Tales from the Elder: Adulteration Issues of Elder Berry

A review of analytical laboratory evidence documenting adulteration and fraud in the international market for elder berry ingredients

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Elder berry *Sambucus nigra*
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Botany and Taxonomy

The European elder* (*Sambucus nigra* L., syn. *S. nigra* subsp. *nigra* L., Viburnaceae) is a shallow-rooted tree that can grow up to 10 m (32.8 feet) tall and yields small, round fruit (6-8 mm in diameter) that are dark purple to violet when ripe. The species is distributed throughout most of Europe, from southern Scandinavia to northern Spain, Italy, and Turkey, and east to the Caucasus Mountains.[1] It has been introduced to North and South America and Oceania. The native range of a closely related and morphologically similar species, American elder (*Sambucus canadensis* L., syn. *S. nigra* subsp. *canadensis* (L.) R. Bolli), extends from Nova Scotia and Quebec south through Florida, the West Indies, and Central America, and west from Manitoba to montane Mexico.[2,3] Other medicinally used elder species include the southern elder (*S. australis* Cham. & Schltdl.), blue elder (*S. cerulea* Raf.), dwarf elder (*S. ebulus* L.), Chinese elder (*S. javanica* subsp. *chinensis* (Lindl.) Fukuoka, syn. *S. chinensis* Lindl.), and Williams elder (*S. williamsii* Hance).[4]

The taxonomy of the main elder species in trade is a matter of debate. The five taxonomic databases[5-9] consulted for this article consider *S. cerulea*, *S. nigra,* and *S. canadensis* to be separate species, placing them alternatively into the Viburnaceae[5,8,9] or Adoxaceae family.[6,7] (The US National Plant Germplasm System also lists *S.*

* Another common name for *S. nigra* is black elder, or European black elder, to distinguish the species from red elder (*S. racemosa*). Similarly, American black elder is used for *S. canadensis*.

nigra subsp. *nigra* as a separate species.) This is despite the most recent taxonomic evaluation of the genus by Bolli (1994),[10] who proposed classifying five formerly separate taxa (including *S. canadensis* and *S. cerulea*) as subspecies of *Sambucus nigra*. Bolli also argued for the placement of the genus in a separate family: Sambucaceae. A review of Bolli's work by Applequist[11] in 2015 supports the subspecies level of *S. nigra* subsp. *canadensis*, but not that of *S. cerulea*, since the latter is more easily distinguished from *S. nigra* based on its morphological characteristics.

Applequist also argued that the genus *Sambucus* should be placed in the Adoxaceae family.[11] However, several publications from 2020 and 2021 place *Sambucus* in the Viburnaceae family,[5,8,9] while most older publications prior to 2015 place it within the Caprifoliaceae family.[4,12,13] Weakley (2020) places *Sambucus* in the Viburnaceae or viburnum family (rather than the now obsolete Adoxaceae). It was also formerly placed in the Caprifoliaceae (pink family), or in some treatments in its own separate family, the Sambucaceae.[3,14]

As if such taxonomic confusion were not enough, sources disagree about the use of the common name "elder" versus "elderberry." The older literature commonly uses the term "elder" for the plant, and specifies the plant parts as "elder berry," "elder leaves," and "elder flowers." More recently, the term "elderberry" has taken hold in the literature for the fruit, while "elderflower" is used for the flower. Some authors even use "elderberry flower" in their publications.[15,16] The European Medicines Agency takes an interesting approach and uses "elderberry"[17] and "elder flower"[18] in their official texts, while the second edition of the *American Herbal Products Association's Herbs of Commerce*[4] specifies that the plant name is "European elder" for *S. nigra* and "American elder" for *S. nigra* subsp. *canadensis*.

History of Use

The berries of European elder have been used for various purposes since before recorded history. Archaeological evidence suggests that European elder trees have been cultivated for millennia. For example, elder seeds discovered in what are now Austria, France, Italy, and Switzerland have been dated to the Stone and Bronze Ages (4000–1000 BCE).[19-22]

Elder berries have longstanding use in herbal medicine. Information on the healing properties of the berry can be found often in writings that date back to antiquity, including in the works of Hippocrates (ca. 460–370 BCE), Pliny the Elder (ca. 23–79 CE), and Dioscorides (ca. 40–90 CE).[13] All parts of the elder tree were used as medicine in medieval Europe with a wide range of indications. John Parkinson's *Theatrum Botanicum* of 1640[23] includes extensive descriptions of the therapeutic uses of the various parts of the elder tree. Parkinson noted:

> [T]he berries also greene or dry, expell the same [choler and tough phlegme†] humors [as the inner bark] and [are] often given with the same successe to helpe the dropsie, by evacuating great plenty of waterish humors. … [T]he decoction of the roote cured the biting of the viper or adder, and also of a mad dogge, and mollified the hardnesse of the mother, if women sit therein, and openeth the veins, and bringeth downe their courses: the berries boyled in wine performe the same effects; the haire of the head or other parts, washed therewith, is made blacke. … [T]he juyce of the berries boyled with a little honey, and dropped into the eares, easeth the paines of them; the decoction of the berries in wine, being drunke, provoketh urine.[23]

Similarly, several parts of the American elder were used in traditional medicine systems of many indigenous peoples, especially in northern and northeastern North America. The Cherokee and Iroquois nations made preparations of American elder berries to treat fevers, and the Cherokee and Rappahannock for rheumatism.[12,24] Berries were also used by several tribes (e.g., the Haisla, Hanaksiala, Mi'kmaq, and Paiute) for gastrointestinal problems.[24] For example, the Mi'kmaq consumed the berries as a purgative and emetic,[12] and the Paiute ate dried ripe berries to treat diarrhea.[24]

While many of these uses and indications have disappeared over time, the flowers and fruits of elder trees are still widely used in traditional herbal medicine.[25] Elder berries are mostly used in the form of a juice or syrup as a mild laxative, diuretic, and diaphoretic agent for the common cold.[13,25,26]

Cultivars and Chemistry

Elder trees are grown as ornamental or fruit-producing plants in many areas of Europe, northern Africa, eastern Asia, and North America. Commercial interest in elder berries and flowers has led to the development of many elder cultivars.[27] Breeding began in the early 20th century and peaked in the middle of the century and led to the creation of several well-known European elder cultivars (e.g., Haschberg, Korsør, Samdal, Sampo, and Samyl) and American elder cultivars (e.g., Adams, Johns, Nova, Scotia, and York). According to industry sources, several cultivars are currently used for commercial purposes. For European elder, these include Allesoe, Haidegg, Haschberg, Korsør, Rubin, Sambu, Samdal, Sampo, Samyl, and Tattin, with Haschberg being the most widely used (T. Borchardt, email to S. Gafner, January 22, 2021; M. Bush, email to S. Gafner, January 21, 2021). Wyldewood 1 reportedly is the most widely used cultivar of American elder,[28] although one industry source suggests that the cultivars Bob Gordon, Pocahontas, and York provide better yields (D. Bennett [INS Farms], oral communication to S. Gafner, February 5, 2021).

† Choler (yellow bile) and phlegm are two of the four medieval humors, or body fluids; blood and black bile are the others. These four humors were believed to have made up the human body's constitution; an imbalance of the humors was believed to be the cause of disease.

Compounds of interest in elder berries include sugars, organic acids, terpenoids, phenolic compounds, and volatile constituents. Several papers have reported the contents of these metabolites, either measured in fresh (fresh weight, FW) or dried (dry weight, DW) fruit. Since elder berries contain between 72% and 78% water,[29] a conversion of literature data obtained from fresh fruits to dry fruit can be calculated approximately by multiplying with a factor of four. European elder contains 2.6–10.5 g glucose, 2.6–6.3 g fructose, and 0.05–1 g sucrose per 100 g FW of berries.[29] The main organic acids are citric acid (10.4–999 mg/100 g FW) and malic acid (7.4–882 mg/100 g FW), with smaller amounts of tartaric and shikimic acids. Ursolic and oleanolic acids are the most important triterpenoids in the berries.[29]

With regard to elder berry constituents, the focus has been mostly on the phenolic compounds, which include proanthocyanidins, anthocyanins, flavonol glycosides, and minor amounts of caffeoylquinic acid derivatives (e.g., chlorogenic acid) and simple phenolics. The anthocyanins in European elder are dominated by cyanidin-3-*O*-glucoside and cyanidin-3-*O*-sambubioside, with smaller amounts of cyanidin-3,5-*O*-diglucoside and cyanidin-3-*O*-sambubioside-5-*O*-glucoside. Total anthocyanin contents in European elder berries vary between 149–953 mg/100 g FW,[29] or between 250–1,368 mg/100 g FW depending on the authors.[30-33] Flavonol glycosides include mainly rutin (29–52 mg/100 g FW) and isoquercitrin (6.4–26.5 mg/100 g FW),[30,33] with small amounts of kaempferol-3-*O*-rutinoside, isorhamnetin-3-*O*-rutinoside, and 3-*O*-glucosides.

American elder berries contain similar amounts of sugars and organic acids. Thomas et al (2015)[34] reported glucose and fructose concentrations of 1.4–2.6 g/100 g FW and 1.4–3.1 g/100 g FW, respectively. Citric acid and malic acid contents were 163–501 mg/100 g FW and 194–441 mg/100 g FW, respectively.[34] Rutin concentrations reportedly range from 3.5–170 mg/100 g FW.[34,35] Rutin is the predominant flavonol in American elder berries as well; however, Thomas et al found slightly higher amounts of isorhamnetin-3-*O*-rutinoside (1.4–16.9 mg/100 g FW) in three out of nine cultivars.[34] Isoquercitrin concentrations were 0.4–48.5 mg/100 g FW.[34,35]

Contrary to the European elder, the anthocyanin profile in American elder berries is dominated by cyanidin-3-*O*-[6-*O*-(*E*)-*p*-coumaroyl]sambubioside-5-*O*-glucoside, so the presence of this *p*-coumaroylated compound can be used as a marker to distinguish among the species. Other anthocyanins in American elder include cyanidin-3-*O*-sambubioside-5-*O*-glucoside, cyanidin-3,5-*O*-diglucoside, cyanidin-3-*O*-glucoside, cyanidin-3-*O*-sambubioside, and cyanidin-3-*O*-[6-*O*-(*Z*)-*p*-coumaroyl]sambubioside-5-*O*-glucoside. Total anthocyanin concentrations in American elder berries range from 208–1,005 mg/100 g FW.[31] Concentration ranges of individual anthocyanins are provided in Table 1. The anthocyanin profiles of *S. cerulea* and *S. ebulus* appear to be similar to the profile of *S. nigra*. No quantitative data on individual anthocyanins in *S. williamsii* are available, although Feng et al (2016) obtained a total anthocyanin content of 32 mg/100 g FW and included an anthocyanin profile identifying cyanidin-3-*O*-(*E*)-*p*-coumaroylsambubioside-5-*O*-glucoside as the major pigment in this species.[36] No other literature references about the anthocyanin profile of *S. williamsii* could be retrieved.

The Elder Berry Market

While elder berry has a long history of use in traditional medicine, the appearance of commercial dietary supplements and herbal medicines with the fruit has been a rather recent occurrence in countries with a tradition of Western herbal medicine. The *Galenica Codex* of 1992,[38] a book with all medicinally used preparations for pharmacists in Switzerland, does not list any product containing elder berries. One of the first commercial elder syrups, Sambucol® (initially produced by Razei Bar Industries, Ltd.; Jerusalem, Israel; and now owned by PharmaCare; Warriewood, NSW, Australia), was launched in 1992.[39]

Elder first appeared in the American Botanical Council's annual *HerbalGram* Herb Market Report in 2008, when it ranked as the 16th top-selling dietary supplement ingredient in the mainstream multi-outlet channel, also known as the mass-market channel.[40] The ranking may be due in part to the popularity of elder flower extracts in many cough lozenges, some of which are also included in the dietary supplement category. A marked increase in popularity was seen from 2017 to 2018 (Figure 1). This may have been caused in part by the severe 2017–2018 influenza season and a 2016 clinical trial showing a reduction in symptoms of the common cold using elder berry.[41] This positive sales trend has continued, and based on available data, 2020 was another record-breaking year for elder product sales, largely due to the COVID-19 pandemic, with an estimated growth of approximately 200% over 2019 sales.[42]

Table 1. Concentrations of Selected Anthocyanins in Berries from Various Elder Species (in mg/100 g FW)[30-33,37]

	Cyanidin-3-*O*-glucoside	Cyanidin-3-*O*-sambubioside	Cyanidin-3,5-*O*-diglucoside	Cyanidin-3-*O*-sambubioside-5-*O*-glucoside	Cyanidin-3-*O*-[6-*O*-(*E*)-*p*-coumaroyl]sambubioside-5-*O*-glucoside
S. canadensis	0.3–62.7	1.7–39.4	6.3–94.6	40.8–195	130.6–594.2
S. cerulea	2.9	63.4	n.d.	n.d.	n.d.
S. ebulus	84.5	244.8	91.6	42.0	n.d.
S. nigra	44.8–739.8	122.2–630.8	5.9–47.1	16.0–82.6	n.d.

n.d. = not determined

Numerous different elder berry preparations are on the market (Figure 2). Many commercial elder berry extracts are standardized to their anthocyanin contents, and extract prices vary based on the concentration of anthocyanins. In 2021, pricing of wholesale bulk elder berry extract containing 7% anthocyanins was between $160-190/kg, while costs for extracts containing 14% anthocyanins ranged between $270-300/kg (C. Tower [Artemis International], email to S. Gafner, February 4, 2021). In contrast, "elder berry" extracts that have been found to be adulterated with black rice (*Oryza sativa*, Poaceae) extract are sold for as little as $14/kg.

Adulteration

As the popularity of elder berry dietary supplements continued to rise during the COVID-19 pandemic due to consumers' increased interest in herbal ingredients with reported immunomodulatory and antiviral effects, shipments of some elder berry ingredients were delayed due to manufacturing closures in China and India and disruptions of transportation and material processing at customs.[53,54] In response, some industry members started to raise concerns about demand outpacing supply and that some elder berry bulk extracts and finished dietary supplements offered during the pandemic were of low quality or adulterated.[55-58]

However, no data explicitly reporting adulteration of elder berries or elder berry extracts could be retrieved in the published scientific literature at the time of this writing (February 2021). On the contrary, some papers suggest that elder berry extracts themselves have been used as adulterants, as undeclared color additives to wine[59,60] or to adulterate bilberry (*Vaccinium myrtillus*, Ericaceae) extracts.[61,62] However, the results of the analysis of commercial elder berry products detailed in a 2016 doctoral dissertation by Joseph Galetti, PhD, suggest that, at that time, elder berry product adulteration was common, even if such adulteration appears to have gone unnoticed by the author.[63] For his graduate work, Galetti analyzed a total of 33 samples for their content of sugars, anthocyanins, organic acids, vitamin C, and total proanthocyanidins. The samples included 29 commercial elder berry dietary supplements, three samples of bulk fruit, and one sample of bulk powder and were sold in the United States (n = 31), Ireland (n = 1), or Switzerland (n = 1).

The finished dietary supplement samples included 14 syrups, five tinctures, four lozenges, three concentrates, and three capsule products. Eight of these samples (two products each of the syrups, tinctures, capsules, and lozenges) were found to contain peonidin, peonidin-3-*O*-glucoside, or peonidin-3-*O*-galactoside, which are anthocyanins that have not been found in elder berry. Additionally, the elder berry bulk powder contained mainly cyanidin-3-*O*-glucoside and peonidin-3-*O*-glucoside, reminiscent of the main anthocyanins found in black rice extract. In the case of an elder berry capsule supplement, Galetti noted that the product had an anthocyanin composition that was not indicative of elder berry, with 80.5% cyanidin-3-*O*-glucoside, 11.6% cyanidin-3-*O*-galactoside, 3.4% cyanidin-3-*O*-arabinoside, 2.9% cyanidin, and 1.7% peonidin-3-*O*-glucoside (calculated as percent of total anthocyanins).[63] The product also had an unusually high level of isocitric acid. Galetti hypothesized that this could be due to the freeze-dried blackberry (*Rubus* spp., Rosaceae) fruit that was also present according to the label. However, peonidin-3-*O*-glucoside is not known to occur in elder berries or blackberries.[64]

Another spurious anthocyanin profile was reported in a 2018 paper on the antioxidant, anti-inflammatory, and cytotoxic effects of an "elder berry" extract.[65] The extract, described by the authors as a "dietary supplement widely available on the world market, that contains fruit elderberry extract *Sambucus williamsii* Hance" contained 88.2% cyanidin-3-*O*-glucoside and 9.7% peonidin-3-*O*-glucoside, again suggesting adulteration with black rice extract.[65]

Figure 1. US Sales of Elder Dietary Supplements from 2011 to 2019[43-51]

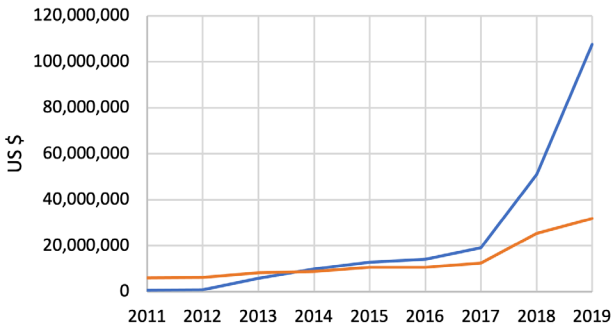
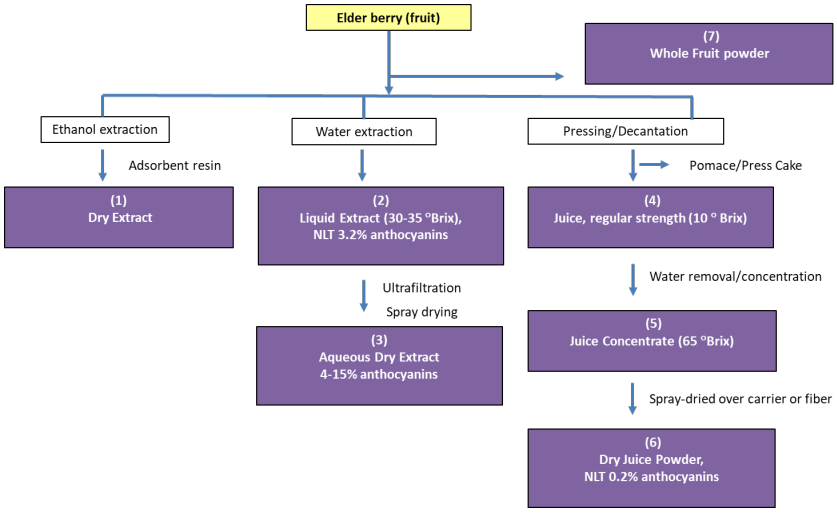


Figure 2. Elder Berry Dietary Supplement Ingredients Available in the United States



The Brix value indicates the number of grams of sucrose present per 100 grams of liquid (e.g., elder berry juice with 10 °Brix contains 10 g sucrose in 100 grams of juice). NLT = no less than. This figure has been modified from Monagas (2021).[52]

Table 2. Results of Elder Berry Product Testing

Company	Method	Adulterated/ Failed Identity Test	Total
Alkemist Labs	HPTLC[b]	32	369
Artemis[a]*	HPTLC[b]/HPLC[c]	4	11
DNA4 Technologies	WGS[b]	0	2
Eurofins	HPTLC[b]	2	55
Gaia Herbs	UV/Vis[b]	0	6
Nature's Way*	HPTLC[d]/HPLC[c]	16	33
Naturex*	HPLC[b]	4	10
NSF International	HPTLC[b]	0	46
Total		**58**	**532**

* These companies included competitors' products in their analyses.

[a] Analysis performed by Alkemist Labs (HPTLC) and Complete Phytochemical Solutions (HPLC)
[b] Proprietary method
[c] United States Pharmacopeia (USP) European Elder berry dry extract monograph[66]
[d] Institute for Nutraceutical Advancement method

Current Industry Data Regarding Elder Berry Authenticity

To assess the current market situation with regard to the authenticity of commercial bulk elder berry extracts and finished products, a request for analytical data was sent to manufacturers of elder berry dietary supplements and contract analytical laboratories.

Methods

In total, 14 companies were asked to participate in this initiative, or voluntarily provided analytical data on elder berry quality. This included nine contract analytical laboratories that specialize in identification of botanical ingredients, three manufacturers of elder berry supplements, and two elder berry extract suppliers. These parties were asked to share data on elder berry analysis in unredacted or redacted form, (i.e., without the name of the supplier or manufacturer to respect confidentiality agreements). Eight organizations provided data from elder berry analyses, of which six shared actual reports of the analysis, while the other two shared topline data on the number of samples that failed identity specifications. The data obtained represent a total of 532 samples, although some of the same samples may have been tested at several laboratories. Test samples included bulk extracts, bulk whole or powdered elder berries, and finished dietary supplement products. Methods of analysis included high-performance thin-layer chromatography (HPTLC, n = 510), high-performance liquid chromatography with visible detection (HPLC-Vis, n = 50), ultraviolet/visible spectrophotometry (UV/Vis) with chemometric analysis (n = 6), and DNA-based identification using whole-genome sequencing (WGS, n = 2). Two laboratories used a combination of HPTLC and HPLC-Vis.

Results

A total of 58 (10.9%) of the 532 samples failed the identity test specifications due to differences in the analytical fingerprint when compared to authentic samples. Adulterated materials were more frequently seen when elder berry manufacturers analyzed competitors' products (Table 2).

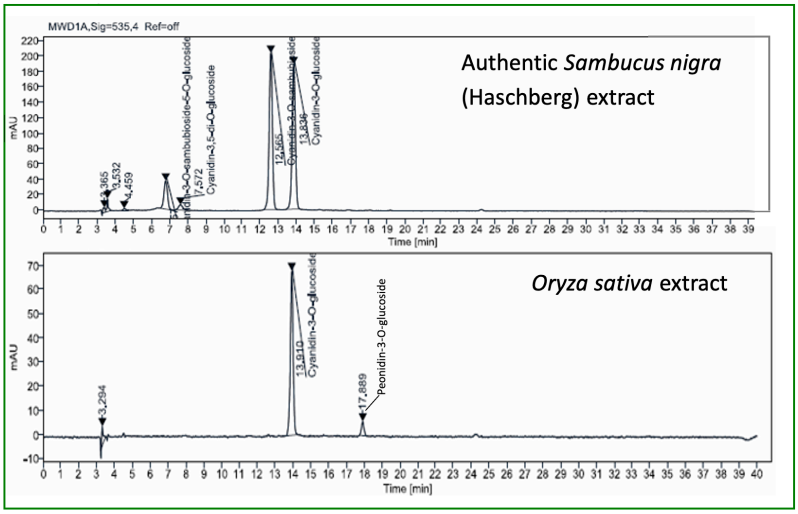
Identification of Adulterants

Two companies attempted to identify the adulterants. Both companies identified black rice extract as a common adulterant based on comparison of the anthocyanin fingerprint with authentic black rice extract (Figure 3)[67] or comparison to published data on the anthocyanin composition of black rice extract. The main anthocyanidin in black rice extract is cyanidin-3-*O*-glucoside. It also contains small amounts of peonidin-3-*O*-glucoside and traces of cyanidin-3,5-*O*-diglucoside and cyanidin-3-*O*-rutinoside, but lacks the characteristic cyanidin-3-*O*-sambubioside present in some authentic commercial elder berry species (Table 1).[68,69] While other adulterants were detected in some of the bulk extracts, the identities of these ingredients were not determined. Additionally, several commercial elder berry bulk extracts and dietary supplement products were highly diluted or did not contain any detectable anthocyanins at all.

One recent change in the US dietary supplement market is the appearance of extracts labeled to be made from the fruit of Williams elder, which is a red-berried elder species that grows in northeastern China, Japan, and Korea.[70] Unlike the modern herbal use of European and American elder, where the flowers or the berries are the plant parts of interest, traditional Chinese medicine employs Williams elder twigs. Known as *jie gu mu*, these twigs are used in combination with other herbs to treat bone fractures.[71-73] Williams elder stems and branches also are used in Korean traditional medicine to treat broken bones and osteoporosis.[74] During this initiative, four bulk samples claiming to contain Williams elder berry extract from two different suppliers were analyzed by HPLC-Vis and/or HPTLC (Figure 4). In the case of one supplier, the samples were found to contain either black rice extract or a mixture of black rice and European elder extracts. The samples from the other supplier had exactly the same anthocyanin composition as European elder berry, thus contradicting the findings by Feng et al,[36] who reported cyanidin-3-*O*-(*E*)-*p*-coumaroylsambubioside-5-*O*-glucoside as the main anthocyanin of Williams elder (see "Cultivars and Chemistry" section),

with other acylated anthocyanins as minor compounds. As such, it is not clear if the second set of bulk samples were European elder mislabeled as Williams elder or if the research by Feng et al was carried out on the wrong species. To further complicate matters, Williams elder is included in Bolli's very broad circumscription of mostly red-fruited species under *S. racemosa,* along with 34 other synonyms.[10] Clearly, other species or variants could be involved in commercial supply chains or laboratory studies, absent a voucher specimen. Further investigations into the composition of Williams elder berries are needed to provide clear criteria on how to distinguish among Williams elder and other *Sambucus* species.

Figure 3. HPLC-Vis Chromatogram of Authentic Elder Berry Extract and a Bulk 'Elder Berry' Ingredient Containing Black Rice Extract



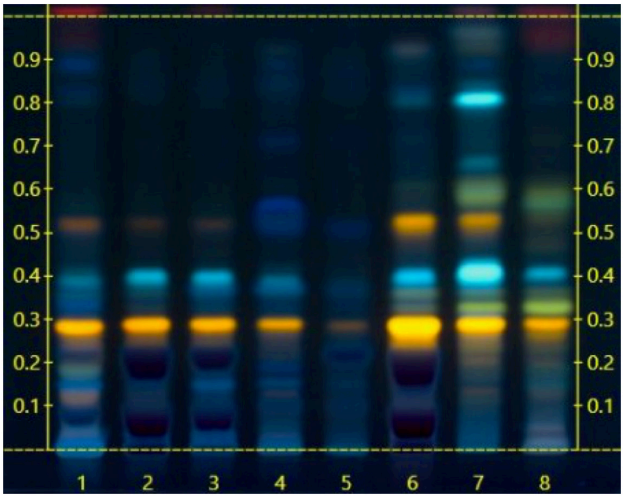
Stability Considerations

Anthocyanins are known to be prone to oxidation, with light, temperature, water content, and pH affecting their stability,[75-78] particularly in liquid formulations.[63,78] Substantial degradation also has been observed in berries from some suppliers that sterilize fruits, usually by steam, before sending them to manufacturers that then make syrups and extracts. These degraded berries are crispy and have a burnt aroma and flavor (R. Upton [American Herbal Pharmacopoeia], email to S. Gafner, February 8, 2021). Steam sterilization treatments may also noticeably change the anthocyanin profile,[76] leading to a more brownish colored product due to the loss of anthocyanins and the formation of various types of polymers.[79,80] As mentioned above, several of the bulk extracts did not exhibit any detectable anthocyanins. It is possible that some of the failing ingredients or products in Table 2 were due to improper manufacturing processes. While not technically adulterated, anthocyanin degradation may compromise the efficacy of the product.

Conclusion

The surge in popularity of elder berry extracts and dietary supplements, combined with supply shortages and increased raw material costs, has created a situation in which some suppliers attempt to gain an unfair market advantage by selling diluted or adulterated elder berry extracts for financial gain. The most common adulterant appears to be black rice extract, but other unidentified materials are used as adulterants as well. While the taxonomic status of American elder and European elder is a matter of scientific debate, the two species can be distinguished based on their anthocyanin profiles. No mislabeling of European elder with American elder, or vice versa, was observed in commercial bulk extracts or finished products. However, one case suggests possible mislabeling of European elder as Williams elder.

Figure 4. HPTLC Analysis of Commercial Elder Berry Extracts



Lanes 1–2: Authentic European elder berry
Lane 3–6: Commercial elder berry products
Lane 7: Authentic European elder flower
Lane 8: Authentic blue elder berry

The results of this investigation indicate that manufacturers of herbal dietary supplements have to remain vigilant and actively establish quality-control assays that help detect issues with adulteration, such as the undisclosed intentional substitution, dilution, and/or spiking of products, which is particularly relevant during times of extraordinary sales increases and/or sudden supply chain dislocations and shortages. HG

References

1. Atkinson MD, Atkinson E. *Sambucus nigra* L. *J Ecology.* 2002;90(5):895-923.
2. Britton NL, Brown HA. *An Illustrated Flora of the Northern United States and Canada.* Vol 3. New York, NY: Dover Publications, Inc.; 1970.

3. Weakley AS. *Flora of the Southeastern United States*. Chapel Hill, NC: University of North Carolina at Chapel Hill, North Carolina Botanical Garden; 2020:1605-1606.
4. McGuffin M, Kartesz JT, Leung AY, Tucker AO. *Herbs of Commerce.* 2nd ed. Silver Spring, MD: American Herbal Products Association; 2000.
5. *Sambucus nigra* L. [Viburnaceae] - Medicinal Plant Names Services. Royal Botanic Gardens, Kew; 2020. Available at: www.theplantlist.org/tpl1.1/record/kew-2486519. Accessed January 15, 2021.
6. The Plant List. Version 1.1. 2013. Available at: www.theplantlist.org/tpl1.1/record/kew-2486519. Accessed January 15, 2021.
7. Info Flora 2004 - 2021 The National Data and Information Center of the Swiss Flora; 2021. Available at: www.infoflora.ch/en/flora/sambucus-nigra.html. Accessed January 15, 2021.
8. Tropicos.org. Missouri Botanical Garden website. 2021. Available at: www.tropicos.org/name/6000026. Accessed January 15, 2021.
9. Germplasm Resources Information Network (GRIN-Taxonomy). United States Department of Agriculture, Agricultural Research Service, National Plant Germplasm System; 2021. Available at: https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomydetail?id=32994. Accessed January 15, 2021.
10. Bolli R. *Revision of the Genus Sambucus.* Vol 223. Berlin, Germany: J. Cramer; 1994.
11. Applequist WL. A brief review of recent controversies in the taxonomy and nomenclature of *Sambucus nigra* sensu lato. *Acta Horticulturae.* 2015;1061:25-33.
12. Moerman DE. *Native American Ethnobotany*. Portland, OR: Timber Press, Inc.; 1998.
13. Brinckmann J, Engels G. European elder. *HerbalGram.* 2013;97:1-7.
14. Wilson KL. Report of the General Committee: 15. *Taxon.* 2016;65(5):1150-1151.
15. Uzlasir T, Kadiroglu P, Selli S, Kelebek H. LC-DAD-ESI-MS/MS characterization of elderberry flower (*Sambucus nigra*) phenolic compounds in ethanol, methanol, and aqueous extracts. *J Food Process Preserv.* e14478.
16. Milena V, Tatjana M, Gökhan Z, et al. Advantages of contemporary extraction techniques for the extraction of bioactive constituents from black elderberry (*Sambucus nigra* L.) flowers. *Ind Crops Prod.* 2019;136:93-101.
17. Assessment report on *Sambucus nigra* L., fructus. London, United Kingdom: European Medicines Agency Committee on Herbal Medicinal Products (HMPC); 2014:1-25.
18. European Union herbal monograph on *Sambucus nigra* L., flos. London, United KIngdom: European Medicines Agency Committee on Herbal Medicinal Products (HMPC); 2018:1-7.
19. Schmidl A, Kofler W, Oeggl-Wahlmüller N, Oeggl K. Land use in the Eastern Alps during the Bronze Age—An archaeobotanical case study of a hilltop settlement in the Montafon (Western Austria). *Archaeometry.* 2005;47(2):455-470.
20. Schmidl A, Oeggl K. Subsistence strategies of two Bronze Age hill-top settlements in the eastern Alps—Friaga/Bartholomäberg (Vorarlberg, Austria) and Ganglegg/Schluderns (South Tyrol, Italy). *Veget Hist Archaeobot.* 2005;14(4):303-312.
21. Bouby L, Fages G, Treffort JM. Food storage in two Late Bronze Age caves of Southern France: Palaeoethnobotanical and social implications. *Veget Hist Archaeobot.* 2005;14(4):313-328.

22. Jacomet S, Brombacher C, Dick M. Palaeoethnobotanical work on Swiss neolithic and bronze age lake dwellings over the past ten years. In: Renfrew J, ed. *New Light on Early Farming*. Edinburgh, Scotland, UK: Edinburgh University Press; 1991:257-276.
23. Parkinson J. *Theatrum Botanicum: The Theater of Plants, or, An Herball of Large Extent*. London, UK: Thomas Cotes; 1640.
24. Native American Ethnobotany - A database of plants used as drugs, foods, dyes, fibers, and more, by native Peoples of North America. 2020. Available at: http://naeb.brit.org/uses/search/?string=sambucus&page=1. Accessed February 23, 2021.
25. Teuscher E, Willuhn G, Loew D. Sambuci fructus. In: Blaschek W, ed. *Wichtl - Teedrogen und Phytopharmaka*. Stuttgart, Germany: Wissenschaftliche Verlagsgesellschaft mbH; 2016:586-588.
26. Demirezer LÖ, Ersöz T, Saraçoğlu İ, Şener B, Köroğlu A, Yalçin FN. Mürver meyvesi. *A'dan Z'ye Tibbi Bitkiler*. Istanbul, Turkey: Hayykitap; 2019:323-324.
27. Charlebois D, Byers PL, Finn CE, Thomas AL. Elderberry: Botany, horticulture, potential. In: Janick J, ed. *Horticultural Reviews.* Vol 37. Hoboken, NJ: Wiley-Blackwell; 2010:213-280.
28. Wilson R, Nickerson G, Fried D, et al. *Growing elderberries: A production manual and enterprise viability guide for Vermont and the Northeast.* Burlington, VT: UVM Center for Sustainable Agriculture, University of Vermont Extension; 2016.
29. Ferreira SS, Silva AM, Nunes FM. *Sambucus nigra* L. fruits and flowers: Chemical composition and related bioactivities. *Food Rev Int.* 2020:1-29.
30. Anton AM, Pintea AM, Rugină O, et al. Preliminary studies on the chemical characterization and antioxidant capacity of polyphenols from *Sambucus* sp. *Dig J Nanomat Bios.* 2013;8(3):973-980.
31. Lee J, Finn CE. Anthocyanins and other polyphenolics in American elderberry (*Sambucus canadensis*) and European elderberry (*S. nigra*) cultivars. *J Sci Food Agric.* 2007;87(14):2665-2675.
32. Wu X, Gu L, Prior RL, McKay S. Characterization of anthocyanins and proanthocyanidins in some cultivars of *Ribes*, *Aronia*, and *Sambucus* and their antioxidant capacity. *J Agric Food Chem.* 2004;52(26):7846-7856.
33. Veberic R, Jakopic J, Stampar F, Schmitzer V. European elderberry (*Sambucus nigra* L.) rich in sugars, organic acids, anthocyanins and selected polyphenols. *Food Chem.* 2009;114(2):511-515.
34. Thomas AL, Byers PL, Gu S, et al. Occurrence of polyphenols, organic acids, and sugars among diverse elderberry genotypes grown in three Missouri (USA) locations. *Acta horticulturae.* 2015;1061:147-154.
35. Mudge E, Applequist WL, Finley J, et al. Variation of select flavonols and chlorogenic acid content of elderberry collected throughout the Eastern United States. *J Food Compost Anal.* 2016;47:52-59.
36. Feng C, Su S, Wang L, et al. Antioxidant capacities and anthocyanin characteristics of the black-red wild berries obtained in Northeast China. *Food Chem.* 2016;204:150-158.
37. Mikulic-Petkovsek M, Schmitzer V, Slatnar A, et al. Investigation of anthocyanin profile of four elderberry species and interspecific hybrids. *J Agric Food Chem.* 2014;62(24):5573-5580.

Elder berry *Sambucus nigra*
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38. Chobaz P, Kohler S, Meier A, Santschi M. *Codex Galenica 1992.* Lausanne, Switzerland: Galenica AG; 1991.
39. Blackburn N. Study shows Israeli elderberry extract effective against avian flu. *Israel21c.* 2006.
40. Cavaliere C, Rea P, Lynch ME, Blumenthal M. Herbal supplement sales experience slight increase in 2008. *HerbalGram.* 2009;82:58-61.
41. Tiralongo E, Wee SS, Lea RA. Elderberry supplementation reduces cold duration and symptoms in air-travellers: A randomized, double-blind placebo-controlled clinical trial. *Nutrients.* 2016;8(4):182.
42. *Forecasting top consumer health trends for 2021 and beyond*. Sarasota, FL: Informa PLC; 2021.
43. Blumenthal M, Lindstrom A, Ooyen C, Lynch ME. Herb supplement sales increase 4.5% in 2011. *HerbalGram.* 2012;95:60-64.
44. Lindstrom A, Ooyen C, Blumenthal M, Lynch ME. Herb supplement sales increase 5.5% in 2012. *HerbalGram.* 2013;99:60-65.
45. Lindstrom A, Ooyen C, Lynch M, Blumenthal M, Kawa K. Sales of herbal dietary supplements increase by 7.9% in 2013, marking a decade of rising sales. *HerbalGram.* 2014;103:52-56.
46. Smith T, Lynch M, Johnson J, Kawa K, Bauman H, Blumenthal M. Herbal dietary supplement sales in US increase 6.8% in 2014. *HerbalGram.* 2015;107:52-59.
47. Smith T, Kawa K, Eckl V, Johnson J. Sales of herbal dietary supplement sales in US increased 7.5% in 2015. *HerbalGram.* 2016;111:67-73.
48. Smith T, Kawa K, Eckl V. Herbal supplement sales in US increase 7.7% in 2016. *HerbalGram.* 2017;115:56-65.
49. Smith T, Kawa K, Eckl V, Morton C, Stredney R. Herbal supplement sales in US increase 8.5% in 2017, topping $8 billion. *HerbalGram.* 2018;119:62-71.
50. Smith T, Gillespie M, Eckl V, Knepper J, Reynolds CM. Herbal supplement sales in US increase by 9.4% in 2018. *HerbalGram.* 2019;123:62-73.
51. Smith T, May G, Eckl V, Reynolds CM. US Sales of Herbal Supplements Increase by 8.6% in 2019. *HerbalGram.* 2020;127:54-67.
52. Monagas JM. Goals and objectives for the elderberry standards development open forum. USP Open Forum: Elderberry Standards Development; January 22, 2021, 2021; Rockville, MD.
53. Mister S. CRN member-identifyed supply chain disruptions for dietary supplements. 2020. Available at: www.crnusa.org/sites/default/files/Daily/2020-03/CRN%20Supply%20Chain%20Disruption%20Summary.pdf. Accessed February 1, 2021.
54. Raterman K. Herbal companies brace for the supply chain impact of COVID-19. *HerbalGram.* 2020;126:66-74.
55. *WholeFoods Magazine* Staff. Artemis raises concerns on adulteration of elderberry. *WholeFoods Magazine.* June 18, 2020.
56. Krawiec S. Alkemist Labs warns industry of falsified certificates of analysis being circulated. *Nutritional Outlook*. May 18, 2020.
57. Daniells S. Experts sound alarm over 2021 botanical supply challenges. NutraIngredients. October 12, 2020.
58. Schultz H. Elderberry demand continues; so does adulteration. NutraIngredients. July 6, 2020.
59. Csapó J, Albert C. Wine adulteration and its detection based on the rate and the concentration of free amino acids. *Acta Agraria Debreceniensis.* 2018;150:139-151.
60. Drábek J, Jalůvková M, Frébort I. Kvantitativní PCR detekce nepovoleného přibarvování vína bezinkami (*Sambucus nigra*). *Chem Listy.* 2007;101:550-555.
61. Foster S, Blumenthal M. The adulteration of commercial bilberry extracts. *HerbalGram.* 2012(96):63-74.
62. Giacomelli L, Appendino G, Franceschi F, Togni S, Pace R. Omne Ignotum pro Magnifico: Characterization of commercial bilberry extracts to fight adulteration. *European Review for Medical and Pharmacological Sciences.* 2014;18(24):3948-3953.
63. Galetti JA. *A competitive assessment of commercial elderberry (*Sambucus *sp.) products and the evaluation of copigmentation within elderberry tinctures*. Orono, ME: School of Food and Agriculture, University of Maine; 2016.
64. Fan-Chiang H-J, Wrolstad RE. Anthocyanin pigment composition of blackberries. *J Food Sci.* 2005;70(3):C198-C202.
65. Strugała P, Loi S, Bażanów B, et al. A comprehensive study on the biological activity of elderberry extract and cyanidin 3-O-glucoside and their interactions with membranes and human serum albumin. *Molecules.* 2018;23(10):2566.
66. United States Pharmacopeia. European elder berry dry extract. *USP43-NF38*. Rockville, MD: United States Pharmacopeial Convention; 2021.
67. Gafner S. Adulteration of european elder berry extracts on the rise. *Botanical Adulterants Monitor.* 2020;20.
68. Bordiga M, Gomez-Alonso S, Locatelli M, et al. Phenolics characterization and antioxidant activity of six different pigmented *Oryza sativa* L. cultivars grown in Piedmont (Italy). *Food Res Int.* 2014;65:282-290.
69. Hou Z, Qin P, Ren G. Effect of anthocyanin-rich extract from black rice (*Oryza sativa* L. *japonica*) on chronically alcohol-induced liver damage in rats. *J Agric Food Chem.* 2010;58(5):3191-3196.
70. Kim HH. *Chemical constituents from Sambuci lignum and their biological activity*. Naju, South Korea: Department of Pharmaceutical Engineering, Dongshin University; 2019.
71. Xiao H-H, Zhang Y, Cooper R, Yao X-S, Wong M-S. Phytochemicals and potential health effects of *Sambucus williamsii* Hance (Jiegumu). *Chin Med.* 2016;11(1):36.
72. Xiao H-H, Sham T-T, Chan C-O, et al. A metabolomics study on the bone protective effects of a lignan-rich fraction from *Sambucus williamsii* ramulus in aged rats. *Front Pharmacol.* 2018;9(932).
73. Yang B, Lin X, Tan J, She X, Liu Y, Kuang H. Root bark of *Sambucus williamsii* Hance promotes rat femoral fracture healing by the BMP-2/Runx2 signaling pathway. *J Ethnopharmacol.* 2016;191:107-114.
74. Suh WS, Subedi L, Kim SY, Choi SU, Lee KR. Bioactive lignan constituents from the twigs of *Sambucus williamsii*. *Bioorganic & Medicinal Chemistry Letters.* 2016;26(8):1877-1880.
75. Wang BC, He R, Li ZM. Antioxidant activity of blueberry anthocyanins. *Food Technol Biotechnol.* 2010;48(1):42-29.
76. Weber F, Larsen LR. Influence of fruit juice processing on anthocyanin stability. *Food Res Int.* 2017;100:354-365.
77. Patras A, Brunton NP, O'Donnell C, Tiwari BK. Effect of thermal processing on anthocyanin stability in foods; mechanisms and kinetics of degradation. *Trends Food Sci Technol.* 2010;21(1):3-11.
78. Gradinaru G, Biliaderis CG, Kallithraka S, Kefalas P, Garcia-Viguera C. Thermal stability of *Hibiscus sabdariffa* L. anthocyanins in solution and in solid state: Effects of copigmentation and glass transition. *Food Chem.* 2003;83(3):423-436.
79. He F, Liang NN, Mu L, et al. Anthocyanins and their variation in red wines. II. Anthocyanin derived pigments and their color evolution. *Molecules.* 2012;17(2):1483-1519.
80. Marszałek K, Woźniak Ł, Skąpska S, Mitek M. High pressure processing and thermal pasteurization of strawberry purée: quality parameters and shelf life evaluation during cold storage. *J Food Sci Technol.* 2017;54(3):832-841.