

Boswellia serrata Adulteration

By Allison McCutcheon, PhD*

American Botanical Council, PO Box 144345,
Austin, TX 78714

*Corresponding author: [email](#)

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Goal: The goal of this bulletin is to provide timely information and/or updates on issues of adulteration of *Boswellia serrata* (Burseraceae) to the international herbal industry and extended natural products community in general. It is intended to complement the previously published works with information on *B. serrata* adulteration by presenting new data on the occurrence of adulteration, the market situation, and consequences for the consumer and the industry.

1. General Information

1.1 Common name: Indian frankincense,¹ boswellia²

1.2 Other common names:

English: Indian olibanum^{2,3}

Assamese: Sallaki⁴

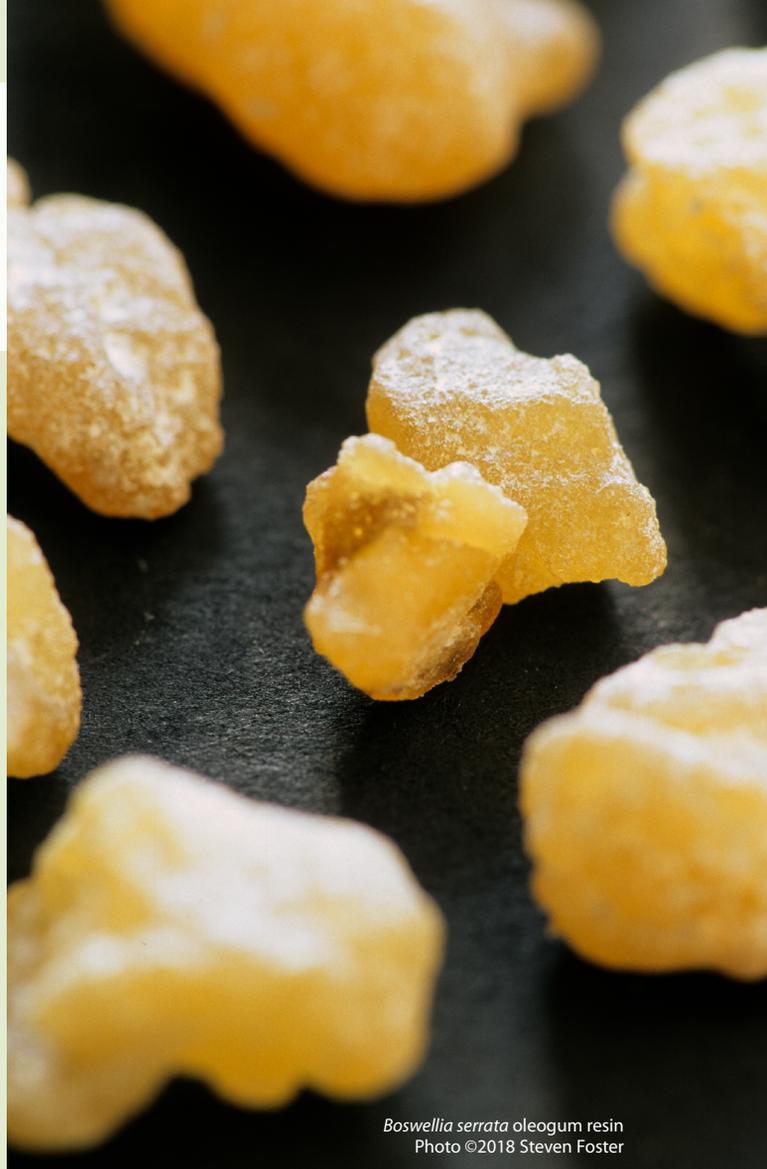
Ayurvedic: Shallaki, susravaa, gajabhakshyaa, salai, gum-kunduru⁵

Bemba: Kundru⁶

Bengali: Luban, salai,⁶ salgai⁷

Chinese: Chi ye ru xiang shu (齿叶乳香树)

French: Arbre à encens de l'Inde, boswellie, encens d'Inde²



Boswellia serrata oleogum resin
Photo ©2018 Steven Foster

Gujarati: Gugal, saleda, dhup,⁶ shaledum, saladi, gugal, saledhi⁴

German: Indischer Weihrauch²

Hindi: Madi, salai, saler, salga, salhe, sali,⁶ anduk, gugal, halar, kundur, loban, lobhan, luban, salaga, salai, salar, salaran, salhe, sel-gond, vellakkunturukkam,⁷ labana⁴

Italian: Incenso indiano⁸

Kannada: Madimar, chilakdupa, tallaki, maddi⁴

Kashmiri: Kunturukkam, samprani⁴

Marathi: Salai cha dink⁴

Pharmacopoeial: Olibanum Indicum,⁹ Gummi Boswellii¹⁰

Punjabi: Salaigonda⁴

Sanskrit: Sallaki, kunduru,⁶ agavrttika, ashvamutri, asraphala, bahusrava, gajabhaksha, gajabhaksya, gajapriya, gajasana, gajashana, gajavallabha, gandhamula,

gandhavira, guggu, hladini, hraswada, jalatiktika, kapit-thaparni, karaka, khapurah, konkanadhoopam, konkanadhupa, kumbhi, [kundara, kundu, kundurakam, kunduru, kundurugugulu, kunduruka, kunduruki, kunduruska, kunduruskah; see comments by Dymock et al.¹¹], lhadini, maherana, maheruna, mocha, nagavadhu, nagavrttika, rasala, salakhi, salasi, salasiniryasam, salasiniryasallaki, sallaki, shallaki, silhabhumika, silhaki, sugandha, sukhamoda, surabhi, surabhisrava, sushrika, susrava, suvaha, vanakarnika, vasamaharuba, viseshadhupa, vrttika, yakshadhupa⁷

Sri Lankan: Kundirikkan¹²

Spanish: Incienso indio¹³

Tamil: Parangisambrani, kungli, kundrikam, gugulu, morada,⁶ kundurukam⁴

Telugu: Anduga, kondagugitamu⁴

Trade names: Salai, kundur luban,² lobhan, salakhi,³ dupa, guggul, kaadar, salai guggul⁷

Unani: Kunder⁵

Urdu: Kunder,⁴ kundur, loban, lobana, sat loban⁷

1.3 Accepted Latin binomial: *Boswellia serrata* Roxb. ex Colebr.^{14,15}

1.4 Synonyms: *Boswellia balsamifera* Spreng., *Boswellia glabra* Roxb., *Boswellia thurifera* Roxb. ex Fleming, *Chloroxylon dupada* Buch.-Ham., *Libanotus asiaticus* Stackh.,^{3,14} *Libanus thuriferus* Colebr.¹⁵

1.5 Botanical family: Burseraceae

1.6 Botanical taxonomy: The genus *Boswellia* consists of 28 species of trees and shrubs.¹⁴ In addition to *B. serrata*, the species *Boswellia frereana* Birdw. (elemi frankincense), *Boswellia papyrifera* (Caill. ex Delile) Hochst. (elephant tree), and *Boswellia sacra* Flueck., syn. *B. carteri* Birdw. (frankincense, olibanum) are also commercially important

species; all four species are traded under the common name frankincense.^{16,17}

Note: Throughout this document, the currently accepted scientific names are used and the older synonyms used in the literature cited are noted in parenthesis. In the literature, *B. carteri* is sometimes spelled *B. carterii*; the former spelling is correct and is used throughout this document.¹⁴⁻¹⁶

1.7 Distribution range: Dry, rocky ridges and slopes, as well as flat terrain in Bangladesh, India, Pakistan, and Sri Lanka.^{12,15} In general, the distribution of *B. serrata* in India includes the Indian Punjab, Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharashtra, Andhra Pradesh, Karnataka, and Tamil Nadu.¹⁸ More specifically, *B. serrata* is found in the following Indian states: Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Chattisgarh, Orissa, West Bengal, and Maharashtra.¹⁹

Boswellia frereana is native to Somalia; it has also been reported in Ethiopia and Yemen.²⁰

Boswellia papyrifera is indigenous to Cameroon, Chad, Ethiopia, Eritrea, Nigeria, Sudan, and Uganda.^{21,22}

Boswellia sacra (syn. *B. carteri*) has a disjunct distribution in Arabia (Oman and Yemen; *B. sacra* phenotype) and Somalia (*B. carteri* phenotype).^{23,24}

1.8 Plant part, form, and production method: Air-dried oleogum resin exudate from the tree bark. In Ayurvedic medicine, the dried resin is most commonly used, while in the American and European markets, *B. serrata* is almost exclusively sold in the form of resin extracts. Extracts may be standardized based on the content of total acids, organic acids, boswellic acids (BA; 60–70%), 3-*O*-acetyl-11-keto boswellic acid (AKBA; 30%), or 3-*O*-acetyl- β -boswellic acid (A β BA; 20%).²⁵

1.9 General use(s): The management of chronic inflammatory conditions including arthritis, bronchial asthma, Crohn's disease, rheumatoid arthritis, and ulcerative colitis.^{4,10}

2. Market

2.1 Importance in the trade: From 2013 to 2016, retail sales of *B. serrata* dietary supplements in the Natural chan-

Table 1. Boswellia Dietary Supplement Sales in the US from 2012–2016

Channel	2013		2014		2015		2016	
	Rank	Sales [US\$]						
Natural ^a	53	1,546,219	48	1,695,605	42	1,884,443	45	2,122,150
Mainstream Multi-Outlet ^b	114	142,923	70	770,654	33	5,966,583	22	13,341,744

^a According to SPINS (SPINS does not track sales from Whole Foods Market.)

^b Data from 2013–2015 according to SPINS/IRI. This channel includes the food, drug, and mass-market sector, military commissaries, and select buyer's clubs and so-called dollar stores. SPINS/IRI data does not include discount department store sales, e.g., possible sales at Walmart and club stores are excluded, or products sold through the internet or health care practitioners.

Sources: Smith et al.²⁶ T. Smith (American Botanical Council) e-mail to S. Gafner, September 2, 2015, September 3, 2015, and February 6, 2018. K. Kawa (SPINS) e-mail to S. Gafner, July 11, 2016.

nel in the United States (US) have shown a steady growth, with an average annual sales increase of 11.1%. Sales growth in the Mainstream Multi-Outlet channel from 2013 to 2016 was impressive, where *B. serrata* dietary supplements showed one of the highest growth rates (413.3% annual average) for any botanical in the United States.

On the supply side, a price range of 100-300 Indian rupees per kilogram (US\$1.47-4.41) boswellia oleogum was listed in a paper on the trade of Indian medicinal plants, co-published in 2017 by the National Medicinal Plants Board and the Indian Council of Forestry Research & Education.²⁷

2.2 Supply sources:

According to the Indian Medicinal Plants Database (IMPD),⁷ *B. serrata* oleogum resin is wildcrafted from dry tropical forests in most Indian provinces, except Assam and Bengal. IMPD reported 500–1000 metric tons was harvested in 2008.⁷ The same harvest volume was given in a 2017 publication by the Indian government.²⁷

3. Adulteration

Known adulterants and substituents: *Boswellia frereana*, *B. sacra* (syn. *B. carteri*), other *Boswellia* species, *Garuga pinnata* (Burseraceae), Pinaceae resin (resin from tree species in the family Pinaceae). Due to boswellia oleogum's becoming locally scarce, instances of replacement of the tree oleogum with bark or with soil collected near the tree has been reported (G. Ravikanth [Ashoka Trust for Research in Ecology and the Environment] email to S. Gafner, April 17, 2018)

While *B. serrata* is the only species used in traditional Indian herbal medicine systems (Ayurveda, Siddha, and Unani), the *Pharmacopoeia of the People's Republic of China* allows the interchangeable use of *B. sacra* with gums of closely related trees from the same genus.²⁸ Similarly, *B. serrata* and *B. sacra* are both used for the same indications in systems of Islamic herbal medicine, although depending on the region, only the locally present *Boswellia* species may be used.^{29,30}

3.2 Sources of information confirming adulteration: Meins et al.²⁵ assessed the boswellic acid (BA) content of 17 top-selling American and European *Boswellia* products using liquid chromatography-mass spectrometry (LC-MS). The specific products were selected based upon data obtained from SPINS for the American market and from IMS OTC for the European market (52-week sales ending December 2014). Six products representing 78% of the units sold and 70% of the market share in the US were purchased, four from retail stores and two over the internet. Eleven European products representing 30% of the units sold and 40% of the market value were purchased from German pharmacies. All of the product labels specified the content was *B. serrata* extract except for one which was labeled "*Boswellia* extract." One product from Italy did

not contain any of the six BAs (see Figure 1) characteristic of *B. serrata* (and *B. sacra*) and another product from the United States contained only trace amounts, "suggesting the absence of *B. serrata* or the use of another *Boswellia* species such as *B. frereana*." Another product had non-acetylated to acetylated BA ratios that were <1, indicating the presence of *B. sacra*,* not *B. serrata* (see section 3.7). In addition, two products did not meet their label claim for BA content and another two products did not declare the use of extracts enriched in AKBA.

Niebler and Buettner²⁴ conducted a comparative analysis of 46 commercial samples of four *Boswellia* species using headspace (HS)–solid phase microextraction (SPME) gas chromatography–mass spectrometry (GC-MS). Of the seven *B. serrata* oleogum resin products that were analyzed, three exhibited abnormalities in their chemical profiles. One showed the typical *B. serrata* profile but had two additional unidentified peaks not found in any other *B. serrata* sample and "a noteworthy peak of β -longipinene (1.4%) was detected, which was otherwise only detected in one other sample from *B. serrata*." Two products contained more than 10 peaks not commonly found in *B. serrata*; longifolene (34.3% and 19.0% of the total peak area) was the highest peak in both chromatograms and α -longipinene (1.7% and 2.1%), longicyclene (2.9% and 2.8%), longicamphylenone (0.44% and not detected), longiborneol (0.46% and 0.26%), and longiborneol acetate (3.0% and 2.3%) were also tentatively identified. These longifolene- and longipinene-type sesquiterpenes are characteristic of Pinaceae resins and it is reported that a sample of Norway spruce (*Picea abies*, Pinaceae) resin produced a similar but not identical chromatogram. The authors hypothesize that these two products may have been adulterated with a Pinaceae resin. Among the samples from the other three *Boswellia* species, another six products were found to contain either a mixture of *Boswellia* species or did not contain the species stated on the label.

As a number of authors have discussed,^{17,22,24,31-33} the scientific literature on the chemical composition of commercial *Boswellia* species contains many conflicting reports, some of which may be due to the use of adulterated or misidentified commercial samples as the research material. For example, Niebler and Buettner²⁴ cite nine other papers which concur with their analysis of authenticated *Boswellia* references samples^{17,22,31,34-39} and note the following:

- Barratta et al.⁴⁰ analyzed material purported to be *B. serrata* (syn *B. thurifera*); however, the chemical profile they presented resembles that of *B. sacra*. "The same disagreement can be found in the study by Van Vuuren et al.,⁴¹ if *B. thurifera* indeed refers to *B. serrata*."
- Kasali et al.⁴² analyzed *B. serrata* material purchased from markets in Nigeria; however, the results resemble the profile of *B. rivae* or *B. neglecta*. Niebler and Buettner also point out that "the only species

*Meins et al.²⁵ refer to the species *B. sacra* and *B. carteri* as separate entities; however, *B. carteri* is a synonym for *B. sacra*.

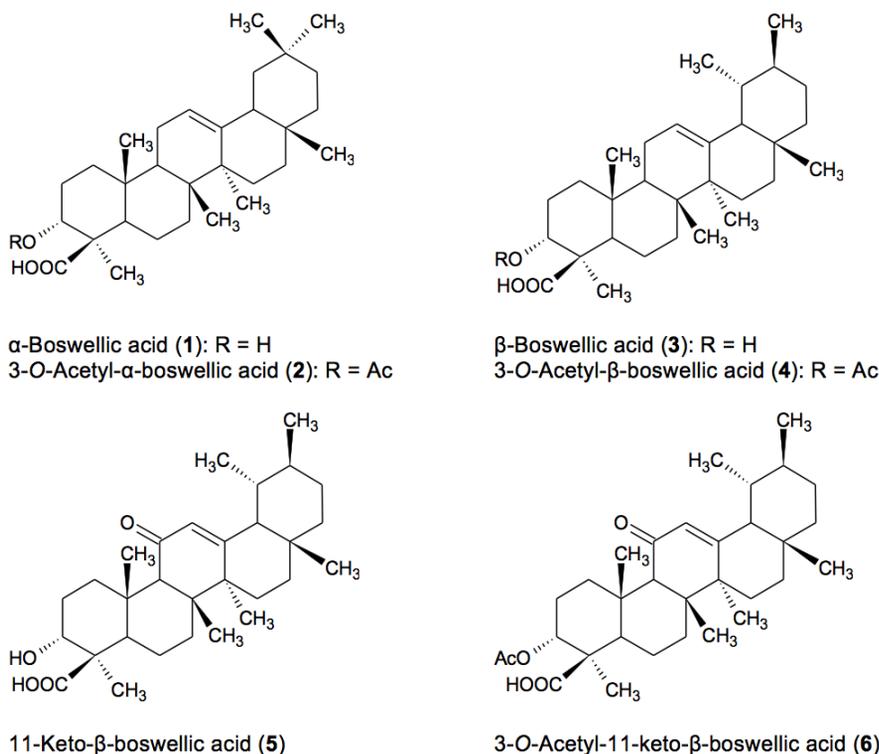
native to Nigeria is *B. dalzielii*, which would better account for its availability on Nigerian markets.”²⁴

- Singh et al.⁴³ reported a notably different chemical composition for *B. serrata* with major peaks for the compounds tetrahydrolinalool, benzyl tiglate, and methylisoeugenol. Niebler and Buettner could not confirm these results.²⁴
- Six studies have reported octyl acetate or incensole acetate as major constituents of *B. sacra* (syn *B. carteri*).⁴⁴⁻⁴⁹ However, Niebler and Buettner did not find appreciable amounts of these compounds in authentic *B. sacra* samples; they note that the chemical profile reported in these articles is characteristic of *B. papyrifera*.²⁴
- Hayashi et al.⁴⁶ identified samples from Oman as *B. frereana* and those from Israel and Turkey as *B. carteri*; however, the data of Niebler and Buettner suggests that the Omani material was *B. sacra* and the Israeli and Turkish material was *B. frereana*.²⁴

In the case of *B. frereana*, Niebler and Buettner could not confirm the presence of notable amounts of β -caryophyllene reported by Van Vuuren⁴¹ in two out of three samples and they note that β -caryophyllene is a major component of *B. sacra*.²⁴

Shanmughanandhan et al.⁵⁰ used the DNA barcode regions *rbcL* and *ITS2* and a DNA reference library for 187 species on Indian herbs to assess the botanical authenticity and potential adulteration of 93 retail herbal products purchased in Coimbatore, India. They reported that “60% were adulterated (i.e., herbal products contained species of plants not listed on the label). Product contamination was [reportedly] evident in 50% of the samples, while 10% of the samples were substituted and 6% of the products contained fillers.” The authors tested only one *B. serrata* product, which was found to be adulterated with DNA from a Lamiaceae species (*rbcL*) and *Trigonella foenum-graecum* (Fabaceae) (*ITS2*). [It should be noted that the reliability of this analytical approach has been questioned due to obvious methodological flaws which made

Figure 1: Structures of the principal boswellic acids in *Boswellia serrata*



the results prone to error,⁵¹ and the veracity of this data appears even more uncertain if the DNA reference material used was the library of 187 Western herbs created by Newmaster et al.^{52]}

Mishra et al.^{53†} reported *Garuga pinnata* (Burseraceae) and *B. sacra* (syn *B. carteri*) as adulterants of *B. serrata*. The Ayurvedic Drugs website⁵⁴ mentions the adulteration of *B. serrata* with moina gum from *Garuga pinnata*, as well as adulteration with *B. sacra* and *B. frereana* “imported from countries of the Gulf and North Africa, sold in the Indian market by the name Kundur.” However, these sources do not indicate how these adulterants were identified, nor the extent to which such adulteration may occur. Moina gum is also listed as an adulterant in a training manual on medicinal plant identification issued by the Andra Pradesh State Forest Department.⁵⁵

3.3 Accidental or intentional adulteration: As *B. frereana* and *B. sacra* do not occur in the same geographical region as *B. serrata*, their presence in *B. serrata* products must be due to either substitution based on interchangeable use in certain cultures (see 3.1), misidentification, or intentional adulteration at some point in the supply chain. The latter two ultimately are indicative of poor quality control. Further, it is difficult to construe the occurrence of pine resin as accidental adulteration.

[†]Mishra et al. cite the source of this information as Alam MZ. *Herbal Medicines*. New Delhi: APH Publishing Corporation, 2008 (not accessed).

3.4 Frequency of occurrence:

There are no published studies on the frequency of *B. serrata* adulteration. Meins et al.²⁵ found 3/17 (18%) and Niebler and Buettner²⁴ reported 3/7 (43%) of the commercial products that they assessed were adulterated. The numerous conflicting reports on the chemical composition of commercial *Boswellia* species in the scientific literature also provides evidence that *Boswellia* adulteration commonly occurs when researchers use material purchased from the commercial market.



Boswellia serrata
Photo ©2018 Dinesh Valke

3.5 Possible safety/therapeutic

issues: The possible safety issues arising from the substitution of *B. serrata* with *B. frereana*, *B. sacra*, or pine resin have not been evaluated although all three have a history of safe traditional use as medicines. The potential impact on therapeutic efficacy remains unknown; however, it may be hypothesized that the substitution of *B. frereana* which does not contain the bioactive BAs of *B. serrata* may result in an ineffective product. While *B. sacra* contains the six BAs characteristic of *B. serrata*, they are present in different proportions and supporting clinical evidence of *B. sacra* anti-inflammatory efficacy is lacking.

3.6 Pharmacopeial standards: The United States Pharmacopeia (USP) defines *B. serrata* as the oleogum resin obtained by incision or produced by spontaneous exudation from the stem and branches and specifies that it must contain not less than 1% of the keto derivatives of β -boswellic acids, calculated on the dried basis as the sum of 11-keto- β -boswellic acid (KBA) and AKBA.⁵⁶ The European Pharmacopoeia (PhEur) specifies a minimum content of 1% KBA and 1% AKBA.⁵⁷

3.7 Analytical methods to detect adulteration: Bioactivity researchers have largely focused on six boswellic acids that are characteristic to *B. serrata* (see Figure 1), α -boswellic acid (α BA), 3-*O*-acetyl- α -boswellic acid (A α BA), β -boswellic acid (β BA), 3-*O*-acetyl- β -boswellic acid (A β BA), AKBA, and KBA. Studies have shown that these six BAs are present in both *B. serrata* and *B. sacra* but are absent in *B. frereana*.^{58,59} *Boswellia serrata* can be distinguished from *B. sacra* based on the ratios of α BA/A α BA and β BA/A β BA which are 0.5-0.9 and 0.7-0.8 respectively in *B. sacra* and 1.7 and 1.2 in *B. serrata*. However, these ratios were obtained with a small number of samples and need to be confirmed in a much larger sample set. According to Frank and Unger, *B. sacra* also exhibits much lower signal intensities of KBA and AKBA compared to *B. serrata*.⁵⁸ Contrarily, it has also been reported that the total BA and AKBA content is higher in *B. sacra* (49% and 7%, respectively) extract compared *B. serrata* which contains 30% and 0.7%, respectively.⁶⁰

Both the USP and PhEur specify the use of thin-layer chromatography (TLC) for identification and high-perfor-

mance liquid chromatography (HPLC) for the quantification of β BA.^{56,57} Paul et al. described a TLC method that allows for the reliable discrimination of *B. papyrifera*, *B. sacra*, and *B. serrata*.¹⁷ Liquid chromatography mass spectrometry⁵⁸ and gas chromatograph mass spectrometry²⁴ methods for differentiating *Boswellia* species have also been published, along with suggested marker compounds for *B. frereana*, *B. papyrifera*, *B. sacra*, and *B. serrata*.^{22,24,31,36}

3.8 Perspectives: The commercial supply of *B. serrata* is sourced almost exclusively from India. Therefore, country of origin provides an important indicator of the potential authenticity of purported *B. serrata* resins. In particular, the botanical identity of material originating from Africa, Arabia, and China should be rigorously verified.

Both *B. papyrifera* and *B. sacra* (and possibly other “non-commercial” species of *Boswellia*) also contain BAs and similarly exhibit analgesic properties. Therefore, quality assurance protocols limited to the quantification of BA content by HPLC may not detect adulteration with these species. And companies that quantify only total acids or total organic acids are at even greater risk of accepting adulterated material. This issue is simply addressed by employing the TLC method for the differentiation of *B. papyrifera*, *B. sacra*, and *B. serrata* described by Paul et al. as a preliminary screening.¹⁷

Over the past decade, the sales of *B. serrata* have continued to grow in proportion with the increasing body of evidence supporting its clinical efficacy. Perhaps the single greatest threat to the continued expansion of this sector is the presence of adulterated, ineffective products in the marketplace.

4. Conclusions

Based on the available data, it appears that the adulteration of *B. serrata* resin is both a common and long-standing occurrence that must be addressed with appropriate quality control protocols. Lack of efficacy due to adulteration with other *Boswellia* species and/or other lower cost resins has the potential to damage or even destroy consumer confidence in *B. serrata* products.

When ordering *B. serrata* from countries where *Boswellia* species can be used interchangeably, e.g., from China, manufacturers that specify a particular species on their

product label should be aware of such interchangeable use and implement adequate quality control measurements to ensure that the purchased materials comply with the identity specifications for the desired species.

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REVISION SUMMARY

Version # , Author,	Date Revised	Section Revised	List of Changes
Version 1, A. McCutcheon	n/a	n/a	none

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