53]       |
| 9      | *Angelica species*                | Root                   | Skin permeation of drugs                                | Skin permeation of ibuprofen across rat abdominal skin                | [54]       |

DPPH: 1,1-diphenyl-1-picrylhydrazyl; ABTS: 2,2-azino-bis(3-ethylbenzo-thiazoline-6-sulfonic acid); EEG: electroencephalographic activity; MDR: multidrug resistance.
Kim et al. [29] determined the EO composition from the rhizomes of *A. gigas*, *A. sinensis*, and *A. acutiloba* by solvent-free solid injector method. Coumarin derivatives such as decursinol angelate (16.83%) and decursin (29.34%) were found to be the most abundant components, followed by lomatins (10.25%), and marmesin (9.33%) in *A. gigas*. Butylidene dihydro-phthalide, (15.23%), butylidene phthalide (14.27%), furfural (16%), and camphene (10.66%) were the main components in *A. sinensis*. Similarly, butylidene phthalide (17.82%) and furfural (13.67%) were registered as the major components in *A. acutiloba*.

Sowndhararajan et al. [14] compared the EO composition of *A. gigas* root by steam distillation and supercritical carbon dioxide extract (SC-CO$_2$). The EO mainly composed of monoterpene hydrocarbons (52.83%), followed by oxygenated sesquiterpenes (25.53%). In these, $\alpha$-pinene (28.64%), $\beta$-eudesmol (14.80%), and $\gamma$-eudesmol (5.97%) were the major components in the EO of *A. gigas* root. However, decursin (40.13%) and decursinol angelate (28.44%) were detected as the most abundant components in SC-CO$_2$. $\alpha$-Pinene (30.89%) was also the major component in the EO of *A. gigas* root extracted by simultaneous steam distillation and extraction method [31]. In another study, the roots of *A. gigas* and *A. acutiloba* were collected from the field of Snyder Research and Extension Farm Rutgers University, New Jersey, and analyzed for their EO composition. The main constituents of the *A. gigas* root EO were ligustilide (47%) and $\gamma$-terpinene (14%). In the case of *A. acutiloba* root EO, $\alpha$-pinene (32%) and nonane (25%) were the major components [28].

Chen et al. [30] compared the volatile compositions of *A. acutiloba* roots, stems, and leaves using steam distillation and headspace solid-phase microextraction (HS-SPME). In all three parts, a total of 61 and 33 compounds were detected by SD and HS-SPME, respectively. In the steam distillation, 3n-butyl phthalide, $\gamma$-terpinene, $p$-cymene, and cis-$\beta$-ocimene were the main compounds. On the other hand, $\gamma$-terpinene and $p$-cymene were the main compounds in HS-SPME. Further, the authors reported that monoterpene components were found to be higher in the HS-SPME sampling method when compared with steam distillation.

In the EO of *A. major*, $\alpha$-pinene (21.8%) and cis-$\beta$-ocimene (30.4%) were found to be the most abundant components [35]. The main components in *A. dahurica* EO were $\alpha$-pinene (46.3%), sabine (9.3%), myrcene (5.5%), 1-dodecanol (5.2%), and terpinen-4-ol (4.9%). In regards to *A. pubescentis* root EO, $\alpha$-pinene (37.6%), $p$-cymene (11.6%), limonene (8.7%), and cryptone (6.7%) were found to be the major components [20]. Champakaew et al. (2015) found that 3-N-butylphthalide, butylidene phthalide, ligustilide, and di-isooctyl phthalate were the main components in *A. sinensis* EO. The composition of EOs of the stem and leaves of *Angelica urumiensis* were studied by Mohammadi et al. [38]. In the EO from the leaves, $\alpha$-cadinol (20.2%), hexahydrofarnesyl acetone (10.03%), and 1-dodecanol (7.55%) were the major components. On the other hand, $\alpha$-cadinol (9.24%) and $\delta$-cadenine (6.11%) were the major components in the EO from the stem. The EO compositions of *A. panicci* were compared by GC-MS liquid injection and headspace-GC-MS modes. In total, 40 compounds were identified in the EO by GC-MS liquid injection, and 44 by HS-GC-MS. In both cases, the main components were $\beta$-phellandrene, $\alpha$-pinene, and $\alpha$-phellandrene [37]. Caryophyllene oxide (61.7%) and $\alpha$-pinene (67.2%) were detected as the most abundant components in EOs of *A. viridiflora* and *A. cincta* aerial parts, respectively [39].

4. Biological Activities of *Angelica* Essential Oils

4.1. Antioxidant

1,1-Diphenyl-2-picrylhydrazil (DPPH) and 2,2-azino-bis(3ethylbenzo-thiazoline-6-sulfonic acid (ABTS) radical scavenging activities are extensively used measures to evaluate the antioxidant potential of plant extracts or compounds. DPPH, nitrite inhibition, and reducing power were determined to assess the antioxidant activity of *Angelica koreana* EO and its major components. m-Cresol (56.12%) showed stronger DPPH scavenging activity than EO (19.31%) and sabine (4.45%) at the concentration of 16 mg/mL. Additionally, sabine exhibited the strongest reducing
power and nitric oxide scavenging activities than the EO fraction or m-cresol [36]. Irshad et al. [24] reported that A. glauca EO exhibited good DPPH radical scavenging and peroxidation inhibition activities. Angelica seed oil showed 39% of DPPH radical scavenging activity at the concentration of 200 μg/mL [40]. The antioxidant activity of A. sinensis was investigated by DPPH, ABTS, and beta-carotene bleaching assays. A. sinensis EO and coniferyl ferulate rich fractions 1 and 2 showed strong DPPH (IC₅₀ of 194.7, 42.4 and 15.2 μg/mL, respectively) and ABTS (IC₅₀ of 98.8, 15.9 and 7.8 μg/mL, respectively) radical scavenging activities. Further, coniferyl ferulate rich fractions 1 and 2 exhibited good β-carotene bleaching activity with IC₅₀ values of 11.0 and 2.0 μg/mL, respectively [46]. In another study, the DPPH radical scavenging activity of A. archangelica EO, α-terpineol, phenyl ethyl alcohol, and their combination were determined. The IC₅₀ values of A. archangelica EO, α-terpineol, and their EO-based combination were 1.04, 66.6, and 3.89 μL/mL, respectively [42].

4.2. Antimicrobial

A. koreana EO and its main components, sabinene and m-cresol, showed antifungal activity against different species of Aspergillus and Trichophyton with minimal inhibitory concentrations (MICs) of 125–1000 μg/mL. In addition, EO exhibited synergistic activity when combined with itraconazole [36]. The EO of A. glauca showed appreciable antimicrobial activity against selected strains of bacteria (Staphylococcus aureus, Bacillus subtilis, Escherichia coli, and Pasteurella multocida) and fungi (Candida albicans, Microsorum anis, Aspergillus flavus, and Fusarium solani). Among the bacterial strains tested, Escherichia coli and Staphylococcus aureus were the most sensitive bacteria with minimum inhibitory concentration (MIC) values of 141.3 and 159.3 μg/mL, respectively. In regards to fungal strains, Microsorum anis was the most sensitive organism with a MIC value of 178.1 μg/mL [24].

The EO of A. archangelica root showed considerable antimicrobial activity against Clostridium difficile, Clostridium perfringens, Enterococcus faecalis, Eubacterium limosum, Peptostreptococcus anaerobios, and Candida albicans. Further, A. archangelica EO showed a weaker antimicrobial activity against the intestinal microflora such as bifidobacteria and lactobacilli. In another study, the EO showed antifungal activity against some species of the Fusarium genus, Botrytis cinerea, and Alternaria solani [20]. A combination of A. archangelica EO: Phenyl ethyl alcohol (PEA): α-terpineol (1:1:1) inhibited the growth of Aspergillus flavus NKDW-7 (aflatoxicogenic strain) and aflatoxin B1 production at 2.25 and 2.0 μL/mL, respectively. At the concentration of 2.0 μL/mL, the combination showed a >90% decrease in ergosterol content in the plasma membrane of Aspergillus flavus [42].

Cavaleiro et al. [55] evaluated the antifungal activity of the EO of Angelica major and its major components, α-pinene and cis-β-ocimene, against clinically important yeasts and molds. A. major EO exhibited a broad spectrum of antifungal activity, including all tested fungi (animal and human pathogenic species or spoilage fungi): Candida spp., C. neoformans, Aspergillus spp., and dermatophytes. α-Pinene was more active against all of the tested fungi than cis-β-ocimene. A. sinensis and A. dahurica EOs exhibited significant antibacterial activity against three mastitis-causing pathogens: Staphylococcus aureus, Staphylococcus chromogenes, and Streptococcus uberis [47]. Tabanca et al. [20] reported that A. pubescens root EO exhibited weak antifungal activity against Colletotrichum acutatum, Colletotrichum fragariae, and Colletotrichum gloeosporioides. In the case of A. dahurica root EO, there was no antifungal activity observed against tested fungal strains.

4.3. Insecticidal

EOs from the root of A. dahurica and A. pubescens were studied as pest management prospective. When compared with A. pubescens EO, A. dahurica EO showed better biting deterrent and insecticidal activity against Aedes aegypti and Stephanitis pyrioides. In mosquito bioassays, components of A. dahurica EO, 1-dodecanol and 1-tridecanol, showed antibiting deterrent activity against Aedes aegypti [20]. Chung et al. [44] investigated the immuno-toxicity effect of EOs from the leaves of A. anomala, A. cartilagino-marginata var. distans, A. czernevia, A. dahurica, A. decursiva, Angelica fallax, A. gigas, and A. japonica. Among them, the EO of A. dahurica showed a significant toxic effect against early
fourth-stage larvae of *Aedes aegypti*, with a LC$_{50}$ value of 43.12 ppm. In another study, out of 33 plant species tested, *A. sinensis* EO showed the best repellent activity against *Aedes aegypti*, with a median complete protection time of 7.0 h [35].

4.4. Behavioral

Repeated administration of nicotine can produce behavioral sensitization, and this is a good model for studying drug addiction. Zhao et al. [43] reported that the inhalation of *A. gigas* EO significantly ameliorated nicotine-induced behavioral sensitization by decreasing dopamine release in the nucleus accumbens and locomotor activity in repeated nicotine-induced rats. Pathak et al. [41] found that the EO of the *A. archangelica* root exhibited antiseizure activity against electrically and chemically-induced seizures in mice. Chen et al. [50] investigated the anxiolytic activity of *Angelica* EO in a mice model. The results revealed that the EO of *Angelica* exhibited considerable anxiolytic-like effects at the concentration of 30.0 mg/kg (orally), as measured in the elevated plus-maze, the light/dark, and the stress-induced hyperthermia tests. In addition, *Angelica* EO significantly improved the behavioral performances in the social interaction test of anxiety and the hole-board test of exploration and locomotor activity in rats [51]. Sharma et al. [45] reported that the EO of *A. glauca* exhibited broncho-relaxant activity against histamine and ovalbumin-induced bronchoconstriction in guinea pigs by decreasing absolute blood eosinophil count, serum levels of immunoglobulin E, and the number of eosinophils and neutrophils in bronchoalveolar lavage fluid. Sowndhararajan et al. [14] investigated the effect of inhalation of EO of *A. gigas* root on electroencephalographic activity in humans. The results revealed that absolute low beta significantly increased at left temporal and left parietal region during the inhalation of the EO of *A. gigas* root, and these changes may contribute to the enhancement of language learning abilities in humans.

4.5. Anti-Inflammatory

Zhang et al. [32] used the metabonomics based on GC-MS to study the possible anti-inflammatory mechanisms of EO of *A. sinensis* in rats with acute inflammation. In the carrageenan-injected rats, treatment with the EO of *A. sinensis* significantly restored the levels of prostaglandin E2, histamine, and 5-hydroxytryptamine in the inflammatory fluid, similar to the normal group. GC-MS analysis identified 14 metabolite biomarkers detected in the inflammatory fluid. Zhong et al. [48] evaluated the anti-inflammatory effect of EOs obtained from processed products of *A. sinensis*. For this purpose, EOs from stir-fried *A. sinensis*, fried *A. sinensis* with alcohol, cooked *A. sinensis* with soil, and fried *A. sinensis* with sesame oil were applied to intervene the carrageenan-induced acute inflammation of the model rats. The results showed that the EOs of *A. sinensis* significantly inhibited the release of prostaglandin E2, histamine, 5-hydroxytryptamine, and tumor necrosis factor-$\alpha$. Furthermore, *A. sinensis* exhibited an anti-inflammatory effect against the lipopolysaccharide (LPS)-induced inflammation rat model by regulating the Krebs cycle, enhancing the glucose content, and restoring the fatty acid metabolism [33].

Li et al. [49] investigated the effects of *A. sinensis* EO on the LPS-induced acute inflammation rat model. *A. sinensis* EO exhibited anti-inflammatory and liver protection effects by inhibiting the secretion of the pro-inflammatory cytokines (tumor necrosis factor-$\alpha$, interleukin-1$\beta$, and interleukin-6), the inflammatory mediators (histamine, 5-hydroxytryptamine, prostaglandin E2, and nitric oxide), the inflammation-related enzymes (inducible nitric oxide synthase and cyclooxygenase 2), as well as promoting the production of the anti-inflammatory cytokines interleukin-10. Wang et al. [19] reported that the EO of *A. dahurica* (at 100 mg/kg) showed anti-inflammatory activity against xylene-induced ear swelling and carrageenan-induced paw edema in a mice model. In addition, the EO significantly alleviated Freund’s complete adjuvant-induced arthritis in rats by improving hind paw swelling and reducing the serum levels of nitric oxide, tumor necrosis factor-$\alpha$, prostaglandin E2, and serum nitric oxide synthase activity.
4.6. Skin Permeation Enhancer

It is well known that EOs can reversibly overcome the stratum corneum barrier to improve the skin permeation of drugs. Chen et al. [53] studied the penetration enhancement effect of five EOs (clove, Angelica, Chuanxiong, Cyperus, and cinnamon) on the transdermal drug delivery of ibuprofen using dysmenorrheal model mice. Among five EOs tested, Chuanxiong and Angelica oils effectively enhanced the transdermal drug delivery of ibuprofen. In another study, turpentine, Angelica, Chuanxiong, Cyperus, cinnamon, and clove oils (at 3% w/v) were evaluated for the potential to enhance the skin penetration of ibuprofen in rats. When compared with azone, the tested EOs had significantly higher penetration enhancement effect and lower skin irritation potential. The results revealed that EOs can enhance the skin permeation of ibuprofen mainly by disturbing the stratum corneum lipids [54].

5. Conclusions

EOs have been isolated from different plant parts of Angelica species. The most abundant components in the EOs were α-pinene, β-pinene, α-phellandrene, β-phellandrene, δ-3-carene, sabinene, γ-terpinene, limonene, p-cymene, ligustilide, butyldiene phthalide, α-cadinol, and β-eudesmol. Based on the previous reports, the EOs from different Angelica species exhibit appreciable antioxidant, antimicrobial, insecticidal and anti-inflammatory activities. In addition, EOs significantly enhance behavioral performances and promote the skin permeation of drugs. Among the different Angelica species, A. archangelica, A. sinensis, and A. dahurica were the most studied plant species in relation to the biological activities of EOs. This review will offer a scientific basis for future studies in relation to biological activities of EO-bearing plants.

Acknowledgments: This work was supported by Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, Forestry and Fisheries (IPET) through High Value-added Food Technology Development Program, funded by Ministry of Agriculture, Food and Rural Affairs (MAFRA) (317044-03) and the research grant from Kangwon National University, Chuncheon, Republic of Korea.

Author Contributions: Kandhasamy Sowndhararajan wrote the manuscript; Ponnuvel Deepa and Minju Kim conducted the literature review; Se Jin Park and Songmun Kim corrected and revised the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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