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Botanical Adulterants Prevention Program
BOTANICAL ADULTERANTS PREVENTION
BULLETIN

# Botanical Adulterants Prevention Bulletin on Echinacea

## (*Echinacea purpurea*, *Echinacea angustifolia*, and *Echinacea pallida*)

**Echinacea** *Echinacea purpurea*
Photo by Steven Foster, ©2025 ABC

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*This publication is dedicated to the memory of Steven Foster (1957–2022), an author, photographer, researcher, botanist, colleague, and friend to those who collaborated with him for the ABC-AHP-NCNPR Botanical Adulterants Prevention Program (BAPP). Among many significant contributions to modern herbal medicine, Foster was known as "Mr. Echinacea" to some in the trade due to his instrumental role in popularizing echinacea as an herbal remedy in the United States and internationally, starting in the late 1970s and continuing for more than 40 years. In 1984, he wrote* Echinacea Exalted! The Botany, Culture, History, and Medicinal Uses of the Purple Coneflowers, *the first popular book on echinacea since the publication of* A Treatise on Echinacea *by the respected Eclectic pharmacist John Uri Lloyd in 1917. Steven was the author of the first BAPP publication and made many important contributions to the program.*

**Echinacea** *Echinacea angustifolia*
Photo by Steven Foster, ©2025 ABC

**Echinacea** *Echinacea pallida*
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**Keywords:** Adulteration, echinacea, *Cistanche* spp., coneflower, *Echinacea purpurea, Echinacea angustifolia*, *Echinacea pallida*

**Goal:** The purpose of this bulletin is to provide information and/or updates on issues related to the adulteration of *Echinacea* species, including the aerial parts of *Echinacea purpurea,* and the roots of *Echinacea purpurea*, *Echinacea angustifolia*, and *Echinacea pallida*.* It is intended for the international herbal industry and the broader natural products community.

This overview aims to highlight the occurrence of adulteration, known adulterants, analytical methods for their detection, the market situation, and the consequences for consumers and the industry. This document aims to support consumers, healthcare practitioners, and industry professionals by addressing concerns related to product quality and adulteration in the market.

## 1. General Information

**Common names**:

*Echinacea purpurea*: Eastern purple coneflower, Kansas snakeroot, snakeroot, broadleaved purple coneflower, scurvy root, Indian head, comb flower, black susans, hedge hog[1]

*Echinacea angustifolia*: Purple coneflower, Narrow-leaved purple coneflower, Kansas snakeroot, snake-root, scurvy root, comb flower, black susans, hedge hog[2]

*The order of species is based on their market prevalence

### 1.2 Common names in other languages:

| | ***E. purpurea*** | ***E. angustifolia*** | ***E. pallida*** |
|---|---|---|---|
| French | Echinacée pourpre, echinacée pourpre de l'Est, echinacée purpurea, rudbeckie pourpre[4] | Echinacée à feuilles étroites, echinacée angustifolia, echinacée pourpre à feuilles étroites, sanicel du Kansas[5] | Echinacée à fleurs pales, echinacée pale, echinacée pallida, echinacée pourpre pâle[6] |
| German | Purpurfarbener Sonnenhut, roter Sonnenhut[7] Purpursonnenhutwurzel (root), Purpursonnenhutkraut (herb)[8] | Schmalblättriger Sonnenhut, schmalblättriger Igelkopf, schmalblättrige Sonnenhutwurzel (root)[9] | Blasser Sonnenhut, blasse Kegelblume,[10] blasser Igelkopf[11,12] |
| Chinese | 紫花松果菊<br>Zǐhuā sōng guǒ jú* | 狭叶松果菊<br>Xiá yè sōng guǒ jú* | 淡紫松果菊<br>Dàn zǐ sōng guǒ jú* |
| Japanese | ムラサキバレンギク<br>紫馬簾菊<br>Murasakibarengiku** | ホソババレンギク<br>細葉馬簾菊<br>Hosobabarengiku** | - |
| Danish | Purpursolhat, havepurpursolhat[13] | Smalbladet solhat[13] | Solhat[13] |
| Dutch | Rode zonnehoed | Smalbladige zonnehoed | Egelzonnehoed |
| Italian | *Echinacea purpurea* | *Echinacea angustifolia* | *Echinacea pallida* |
| Russian | Эхинацея пурпурная[14] | Эхинацея узколистная[15] | Эхинацея бледная[16] |
| Ukrainian | Ехінацея пурпурова*** | Ехінацея вузьколиста*** | Ехінацея бліда*** |
| Spanish | Equinácea púrpura[17] | Equinácea de hoja estrecha[18] | Equinácea pálida[18] |
| Swedish | Röd solhatt[19] | Smalbladig läkerudbeckia, liten läkerudbeckia, smalbladig solhatt[19] | Blek solhatt, läkerudbeckia[19] |

* F. Bai (BeiGene) email to ÜŞ Harput Döner, November 22, 2024.

** A. Nagatsu (Kinjo Gakuin University, Nagoya), email to ÜŞ Harput Döner, November 22, 2024.

*** O. Mykhailenko (National University of Pharmacy, Kharkiv) email to S. Gafner, December 11, 2024.

*Echinacea pallida*: Pale purple coneflower[3]

**1.3 Accepted Latin binomial:** *Echinacea purpurea* (L.) Moench, *Echinacea angustifolia* DC., *Echinacea pallida* (Nutt.) Nutt.[20-22]

**1.4 Synonyms:**

*Echinacea purpurea: Brauneria purpurea* (L.) Britton, *Echinacea intermedia* Lindl. ex Paxton, *Echinacea purpurea* f. *liggettii* Steyerm., *Echinacea purpurea* f. *purpurea, Echinacea purpurea* var. *arkansana* Steyerm., *Echinacea purpurea* var. *purpurea, Echinacea serotina* (Nutt.) D.Don ex G.Don, *Helichroa purpurea* Raf., *Rudbeckia purpurea* L., *Rudbeckia purpurea* var. *purpurea, Rudbeckia purpura* var. *purpurea, Rudbeckia serotina* (Nutt.) Sweet [23,24]

*Echinacea angustifolia*: *Echinacea angustifolia* var. *strigosa* McGregor, *Echinacea pallida* var. *strigosa* (R.L.McGregor) Gandhi,[25] *Echinacea pallida* var. *angustifolia* (DC.) Cronquist[26]

*Echinacea pallida: Brauneria pallida* (Nutt.) Britton, *Echinacea pallida* f. *albida* Steyerm., *Echinacea pallida* f. *pallida, Echinacea pallida* var. *pallida, Rudbeckia pallida* Nutt[3]

**1.5 Botanical family**: Asteraceae

**1.6 Morphological characteristics:** The following paragraphs provide detailed descriptions of the plant parts, including their botanical characteristics.

*Echinacea purpurea* (L.) Moench: *Echinacea purpurea* is a vigorous, herbaceous perennial plant that grows to a height of 120 cm. The stem is branched, and often pubescent, with short, stiff trichomes in the upper portion. Basal leaves are cauline, lanceolate to broadly ovate, their bases usually rounded to cordate in large leaves. Leaf margins are toothed in all but the smallest leaves. Leaves have 3 or 5 main leaf veins with branching secondary veins; both surfaces are variously hirsute to hispid with short bicellular hairs or mostly adaxially. The inflorescence is a radiate capitulum that can grow up to 15 cm in diameter. Ray florets are dark pink to purple, spreading or reflexed, and five to 8 times longer than wide. Disc florets are 4.5–5.7 mm long, with lobes that are greenish to pink and, rarely, purple, yellow, or orange. *Echinacea purpurea* possesses a fibrous root system that grows up to 15 cm long and has a shorter rhizome that is light or dark brown to yellowish brown or black.[7,27,28]

*Echinacea angustifolia* D.C.: *Echinacea angustifolia* is a perennial plant with simple or rarely branched stems, typically reaching 10–60 cm in height, smooth or hirsute in the lower part, hirsute to tuberculate-hirsute in the upper part. The leaves are basal and cauline, alternate, narrowly lanceolate to lanceolate or elliptical, and range from 5–30 cm in length, with three to five veins, parallel. The leaf margins are entire. The upper and lower leaf surfaces are densely hirsute to tuberculate-hirsute. The flower head (capitulum) is 4.0–7.5 cm in diameter, with light pink to medium purple ray florets that measure 2–4 cm long and 5–8 mm wide and are pubescent, with toothed apex. The disk florets are tubular, and usually purplish. The root is cylindrical, slightly tapering or twisted, 10–20 cm long, and 0.4–1.3 cm in diameter, with its uppermost (rhizome) portion up to 1.5 cm wide. Wild-harvested roots may branch, while cultivated roots can be multi-branched from the crown. The root has a grayish-brown to purplish-brown exterior, slightly wrinkled with V-shaped stem scars, and a short, fibrous fracture.[9,28,29]

*Echinacea pallida* (Nutt.) Nutt.: *Echinacea pallida* is a perennial plant with a stem that is simple to rarely branched from lower nodes. The plant is similar to *E. angustifolia*, but generally taller. The erect stems grow up to 40–90(–110) cm in height, sparsely hirsute in the lower part, and more densely haired in the upper part. The basal leaves are cauline, oblong lanceolate to long-elliptical, hirsute on both surfaces, alternate, triple-veined, and measure up to 25 cm in length and 2.5–4 cm in width. The plant produces solitary flower heads with pale pink, 4–9 cm long, 0.5–0.8 cm wide ray florets that are strongly reflexed toward the stem. The ray florets surround a domed, reddish-brown disk of florets. The plant has a cylindrical, slightly tapering, large taproot similar to the one of *E. angustifolia*. The taproot can reach 10–20 cm long and 0.4–1 cm in diameter (the uppermost portion [rhizome] can reach up to 1.5–2 cm wide), with minimal branching.[3,10,28,29]

**1.7 Distribution:** The distribution of *Echinacea* species varies across North America. Each species has its own native area and habitat.

*Echinacea purpurea* is native to the Northeast, Southeast, and Midwest regions of the United States and is found particularly in open woodlands and prairies ranging from Iowa and Ohio south to Louisiana and Georgia.[30,31] It flowers primarily from June to July, occasionally extending into August.[7] Unfortunately, due to overharvest and loss of habitat, it is absent from most of its native growing areas.

*Echinacea angustifolia* is native to Western Canada to the north-central United States, primarily growing in temperate habitats like dry, rocky upland prairies,

barrens, and plains. Its flowering period is from May to July.[9,26,32,33]

*Echinacea pallida* is native to the central region of the United States, particularly in the Mississippi Valley, the southeastern Great Plains, and the region around southern Lake Michigan. It thrives in prairies and dry, rocky soils and flowers from June to July.[3,10,30]

**1.8 Plant part and form:** Globally, the most commonly used *Echinacea* species in various applications are *E. purpurea, E. angustifolia,* and *E. pallida,* in that order. Echinacea preparations are made from one or more plant parts of these three species. These include the fresh, above-ground parts of *E. purpurea* harvested during flowering, as well as the fresh or dried roots of *E. purpurea, E. angustifolia,* and *E. pallida*.[34-36] Commercial echinacea preparations are available in different forms, including dried root or herb (whole, cut, or powdered), liquid or dry extracts, tinctures, dried or fresh-pressed juice, teas, liquid preparations, tablets, capsules, and even injectable preparations.[37] Injectable preparations were previously available in Europe but are now banned in Germany and other countries due to the potential risk of severe allergic reactions, including anaphylactic shock, in hypersensitive individuals.[38,39] In North America, encapsulated powders, tinctures, and extracts made from both the roots and aerial parts of *E. purpurea* and *E. angustifolia* are commonly marketed. In Europe, the pressed juice of *E. purpurea* aerial parts or hydroalcoholic extracts from the fresh herb and roots of *E. purpurea* are sold as over-the-counter (nonprescription) medicines.[40] *Echinacea angustifolia* is found in homeopathic remedies in Europe (W. Weber [Schwabe Group] email to S. Gafner, December 11, 2024, and R. Schoop [A. Vogel, AG Switzerland] email to S. Gafner, January 24, 2025) and the United States, but they are not included in the US Homeopathic Pharmacopoeia.

**1.9 General use[s]:** *Echinacea* species have long been valued for their medicinal properties. Historically, many Native American tribes used *E. purpurea, E. angustifolia*, and *E. pallida* to treat toothaches, coughs, digestive issues, throat problems, and cold or flu symptoms. *E. angustifolia* and *E. pallida* were especially common for pain relief, treating snakebites, and managing skin conditions. In contrast, *E. purpurea* was mostly used for coughs or throat ailments.

Among the three species, *E. angustifolia* was the most widely used. Its traditional uses closely resemble those of *E. pallida*. This similarity is largely due to historical confusion between the two species. The widespread use of *E. angustifolia* and *E. pallida* for toothache relief is notable among tribes like the Blackfoot, Cheyenne, Dakota, Lakota, Omaha, Pawnee, Ponca, and Winnebago. Meanwhile, *E. purpurea* appears more often for coughs and venereal issues, especially among the Choctaw and Delaware.[1-3,41,42] The first commercial *Echinacea* preparation, Meyer's Blood Purifier, was introduced to the US market around 1880, primarily for treating rheumatism, neuralgia, and snakebites.[43] The first report on *Echinacea* was published in Europe in 1897, and *Echinacea* root was included in Dr. Wilmar Schwabe´s Homeopathic Pharmacopoeia in 1924. Madaus (1939) and Vogel (1950) later established *Echinacea* cultivation in Germany and Switzerland, respectively.[43]

Current interest in echinacea focuses on its immunomodulatory properties, particularly its role in the prevention and treatment of the common cold, influenza, and upper respiratory tract infections.[31,37,44,45] *Echinacea* extracts are widely used as ingredients in dietary supplements and herbal medicines, primarily for their ability to stimulate the immune system and help prevent inflammatory and viral diseases.[34,46] *Echinacea purpurea* is commonly included in dietary supplements and teas that are aimed at supporting immune health and reducing cold symptoms. Additionally, it is used in topical preparations for skin conditions.[44,46-48] *Echinacea angustifolia* and *E. pallida* are employed primarily as root extracts for similar purposes.[49,50] A publication from 2024 reported an investigation into the possibility of *Echinacea* products reducing the need for antibiotic prescriptions for people by preventing respiratory tract infections and their complications.[51]

**1.10 Key constituents and chemical markers:** *Echinacea* extracts have a complex chemical composition (Table 1). Caffeic acid derivatives like cichoric acid and caftaric acid are prominent in *E. purpurea* herb and root. Cichoric acid is found in all flowers of commercially used *Echinacea* species (1.2–3.1%) and the root of *E. purpurea* (0.6–3.2%).[45] Echinacoside is the major caffeic acid derivative of *E. pallida* and *E. angustifolia* roots but is largely absent or found only in trace amounts in both the herb and roots of *E. purpurea*.[37] In *E. angustifolia*, the highest concentrations of cynarin (1,3-dicaffeoylquinic acid) and echinacoside are found in the root bark and secondary roots.[37,44,46,52]

The European Pharmacopoeia defines caffeic acid derivatives as marker compounds for evaluating *Echinacea* materials. According to the European Pharmacopoeia, 11th edition, *E. purpurea* roots should contain a minimum of 0.5%, while aerial parts should

contain at least 0.1% of the sum of caftaric acid and cichoric acid. The echinacoside content in *E. angustifolia* and *E. pallida* roots should not be less than 0.5% and 0.2%, respectively.[45,53-56] Figure 1 shows the chemical structures of key compounds characteristic of *Echinacea* species.

Alkamides, also known as alkylamides, are important lipophilic constituents in *Echinacea* species, especially in *E. purpurea* and *E. angustifolia*, while only trace amounts are found in *E. pallida*. Alkamides are believed to contribute significantly to anti-inflammatory properties of *Echinacea* species.[37,46,57,58] They are also known for causing a tingling and numbing sensation in the lips and tongue when chewing plants that contain these compounds.[57-59] *E. pallida* has almost no numbing effect but is rather very acrid.[10] More than 25 different alkamide structures have been identified from *Echinacea* species. Structurally, they are characterized by the presence of isobutyl or 2-methylbutyl amines linked to an unsaturated fatty acid chain containing one or more double or triple bonds. The major alkamides in *E. purpurea* are predominantly 2,4-diene type compounds, while *E. angustifolia* roots contain primarily monoene alkamides and tetraenes.[60]

Polysaccharides and glycoproteins from the aerial parts of *E. purpurea* and the roots of *E. pallida* and *E. angustifolia* have been extensively studied for their immunomodulatory effects, particularly in response to infections or wound healing.[44,46] The aerial parts and roots of *E. purpurea* contain heterogeneous polysaccharides, including arabinogalactans and an arabinogalactan-containing glycoprotein composed of arabinose, galactose, and galactosamine.[37,61] In contrast, *E. angustifolia* root mostly contains a high molecular weight pectin, which is rich in galacturonic acid methyl esters, along with low molecular weight polysaccharide inulin.[62] A high molecular weight fraction of *E. pallida* also contains polysaccharides and glycoproteins that have demonstrated in vitro antiviral and immune stimulatory activity by enhancing mouse splenocytes and production of IFN-γ and IgM.[60,63]

Essential oils are present in varying amounts in the root, leaf, flowers, and aerial parts of *Echinacea* species with different yields and chemical compositions. The yield of essential oil from *Echinacea* roots generally ranges from 0.3 to 2.4% (v/w), while that of the aerial parts varies between 0.1 and 1.8% (v/w).[37,46,52]

Overall, the distinct chemical profiles of these compounds contribute to the medicinal properties and uses of each *Echinacea* species. Table 2 compares the levels of major compounds in *Echinacea* species and provides an overview of their key constituents.

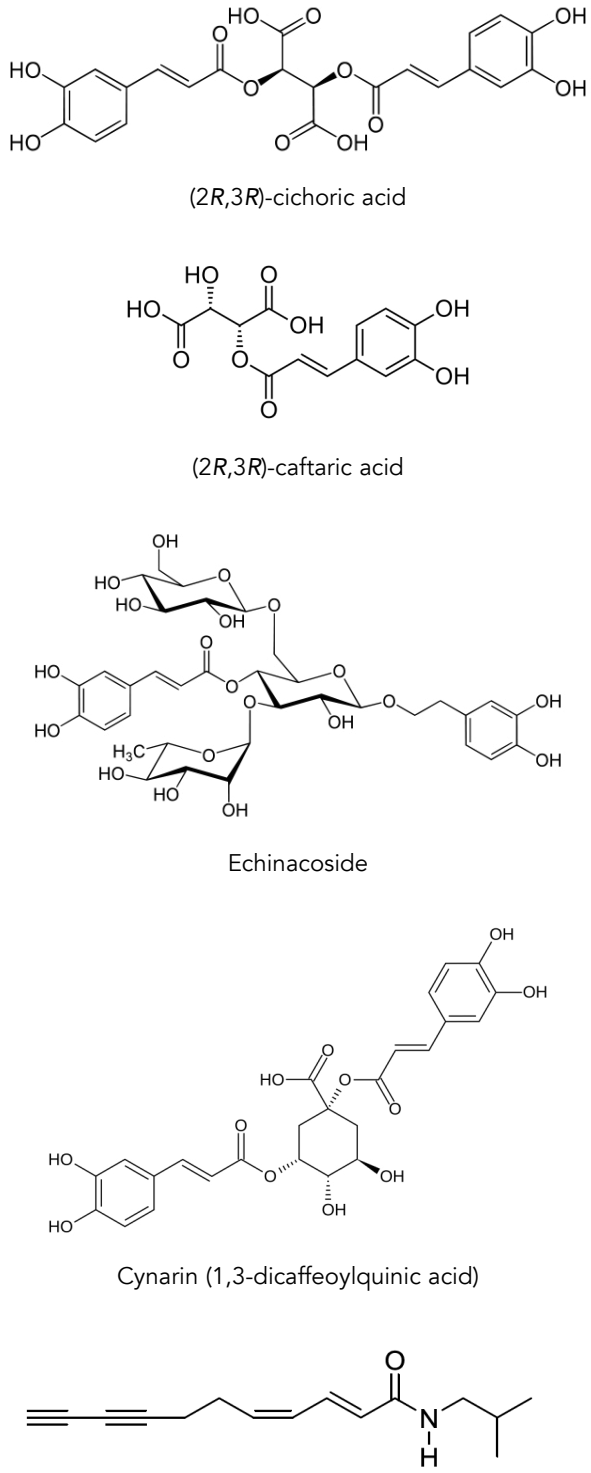



**Figure 1. Key Compounds of *Echinacea* Species**

## 2. Market

### 2.1 Importance in the trade:

Herbal products derived from the roots and aerial parts

of *E. purpurea* and the roots of *E. angustifolia* and *E. pallida* are among the most widely used herbal supplements in Europe and North America.[72] The preferences for *Echinacea* species vary significantly by region and by availability, influencing the types of products available to consumers. Although *E. angustifolia* has traditionally been the most widely used species (see Section 1.9), *E. purpurea* is less challenging to cultivate and produces higher yields, which has led to its wider global use.[31,33] As a result, *E. purpurea* and *E. angustifolia* are the most commonly used species in North America, whereas in Europe, *E. purpurea* and *E. pallida* are more popular.[40]

The echinacea extract market size in the US Mainstream Channel reached close to $25 million in 2023.[73] *Echinacea purpurea* is the most commercially significant species.[44] Germany, France, the United Kingdom, Italy, Spain, Poland, and the Netherlands are the European countries with the biggest opportunities for marketers of immune-stimulating botanicals, including echinacea. These countries have a strong natural health product industry and a growing consumer demand for *Echinacea*-containing products, many of which are sold as food supplements.[74]

Regarding herbal ingredients, the European Advisory Services (EAS) highlighted that ginkgo (*Ginkgo biloba*, Ginkgoaceae), followed by echinacea, was the most commercially significant botanical in the combined markets of 17 EU Member States. However, it is worth noting that echinacea is also included in products registered as medicinal drugs. The European Medicines Agency's (EMA's) Herbal Medicinal Products Committee (HMPC) has established herbal monographs for all three *Echinacea* species.[75,76]

**Supply sources:**

Since *Echinacea* plants are native to North America, all wildcrafted material originates exclusively from this region. According to the American Herbal Pharmacopoeia (AHP), wild populations of *E. purpurea* are scattered and typically of low density. As a result, all commercial supplies of this species are cultivated.[7,31] From 1999 to 2017, *E. angustifolia* was the only *Echinacea* species reported to have significant amounts of wild-harvested dried root, reaching 13 metric tons in 2017.[33,77] The wild-harvest tonnage survey of *E. angustifolia* root showed a substantial fluc-

**Table 1. Major Constituents of *Echinacea* Species Used Medicinally**[31,44-46]

| **Species** | ***E. purpurea*** | ***E. purpurea*** | ***E. angustifolia*** | ***E. pallida*** |
|---|---|---|---|---|
| **Plant Part** | Root | Herb | Root | Root |
| **Constituents** | – Alkamides<br>– Caffeic acid esters, mainly cichoric and caftaric acid<br>– Polysaccharides<br>– Polyacetylenes | – Alkamides<br>– Caffeic acid esters, mainly cichoric and caftaric acid<br>– Polysaccharides<br>– Polyacetylenes | – Alkamides<br>– Caffeic acid esters, mainly echinacoside and cynarin<br>– Polysaccharides<br>– Polyacetylenes | – Caffeic acid esters, mainly echinacoside<br>– Polysaccharides<br>– Polyacetylenes |

**Table 2. Levels* of Major Constituents in *Echinacea* Species Used Medicinally**[44,57,63-71]

| **Species** | ***E. purpurea*** | ***E. purpurea*** | ***E. angustifolia*** | ***E. pallida*** |
|---|---|---|---|---|
| **Plant Part** | Root | Herb | Root | Root |
| **Alkamides** | 0.12–2.8 | 0.2–3.9 | 0.19 | < 0.01 |
| **Echinacoside** | < 0.01 | < 0.01 | 0.83–1.55 | 0.07–1.7 |
| **Cichoric acid** | 0.6–3.2 | 0.5–2.8 | < 0.1 | 0.01–0.22 |
| **Caftaric acid** | 0.2–0.6 | 0.2–0.9 | < 0.01 | < 0.01 |
| **Cynarin** | < 0.01 | < 0.01 | 0.07–0.12 | < 0.01 |

*All values are mean % w/w of dried plant material

tuation over the years and dropped to one metric ton in 2023. No wild-harvested *E. purpurea* or *E. pallida* roots were documented between 1997 and 2017. However, for both 2020 and 2021, 1.9 and 1.5 metric tons, respectively, of wild-harvested *E. pallida* roots were recorded, possibly due to an increase in demand during the COVID-19 pandemic.

The volume of cultivated *E. angustifolia* dried root in North America dropped from 71 metric tons in 2014 to below one metric ton in 2015, then increased again in subsequent years to reach 51 metric tons in 2023. On the other hand, cultivated North American *E. purpurea* dried root harvest reached 117 metric tons in 2020, with a decrease to 58 metric tons in 2022 followed by an increase to 109 metric tons in 2023. The reported harvest of cultivated *E. purpurea* aerial parts increased 189 metric tons in 2020 and then settled 140 metric tons in 2023. Pandemic-related supply and demand factors played a key role in these fluctuations.[77,78] The only published information retrieved on cultivation areas outside North America is from the early 2000s: Using the average root yield of 1.7–5.8 metric tons/ha for Germany, and a 60 ha cultivation area for *E. purpurea* in the year 2000 in Germany, an estimated 102–348 metric tons of *E. purpurea* roots was cultivated in that year.[79]

In North America, a significant part of the supply comes from certified organic farms located in the Pacific Northwest (British Columbia, Oregon, Washington), the Midwest (Michigan, Minnesota, Wisconsin), and the East Coast region (Maine, New York, North Carolina, Vermont), among other states. The majority of *Echinacea* is grown in the Western region, with the Pacific Northwest leading in terms of production volume (E. Fletcher [Native Botanicals Inc.] email to S. Gafner, December 11, 2024). In Europe, the commercial supply primarily originates from farms in Germany and Switzerland, with additional material sourced from France, Austria, Italy, the Netherlands, Spain, Ukraine, and other countries.[31] New Zealand, Russia, Iran, China, and the Republic of South Africa (RSA) also have well-established cultivation of *Echinacea*, primarily *E. purpurea* and *E. pallida*.[80-83]

Commercial cultivation of *E. purpurea* began in Switzerland and Germany in the 1930s by naturopaths Alfred Vogel and Gerhard Madaus, while large-scale commercial cultivation in the United States did not start until the 1980s.[31] In Russia, the cultivation of *E. purpurea* began after the plant was introduced from North America in 1924, with the first field production starting in southern Russia in 1936. Field production of *Echinacea* has been established in countries in South and Central America, including Brazil, Chile, Argentina, and Costa Rica, since 1998. Currently, the RSA has commercial production of hydroalcoholic extracts that supply some of the bulk *Echinacea* ingredients to Western European and North American markets.[75,83]

**Echinacea** *Echinacea angustifolia*
Photo by Steven Foster, ©2025 ABC

## 2.3 Market dynamics:

The *Echinacea* supplement market in the United States experienced notable fluctuations from 2018 to 2023, as reflected in sales data from the *HerbalGram* Herb Market Reports (Table 3). In the Natural Channel, which includes sales figures from natural and health food stores, *Echinacea* sales peaked in 2020 at approximately $12.86 million, ranking 9th among herbal supplements. This surge was likely driven by increased consumer interest in immune-supportive products during the early stages of the COVID-19 pandemic. The increase in sales during the pandemic was also noticeable in Germany and the entire European market. Specifically, from March/April 2019 to March/April 2020, sales volumes of *E. purpurea* and *E. pallida* increased by 195.6% and 199.4%, respectively (T. Brendler [Plantaphile] email to S. Gafner, July 14, 2020).

A wide range of *Echinacea* products is available on the market in Germany, all of which have been authorized or registered under pharmaceutical law and most of which were initially approved long before the HMPC monographs were developed. In the 2021 ranking of best-selling pharmacy-only medicines in Germany published by the newspaper *DIE ZEIT*, four *Echinacea*

products were in the top ten and they became more popular during the SARS-CoV-2 pandemic.[84] Sales growth in Europe, especially in Switzerland, has demonstrated greater sustainability and has persisted after 2020. In a more regulated market primarily composed of registered pharmaceutical-level *Echinacea* brands, sales have experienced fewer fluctuations and continue rising beyond the pandemic.

The year-to-year sales data from the US mainstream multi-outlet channel (MULO, Table 3) are more difficult to interpret, as the way such data was analyzed by SPINS, a leading market research company, has undergone several changes. The numbers that represent the change in sales compared to the previous year, therefore, give a better idea of the interest in echinacea. *Echinacea* ranked 2nd in 2018 with sales of $110.33 million, indicating strong mainstream consumer demand at that time in the United States. There was a notable sales spike in 2020 due to the start of the COVID-19 pandemic and a notable decrease in sales in the following year.[73,85-88] The large decrease in echinacea sales in 2021 is likely a result of market saturation after the initial peak during the pandemic. The spike in demand during the pandemic may also not have been sustained due to increased competition from other immune-support supplements like elder (*Sambucus nigra*, Viburnaceae) berry, ashwagandha (*Withania somnifera*, Solanaceae) root, mushrooms, and vitamins.[88] Moreover, consumer preferences have shifted toward multi-herb formulations rather than single-herb supplements.[87] It is not clear what caused the decrease in echinacea sales in 2023 compared to 2022, as the estimated number of influenza cases was comparable to pre-pandemic years.[89] Echinacea supplements remain among the top 25 best-selling herbal products, showing their continued significance in the market. The stabilization of sales in the natural channel indicates sustained consumer interest within the natural health food sectors. While sales have declined in mainstream retail outlets, echinacea's ongoing popularity highlights its established role in herbal supplements and its importance to people seeking natural health remedies.

## 3. Adulteration

### 3.1 Known adulterants:

*Echinacea* species, particularly *E. purpurea*, are subject to adulteration with various plant materials, which can compromise the quality and efficacy of echinacea products. Roots of American feverfew (*Parthenium integrifolium*, Asteraceae) were a common adulterant of *Echinacea* root products due to morphological similarities when cut and sifted, although they possess distinct flavor and fragrance characteristics. Another factor that may contribute to this confusion is the shared common name "snakeroot" for both species.[46,90,91] Educational campaigns for improved quality control measures have substantially reduced or altogether eliminated the occurrence of this specific adulterant in the market.[92] Roots of other plant species, such as *Lespedeza capitata* (Fabaceae),[90,93-96] *Eryngium aquaticum* (Apiaceae),[90,93-97] and several members of the Asteraceae family, e.g., *Rudbeckia nitida*,[90,93-95,97] *Helianthus annuus*,[90,93-96] *Echinacea atrorubens*,[46] *Liatris aspera*,[90,94,95] and *Liatris punctata*,[46] are also listed as historic adulterants for *Echinacea* species, but no such occurrences have been reported in the past few years.

A recent investigation by herbal dietary supplement manufacturer NOW Foods (Bloomingdale, IL) highlighted the adulteration of an *E. angustifolia* extract with *Cistanche* (Orobanchaceae) species.[94,98,99] *Cistanche* is widely used in traditional Chinese medicine (TCM), and the trade of *C. deserticola* is regulated under the Convention on International Trade in

**Table 3. Sales Data for Echinacea Dietary Supplements in the United States from 2018–2023**[73,85-88]

| | 2023 | | 2022 | | 2021 | | 2020 | | 2019 | | 2018 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rank | Sales ($) | Rank | Sales ($) | Rank | Sales ($) | Rank | Sales ($) | Rank | Sales | Rank | Sales ($) |
| US Natural Channel[a] | 14 | 9,204,852 | 13 | 9,047,270 | 15 | 7,600,413 | 9 | 12,856,524 | 9 | 10,401,555 | 9 | 9,979,769 |
| US MULO Channel[b] | 18 | 24,665,527 | 9 | 30,209,717* | 11 | 41,197,214 | 7 | 57,345,210 | 2 | 120,731,014 | 2 | 110,331,569 |
| % Change in MULO sales volume over the previous year | –18.4% | | +5.1% | | –24.3% | | +36.8% | | +4.9% | | +15.1% | |

[a] This channel includes co-ops, associations, independent stores, and large regional chains (excluding Whole Foods Market and Trader Joe's) and other full-format stores with $2 million+ in annual sales representing more than 2000 stores.
[b] This channel includes grocery outlets, drug outlets, and selected retailers across mass merchandisers, including Walmart, club, dollar, and military stores representing more than 105,000 retail locations.
* This number is the updated 2022 sales total after SPINS implemented data coding and channel definition changes in 2023.

Endangered Species of Wild Fauna and Flora (CITES), Appendix II, to prevent unsustainable use.[100] Generally, four species of *Cistanche* are encountered in the market. *Cistanche deserticola* and *C. tubulosa* are official species listed in the Chinese Pharmacopoeia as Cistanches herba. The other two species, *C. salsa* and *C. sinensis*, are consumed in certain regions or are considered adulterants of Cistanches herba.[101] Due to the similarity in phenylethanoid profiles, especially the high concentrations of echinacoside, *Cistanche* species can be used to intentionally adulterate *E. angustifolia* extracts. The average market prices of Cistanches herba in TCM markets are lower than those of *E. angustifolia* root in the United States and Europe (J. Brinckmann [American Botanical Council] email to S. Gafner, December 12, 2024), suggesting that some companies may purposefully bypass CITES documentation by mislabeling *Cistanche* extracts as *E. angustifolia* or *E. pallida*. Although *E. angustifolia*, *E. pallida*, and *Cistanche* species all contain echinacoside in their phenylethanoid compositions, their overall chemical profiles differ significantly. *Cistanche* species are characterized by high levels of verbascoside (also known as acteoside), tubuloside A, and cistanosides, which can be used to differentiate them from *Echinacea* species. These distinct compounds in *Cistanche* serve as chemical markers for identification and help in preventing adulteration.[99,101,102] In addition to adulteration with different plant species, mix-ups can also occur among species of the genus *Echinacea*. The roots of *E. angustifolia*, *E. pallida,* and *E. atrorubens* are sometimes confused due to their macroscopic and microscopic similarities. Their identification is also challenging due to overlapping growing region and frequent hybridization between species.[29,103-105]

Studies examining echinacea preparations have observed that some of the marker components are present in low amounts or are altogether absent. This could be due to a breakdown of active ingredients, which can occur during processing and storage (especially when fresh plant material is used), or due to the prevalence of highly diluted extracts, which has been the subject of another BAPP publication.[106,107] The quality of *Echinacea* roots for commercial applications depends on various factors, including seed stock quality, soil type, planting time, seed viability, moisture levels, temperature fluctuations, fertilization methods, pest control, harvest timing, and post-harvest handling procedures.[44] For instance, very dense plant populations have led to increased biomass production, but the cichoric acid concentration in the plant decreased, which highlights the impact of cultivation

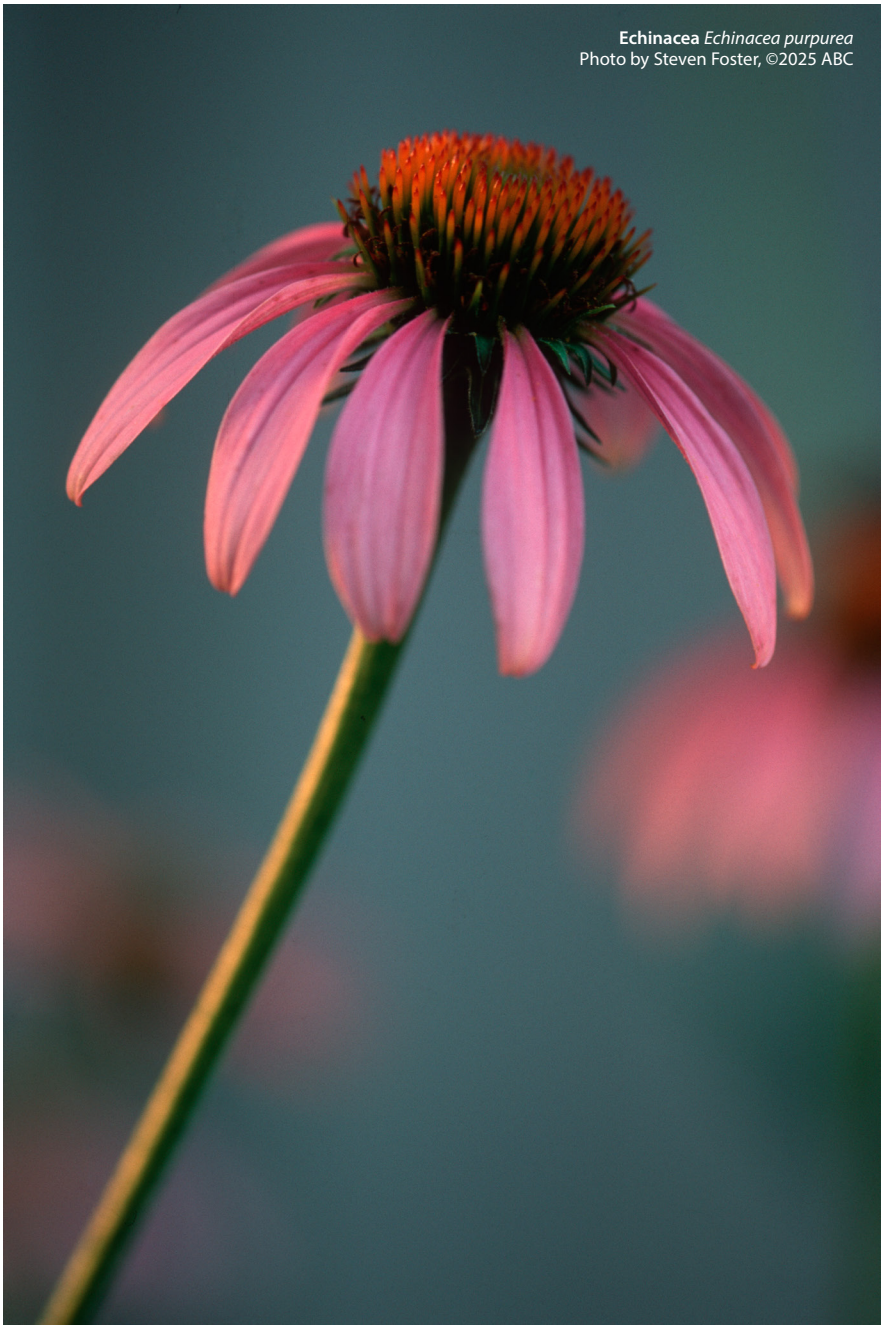
**Echinacea** *Echinacea pallida*
Photo by Steven Foster, ©2025 ABC

Echinacea *(Echinacea purpurea, Echinacea angustifolia,* and *Echinacea pallida)*

practices on root quality.[108,109] Caffeic acid derivatives and alkamides are sensitive to heat and humidity, and increased temperature and humidity can cause significant losses in these compounds.[69,110]

Another possibility is that some of these products contain large amounts of often-undisclosed excipients, such as maltodextrin or rice (*Oryza sativa*, Poaceae).[106,107] These highly diluted extracts or plant materials are not seen as a safety concern, but they often do not deliver the expected herbal benefits, which may conflict with labeling claim rules. A unique historical case of dilution was reported by James Kababick (Flora Research Laboratories email to S. Gafner, February 3, 2025), when a manufacturer noticed the presence of large amounts of the mineral pyrite attached to a magnetic roller. The presence of substantial concentrations of the mineral, added to increase the weight of the root powder, was eventually confirmed by Flora Research Laboratories.

Adulteration, species mix-ups, dilution, and variations in the quality or standardization of raw plant materials highlight the importance of following proper quality control methods and ensuring accurate species identification in echinacea products. The situation in the United States differs significantly from that in Europe, where certain *Echinacea* products are classified as pharmaceutical-grade and are registered with regulatory authorities. In Europe, continuous and rigorous quality checks are mandatory before herbal medicinal products are released to the market, ensuring the highest standards of quality.



**Echinacea** *Echinacea purpurea*
Photo by Steven Foster, ©2025 ABC

### 3.2 Sources of information supporting confirmation of adulteration:

The adulteration of echinacea products has been a documented concern for over a century. *Parthenium integrifolium* has been recognized as a historical adulterant of *Echinacea*, with its presence reported in commercial *Echinacea* lots since the early 1900s.[31,90] In 1985, Bauer et al identified four new sesquiterpene esters from material believed to be *E. purpurea*. Later, they discovered the test material was actually *P. integrifolium* and confirmed that *P. integrifolium* was a widespread adulterant in *E. purpurea* products.[90,91,111-113] This adulteration was detected as recently as 2002 in an American finished product using HPTLC analysis.[114] Although various adulterants are mentioned in the literature,[93,95] studies have confirmed the presence of unidentified botanical ingredients in commercial products rather than specific adulterants.[107] For example, Gilroy et al analyzed echinacoside and cichoric acid levels in 59 echinacea products and found that label claims were consistent with

the contents in only 52% of samples.[115]

Additionally, an investigation of 53 *Echinacea* herbal products marketed across Europe revealed significant differences between ingredients listed on the label and those detected using DNA metabarcoding. All tested products showed inconsistencies, resulting in an overall 57% discrepancy between the labeled ingredients and the actual contents, including instances of mixtures of *Echinacea* species in products claiming to contain a single ingredient.[95] Supporting this, Orhan et al analyzed echinacea adulteration reports published between 2000 and 2023 and found that none of the previously reported adulterants were detected in the studies summarized in their analysis. However, they discovered that 57 out of 200 bulk ingredients and finished products were adulterated and/or mislabeled, a 29% adulteration rate.[94] Additionally, potential adulteration with other *Echinacea* species and dilution of ingredients with substantial amounts of undisclosed excipients such as rice and maltodextrin have become apparent, raising concerns about product authenticity and efficacy.[97,98,106,107] These issues highlight the ongoing challenges in ensuring the quality, integrity, and safety of *Echinacea* products in the marketplace.

### 3.3 Accidental or intentional adulteration:

Adulteration of *Echinacea* products began in the United States even before its exportation to Europe, which started in 1939.[93] High demand and increased prices for echinacea may contribute to a higher risk of adulteration, whether intentional or accidental. For *E. angustifolia* and *E. pallida*, morphological differentiation is very challenging, leading to occasional substitution or mislabeling.[96,105,115] Before 1987, many studies that claimed to focus on *E. angustifolia* were examining *E. pallida* due to inadequate species identification methods.[10,90] In most cases, such mislabeling is considered accidental, although some cases of intentional adulteration may occur when root material is substituted with aerial parts or heavily diluted for economic gain. Since the wholesale costs for *E. purpurea* roots are about a quarter of those of *E. angustifolia*, and about half of those of *E. pallida*, it is possible that some of the observed mislabeling issues are attempts to lower costs by substituting *E. angustifolia* or *E. pallida* with *E. purpurea*. Adulteration with aerial parts can often be detected by observing a strong chlorophyll band in HPTLC. Edward Fletcher from Native Botanicals, Inc., notes that adulteration does not appear to be an issue at the crude raw material stage but may become more frequent in later stages of the production process (email to S. Gafner, December 11, 2024). These issues emphasize the importance of proper species identification and strict quality control measures in the production of *Echinacea* products to ensure their authenticity and effectiveness.

### 3.4 Frequency of occurrence:

There is no comprehensive published study quantifying the frequency of *Echinacea* adulteration, but information from various publications indicates that adulteration remains a significant issue. In the most extensive investigation to date, Orhan et al analyzed echinacea adulteration reports published between 2000 and 2023 and found that 57 out of 200 (28%) bulk ingredients and finished products were adulterated with unidentified botanical ingredients and/or were mislabeled.[94] This suggests that adulteration, whether intentional or accidental, continues to be a concern in the echinacea market.

### 3.5 Possible safety/therapeutic issues:

*Echinacea* species are generally well tolerated when used at recommended doses, with a low incidence of adverse effects. Clinical trials involving the most common echinacea species, *E. purpurea,* have not indicated significant safety concerns over extended periods in large populations.[116-118] Most reported adverse events are mild and temporary, commonly involving gastrointestinal disturbances or skin reactions, which are also seen with placebo at a comparable frequency.[61,63,119] Although *Echinacea*-induced hepatitis is extremely uncommon and only a few reports can be found in the literature, *Echinacea* should be used with caution in patients with liver impairment.[120-122] Hypersensitivity reactions, including severe allergic responses, have been reported, though such cases are rare and mostly in relation to intravenous application.[39,123-126] Individuals who are allergic to plants in the Asteraceae family are advised to avoid echinacea products due to the potential for allergic reactions. This precaution is particularly important for atopic or immunosuppressed patients.[48-50]

There have been no reported cases of toxicity resulting from adulteration.[31] In light of the most recently reported adulterant, *Cistanche* species,[99] it is important to note that these herbs are popular in the health food market in China because of their putative nourishing properties. Research on the toxicity and safety of Cistanches herba indicates that this herbal ingredient is generally considered safe but conclusive evidence from toxicity studies is largely missing.[102,127]

Therefore, when evaluating adulteration, a greater concern may be the potential lack of expected therapeutic effects due to the excessively diluted products, or accidental or intentional mixing of different *Echinacea* or substitute species. Such species mix-ups can alter the chemical composition of the product,

potentially leading to a reduction in efficacy.[31,98] While *E. purpurea* and *E. angustifolia* are widely used for their roles in supporting the immune system and treatment of upper respiratory tract infections, the effects of *E. pallida* remain less clear as it has been less studied.[128] Despite this, it is included in some formulations aimed at immune support. The authenticity and correct identification of *Echinacea* species in products are crucial to provide the intended health benefits to consumers.

### 3.6 Analytical methods to detect adulteration:

Before discussing the analytical methods used to detect adulteration in *Echinacea* products, it is important to highlight the morphological similarities among echinacea species, particularly between *E. angustifolia* and *E. pallida*. These similarities have often led to confusion in the medicinal plant market, resulting in the misidentification of specimens.[44,90]

To address these challenges, the study of morphological, microscopical, and chemical characteristics of *Echinacea* is crucial. Detailed descriptions, photographs, and illustrations of the morphology and microscopy of *E. purpurea, E. angustifolia, E. pallida*, and *P. integrifolium* that differentiate between the species and select adulterants are provided in the monographs of the American Herbal Pharmacopoeia (AHP), European Pharmacopoeia (Ph. Eur.), United States Pharmacopoeia (USP), and several other publications.[7,9,10,29,129] Similar macroscopic and microscopic features of three echinacea species make identification difficult, particularly for the microscopic evaluation when samples are in powdered form.[130]

In addition, DNA-based methods have been described as useful tools for identifying adulteration in echinacea materials.[93] The random amplified polymorphic DNA (RAPD) technique is reportedly helpful for the discrimination between *E. purpurea, E. angustifolia, E. pallida,* and *E. atrorubens*. RAPD markers are sensitive enough to detect the presence of *P. integrifolium*, a historical adulterant of *Echinacea*.[131,132] However, RAPD assays are known for their poor reproducibility, hence, newer genetic techniques have been developed. Zhang et al noted that DNA barcoding methods (using the *matK*, *rbcL*, and ITS regions) are not suitable for distinguishing *Echinacea* species but demonstrated that direct sequencing of genomic DNA to obtain complete chloroplast genomes using Next Generation Sequencing (NGS) technologies can effectively differentiate nine

**Echinacea** *Echinacea purpurea*
Photo by Steven Foster, ©2025 ABC

*Echinacea* species.[96]

Validated analytical methods for determining identity and detecting known adulterants are available for all three *Echinacea* species in the AHP, USP, the Farmacopea Herbolaria de los Estados Unidos Mexicanos (FHEUM), and Ph. Eur. monographs. Additionally, there are monographs for all three species in the national pharmacopoeias of Switzerland (Ph. Helv.) and the United Kingdom (BP), which are harmonized and identical with Ph. Eur. Quality monographs for the flowering aerial parts of *E. purpurea* are also included in the state pharmacopoeias of Belarus and the Russian Federation (J. Brinckmann, email to S. Gafner, December 12, 2024). Thin-layer chromatography (TLC) and high-performance liquid chromatography with ultraviolet detection (HPLC-UV) assays are recommended by AHP, USP, and Ph. Eur. for identification of the major constituents in echinacea and the qualitative determination of impurities using chromatographic fingerprints. TLC and especially high-performance thin-layer chromatography (HPTLC) are used for the identification of *Echinacea* species based on their alkamide and caffeic acid derivatives profiles. Each of the three primary species produces characteristic fingerprints, allowing for confident identification.[91,92,114,133,134]

Reich et al (2008) summarized a procedure for HPTLC-based identification of echinacea. Confounding species such as *E. atrorubens, L. punctata,* and *P. integrifolium* exhibit a considerably different fingerprint profile, facilitating their distinction from authentic *Echinacea* species.[92,133] In addition, TLC with video densitometry and HPTLC with high-resolution plate imaging allow the quantitative determination of certain marker compounds (echinacoside, cichoric acid, and chlorogenic acid) in commercial echinacea formulations.[135,136] Raclariu et al (2018) tested 53 echinacea products including herbal teas, capsules, tablets, and extracts marketed across Europe using a combination of HPTLC and DNA metabarcoding. Their study revealed significant discrepancies between labeled ingredients and those detected, with an ingredient fidelity of only 43%.[95] Another DNA-based identification method, genome skimming, was used to evaluate 20 commercially available *Echinacea* dietary supplements products, together with DNA metabarcoding and HPLC-UV. In this study, HPLC-UV successfully identified *Echinacea* species in most products, but there were discrepancies in the detection of adulterants, especially in multi-ingredient products. DNA metabarcoding also had limitations, failing to provide species-level identification in several cases, and only identifying plants at the family level. Compared to metabarcoding, genome skimming provided more detailed results, identifying *Echinacea* species to genus and species levels. It also detected the presence of other plants, such as rice (not listed on the label, although frequently used as an excipient) and goldenseal (*Hydrastis canadensis* [Ranunculaceae], listed on the label). In addition, genome skimming identified *E. laevigata* in a product where *E. purpurea* was expected.[107] These studies highlight the importance of combining both chemical and DNA-based methods for comprehensive product authentication, as both methods alone may not be sufficient to fully identify adulteration, particularly in complex, multi-ingredient formulations.

Numerous studies have used HPLC with single-wavelength UV or diode array detection (DAD) for determining major constituents in *Echinacea* and qualitatively detecting impurities. Fully validated HPLC-UV methods are widely available for analyzing caffeic acid derivatives. Specifically, quantitative HPLC-UV and HPLC-DAD systems have been employed extensively to measure caftaric acid, chlorogenic acid, cynarin, echinacoside, and cichoric acid in powdered raw materials or commercial extracts of *E. purpurea, E. angustifolia*, and *E. pallida*.[65,137-139] To enhance analytical capabilities, HPLC-DAD coupled with electrospray ionization mass spectrometry (HPLC-DAD/ESI-MS) or other types of MS offers the advantage of having MS data to support structure confirmation. An ultra-fast liquid chromatography method with DAD and tandem mass spectrometry (UFLC-DAD-MS/MS) was developed for the qualitative analysis of alkamides in *Echinacea* root materials and commercial products. The alkamides are readily ionized in positive mode due to the presence of a nitrogen atom and are particularly suitable for MS detectors.[57]

For the analysis of volatile compounds in *Echinacea* species, gas chromatography-mass spectrometry (GC-MS) remains the preferred analytical technique, for both qualitative and semi-quantitative characterization. High molecular weight components, such as polysaccharides and glycoproteins, require more complex analyses, which may include matrix-assisted laser desorption ionization time-of-flight mass spectrometry (MALDI-TOF-MS) and nuclear magnetic resonance (NMR) for characterization. The quantification of these components has been achieved using HPLC with evaporative light-scattering detector (HPLC-ELSD).[46,140] Some authors have proposed to quantify the polysaccharides after isolation and hydrolysis using a color reaction involving phenol and sulfuric acid, but results are often difficult to reproduce in practice.[141,142] Polysaccharide analysis remains inconclusive for the identification of the species and is quantitatively challenging. Additionally, hyperspectral imaging combined with multivariate data analysis has been reported to differentiate the three main *Echinacea* species and identify those present in commercial products.[143]

## 4. Conclusions

Despite substantial fluctuations in global sales, echinacea products rank among the most popular herbal products. Reports of adulteration, mislabeling, and species mix-ups in echinacea products highlight the ongoing challenges in ensuring their quality and efficacy. While advancements in quality control measures have reduced or eliminated certain types of adulteration, such as the substitution with *P. integrifolium* roots, other concerns remain, including species misidentification, adulteration with *Cistanche* species, and undeclared excessive dilution. These occurrences emphasize the importance of strict quality control measures, accurate species identification, and proper harvesting and processing methods to maintain the integrity of echinacea products.

Morphological (macro- and microscopic) and organoleptic assessments provide rapid and cost-effective methods for authenticating *Echinacea* species. For example, the tingling sensation is characteristic of *E. purpurea* and *E. angustifolia*, allowing a distinction from *E. pallida*. In addition, HPLC-UV/Vis, HPLC-UV/Vis-ESI-MS, HPLC-ESI-MS/MS, HPTLC, and GC have been used for the analysis of compounds present in *Echinacea* raw materials and products. HPLC-UV and HPLC-DAD have been primarily used for identifying and quantifying key constituents and impurities. HPLC coupled with mass spectrometry enhances the ability to identify impurities and provides structural information. Combining chromatographic methods with high-resolution digital plate imaging, hyperspectral imaging, or DNA-based methods offers a comprehensive approach to detecting adulteration in *Echinacea* products and species mix-ups. Traceable sourcing from certified cultivation or wild collection following good agricultural and collection practices (GACP) will also significantly reduce the risk of adulteration or mix-ups. Since adulteration patterns of echinacea continue to evolve, regular monitoring and effective quality control measures of the products are essential to ensure the authenticity and effectiveness of *Echinacea* products.

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**Echinacea** *Echinacea pallida*
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## Revision summary

| Version # , Author, | Date Revised | Section Revised | List of Changes |
|---|---|---|---|
| Version 1, Ü. Şebnem Harput Döner, Stefan Gafner | N/A | N/A | None |