

## Review

# Selected Plants as Sources of Natural and Active Ingredients for Cosmetics of the Future

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**Abstract:** A clear trend of replacing synthetic cosmetic ingredients with natural ones can be observed in modern cosmetology. This entails the need to search for bioactive ingredients in the natural environment, especially in plants. This paper presents a comprehensive overview of dermatological, cosmetic, and pharmacological properties of highly potent plants, namely *Acmella oleracea* (*A. oleracea*), *Centella asiatica* (*C. asiatica*), *Psoralea corylifolia* (*P. corylifolia*), *Plantago lanceolata* L. (*P. lanceolata* L.), and *Solidago virgaurea* L. (*S. virgaurea* L.). Biological activity and phytochemical constituents are presented for all plants, but special attention is paid to ingredients of particular value to the cosmetics industry. The advantages of spilanthal and bakuchiol as a replacement for the popular botulinum toxin and retinol are discussed. Natural habitats, ethnomedical importance, cultivation area, as well as extraction methods of active plant ingredients are presented in detail. A wide spectrum of biological activity indicates the enormous potential of the presented plants in formulating new cosmetic and dermatological preparations.

**Keywords:** active ingredients for cosmetics; extraction; *Acmella oleracea*; *Centella asiatica*; *Psoralea corylifolia*; *Plantago lanceolata*; *Solidago virgaurea*



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## 1. Introduction

For many years, various bioactive substances derived from plant material have been the focus of scientific research, both as potential therapeutic agents, and valuable ingredients that provide the claimed effects of cosmetic preparations (e.g., betulinic acid and betulin extracted from the bark of white birch (*Betula pubescens*) [1], paclitaxel isolated from the bark of *Taxus brevifolia* (*Pacific Yew*) [2], jojoba [3], tea tree oil (*Melaleuca alternifolia*) [4,5], and chamomile (*Matricaria chamomilla* L.) [6].

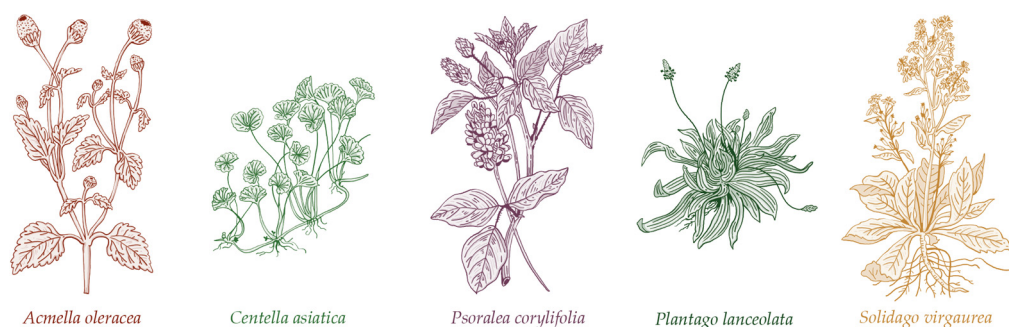
The development of a healthy and environmentally friendly lifestyle has led to an increased interest in natural products, including phytocosmetics. Natural cosmetics are most often chosen by individuals who care about the environment, health, and beauty, and phytotherapy is widely considered a safe alternative to conventional therapies, sometimes even the only effective one in the case of certain skin conditions [7,8].

The constantly growing interest in natural materials poses a significant challenge for cosmetic companies. Ensuring high-quality cosmetic products requires interdisciplinary collaboration among chemists, cosmetologists, botanists, toxicologists, and biologists. The desire to keep up with increasing competition necessitates the introduction of innovative components and continuous search for new, natural ingredients that are equally as active,

or even more effective than conventional, often synthetic ones. The cost of obtaining natural raw materials from certified crops is often higher than that of synthetic materials. However, the effort and resources invested in introducing natural formulations are rewarded with certifications awarded to organic products (COSMOS, Ecocert, Cosmebio, Soil Association, BDIH, NaTrue, ICEA, Vegan Society), increased attractiveness of the product, and consequently, greater consumer interest and trust [9]. Moreover, utilizing what nature offers has become a symbol of a holistic approach to health care and environmental concern.

Plants, being a rich source of bioactive substances, serve as a crucial driver for the cosmetics industry. Therefore, it is imperative to actively seek out, discover, and integrate these botanical ingredients into cosmetic formulations. Modern cosmetology is based on well-known and valued plants, especially those used for many years in folk medicine. Valuable information about the interesting properties of many plants, especially those useful in treating various diseases but also beneficial for the skin, can be found in sources of ancient knowledge, such as medieval herbals created at the time's centers of science, or prehistoric accounts and legends about skin treatment methods.

In this paper, we present a review of the state of knowledge, based on historical sources and the latest scientific reports, regarding the dermatological, cosmetic, and pharmacological properties of several interesting plants, such as *Acmella oleracea* (*A. oleracea*), *Centella asiatica* (*C. asiatica*), *Psoralea corylifolia* (*P. corylifolia*), *Plantago lanceolata* L. (*P. lanceolata* L.), and *Solidago virgaurea* L. (*S. virgaurea* L.) (Figure 1).

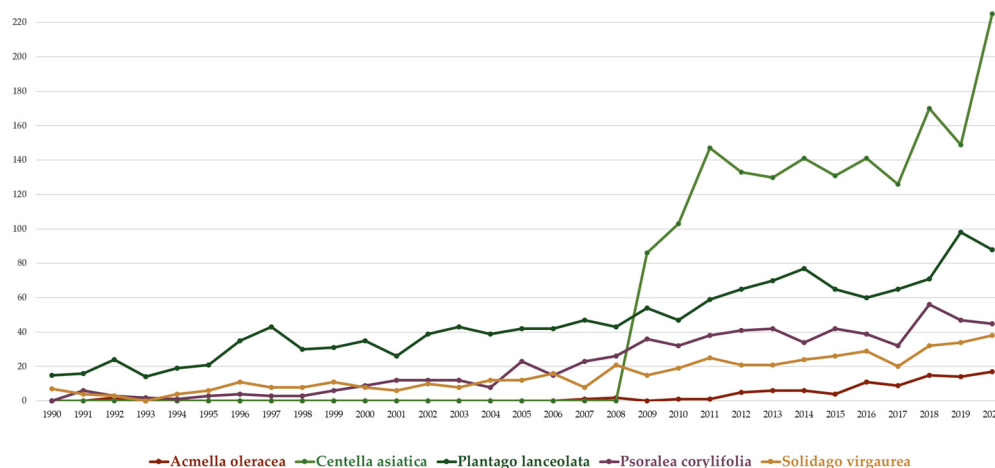


**Figure 1.** Selected plants as sources of active ingredients for cosmetics.

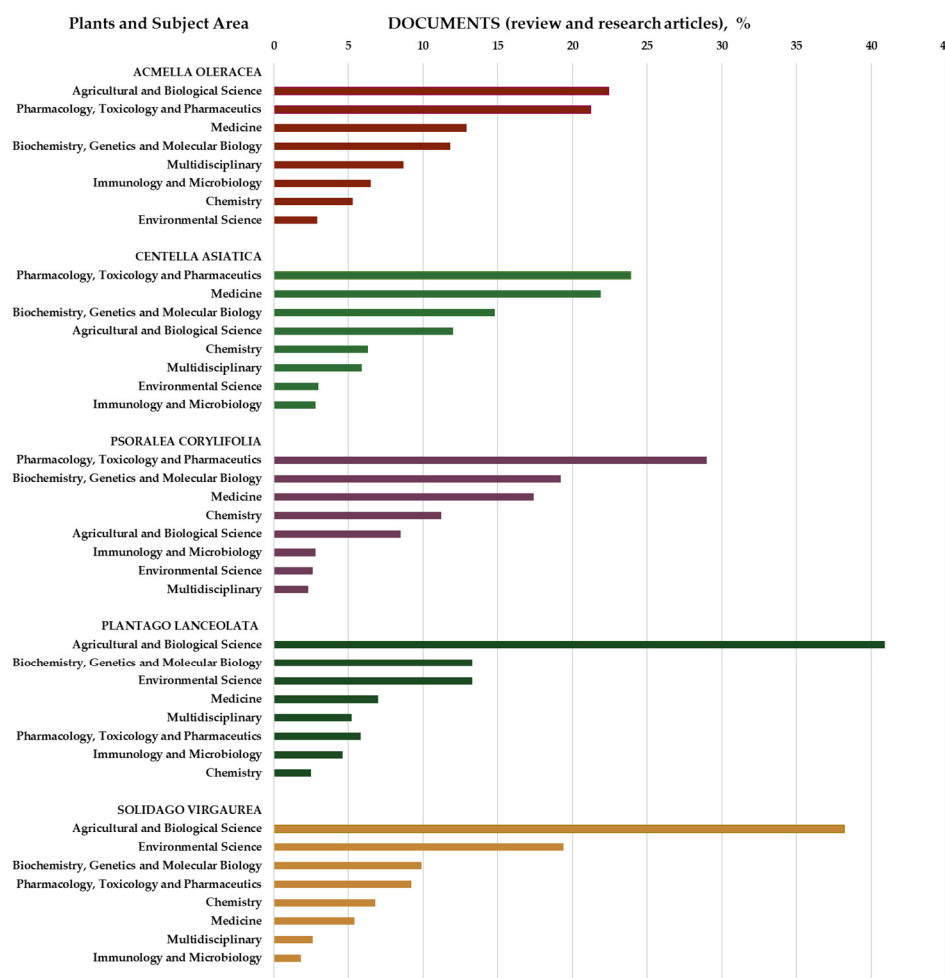
We examined the natural habitats and cultivation areas of these plants, which is followed by an overview of the bioactive substances found in extracts derived from them. We emphasized ingredients that hold particular value for the cosmetics industry. The wide spectrum of biological activity indicates the enormous potential of *A. oleracea*, *C. asiatica*, *P. corylifolia*, *P. lanceolata* L., and *S. virgaurea* L. in formulating new cosmetic and dermatological preparations.

When searching for plants desirable from the perspective of the cosmetics industry, we considered the following criteria: (1) a wide spectrum of biological properties; (2) desired effects in cosmetics, including anti-aging, anti-wrinkle, soothing or eliminating skin redness and discoloration, assisting in acne treatment, scar reduction, firming, and anticellulite effects; (3) stability of active ingredient(s) present in the plant; (4) presence of bioactive substances in all parts of the plant, which reduces costs associated with preparing plant material for cosmetic raw material production; and (5) availability, easy of cultivation, and low price of the plant.

The growing interest in the selected plants is confirmed by numerous scientific reports (Figure 2, based on the Scopus database). However, the application of these plants mentioned in the literature reports mostly include agricultural industry, biological sciences, ecology, medicine, pharmaceuticals, pharmacology, toxicology, immunology, microbiology, and chemistry, without specific reference to the cosmetics industry. This indicates that their potential as cosmetic raw materials has not yet been fully appreciated. Applications in cosmetics can only be found in the multidisciplinary category (Figure 3, based on the Scopus database).



**Figure 2.** Annual number of publications (review and research articles) dealing with *A. oleracea*, *C. asiatica*, *P. corylifolia*, and *P. lanceolata*, *S. virgaurea*. The literature search was performed in the *Scopus database* for the years 1990–2020, (access on 20 December 2023).



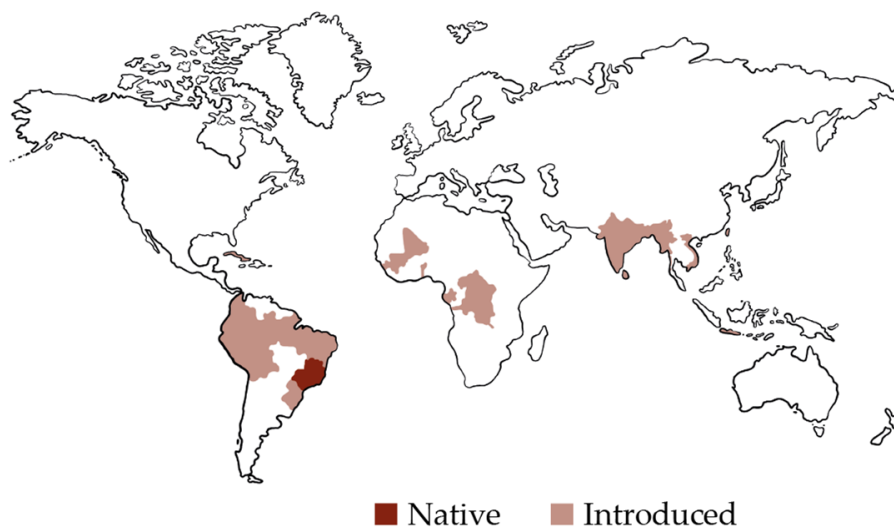
**Figure 3.** Documents by subject area dealing with *A. oleracea*, *C. asiatica*, *P. corylifolia*, *P. lanceolata*, and *S. virgaurea*. The literature search was performed in *Scopus database*, for the 1990–2020 period, (access on 20 December 2023).

## 2. *Acmella oleracea*

### 2.1. General Description

*A. oleracea* L. R.K. Jansen (syn. *Spilanthes acmella* L., *Spilanthes oleracea* L.), also known as jambu, paracress, or toothache plant, is included in the species of aster plants (*Compositae*), among which are *Spilanthes calva*, *Spilanthes americana*, *Spilanthes alba*, and *Spilanthes ocymifolia*.

The native range of this species is a cultigen of Brazil. *A. oleracea* grows in the tropical climate of South America, Africa, Southeast Asia, and Australia (Figure 4 and Table S1 in Supplementary Materials), reaching heights of 20 to 60 cm. Its characteristic feature is conical yellow inflorescences with a distinctive red spot in the central part of the flower. This odorless plant has long, slightly brown stems and dark green heart-shaped leaves. Leaves, flowers, and stems are used as materials for cosmetic production [10,11].



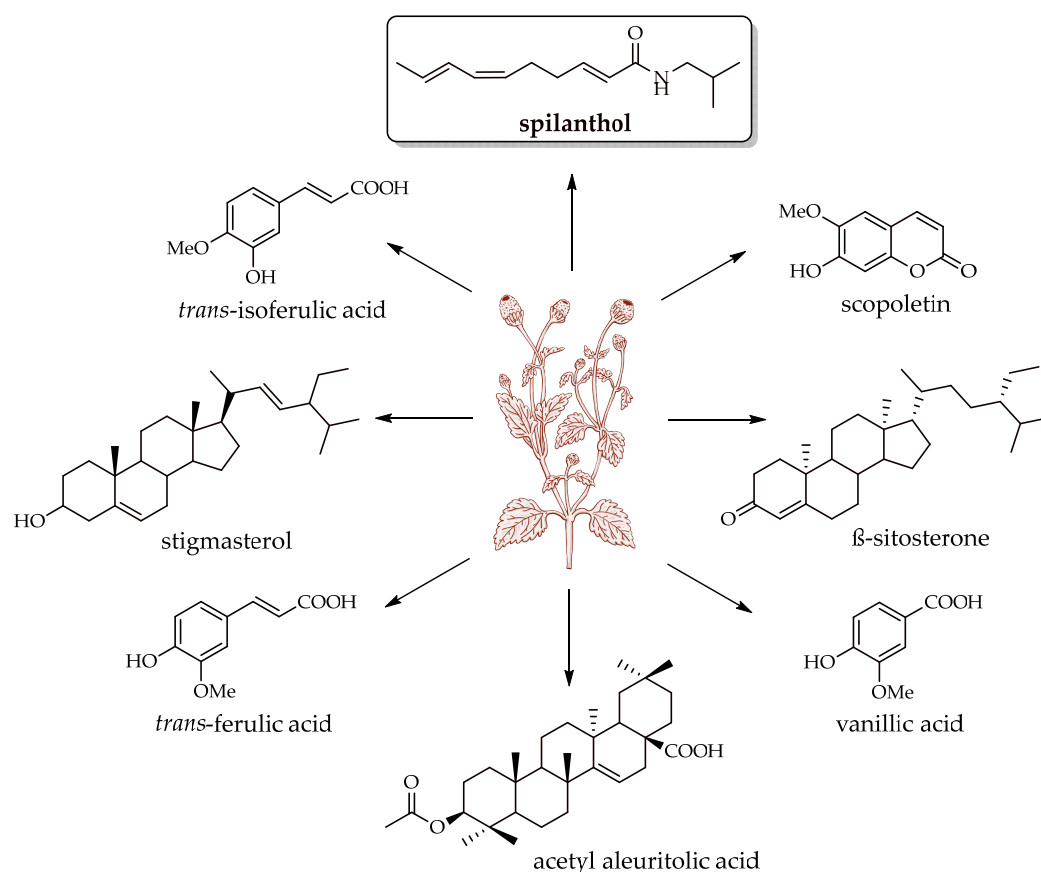
**Figure 4.** Areas of natural occurrence and cultivation of species *A. oleracea* (prepared based on <https://powo.science.kew.org>, accessed on 15 February 2024).

### 2.2. Ethnomedical Importance

*A. oleracea* has a long history of traditional use in cuisines and medicines in several different civilizations [12,13]. The extract of the jambu plant was first used in folk medicine (India) as a remedy for tooth and gum pain. It was also applied to treat snake bite wounds (Ethiopia, flower infusion) and as a medicinal agent for various conditions including skin problems, throat ailments, and rheumatoid arthritis [14–16]. It has also been observed that chewing freshly picked flowers or leaves of *A. oleracea* causes salivation and tingling of the tongue, leading to a numbing effect (hence the name: toothache plant) [17,18].

### 2.3. Phytochemical Constituents

Plants of the *Acmella* genus are characterized by a high content of biologically active compounds, including *N*-alkylamides, vanillic acid, scopoletin, 3-acetylaleuritolic acid, *trans*-ferulic acid, *trans*-isoferulic acid, stigmasterol, and sitosterone (Figure 5) [14,16,17]. The most active *N*-alkylamide responsible for the biological properties and sensory effects of the plant (such as tingling, salivation) is (2*E*,6*Z*,8*E*)-*N*-(2-methylpropyl)-2,6,8-decatrienamide, commonly known as spilanthol (syn. affinin) [14–22].



**Figure 5.** The most important bioactive substances from *Acmella oleracea* [14–17].

#### 2.4. Biological Activity of *A. oleracea*

The broad spectrum of biological activity of *A. oleracea* includes anti-inflammatory [12,14–17], antioxidative [15], antifungal [14–17,23,24], analgesic [12,14,17,25,26], and bacteriostatic effects [12,16,17,24,26]. Due to its documented anti-inflammatory and locally anesthetic properties, extracts from jambu are used as components in dental care products for pain reduction, such as toothpaste, dental gels, and mouth rinses, as well as medical products for mouth ulcers, abscesses, or other oral cavity lesions caused by mechanical trauma from orthodontic interventions [15,25,27–30].

The cosmetic industry is interested in the ability of spilanthol to reduce or even inhibit the contraction of subcutaneous facial muscles, which ultimately contributes to smoothing and reducing facial expression wrinkles. Due to this property, cosmetics containing spilanthol are called natural herbal botox, and extracts of *A. oleracea* (INCI: *Spilanthes acmella extract*) are more frequently appearing in anti-wrinkle and anti-aging skincare products [31–38].

#### 2.5. Spilanthol as an Alternative to Botulinum Toxin

Aging is a complex biological process that involves many factors, such as genetic predispositions and environmental influence. Age-related changes in skin appearance, including wrinkle formation, irregular pigmentation, and dryness, are caused by a reduction in the thickness of the epidermis, the dermal–epidermal junction, and reduction in the content of extracellular matrix components. However, the formation of facial expression wrinkles is primarily associated with decreased tension in facial muscles. One of the most popular treatments used for neuromuscular disorders and in aesthetic practice to reduce facial expression wrinkles (forehead lines, crow’s feet, or wrinkles around the mouth) is botulinum toxin (BoNT) produced by the bacteria *Clostridium botulinum* as well as rare strains of *Clostridium butyricum* and *Clostridium baratii* [39,40].

The use of *BoNT* carries the risk of side effects such as redness at the injection site, local pain, excessive lowering or raising of the eyebrows in the treatment of forehead wrinkles, drooping of the corner of the mouth or eyelids [41]. Despite possible side effects, high cost, and injectable form of product dosing, the number of people undergoing *BoNT* treatment continues to grow steadily. A safe alternative to *BoNT* may be spilanthal. Scientific reports suggest that both jambu extract and pure spilanthal block the subcutaneous muscle contractions, resulting in facial wrinkle smoothing [35,37]. It is important to note that the action of spilanthal is not solely based on blocking the contractile activity of facial muscles; it also demonstrates nurturing and firming effects by stimulating fibroblasts to produce elastin and collagen (Table 1) [17].

**Table 1.** The comparison of properties and activities of spilanthal and *BoNT* [34,35].

| <b>SPILANTHOL</b><br><i>Natural Herbal Botox</i> | <b>BOTULINUM TOXIN</b><br><i>Botox</i>   |
|--|--|
| substance of plant origin                        | substance produced by <i>Clostridium botulinum</i> bacteria  |
| safe   | toxic  |
| slight effect of wrinkles smoothing              | instant and strong effect of wrinkles smoothing  |
| applied on skin                                  | applied by injection   |
| applied by customer                              | applied through medical procedure performed under the supervision of a specialist  |
| moderate price                                   | high price   |
| safe for pregnant and breastfeeding woman        | prohibited for use by pregnant and breastfeeding woman   |
| no side effects                                  | possible side effects: <ul style="list-style-type: none"> <li>- swelling and bruising at the injection site;</li> <li>- redness and dryness of the skin;</li> <li>- localized pain, muscle tremors.</li> </ul> |

The majority of anti-wrinkle and anti-aging cosmetic compositions focus on strengthening the dermis or reducing the action of face muscle tissue. Extract from the plant *A. oleracea* is increasingly being used as a key ingredient in such cosmetics because the spilanthal contained in it suppresses the action of subcutaneous facial muscles. Spilanthal restricts the transmission of nerve impulses by blocking the activity of calcium and sodium-potassium channels present in the cell membrane of neurons. Blocking the exchange of sodium ions through the neuronal cell membrane completely prevents its depolarization, thereby preventing the generation of nerve impulses. The time of action on sensory nerves depends on the dose and site of spilanthal administration. In vitro studies have shown that a 0.6% volume concentration of the extract blocks muscle contractions rapidly, and a concentration of 1.2% maintains this effect for 24 h. A concentration of 2% demonstrated a smoothing effect on wrinkles after 24 h and continued to increase this result over the next 28 days [35–38].

### 3. *Centella asiatica*

#### 3.1. General Description

*C. asiatica* L. Urban (syn. *Gotu Kola coriacea* Nannfd., *Hydrocotyle asiatica* L., *Hydrocotyle lunata* Lam., and *Trisanthus cochinchinensis* Lour.) is a tropical medicinal plant from the *Apiaceae* family (*Umbellifere*) [42].

It is cultivated in tropical and subtropical regions of Asia. It also grows in Australia, South Africa, Madagascar, and in selected areas of North, Central, and South America. (Figure 6 and Table S1 in Supplementary Materials) [43].





**Figure 6.** Areas of natural occurrence and cultivation of species *C. asiatica* (prepared based on <https://powo.science.kew.org>, accessed on 18 February 2024).

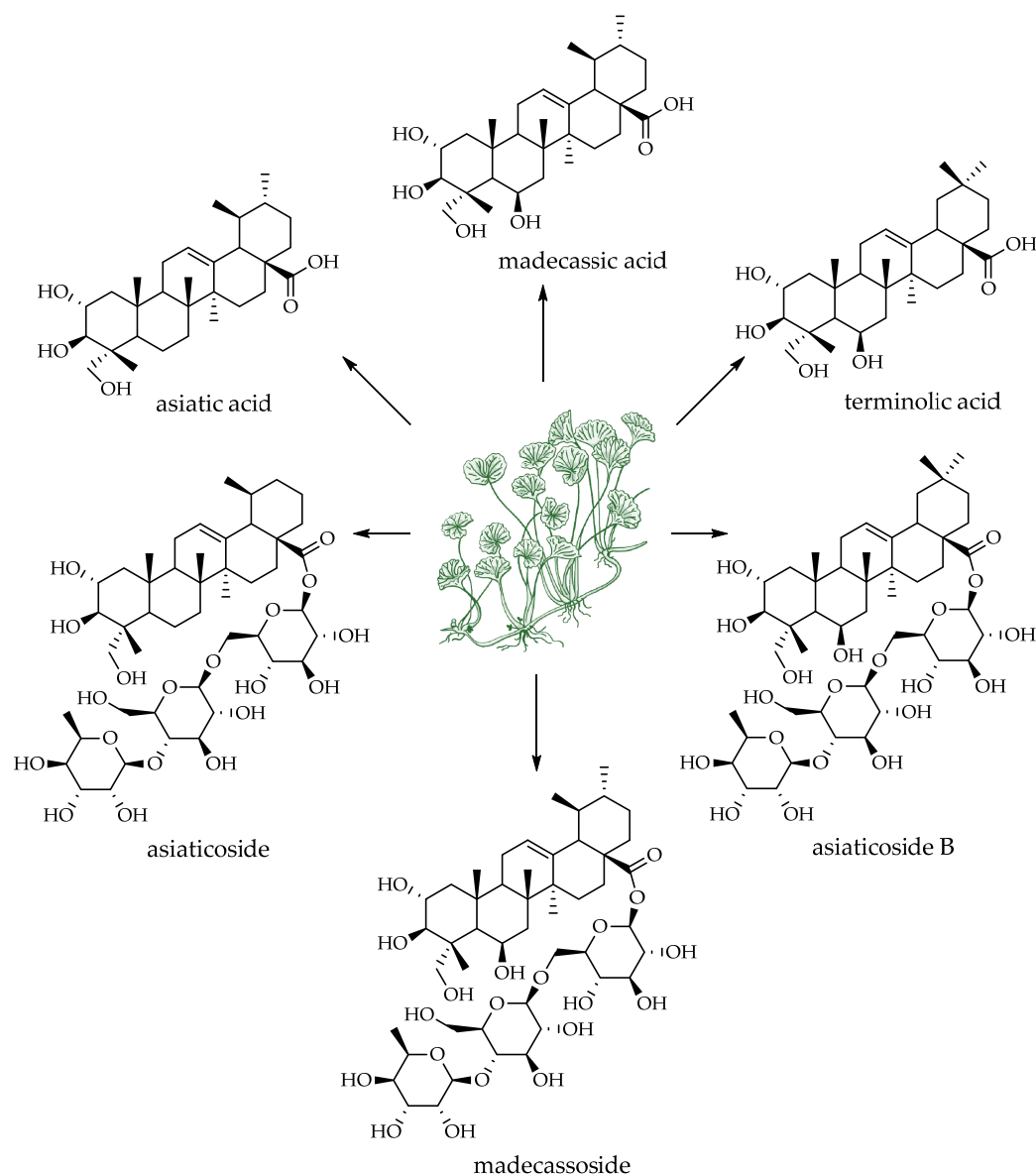
*C. asiatica* is a short plant with a long, thin, and sprawling stem. Its leaf blade is rounded or kidney-shaped, with serrated edges. It is smooth on the upper surface with thick radiating veins. The diameter of the leaf blade ranges from 1 to 6.3 cm. The inflorescence ranges in color from white to pale pink to dark red and consists of delicate, stalkless flowers, usually gathered in 3–4 umbel-shaped clusters. The fruits of *C. asiatica* are round or oval, resembling berries in shape. The optimal growth conditions for this plant are shaded areas with high humidity, where the soil is clayey, sandy, and rich in organic matter. The entire plant, including leaves, stems, flowers, roots, and seed pods, is utilized as a raw material in the pharmaceutical and cosmetic industries [44,45].

### 3.2. Ethnomedical Importance

*C. asiatica* is a medicinal plant used in traditional medicine in Asian countries for over 3000 years. References to it can be found in the oldest books of Ayurvedic medicine and *Traditional Chinese Medicine* (TCM). Due to the popularity of the legend claiming that the plant healed the wounds of Bengal tigers, it is colloquially known as tiger grass. The Hindus used this plant to treat slow-healing wounds, swelling, and to alleviate symptoms of diseases such as leprosy, lupus, psoriasis, common acne, and eczema. According to folk medicine records, it was attributed with analgesic, anti-inflammatory, antiviral, and antidepressant properties [43,45,46]. In the 19th century, both the plant and the extract obtained from it were included in the official list of medicines in India as an effective remedy for dermatological disorders, and over the years they were included in the Chinese Pharmacopoeia, British Herbal Pharmacopoeia, European Pharmacopoeia, French Pharmacopoeia, and many others [43,45,47].

### 3.3. Phytochemical Constituents

The wide range of biological activities of *C. asiatica* is attributed to pentacyclic triterpenoids of the ursane and oleanane types, especially triterpene acids and their derivatives. The most well-known ones are asiaticoside, madecassoside, asiatic acid, and madecassic acid (Figure 7) [42,48]. *C. asiatica* is also rich in vitamins (A, C, B-group vitamins) and mineral components such as macro- and microelements (including potassium, calcium, sodium), essential for the proper functioning of the organisms. Flavonoids, essential oils, and carotenoids such as lutein and  $\beta$ -carotene also influence the activity of the plant extract [44,46,49].



**Figure 7.** The most important bioactive ingredients from *Centella asiatica* [42,48].

### 3.4. Biological Activity

Cosmetics containing *C. asiatica* extract (INCI: *Centella Asiatica Extract*) assist in smoothing facial expression wrinkles and preventing the formation of new ones, counteracting the appearance of stretch marks, and reducing scars [50,51]. The bioactive ingredients found in the plant (Section 3.3) prevent excessive accumulation of fat in cells, thus exhibiting anti-cellulite properties, improving skin elasticity, and consequently resulting in a slimming and firming effect. Moreover, the antioxidant properties of *C. asiatica* components contribute to delaying the skin aging process. By stimulating the peripheral circulation, the *C. asiatica* extract strengthens hair, accelerates its growth, and inhibits its loss [47,48,50].

Madecassoside present in *C. asiatica* extracts protects skin against lipid peroxidation, as well as intensifies synthesis of collagen while stimulating angiogenesis. It also enhances the infiltration of inflammatory cells and supports re-epithelialization to facilitate nearly complete wound closure in burned skin.

Asiaticoside has similar activity to madecassoside. It exhibits antibacterial and anti-inflammatory properties, thereby supporting the treatment of deep, slow-healing wounds and burns, and accelerates the scar reduction process [47,50]. The activity in wound healing process is associated with promoting the angiogenesis (e.g., by stimulation of vascular



endothelial growth factor production) and also with suppressing apoptosis and increasing cellular proliferation. Additionally, by increasing the level of type I collagen (through T $\beta$ RI kinase-independent Smad signaling pathway) it triggers an anti-wrinkle response [50].

Furthermore, the bioactive components of this plant positively affect sleep quality. Therapeutic effects have been observed in gastrointestinal diseases (including stomach ulcers, duodenal ulcers, and inflammatory bowel disease) as well as a positive impact on the cardiovascular system (including lowering arterial blood pressure and reducing symptoms of venous insufficiency in the lower limbs) [52,53].

#### 4. *Psoralea corylifolia*

##### 4.1. General Description

*P. corylifolia* L. (syn. *Bakuchi*, *Cullen corylifolium* L. Medik) is an annual plant with simple, serrated leaves ranging from round to ovoid in shape. It has narrow, long, lanceolate and curved stems. Small pale purple flowers are gathered in dense, spiny clusters on short single-flower stalks in the leaf axils. The plant naturally occurs in South-Central China, Bangladesh, India, Iraq, Myanmar, Assam, Djibouti, Oman, Somalia, Sri Lanka, Vietnam, Yemen, and the Western Himalayas (Figure 8 and Table S1 in Supplementary Materials) [54,55].



**Figure 8.** Areas of natural occurrence and cultivation of species *P. corylifolia* (prepared based on <https://powo.science.kew.org>, accessed on 20 January 2024).

##### 4.2. Ethnomedical Importance

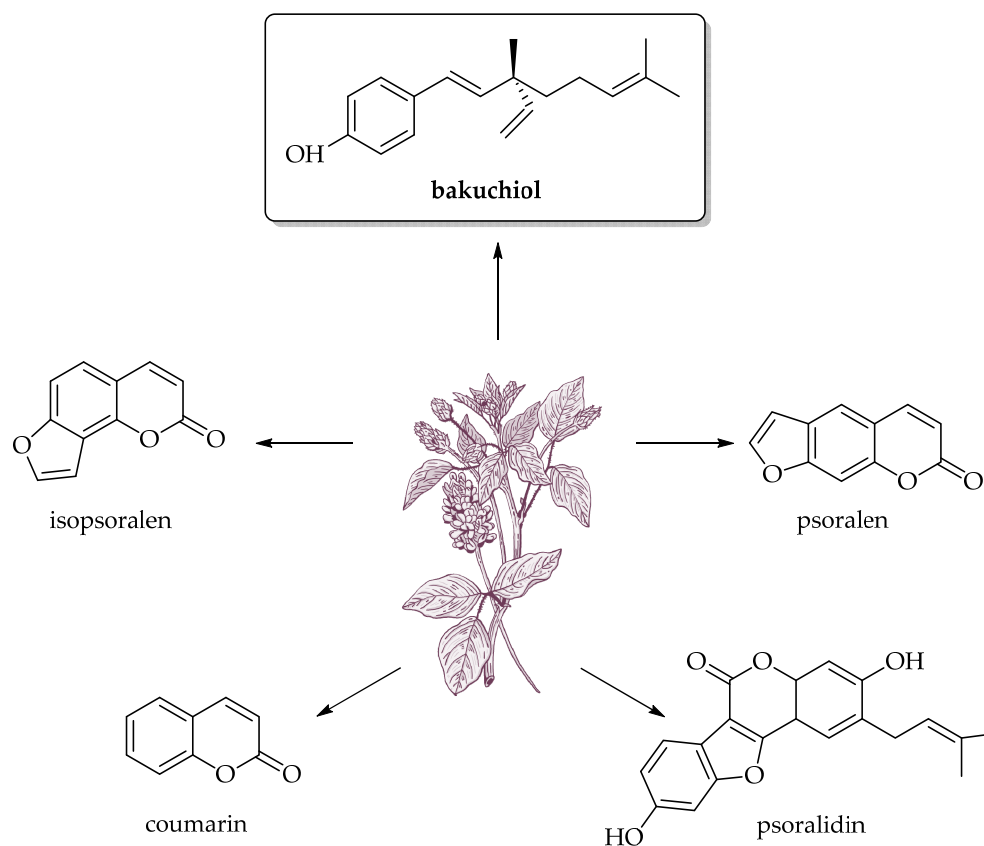
Since the fifth century, *P. corylifolia* L. has been used in traditional Indian and Chinese medicine to treat various diseases, especially skin inflammation [56]. Its name comes from the Greek word *psoraleos*, meaning “afflicted with itching or leprosy” [57].

The external application of Bakuchi seed oil, in the form of ointment or paste, has long been used in Ayurveda to treat numerous skin conditions such as discoloration, eczema, leukoderma, psoriasis, and leprosy. Meanwhile, the roots of the plant have been used in the treatment of dental caries [56–58].

##### 4.3. Phytochemical Constituents

*P. corylifolia* L. is a source of many active substances such as meroterpenes, furanocoumarins, coumarins, flavonoids, and terpenoids, which belong to secondary metabolites (Figure 9). In 1973, Mehta for the first time isolated from this plant an active substance with a characteristic structure (IUPAC: 4-[(1E,3S)-3-ethenyl-3,7-dimethylocta-1,6-dienyl]phenol), which he named bakuchiol (syn. *chiba*, *drupanol*) [59,60]. The analysis of the chemical composition of extracts obtained from different parts of the plant showed that

bakuchiol is present in all its parts and at every stage of its development, with its maximum amount found in the seeds [61].



**Figure 9.** The most important bioactive substances from *Psoralea corylifolia* [60].

#### 4.4. Biological Activity

*P. corylifolia* is an effective remedy against fever, skin diseases, and internal ulcers and also serves as a sedative [62]. Its leaves are used to treat inflammation of the skin and mucous membranes, swelling of the skin, as well as to alleviate diarrhea [63]. The Bakuchi plant is also used in the treatment of tinea, eczema, rough and discolored dermatosis with cracks, and scabies [64]. The essential oil obtained from this plant improves the condition of skin, hair, and nails. The seeds have antipyretic and alexiteric properties. They are also used in disorders of the biliary tract [65,66]. Seed extracts (psoralen, isopsoralen) have antidiabetic, antidepressant, anticancer, antibacterial, and antioxidant properties [67,68]. They can also be applied to cure conditions such as cough, asthma, nephritis, alopecia areata, and bleeding [69].

#### 4.5. Bakuchiol as an Alternative to Retinol

Although bakuchiol has been known since 1973 and exhibits many valuable biological properties, its first commercial use in cosmetic products did not occur until 2007 [70]. Clinical studies have confirmed that bakuchiol has antibacterial [71], anti-acne [70,71], depigmenting, moisturizing, anti-inflammatory, anti-aging [70], and antioxidant effects [71,72]. Furthermore, according to the CosIng database (Cosmetic Ingredient Database), bakuchiol is a safe component of cosmetic products that does not irritate or cause allergies. It can be used year-round and at any time of day because of its resistance to sunlight, so it does not require additional external skin protection against UV radiation [70,73,74]. Bakuchiol has high photochemical and hydrolytic stability and blends well with various emollients [75–77]. Due to these biological activities, the interest in the application of bakuchiol in cosmetic and pharmaceutical formulations is growing [73].

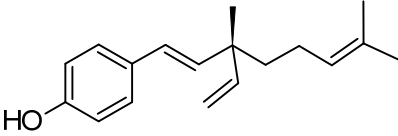
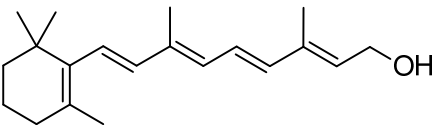
Bakuchiol affects multiple cellular pathways. It is involved in the modulation of retinoic acid receptor genes, as well as stimulation of genes responsible for the production of collagen. It stimulates the critical extracellular matrix component and reduces expression of IL8 and p16 in aging skin. It was shown to enhance the epidermal regeneration process and wound healing. Additionally, it inhibits the activity of tyrosinase and  $\alpha$ -melanocyte, leading to a reduction in pigmentation intensity of skin and regulates seborrhea [73,75].

Bakuchiol does not exhibit structural similarity to retinol, but due to its similar action and bioactive effects, it has recently been recognized as a plant-derived and functional substitute for retinol [73,78]. Bakuchiol, being more tolerated and safer, lightens skin discolorations to the same extent as retinol [75]. It shows more favorable regenerative properties, resulting from a significant improvement in collagen stimulation compared to retinol [73,75].

Retinoids are used in many skin conditions such as acne or psoriasis, and they also exhibit effective anti-aging effects. However, retinoid therapy carries many negative side effects, such as irritation, redness, burning, dryness, and peeling of the skin, which limits their use in individuals with sensitive skin [73,79].

Additionally, retinoids have teratogenic effects, making them unsuitable for use by pregnant women (Table 2) [79].

**Table 2.** The comparison of properties and activities of bakuchiol and retinol [73–75,78,79].

| BAKUCHIOL  | RETINOL  |
|--|--|
|  |  |
| substance of plant origin  | substance of plant origin<br>in cosmetic formulas synthetic derivative<br>is applied |
| high photostability  | sensitive to UV radiation  |
| does not need additional UV light protection                                       | need additional UV light protection  |
| gently exfoliates the epidermis  | strongly exfoliates the epidermis  |
| inhibits oxidative stress  | enhances oxidative stress  |
| prevents the formation of free radicals  | enhances the formation of free radicals  |
| can be applied during day time   | cannot be applied during day time  |
| safe for pregnant and breastfeeding women  | prohibited for use by pregnant and<br>breastfeeding woman                            |

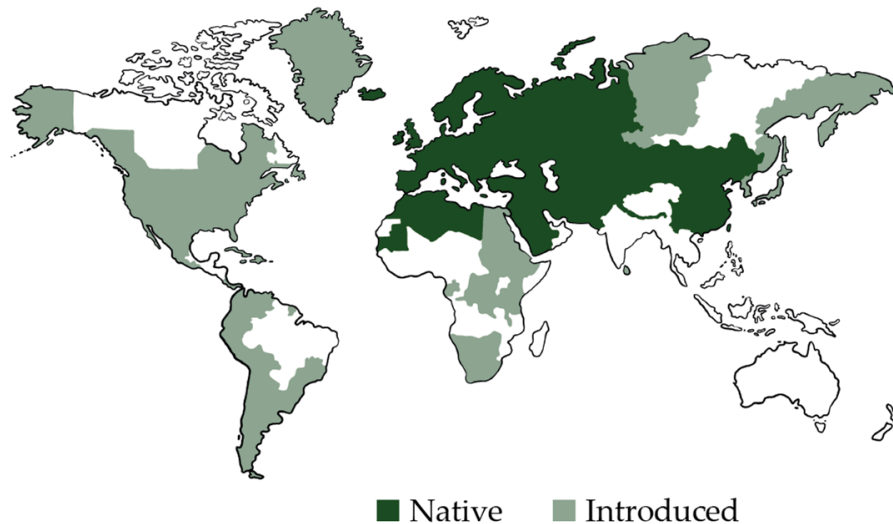
**5. *Plantago lanceolata* L.**

**5.1. General Description**

*P. lanceolata* L. (syn. longleaf plantain, ribwort plantain) is a plant belonging to the plantain family. It forms a rosette of long, narrow leaves with sharp tips. Both the leaf and stem feature parallel venation in the form of a midrib and adjacent thin lateral veins. *P. lanceolata* L. has small flowers set in bracts, clustered in dense spike-like inflorescences at the top of long leafless flowering stems. The floral corolla has a short tube and four petals in a white or brownish-pink color. Smooth and shiny fruits and reddish-brown seeds shaped like collars are set in oval capsules. The roots are numerous and fibrous, with short rhizomes occurring beneath the soil surface. During flowering (from May to September), the flowering stems reach heights of up to 40 cm [80,81].

*P. lanceolata* L. grows wild as a weed among cultivated crops, especially alfalfa, clover, flax, and winter and spring cereals, in the northern hemisphere in the temperate climate zone. It proliferates abundantly in meadows, pastures, as well as lawns, and agricultural

wastelands with black soil or loamy sandy soils [82]. This species originally comes from Europe, but now occurs in every corner of the world, e.g., in the USA, Australia, New Zealand, Japan, and many countries in Africa (Figure 10 and Table S1 in Supplementary Materials) [83].



**Figure 10.** Areas of natural occurrence and cultivation of *P. lanceolata* L. (prepared based on <https://powo.science.kew.org>, accessed on 20 February 2024).

### 5.2. Ethnomedical Importance

In folk medicine, *P. lanceolata* L. was used as an antibacterial and anti-inflammatory agent, which was supportive in the treatment of hoarseness, dry chronic cough, gastrointestinal inflammation, and urinary tract infections [80]. Compresses made from the leaves relieved pain in the case of limb fractures or swelling, and also aided in wound and abscesses healing [84]. The juice provided relief at scorpion or snake bite sites [82,85].

In China, the leaves and seeds of this plant were used to prepare expectorants and diuretics. In ancient Greece and Rome, longleaf plantain infusions were recommended for the treatment of dysentery [86]. Saint Hildegard (1098–1179) used plantain juice to eliminate freckles and to alleviate symptoms of bloody vomiting. The seeds were believed to prevent miscarriages [87]. At the turn of the 15th and 16th centuries, macerates based on *P. lanceolata* L. were used in the treatment of tuberculosis, inflammatory conditions of the eyes, throat, skin, and oral cavity [88]. Friedrich (1845) recommended the use of this plant for lung congestion, gastric and urinary tract inflammation, anemia, and gum bleeding. Hair rinses with *P. lanceolata* L. macerate were believed to prevent hair brittleness or excessive hair loss [87]. This plant was also used as an ingredient in food and animal feed [80].

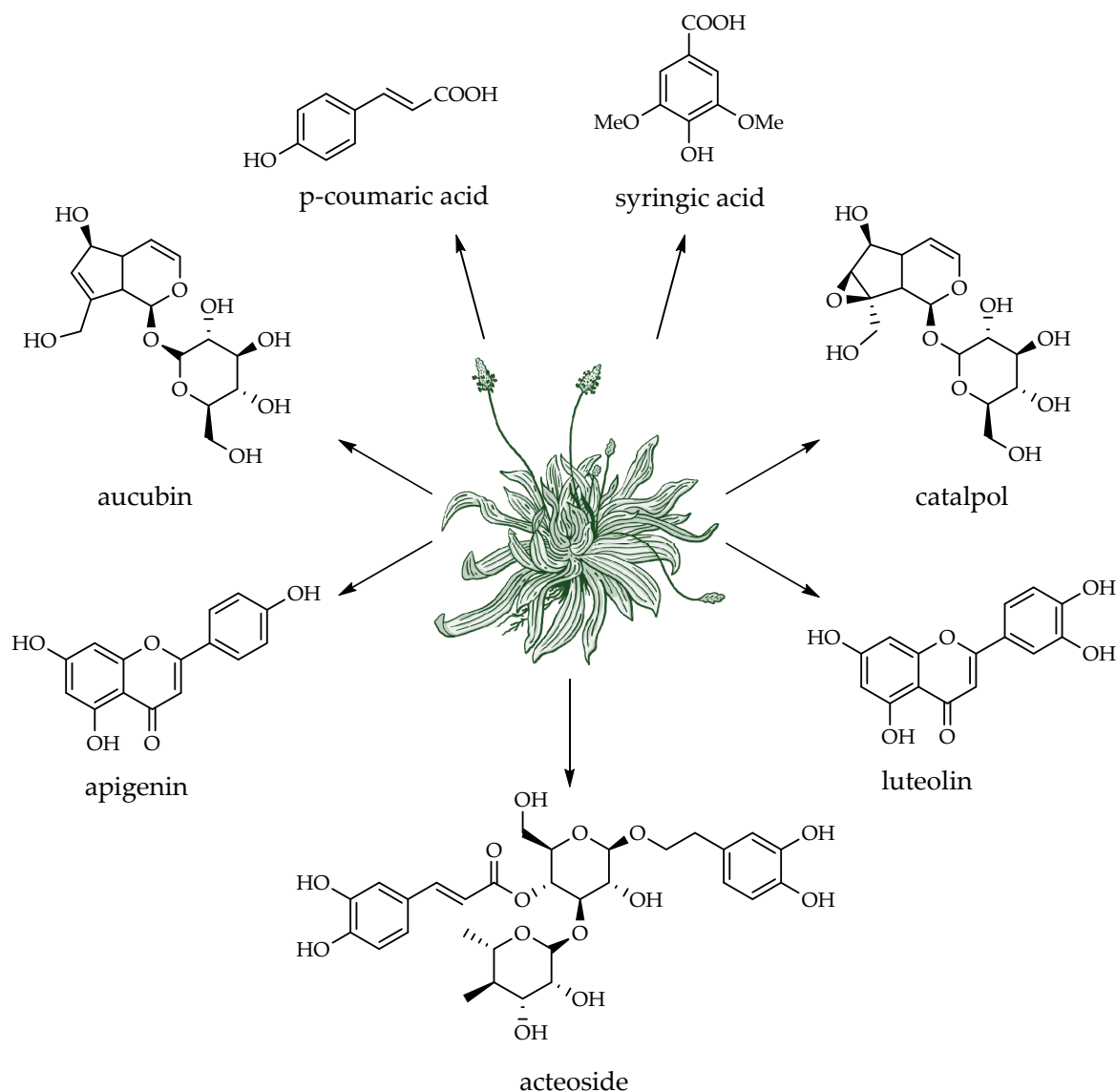
It has been reported that infusion from *Plantago* can be applied internally for treating of bronchitis, asthma, and sinusitis. Moreover, it alleviates symptoms of irritable bowel syndrome, hemorrhoids, and inflammation of the cervix or bladder. It also provides an astringent effect and stimulates wound healing [89].

*P. lanceolata* L. also exhibits the properties of heavy metal accumulation from the air, qualifying the plant as an indicator of them in industrially polluted areas [90].

### 5.3. Phytochemical Constituents

The medicinal properties can be assigned to each part of the plant, although leaves are most commonly used as a raw material. The extract obtained from the leaves of *P. lanceolata* L. mainly contains polyphenols, flavonoids (baicalein and scutellarein), tannins, alkaloids, terpenoids, organic acids (ascorbic, benzoic, cinnamic, fumaric, and vanillic acids), mucilaginous substances, pectins, and mineral salts (compounds containing silicon,

zinc, potassium, and iron) [80]. The leaves are also a source of iridoid glycosides (aucubin, catalpol, globularin, and asperuloside), and propionic glycosides (verbascoside, plantamajoside, isoverbascoside, and lavandulifolioside) [91,92]. Phytochemical analyses of *Plantago* species also confirm the presence of derivatives of caffeic acid, coumarin, fats, and oils (Figure 11) [84].



**Figure 11.** Chosen bioactive substances from *Plantago lanceolata* L. [80].

#### 5.4. Biological Activity

The active ingredients obtained from *P. lanceolata* L. include flavonoids, which have anti-inflammatory, antihistamine, and anticancer properties. They neutralize free radicals and chelate metals. In addition, flavonoids protect the skin from harmful ultraviolet radiation, inhibit certain enzymes, and prevent the oxidation of lipid substances. Tannins have astringent properties on the skin. Another group of bioactive chemicals present in plant extract are iridoid glycosides, which are responsible for antibiotic, antihepatotoxic, anti-inflammatory, spasmolytic, antiviral, and anti-stress effects. Additionally, *P. lanceolata* L. is known for its diuretic and antispasmodic properties. Propionic glycosides exhibit antibacterial, antioxidant, anti-inflammatory, and anticancer effects [80,93].

Phytosterols (such as sitosterol, stigmasterol, and campesterol) are responsible for anti-inflammatory effects. It has been observed that they reduce swelling and redness

of the skin. Furthermore, they lower cholesterol levels in the blood and have antipyretic properties. In addition, they have been documented to inhibit the growth of tumors in colon, stomach, breast, and lung [93,94].

Acetoside ester, also known as verbascoside, is used as the main ingredient in syrup against cold [84]. Verbascoside is also applied in other pharmaceutical preparations used to treat neurodegenerative diseases and pain [89]. There have been some reports of the development of liquid crystals containing plantain extract. In this form, the bioactive ingredients, especially verbascoside, would be protected against hydrolysis [95].

The extract from this plant has also been studied as a wound healing agent. The results of studies conducted on rats and mice showed that the kinetics of wound healing increased. A reduction in scar formation was also observed. The wound healing activity of *P. lanceolata* L. extracts is associated with modulation of all processes involved in that process (proliferation, migration, differentiation, and induction of fibroblasts to myofibroblasts transition, and extracellular matrix formation/organization) [96,97]. The presence of iridoid glycosides makes it possible to use *P. lanceolata* L. extract as an insecticide [80]. The *P. lanceolata* L. plant is also characterized by high anti-aging effectiveness [87]. Its water infusions and stabilized juices are used as an active ingredient in cream and mask formulas. The presence of salicylic acid in leaf extracts also shows antibacterial and anti-inflammatory activity, resulting in cleansing and protective properties of skin care products [80].

## 6. *Solidago virgaurea* L.

### 6.1. General Description

*S. virgaurea* L. (syn. goldenrod) is a perennial plant, occurring in more than 190 species, subspecies, and varieties [98]. *Solidago* means “which consolidates”, in reference to its use in the healing of wounds.

It is composed of a cylindrical rhizome. Its round and stiff stem, branching at the upper part, can reach a height of 1 m. The simple leaves on the midrib are arranged alternately, and at the lower part of the plant are ovate or have ovate-elliptic blades. Upper leaves have short stems and linear-oblong or elliptic blades with toothed or full edges. Goldenrod has distinctive radial yellow flower heads in the form of rosettes clustered in a panicle or corymb [99].

The largest areas of natural occurrence of *S. virgaurea* L. are found in North America, where it originates. Currently, it is widespread worldwide (Figure 12 and Table S1 in Supplementary Materials) [100]. It is used as an herbaceous plant, but it is also cultivated for ornamental purposes [99]. In Europe and Asia, the most common varieties are *S. virgaurea* L., *S. canadensis* L., and *S. gigantea* Aiton; in North America, most common is *S. odora* Aiton, while in South America it is *S. chilensis* Meyen [101,102].

### 6.2. Ethnomedical Importance

The leaves and flowers of *S. virgaurea* L. were used by the Menominee, Chippewa, Alabama, and Potawatomi Indians to make tea used for fever, colds, and chest pains. Goldenrod juice or ointment mixed with butter was previously used to treat eczema, wounds, and burns [99]. The roots or stems of *S. canadensis* L., mixed with bear fat, were used to make hot poultices or enemas. Extracts from the stems were taken internally as a tonic and stimulant. *S. altissima* was used to treat burns, female ailments, as well as sprains and muscle fatigue. From dried and powdered roots of *S. juncea*, infusions were prepared and used in convulsions and to treat purulent wounds, boils, and lung diseases. The Chippewa Indians used *S. rigida* for treating cut wounds, while a decoction of *S. rigida* roots was taken internally to treat urinary retention-related ailments [99].





**Figure 12.** Areas of natural occurrence and cultivation of species *S. virgaurea* (prepared based on <https://powo.science.kew.org>, accessed on 20 January 2024).

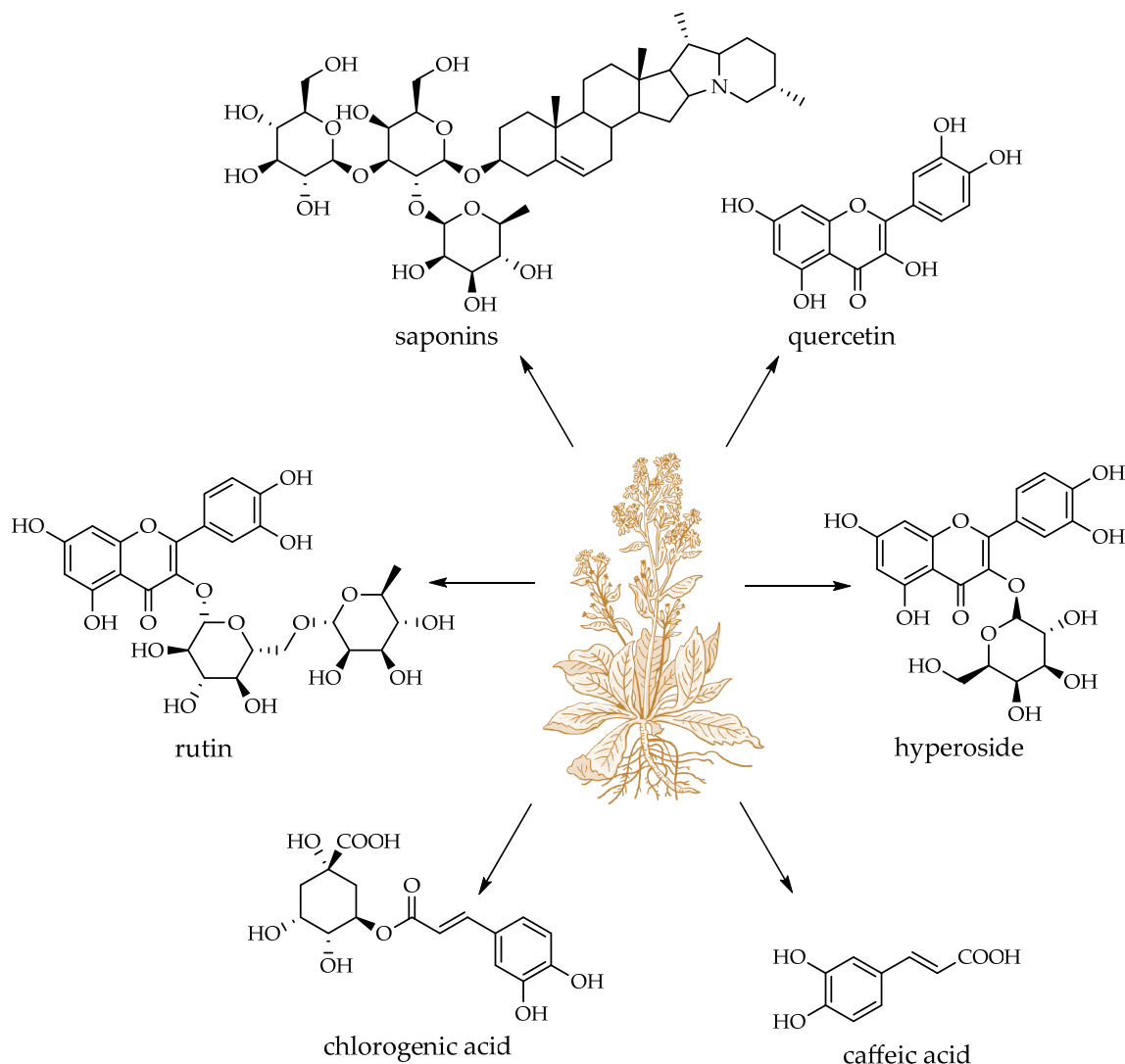
### 6.3. Phytochemical Constituents

According to the literature, the presence of polyphenolic compounds in extracts of *Solidago* species may be responsible for their biological properties. Flavonoids, saponins, caffeoylquinic acid derivatives, salicylic acid derivatives, clerodane-type diterpenes, polysaccharides, and essential oils have been reported as bioactive constituents of extracts. It has been revealed that the active substances responsible for antioxidant and anti-inflammatory activity are mainly caffeoylquinic acids and their derivatives [103–110]. Triterpenes, leiocarposide, rutin, and quercetin are also responsible for anti-inflammatory properties. The flavonoid fraction (quercetin and its derivatives), hydroxycinnamic acid fraction, saponin fraction, and leiocarposide are responsible for the well-known diuretic properties of goldenrod. Leiocarposide also acts as an analgesic. Triterpene saponins are responsible for antifungal properties, while saponins,  $\alpha$ -tocopherol quinone, 2-phyten-1-ol,  $\beta$ -dyktyopterol, and 3,5-dicaffeoylquinic acid methyl ester exhibit cytotoxic and anticancer properties. 5-di-O-caffeoylquinic acid inhibits fat cell production [111–118]. Figure 13 presents the most important bioactive constituents of *S. virgaurea* L.

### 6.4. Biological Activity

The aqueous or water–alcohol extracts of the herb *S. virgaurea* L. exhibit anti-inflammatory, spasmolytic, diuretic, analgesic, and hypotensive effects [98]. By facilitating the elimination of harmful metabolites (sodium chloride, ammonia, and uric acid), they act detoxifying and anti-edematous. Aqueous extracts of *S. virgaurea* L. also treat gastrointestinal ailments [99]. Additionally, it has antioxidant, antihypertensive, antibacterial, antifungal, antiparasitic, cytotoxic, anticancer, antimutagenic, anti-adipogenic, antidiabetic, and cardioprotective properties [98]. European goldenrod extract blocks the negative effects of fibroblast aging, making it an active addition for anti-aging cosmetics [119].

It seems that *Solidago*, despite its huge area of natural occurrence and wide spectrum of biological activity, has not yet been fully appreciated by the cosmetics industry in Europe [120]. Moreover, *Solidago* species are considered very invasive and one of the most aggressive plants in Europe. Therefore, it is important to find a practical, wide use for this plant [121].



**Figure 13.** The most important bioactive substances from *Solidago virgaurea* L. [98].

## 7. The Most Important Applications of *A. oleracea*, *C. asiatica*, *P. corylifolia*, *P. lanceolata*, and *S. virgaurea* Extracts and Bioactive Ingredients

In order to systematize the information provided in this article, in Table 3 we have listed chosen literature sources describing the most important biological activities and applications of the plants *A. oleracea*, *C. asiatica*, *P. corylifolia*, *P. lanceolata* L., and *S. virgaurea* L. Applications have been divided into three groups: medicine; pharmacology, toxicology, and pharmaceutics; and cosmetology.

Extracts from the plants described in this work are already being used in selected cosmetic formulations. Their excellent biological properties are attributed to the chemical substances, which are mainly phenolic acids, flavonoids, and triterpenoids. Table 4 presents the activities of plant extracts, as well as the activities of substances permitted for use in cosmetic formulas. The exact quantity of bioactive ingredients used in products is often protected by patent law, thus the access to such information is limited.

**Table 3.** Biological activity and application of bioactive components of chosen plants in medicine, pharmacology and cosmetology.

| PLANT                       | MEDICINE          |                   |                       |               |                   | PHARMACOLOGY, TOXICOLOGY, PHARMACEUTICS |                      |                           |                       |                   |              |                  |                |                  |                 |                           |                       |                   | COSMETOLOGY               |                  |                          |                  |                        |                       |           |                   |                |         |   |                           |                         |                   |                |                           |              |
|-----------------------------|-------------------|-------------------|-----------------------|---------------|-------------------|---|----------------------|---------------------------|-----------------------|-------------------|--------------|------------------|----------------|------------------|-----------------|---------------------------|-----------------------|-------------------|---------------------------|------------------|--------------------------|------------------|------------------------|-----------------------|-----------|-------------------|----------------|---------|---|---------------------------|-------------------------|-------------------|----------------|---------------------------|--------------|
|                             | Antiviral         | Antiseptic        | Antimicrobial         | Antiparasitic | Anti-stress       | Insecticide                             | Analgesic            | Anti-inflammatory         | Antihistamines        | Antibiotic        | Antidiabetic | Neuroprotective  | Antidepressant | Immunomodulating | Radioprotective | Anticancer                | Diuretic              | Antipyretic       | Spasmolytic               | Cardioprotective | Hepatoprotective         | Gastroprotective | Ultraviolet protection | Astringent            | Migrating | Anti-acne         | Scar reduction | Firming | Strengthening hair, accelerating growth, stopping hair loss | Antioxidant               | Anti-aging              | Anti-pigmentation | Anti-cellulite | Regenerate the skin       | Anti-wrinkle |
| <i>Acemella oleracea</i>    |                   | [14, 17, 24, 26]  | [12–14, 17, 24, 34]   |               |                   | [14, 17, 26]                            | [17, 23, 25, 27, 28] | [12, 14, 17, 20, 22]      |                       |                   |              |                  | [12]           |                  |                 | [12]                      | [12]                  |                   |                           |                  |                          | [12]             |                        |                       |           | [31–34]           |                | [33]    |   | [12, 17]                  | [20, 31–34]             |                   |                | [12, 20, 31, 33, 35, 37]  |              |
| <i>Centella asiatica</i>    | [43, 46]          | [48]              | [43, 44, 53]          |               | [48]              |   | [43, 46]             | 44, 46, 47, 52, 53]       |                       |                   | [44, 52, 53] | [42, 44, 52, 53] | [42, 43]       | [46, 52, 53]     |                 | [44, 46, 53]              |                       |                   |                           | [44–46, 52, 53]  |                          |                  |                        |                       |           |                   | [47, 49, 122]  |         | [47, 49, 122]   | [42, 44–47, 51, 52]       | [47, 49, 122]           |                   | [47, 49, 122]  | [48, 123]                 |              |
| <i>Psoralea corylifolia</i> |                   |                   | [56, 60, 70, 71, 124] |               |                   |   |                      | [56, 70, 124]             |                       |                   | [67, 125]    |                  | [56, 70, 124]  |                  |                 | [56, 60, 70, 72]          |                       | [124]             |                           | [70, 126]        | [56, 57, 59, 65, 66, 70] |                  |                        |                       |           | [70, 71, 76, 127] |                |         | [57, 59, 65, 66]  | [56, 60, 67, 70, 78, 125] | [70, 73, 77, 78, 127]   | [64, 128]         |                |                           |              |
| <i>Plantago lanceolata</i>  | [91, 92, 129–132] | [91, 92, 129–132] | [80, 95]              | [80]          | [91, 92, 129–132] | [91, 92, 129–132]                       |                      | [80, 91, 92, 95, 129–133] | [89, 91, 92, 129–132] | [91, 92, 129–132] |              | [89]             |                |                  |                 | [80, 89, 91, 92, 129–133] | [89, 91, 92, 129–132] | [91, 92, 129–132] | [80, 89, 91, 92, 129–132] |                  | [89, 91, 92, 129–132]    |                  | [91, 92, 129–132]      | [89, 91, 92, 129–132] | [94, 133] |                   |                |         | [80, 91, 92, 95, 129–135]                                   |                           | [80]                    | [91, 92, 129–132] |                | [80, 89, 91, 92, 129–133] |              |
| <i>Solidago virgaurea</i>   |                   | [98]              |                       | [98]          |                   |   | [98]                 | [98, 111–118]             |                       |                   |              |                  | [136]          | [136]            | [136]           | [136]                     | [98]                  | [98]              | [98]                      | [136]            | [136]                    |                  | [136]                  |                       |           |                   | [136]          |         | [98]  |                           | [104, 106–110, 136–138] | [119, 136]        |                |                           | [136]        |

**Table 4.** Biological activities of extracts and bioactive constituents from chosen plants.

| Plant                       | INCI Name  | CAS                                | Biological Activity   |
|-----------------------------|--|------------------------------------|---|
| <i>Acmella oleracea</i>     | <i>Acmella oleracea</i> extract<br><i>Spilanthes Acmella</i> extract | 90131-24-1                         | Antimicrobial<br>Skin protecting<br>Skin conditioning<br>Hair conditioning                                  |
| <i>Centella asiatica</i>    | <i>Centella asiatica</i> lea   | 84696-21-9                         | Skin conditioning (humectant)<br>Antioxidative<br>Skin protecting<br>Cleansing, smoothing, soothing, toning |
| <i>Psoralea corylifolia</i> | <i>Psoralea corylifolia</i> fruit extract                            | brak                               | Skin conditioning<br>Skin toning  |
| <i>Plantago lanceolata</i>  | <i>Plantago lanceolata</i> extract                                   | 85085-64-9                         | Antimicrobial<br>Skin conditioning  |
| <i>Solidago virgaurea</i>   | <i>Solidago virgaurea</i> extract                                    | 85117-06-2                         | Skin conditioning   |
| <i>Centella asiatica</i>    | Madecassic acid  | 18449-41-7                         | Skin conditioning   |
|                             | Madecassoside <sup>a</sup>   | 34540-22-2                         | Antioxidative<br>Skin conditioning  |
| <i>Centella asiatica</i>    | Asiatic acid <sup>a</sup>  | 464-92-6                           | Skin conditioning   |
| <i>Centella asiatica</i>    | Asiaticoside <sup>a</sup>  | 16830-15-2                         | Antioxidative<br>Skin conditioning<br>Perfuming   |
| <i>Psoralea corylifolia</i> | Bakuchiol <sup>a</sup>   | 10309-37-2                         | Antimicrobial<br>Antioxidative<br>Skin conditioning<br>Emollient  |
| <i>Psoralea corylifolia</i> | Coumarin <sup>b</sup>  | 91-64-5                            | Perfuming   |
| <i>Plantago lanceolata</i>  | Syringic acid <sup>a</sup>   | 530-57-4                           | Antioxidative   |
| <i>Plantago lanceolata</i>  | Apigenin <sup>a</sup>  | 520-36-5                           | Antioxidative<br>Hair conditioning  |
| <i>Plantago lanceolata</i>  | Luteolin <sup>a</sup>  | 491-70-3                           | Skin conditioning   |
| <i>Salidago virgaurea</i>   | Saponins <sup>a</sup>  | 8047-15-2 11006-75-0<br>72231-29-9 | Cleansing<br>Surfactant   |
| <i>Salidago virgaurea</i>   | Quercetin <sup>a</sup>   | 117-39-5                           | Antioxidative<br>Skin conditioning  |
| <i>Salidago virgaurea</i>   | Rutin <sup>a</sup>   | 153-18-4 130603-71-4               | Antioxidative<br>Hair conditioning<br>Skin conditioning   |
| <i>Salidago virgaurea</i>   | Chlorogenic acid <sup>a</sup>  | 327-97-9 72690-58-5                | Antioxidative<br>Skin conditioning<br>Skin protecting   |
| <i>Salidago virgaurea</i>   | Caffeic acid   | 331-39-5                           | Antioxidative<br>Perfuming  |

Based on CosIng database: <https://ec.europa.eu/growth/tools-databases/cosing/> (accessed on 11 April 2024)

<sup>a</sup> According to Regulation (EC) No 1223/2009 of the European Parliament and of the Council of 30 November 2009 on cosmetic products, there are no dose restrictions; <sup>b</sup> The presence of substances must be listed in the ingredient list specified in Article 19(1)(g) when their concentration exceeds 0.001% in leave-on products and 0.01% in rinse-off products.

The plants described in the article are increasingly being chosen and used to prepare natural cosmetic ingredients. Among the offerings of cosmetic companies worldwide, various types of products are developed with extracts from *A. oleracea*, *C. asiatica*, and *P. corylifolia*, including those for facial skin care (toners, gels, foams, micellar waters, creams, serums, masks, ampoules), as well as body lotions, shampoos, and hair conditioners. The potential for using *P. lanceolata* and *S. virgaurea* in the cosmetics industry remains untapped. In Table 5, the chosen cosmetic products containing plant extracts that are

already available on the market are presented. Also, the declared by manufacturers' effects of the formulations are specified.

**Table 5.** Cosmetic products containing *A. oleracea*, *C. asiatica*, and *P. corylifolia* extracts as bioactive ingredients [20,31,33,35,37,47,49,74,78].

| Plant                       | Cosmetic Product | Declared Product Effect   |
|-----------------------------|------------------|---|
| <i>Acmella oleracea</i>     | Face cream       | Anti-wrinkle, anti-inflammatory, regenerating                               |
|                             | Emulsion         | Anti-wrinkle, moisturizing, regenerating                                    |
|                             | Serum            | Anti-wrinkle, anti-aging, regenerating                                      |
|                             | Eye cream        | Anti-wrinkle, anti-inflammatory, regenerating                               |
| <i>Centella asiatica</i>    | Face tonic       | Soothing irritation, moisturizing   |
|                             | Serum            | Moisturizing, anti-inflammatory, regenerating, soothing irritation, firming |
|                             | Eye cream        | Revitalizing, anti-wrinkle  |
|                             | Face cream       | Soothing irritation, moisturizing   |
|                             | Spot cream       | Anti-acne, anti-inflammatory, moisturizing                                  |
|                             | Body lotion      | Smoothing, firming  |
|                             | Hair oil         | Strengthening hair, preventing excessive hair loss                          |
|                             | Hair conditioner | Strengthening hair follicles, preventing excessive hair loss                |
|                             | Shampoo          | Moisturizing, strengthening hair follicles                                  |
| <i>Psoralea corylifolia</i> | Night face cream | Anti-wrinkle, anti-acne   |
|                             | Day face cream   |   |
|                             | Serum            | Anti-acne   |

#### 8. Methods of Extracting Bioactive Ingredients from *A. oleracea*, *C. asiatica*, *P. corylifolia*, *P. lanceolata*, and *S. virgaurea*

In the newest literature, the trend for extraction of valuable plant ingredients with biological activity is focusing on applying techniques that have lower impacts on natural environment, such as extraction with supercritical fluids. Application of deep eutectic solvents is also gaining increasing interest. These solvents enable the selective and efficient isolation of specific chemicals depending on the solvent used [139]. Furthermore, they can be used for the pretreatment of plant material, which facilitates subsequent extraction [140]. However, traditional isolation methods, such as maceration or extraction in Soxhlet's apparatus, are still often employed as effective techniques for isolation of plant ingredients, especially those mentioned in this work [141–144]. Table 6 presents the review of extraction methods of active chemicals from *A. oleracea*, *C. asiatica*, *P. corylifolia*, *P. lanceolata*, and *S. virgaurea*. These were often experiments aimed at confirming the presence and content of individual ingredients in the extract. It should also be emphasized that authors often only provide extraction efficiency. In some studies, individual components of the extract are provided, but the units used are very different. Therefore, in Table 6 one of the columns is entitled "obtained results".

**Table 6.** Methods of extraction of bioactive ingredients of *Acmella oleracea*, *Centella asiatica*, *Psoralea corylifolia*, *Plantago lanceolata*, and *Solidago virgaurea*.

| Plant                   | Plant Material        | Extraction Method | Solvents, v/v           | Temp., °C | Time, h | Product    | Obtained Results | Refs.    |
|-------------------------|-----------------------|-------------------|-------------------------|-----------|---------|------------|------------------|----------|
| <i>Acmella oleracea</i> | flowers               | maceration        | MeOH 99%                | r.t.      | nd      | spilanthol | 8.72 mg/g DPM    | [14,145] |
| <i>Acmella oleracea</i> | flowers               | maceration        | EtOH 95%                | r.t.      | nd      | spilanthol | 2.93 mg/g DPM    | [15]     |
| <i>Acmella oleracea</i> | flowers               | extraction        | MeOH                    | r.t.      | 20 h    | extract    | 56.20 mg/g DPM   | [26]     |
| <i>Acmella oleracea</i> | flowers               | extraction        | Hx                      | r.t.      | 20 h    | extract    | 19.80 mg/g DPM   | [26]     |
| <i>Acmella oleracea</i> | flowers               | extraction        | AcOEt                   | r.t.      | 20 h    | extract    | 5.00 mg/g DPM    | [26]     |
| <i>Acmella oleracea</i> | leaves                | maceration        | MeOH                    | r.t.      | nd      | extract    | 50.00 mg/g DPM   | [146]    |
| <i>Acmella oleracea</i> | leaves                | SE                | MeOH                    | 65        | nd      | extract    | 0.18 mg/g DPM    | [147]    |
| <i>Acmella oleracea</i> | leaves                | SE                | EtOH                    | r.t.      | nd      | extract    | 13.2%            | [148]    |
| <i>Acmella oleracea</i> | leaves                | SE                | Petroleum ether (60–80) | b.t.      | nd      | extract    | 20.00 mg/g DPM   | [149]    |
| <i>Acmella oleracea</i> | leaves                | SE                | DCM                     | b.t.      | nd      | extract    | 13.00 mg/g DPM   | [149]    |
| <i>Acmella oleracea</i> | leaves                | maceration        | H <sub>2</sub> O        | 100       |         | extract    | nd               | [150]    |
| <i>Acmella oleracea</i> | leaves                | maceration        | H <sub>2</sub> O        | 40        |         | extract    | 88.24 mg/g DPM   | [151]    |
| <i>Acmella oleracea</i> | leaves, flowers, bark | maceration        | MeOH                    | r.t.      | 15 days | extract    | 29.52 mg/g DPM   | [152]    |
| <i>Acmella oleracea</i> | leaves, flowers, bark | maceration        | AcOEt                   | r.t.      | 15 days | extract    | 17.14 mg/g DPM   | [152]    |
| <i>Acmella oleracea</i> | leaves, flowers, bark | maceration        | Hx                      | r.t.      | 15 days | extract    | 10.48 mg/g DPM   | [152]    |
| <i>Acmella oleracea</i> | leaves, flowers, bark | maceration        | CHCl <sub>3</sub>       | r.t.      | 15 days | extract    | 9.52 mg/g DPM    | [152]    |
| <i>Acmella oleracea</i> | leaves, flowers, bark | maceration        | EtOH 95%                | r.t.      | nd      | extract    | 7.7 g/g DPM      | [153]    |
| <i>Acmella oleracea</i> | leaves, flowers, bark | maceration        | EtOH                    | r.t.      | 48 h    | extract    | 15.04 g/g DPM    | [23]     |
| <i>Acmella oleracea</i> | leaves, flowers, bark | maceration        | MeOH                    | 40        | 9 days  | extract    | 0.40 mg/g DPM    | [154]    |
| <i>Acmella oleracea</i> | leaves, flowers, bark | maceration        | Hx                      | r.t.      | 48 h    | extract    | 10.74 g/g DPM    | [23]     |
| <i>Acmella oleracea</i> | leaves, flowers, bark | maceration        | EtOH 95%                | 40        | 11 days | extract    | 3.0%             | [155]    |
| <i>Acmella oleracea</i> | leaves, flowers, bark | maceration        | Hx                      | 40        | nd      | extract    | 14.8%            | [156]    |
| <i>Acmella oleracea</i> | leaves, flowers, bark | SE                | EtOH 70%                | 79        | nd      | extract    | nd               | [157]    |
| <i>Acmella oleracea</i> | all parts             | maceration        | MeOH                    | 25        | 24 h    | extract    | 450.00 mg/g DPM  | [10]     |



Table 6. Cont.

| Plant                    | Plant Material | Extraction Method         | Solvents, v/v                      | Temp., °C | Time, h | Product   | Obtained Results   | Refs.    |
|--------------------------|----------------|---------------------------|------------------------------------|-----------|---------|---|--|----------|
| <i>Acmella oleracea</i>  | all parts      | maceration                | CHCl <sub>3</sub>                  | 25        | 24 h    | extract   | 430.00 mg/g DPM  | [10]     |
| <i>Acmella oleracea</i>  | all parts      | maceration                | Petroleum ether                    | 25        | 24 h    | extract   | 140.00 mg/g DPM  | [10,158] |
| <i>Acmella oleracea</i>  | root           | maceration                | Benzine/Et <sub>2</sub> O<br>1/1   | 25        | 48 h    | extract   | nd   | [159]    |
| <i>Centella asiatica</i> | leaves         | SE                        | MeOH                               | no data   | 24 h    | phenols<br>flavonoid<br>ascorbic acid   | 10.00 mg/g DPM<br>45.00 mg/g DPM<br>35.00 mg/g DPM   | [160]    |
| <i>Centella asiatica</i> | leaves         | SE                        | AcOEt 99%                          | b.t.      | 5 h     | extract   | nd   | [161]    |
| <i>Centella asiatica</i> | leaves         | maceration                | AcOEt 99%                          | r.t.      | 7 days  | extract   | nd   | [161]    |
| <i>Centella asiatica</i> | leaves         | maceration                | EtOH 70%                           | r.t.      | 48 h    | madecassoside<br>asiaticoside B<br>asiaticoside<br>triterpenoid<br>madecassic acid<br>terminolic acid<br>asiatic acid<br>triterpene | 0.70 wt% of extract<br>0.96 wt% of extract<br>1.14 wt% of extract<br>2.80 wt% of extract<br>0.14 wt% of extract<br>0.09 wt% of extract<br>0.20 wt% of extract<br>3.23 wt% of extract | [162]    |
| <i>Centella asiatica</i> | leaves         | MAE<br>2450 MHz, 600<br>W | EtOH 96%                           | 75        | nd      | triterpenoids<br>madecassoside<br>asiaticoside<br>madecassic acid   | 2.20 mg/g DPM<br>8.60 mg/g DPM<br>5.60 mg/g DPM<br>3.10 mg/g DPM   | [163]    |
| <i>Centella asiatica</i> | leaves         | UAE<br>40 kHz;<br>216 W   | AcOEt 99%                          | 70        | 5 h     | extract   | nd   | [161]    |
| <i>Centella asiatica</i> | leaves         | SFE<br>(35 MPa)           | EtOH 95%/CO <sub>2</sub><br>(1/25) | 60        | 3 h     | madecassoside<br>asiaticoside B<br>asiaticoside<br>triterpenoid<br>madecassic acid<br>terminolic acid<br>asiatic acid<br>triterpene | 0.66%<br>0.96 wt% of extract<br>1.18 wt% of extract<br>2.80 wt% of extract<br>0.43 wt% of extract<br>0.31 wt% of extract<br>0.58 wt% of extract<br>4.11 wt% of extract               | [162]    |

Table 6. Cont.

| Plant                    | Plant Material  | Extraction Method | Solvents, v/v                     | Temp., °C | Time, h | Product  | Obtained Results  | Refs. |
|--------------------------|-----------------|-------------------|-----------------------------------|-----------|---------|--|---|-------|
| <i>Centella asiatica</i> | leaves, flowers | maceration        | EtOH 75%                          | r.t.      | 3 days  | madecassic acid<br>asiatic acid  | 0.18 wt% of DPM   | [164] |
| <i>Centella asiatica</i> | all parts       | SE                | AcOEt 99%                         | b.t.      | 5 h     | extract  | 87.0%   | [161] |
| <i>Centella asiatica</i> | all parts       | maceration        | AcOEt 99%                         | r.t.      | 7 days  | extract  | 76.0%   | [161] |
| <i>Centella asiatica</i> | all parts       | maceration        | EtOH 95%                          | 60        | 2 h     | madecassoside<br>asiaticoside<br>madecassic acid<br>asiatic acid       | 0.86 wt%<br>0.17 wt%<br>0.05 wt%<br>0.03 wt%  | [165] |
| <i>Centella asiatica</i> | all parts       | maceration        | MeOH 90%                          | 66        | 6 h     | phenols<br>saponins  | nd  | [166] |
| <i>Centella asiatica</i> | all parts       | maceration        | EtOH                              | r.t.      | 24 h    | saponins   | nd  | [167] |
| <i>Centella asiatica</i> | all parts       | maceration        | EtOH                              | 60        | 1,5 h   | polyphenols<br>carotenoids   | 2.24 mg/g DPM<br>3.47 mg/g DPM  | [168] |
| <i>Centella asiatica</i> | all parts       | maceration        | EtOH/H <sub>2</sub> O<br>65/35    | 45        | 1 h     | polyphenols<br>carotenoids   | 3.99 mg/g DPM<br>2.37 mg/g DPM  | [168] |
| <i>Centella asiatica</i> | all parts       | maceration        | EtOH/H <sub>2</sub> O<br>30/70    | 30        | 0,5 h   | polyphenols<br>carotenoids   | 3.31 mg/g DPM<br>0.98 mg/g DPM  | [168] |
| <i>Centella asiatica</i> | all parts       | maceration        | EtOH 80%/H <sub>2</sub> O<br>1/20 | r.t.      | 24 h    | phenols<br>triterpene saponins   | nd  | [169] |
| <i>Centella asiatica</i> | all parts       | maceration        | Petroleum ether<br>60–80,         | r.t.      | nd      | extract  | 2.80 wt%  | [170] |
| <i>Centella asiatica</i> | all parts       | maceration        | MeOH                              | r.t.      | nd      | extract  | 13.80 wt%   | [170] |
| <i>Centella asiatica</i> | all parts       | maceration        | Chloroform                        | r.t.      | nd      | extract  | 3.80 wt%  | [170] |
| <i>Centella asiatica</i> | all parts       | SE                | MeOH                              | 60        | 6 h     | alkaloids<br>phenols<br>tannins<br>flavonoids<br>tepenoids<br>saponins | 15.66 mg/g extract<br>43.70 mg/g extract<br>30.09 mg/g extract<br>13.20 mg/g extract<br>3.08 mg/g extract<br>52.10 mg/g extract | [171] |

Table 6. Cont.

| Plant                    | Plant Material | Extraction Method         | Solvents, v/v                  | Temp., °C | Time, h   | Product   | Obtained Results  | Refs.     |
|--------------------------|----------------|---------------------------|--------------------------------|-----------|---|---|---|-----------|
| <i>Centella asiatica</i> | all parts      | SE                        | EtOH                           | 45        | nd  | polyphenols<br>flavonoids<br>tannins<br>vitamin C<br>β-carotene | 21.10 mg/g extract<br>9.30 mg/g extract<br>85.70 mg/g extract<br>12.50 mg/g extract<br>1.10 mg/g extract  | [172]     |
| <i>Centella asiatica</i> | all parts      | SE                        | EtOH 50%                       | 45        | nd  | polyphenols<br>flavonoids<br>tannins<br>vitamin C<br>β-carotene | 45.20 mg/g extract<br>14.60 mg/g extract<br>59.70 mg/g extract<br>9.50 mg/g extract<br>0.70 mg/g extract  | [172]     |
| <i>Centella asiatica</i> | all parts      | SE                        | H <sub>2</sub> O               | 45        | nd  | polyphenols<br>flavonoids<br>tannins<br>vitamin C<br>β-carotene | 35.60 mg/g extract<br>11.70 mg/g extract<br>60.70 mg/g extract<br>13.30 mg/g extract<br>0.20 mg/g extract | [172]     |
| <i>Centella asiatica</i> | all parts      | UAE<br>125W               | H <sub>2</sub> O               | no data   | 20 min  | asiaticoside<br>asiatic acid                                    | 4.75 mg/g DPM<br>7.09 mg/g DPM  | [173]     |
| <i>Centella asiatica</i> | all parts      | UAE<br>40 kHz, 216 W      | AcOEt 99%                      | 70        | 5 h   | extract   | 90.0%<br>(yield of extract)   | [161]     |
| <i>Centella asiatica</i> | all parts      | UAE                       | MeOH 90%                       | nd        | 0.5 h   | asiaticoside<br>madecassoside<br>triterpenoids                  | 6.42 mg/g DPM<br>5.89 mg/g DPM<br>12.69 mg/g DPM  | [174]     |
| <i>Centella asiatica</i> | all parts      | EPME with<br>3% cellulase | Deionized water                | 45        | 30 min<br>enzymatic<br>reaction<br>and<br>2 min of<br>radiation | asiaticoside  | 27.1%<br>(yield of extract)   | [161,175] |
| <i>Centella asiatica</i> | all parts      | MAE                       | MeOH-H <sub>2</sub> O<br>(9/1) | 70        | 20 min  | madecassoside<br>asiaticoside<br>asiatic acid                   | nd  | [176]     |

Table 6. Cont.

| Plant                      | Plant Material | Extraction Method | Solvents, v/v    | Temp., °C | Time, h | Product  | Obtained Results  | Refs. |
|----------------------------|----------------|-------------------|------------------|-----------|---------|--|---|-------|
| <i>Centella asiatica</i>   | all parts      | SHWE 40MPa        | H <sub>2</sub> O | 250       | 5 h     | asiaticoside<br>asiatic acid   | 10.00 mg/g DPM<br>7.80 mg/g DPM   | [177] |
| <i>Plantago lanceolata</i> | leaves         | SE                | MeOH 40%         | b.t.      | 0.5 h   | Extract:<br>acteoside (5.99%)<br>aucubin (2.34%)<br>catalpol (1.21%)   | 25.2 g extract/g DPM  | [95]  |
| <i>Plantago lanceolata</i> | leaves         | SE                | MeOH             | b.t.      | 12 h    | verbascoside<br>aucubin  | 1.74% DPM<br>0.24% DPM  | [89]  |
| <i>Plantago lanceolata</i> | leaves         | maceration        | EtOH             | r.t.      | night   | protocatechuic acid<br>cafeic acid<br>ferulic acid<br>sinapic acid<br>o-cumanic<br>rutin<br>myricetin<br>quercetin<br>kaempferol | 3.88 µg/mL extract<br>5.23 µg/mL extract<br>7.84 µg/mL extract<br>9.78 µg/mL extract<br>12.26 µg/mL extract<br>13.37 µg/mL extract<br>15.27 µg/mL extract<br>16.99 µg/mL extract<br>12.16 µg/mL extract | [133] |
| <i>Plantago lanceolata</i> | leaves         | UAE USE           | ACN 30%          | 25        | 0.4     | esculetin  | 111.40 mg/g DPM   | [178] |
| <i>Plantago lanceolata</i> | aerial parts   | SE                | MeOH             | b.t.      | 48      | phenolic compounds<br>flavonoids<br>phenylpropanoid<br>glycosides<br>iridoids  | 8.16% extract<br>1.24% extract<br>2.18% extract<br>traces   | [178] |
| <i>Plantago lanceolata</i> | aerial parts   | maceration        | MeOH 80%         | r.t.      | 72      | phenolic acids<br>flavonoids<br>coumarins  | 8.49 mg/g DPM<br>0.18 mg/g DPM<br>0.01 mg/g DPM   | [179] |

Table 6. Cont.

| Plant                       | Plant Material | Extraction Method  | Solvents, v/v    | Temp., °C | Time, h | Product  | Obtained Results   | Refs. |
|-----------------------------|----------------|--------------------|------------------|-----------|---------|--|--|-------|
| <i>Plantago lanceolata</i>  | all parts      | vapor distillation | H <sub>2</sub> O | b.t.      | 5       | monoterpenes<br>ox. monoterpenes<br>sesquiterpenes<br>ox. sesquiterpenes<br>ox. diterpenes<br>apocarotenoids<br>aldehydes and ketones<br>alcohols<br>phenols and phen. eters<br>fatty acids<br>esters<br>aliphatic hydrocarbons<br>aromatic hydrocarbons | 0.65–1.21% of extract<br>4.29–13.18% of extract<br>0.15–1.11% of extract<br>1.35–3.98% of extract<br>3.21–5.49% of extract<br>1.54–2.25% of extract<br>6.91–10.03% of extract<br>3.82–9.19% of extract<br>0.07–4.06% of extract<br>27.97–52.05% of extract<br>0.48–1.82% of extract<br>0.27–0.46% of extract<br>0.36–7.06% extract | [180] |
| <i>Plantago lanceolata</i>  | seeds          | maceration         | MeOH 60%         | r.t.      | bd      | extract  | nd   | [135] |
| <i>Psoralea corylifolia</i> | seeds          | SFE (100 bar)      | EtOH 96%         | 45        | nd      | bakuchiol  | 1.50%  | [181] |
| <i>Psoralea corylifolia</i> | seeds          | SFE (250 bar)      | CO <sub>2</sub>  | 40        | 7 h     | Extract:<br>bakuchiol (81.42%)<br>psoralen (1.65%)<br>iso-psoralen (4.27%)   | 6.57% extract  | [181] |
| <i>Psoralea corylifolia</i> | seeds          | SFE (280 bar)      | CO <sub>2</sub>  | 40        | 4 h     | Extract:<br>bakuchiol (79.68%)<br>psoralen (1.23%)<br>iso-psoralen (3.14%)   | 5.90% extract  | [181] |
| <i>Psoralea corylifolia</i> | seeds          | SFE (280 bar)      | CO <sub>2</sub>  | 40        | 7 h     | Extract:<br>bakuchiol (80.96%)<br>psoralen (1.52%)<br>iso-psoralen (4.15%)   | 6.29% extract  | [181] |
| <i>Psoralea corylifolia</i> | seeds          | SFE (280 bar)      | CO <sub>2</sub>  | 40        | 5.5 h   | Extract:<br>bakuchiol (80.25%)<br>psoralen (1.23%)<br>iso-psoralen (3.15%)   | 8.58% extract  | [181] |

Table 6. Cont.

| Plant                       | Plant Material        | Extraction Method | Solvents,<br><i>v/v</i> | Temp., °C | Time,<br>h | Product  | Obtained Results                | Refs. |
|-----------------------------|-----------------------|-------------------|-------------------------|-----------|------------|--|---------------------------------|-------|
| <i>Psoralea corylifolia</i> | seeds                 | maceration        | MeOH                    | r.t.      | 0.5 h      | Extract:<br>akteozyd (5.99%)<br>aukubina (2.34%)<br>katalpol (1.21%) | 0.25 g/g DPM                    | [181] |
| <i>Solidago virgaurea</i>   | leaves, flowers       | maceration        | EtOH 70%                | 20        | 2.7 h      | quercetin  | 1300 µg/mL extract              | [182] |
| <i>Solidago virgaurea</i>   | leaves, flowers       | maceration        | EtOH 98%                | 20        | 2.7 h      | quercetin  | 700 µg/mL extract               | [182] |
| <i>Solidago virgaurea</i>   | leaves, flowers       | maceration        | H <sub>2</sub> O        | 20        | 2.7 h      | quercetin  | 300 µg/mL extract               | [182] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | maceration        | EtOH 40%                | r.t.      | 1 h        | saponins   | 0.94 wt% of extract             | [183] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | maceration        | EtOH 60%                | r.t.      | 1 h        | saponins   | 9.80 wt% of extract             | [183] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | maceration        | EtOH 80%                | r.t.      | 1 h        | saponins   | 0.91 wt% of extract             | [183] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | maceration        | EtOH 96%                | r.t.      | 1 h        | saponins   | 0.78 wt% of extract             | [183] |
| <i>Solidago virgaurea</i>   | leaves                | SLE               | H <sub>2</sub> O        | r.t.      | 5 h        | polyphenols<br>phenolic acid   | 23.52 µg/g DPM<br>1.42 µg/g DPM | [184] |
| <i>Solidago virgaurea</i>   | bark                  | SLE               | H <sub>2</sub> O        | r.t.      | 5 h        | polyphenols<br>phenolic acid   | 6.39 µg/g DPM<br>0.61 µg/g DPM  | [184] |
| <i>Solidago virgaurea</i>   | flowers               | SLE               | H <sub>2</sub> O        | r.t.      | 5 h        | polyphenols<br>phenolic acid   | 17.38 µg/g DPM<br>0.92 µg/g DPM | [184] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | maceration        | EtOH 96%                | r.t.      | 15 h       | sugars and cyclitols   | 2.47 mg/g DPM                   | [185] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | maceration        | EtOH 70%                | r.t.      | 15 h       | sugars and cyclitols   | 6.58 mg/g DPM                   | [185] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | maceration        | H <sub>2</sub> O        | r.t.      | 15 h       | sugars and cyclitols   | 14.00 mg/g DPM                  | [185] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | SE                | EtOH 96%                | b.t.      | 5 h        | sugars and cyclitols   | 0.99 mg/g DPM                   | [185] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | SE                | EtOH 70%                | b.t.      | 5h         | sugars and cyclitols   | 2.67 mg/g DPM                   | [185] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | SE                | H <sub>2</sub> O        | b.t.      | 5 h        | sugars and cyclitols   | 2.08 mg/g DPM                   | [185] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | PLE<br>(10MPa)    | EtOH 96%                | 50        | 3 × 0.3 h  | sugars and cyclitols   | 7.53 mg/g DPM                   | [185] |
| <i>Solidago virgaurea</i>   | leaves, bark, flowers | PLE<br>(10MPa)    | EtOH 70%                | 50        | 3 × 0.3 h  | sugars and cyclitols   | 8.53 mg/g DPM                   | [185] |



Table 6. Cont.

| Plant                     | Plant Material        | Extraction Method | Solvents, v/v              | Temp., °C | Time, h   | Product              | Obtained Results | Refs. |
|---------------------------|-----------------------|-------------------|----------------------------|-----------|-----------|----------------------|------------------|-------|
| <i>Solidago virgaurea</i> | leaves, bark, flowers | PLE (10MPa)       | H <sub>2</sub> O           | 50        | 3 × 0.3 h | sugars and cyclitols | 35.51 mg/g DPM   | [185] |
| <i>Solidago virgaurea</i> | leaves, bark, flowers | UAE               | EtOH 96%                   | 50        | 2 × 0.5 h | sugars and cyclitols | 0.34 mg/g DPM    | [185] |
| <i>Solidago virgaurea</i> | leaves, bark, flowers | UAE               | EtOH 70%                   | 50        | 2 × 0.5 h | sugars and cyclitols | 1.77 mg/g DPM    | [185] |
| <i>Solidago virgaurea</i> | leaves, bark, flowers | UAE               | H <sub>2</sub> O           | 50        | 2 × 0.5 h | sugars and cyclitols | 3.27 mg/g DPM    | [185] |
| <i>Solidago virgaurea</i> | leaves, bark, flowers | SFE (10MPa)       | CO <sub>2</sub> , EtOH 96% | 50        | 1 h       | sugars and cyclitols | 1.52 mg/g DPM    | [185] |
| <i>Solidago virgaurea</i> | leaves, bark, flowers | SFE (10MPa)       | CO <sub>2</sub> , EtOH 70% | 50        | 1 h       | sugars and cyclitols | 5.24 mg/g DPM    | [185] |

b.t—boiling point; nd—no data; r.t.—room temperature; DPM—dry plant material; EPME—enzymatic pretreatment followed by microwave extraction; MAE—microwave-assisted extraction; PLE—pressurized liquid extraction; SE—Soxhlet extraction; SFE—supercritical fluid extraction; SFME—solvent-free microwave extraction; SHWE—subcritical hot-water extraction; SLE—solid–liquid extraction; UAE—ultrasound-assisted extraction; VMAE—vacuum microwave-assisted extraction.

In many instances, uncovering the true content of specific bioactive compounds in studied plants proves challenging. It depends on the techniques employed for extraction and separation. Consequently, there exists a notable variance in findings among different researchers, as highlighted in Table 6. Moreover, it is evident that the concentration of active constituents is contingent upon factors such as the region, climate, and the specific part of the plant being examined.

## 9. Future Challenges and Prospects

The cosmetics industry constantly offers consumers new cosmetics with improved composition, based on natural ingredients. New, more effective methods of identifying and isolating plant active ingredients are constantly being developed. It is highly probable that many more new active substances of plant origin will be identified in the near future. It is extremely important to examine their biopotentials and application profiles.

As social awareness increases, more and more products on the cosmetics market have labels with attractive slogans such as eco-, bio-, organic, or natural. Producers, taking advantage of the popularity of the ecological trend, consciously use such terms to encourage the purchase of their products. However, is the composition of such raw materials always known and confirmed? It should be remembered that the active substances contained in plant extracts, although they constitute only a small percentage of the weight of the entire cosmetic, determine its activity and are the most important components. The composition of such additives, both quantitative and qualitative, may vary depending on the variety, stage of development, region of occurrence and growth conditions, or part of the plant. Therefore, it seems advisable to determine the content of specific active ingredients in the raw material in order to ensure the declared effect of the cosmetic.

The plants described in this paper (*A. oleracea*, *C. Asiatica*, *P. corylifolia*, *P. lanceolata*, and *S. virgaurea*) have a wide spectrum of biological activity, which opens up many areas of their applications, e.g., cosmetics, pharmaceuticals, insecticides, metal indicators, removal of heavy metals from contaminated areas, or food additives. All of them were historically used in the form of aqueous or alcoholic extracts, and less often as dried and powdered plant parts.

Currently, increasing interest in spilanthol isolated from *Acmella oleracea* (natural herbal botox), bakuchiol contained in the extract from *Psoralea corylifolia* (a natural substitute for retinol), and extract from *Centella asiatica*, as natural, safe and effective components of cosmetic preparations can be observed. On the other hand, the popular plants *Plantago lanceolata* and *Solidago virgaurea* remain underestimated by the cosmetics industry. Plants of the *Solidago* species are currently considered the most aggressive and invasive plants in Europe, so it is very important to find a practical, wide application for this raw material [121].

**Supplementary Materials:** The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/app14083487/s1>, Table S1: Supporting information includes table with the plant species and the countries list where the plants are found.

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