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BULLETIN

# Adulteration of Aloe Vera (*Aloe vera*) Leaf Ingredients

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**Aloe** *Aloe vera*
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**Goal:** The goal of this bulletin is to provide timely information and/or updates on issues of adulteration and mislabeling of aloe vera leaf juice ingredients that purport to meet the quality standard established by the International Aloe Science Council (IASC), an international trade association of aloe vera leaf juice ingredient producers and product manufacturers based in the United States and founded in 1980, applicable for use in dietary supplement, personal care, and cosmetic products**.** The bulletin may serve as guidance for quality control personnel, the international herbal products industry, and the extended natural products community in general. It is also intended to present a summary of the scientific data and methods on the occurrence of species substitution and adulteration, the market situation, and economic and safety consequences for the consumer and the industry.

## Definitions:

*Aloe vera leaf*: The aloe vera leaf in its entirety. It can be used as the raw material for the manufacture of aloe vera leaf juice ingredients.[1]

*Aloe vera whole leaf*: The use of the term 'whole' was introduced to differentiate ingredients where the entire leaf is used as a starting raw material to create aloe vera leaf juice (without the latex component) from those that start with inner leaf as the raw material. However, the use of this term has led to confusion, since aloe vera whole leaf juice may be mistaken for a material containing latex.

*Aloe vera inner leaf*: The inner leaf (the clear, central parenchymatous tissues of the aloe leaf) that may be used as the raw material for aloe vera inner leaf juices.[1]

*Aloe vera leaf gel*: In order to differentiate the inner leaf gel-like starting material from finished products that are gels by virtue of added jelling agents, the IASC defined aloe vera leaf gel as a liquid product with or without added thickening agents.[1,2] The World Health Organization (WHO) defines aloe vera gel as the colorless mucilaginous gel obtained from the parenchymatous cells in the fresh leaves of *Aloe vera*.[3] This is also correct, but is not generally found as an ingredient in finished products unless present as pulp.

*Aloe vera inner leaf juice*: According to the IASC, aloe vera inner leaf juice is manufactured by stripping off the outer leaf rind before further processing.[2] It may contain pulp or be pulp free. When thickening agents are added, it may be called a gel.[1] It may also have trace anthrones, which — depending on the manufacturing steps — may be removed through further processing. When dried, it is properly called aloe vera inner leaf dry juice, though common industry shorthand for this ingredient is 200x because 200 parts of liquid inner leaf juice yield approximately one part dry juice.

*Aloe vera leaf juice*: According to the IASC, aloe vera leaf

juice is manufactured by first macerating the entire leaf, rind and all. The bitter yellow anthrone-rich latex from the rind is removed by filtration, which is often accomplished via absorption by activated charcoal.[1] This process is known as decolorization and is routinely done for finished ingredients that may be referred to as aloe vera decolorized, charcoal filtered, purified, or filtered leaf juice. Common industry shorthand for this ingredient when dried to a dry juice is 100x because about 100 parts of aloe vera leaf juice yield approximately one part dry juice.

The term *juice* has also been used to refer to aloe latex (the WHO specifies aloe juice as the bitter yellow exudate originating from the bundle sheath cells of the leaf) which when inspissated (thickened) becomes the anthrone-rich laxative drug derived from some species of *Aloe*.[3]

## 1. General Information

**1.1 Common names**: Aloe vera, aloe, Barbados aloe, burn plant, Curaçao aloe, lily of the desert, true aloe, medicinal aloe, West Indian aloe.[4-8]

**1.2 Other common names**:

*Afrikaans*: Aalwyn[9]

*Chinese*: Luhui ye (蘆薈葉) [6-8]

*Danish*: Laegealoe[9]

*Dutch*: Aalewee, aloe[9]

*French*: Aloès, aloe vera, aloès vulgaire, aloès des Barbades[6,9,10]

*German*: Aloe, echte Aloe, Barbados Aloe, Curaçao Aloe[6,9-11]

*Italian*: Aloe delle Barbados, aloe di Curaçao, aloe mediterranea[9]

*Japanese*: Aroebera (アロエベラ)[9]

*Portuguese*: Azebre vegetal, babosa, babosa-medicinal, erva-babosa, aloe dos Barbados[6,9]

*Russian*: Алоэ (aloe), столетник (stoletnik)

*Sanskrit*: Ghrita kumara, kanyasara (dried juice of leaf)[7]

*Spanish*: Acibar, aloe, penca sabila, sábila, sávila, zábila[3,6,9,12]

*Swedish*: Äkta aloe[9]

**1.3 Accepted Latin binomial:** *Aloe vera* (L.) Burm. f.

**1.4 Synonyms:**
*Aloe barbadensis* Mill.[6-8,12,13]
*Aloe vulgaris* Lam.[13]

**1.5 Botanical family**: Xanthorrhoeaceae (alternatively placed in Aloaceae and Asphodelaceae)[3,6,8,13,14]

**1.6 Distribution:** *Aloe* species are found in sub-Saharan Africa, the Arabian Peninsula, on Madagascar, and some smaller islands off the east coast of Africa. *Aloe* is a diverse group of more than 600 species.[8,9,13] *Aloe vera* is especially abundant in southern and eastern Africa, and long thought to be a native there. From this area, it was subsequently introduced into northern Africa and other parts of the world.[3] In the United States it grows in the southern states of Texas, Arizona, and Florida.[6,8,14] In Mexico it is grown in the Northeastern states of Tamaulipas, Durango, San Luis Potosi, and Zacatecas, and also in Campeche and Yucatan.[8,15] *Aloe vera* was also introduced and is cultivated in many tropical and subtropical countries including Argentina, Belize, Bolivia, China, Colombia, Ecuador, El Salvador, Guatemala, Honduras, India, the Dominican Republic, North Africa, Saudi Arabia, Thailand, Yemen, and Venezuela.[6,14] The plant grows in stony outcrops and sandy plains, roadsides, and similar places, in full sun, from sea level to 1,300 m (4,265 ft).[6]

**1.7 Plant part and form:** A number of ingredients are made from aloe leaf, which include the two juices: aloe vera inner leaf juice, and aloe vera leaf juice (generally decolorized). When dried (freeze-drying is one technique), the dry juices have been commonly called 200x and 100x aloe vera powders, respectively (see Definitions in the introduction).

Aloe for use as a laxative, defined by the USP monograph[16] as the dried latex of the leaves of *A. vera*—known in commerce as aloe vera, Curaçao aloe, or Barbados aloe—or of *A. ferox*, or of hybrids of *A. ferox* with *A. africana* and *A. spicata*, known in commerce as Cape aloe, is not within the scope of this document.

**1.8 General use[s]:** Aloe's first known historic use dates back almost 6,000 years. Its medicinal application was first documented on a Mesopotamian clay tablet dating from 2100 BCE, and the Ebers Papyrus (ca. 1550 BCE), discovered in Egypt in 1873, listing at least 12 aloe-containing preparations for treating internal and external ailments.[14] Dioscorides, in *De Materia Medica* (65 AD), listed 19 different uses and actions of aloe, including as a purgative (for constipation) when drunk with water or milk, as a means to stop bleeding hemorrhoids when used internally, and for the treatment of ulcers and wounds, skin afflictions, and boils, when used externally.[3,5,6,14,17] Contemporary uses of aloe vera gel, inner leaf juice, and decolorized leaf juice include treatment of abrasions, burns, inflammation, insect bites, psoriasis, skin irritations and fungal infections, UV-radiation damage; as an emollient; as a common cosmetic ingredient, and as a wound-healing agent.[3,5,6,14,17] The use of the inner and decolorized whole leaf juices as commercial ingredients is relatively new.

Internally, aloe vera leaf juices have been used for diabetes, coughs and sore throat, kidney pains, digestive problems, stomach ulcers, and jaundice. The yellow latex of the leaves is also used as a laxative.[3,5,17] Aloe vera inner leaf is used as a general tonic for the circulatory, digestive, genitourinary, and female reproductive systems, and in the treatment of fever, constipation, obesity, conjunctivitis, joint inflammation, jaundice and hepatitis, menstrual dysregulation, and tumors.[6]

**1.9 Nomenclature considerations:** The earliest confu-

sion about the naming of the aloe plant is described in the Old Testament. The name "tree aloe" refers to a plant with an aromatic resin belonging to a different species in a different family, *Aquilaria agallocha* (Thymelaeceae), and the name "lign aloe" refers to *A. malaccensis*.[6,9] 'Aloes' in the New Testament (John 19: 39), however, refers to a material derived from a true species of *Aloe*, *Aloe perryi* Baker (syn. *Aloe succotrina* Weston).[9] Indeed, a number of aloe species were used interchangeably in Europe to make purgative preparations.[3,5,6,14,17] In the past 100 years, many aloe species were clumped generically with the name "aloe" and considered synonyms. Socotrine aloe (Socotra), Curaçao aloe, bitter aloe, and Cape aloe were interchangeable vernacular names given to various species of *Aloe* including *A. perryi*, *A. vera*, *A. ferox* and hybrids of *A. ferox*, with *A. africana* and *A. spicata* considered synonyms in the past.[4]

The United States Pharmacopeia (USP) official Aloe monograph for over-the-counter stimulant laxative drugs still includes several aloe species (*A. vera*, *A. ferox*, or hybrids of *A. ferox* with *A. africana* and *A. spicata*) in its description,[16] as do pharmacopeias in Europe and other parts of the world.[5,17] In the American health food and cosmetic markets *A. vera* is the predominant species used. The term "aloe vera" in this bulletin will be used generically in reference to the *Aloe vera* species. The nomenclature of ingredients used in labels of aloe products have lacked uniformity and precision. The IASC suggests all aloe vera products must include the Standardized Common Name "aloe vera" and specify the plant part/type of ingredient (i.e., "leaf" if the leaf is used in its entirety or "inner leaf").

## 2. Market

**2.1 Importance in the trade:** In 2003, IASC estimated that raw material sales of aloe vera leaf and leaf-derived ingredients were between $70-90 million globally with 35% growth expected over the next five years. At that time, the United States was by far the largest single seller of aloe vera as an ingredient with 60-65% of total sales, with Latin America constituting another 20-25%, and Asia and the Pacific Rim (Australia, China and India) together making up 10% of the market. Trade in finished products containing aloe ingredients, was estimated to be over $35 billion globally in 2003.[18] The importance of aloe vera as a source for ingredients in the food, cosmetic, dietary supplement, and personal care industries was emphasized by the market research company IMARC which reported that the global market value for aloe vera 'gel' was US $507 million in 2017.[19]

**2.2 Supply sources:** Aloe vera is extensively cultivated in many parts of the world, but Thailand, Mexico, and the United States continue to be the largest producers of aloe vera ingredients. According to two reports, Thailand is the biggest producer of aloe vera gel, accounting for around one-third of the total global production. More recently, China has emerged as an important supplier for aloe vera. Other leading producers in the North, Central, and South American region include Mexico, the Dominican Republic, the United States, and Costa Rica.[20] African countries with the largest aloe vera production include Nigeria and Kenya.[21]

**2.3 Market dynamics:** A recent report from the IMARC Group, a market research company, indicated that the global aloe vera 'gel' market was worth US $465 million in 2016, growing at a Compound Annual Growth Rate (CAGR) of around 11% during 2009-2016.[20] The market seems to have been growing steadily over the last decade, driven by varied and increasing usage of aloe vera leaf juices in food, health care, and cosmetic industries with the healthcare and personal care sectors being the two biggest drivers of aloe vera juice ingredient consumption.[20,22,23] (J. Wilson [IASC] email, June 28, 2017)

According to Future Market Insights (FMI), a provider of syndicated marketing research reports, the global aloe vera ingredient market is segmented, based on product type into various forms: aloe vera leaf juice, inner leaf juice, and others. In 2015, the aloe vera leaf juices segment dominated the market in terms of value and volume, and it is expected to remain dominant over the forecast period (up to 2026). Meanwhile, the aloe vera (whole) leaf juice segment is expected to expand at the highest CAGR in terms of value during the forecast period.[21]

## 3. Adulteration

**3.1 Known adulterants:** Materials used to adulterate aloe vera inner leaf juice and juice powder include undeclared amounts of other aloe species and juice made from whole aloe vera leaf. Substitution of dried powdered aloe leaf juices with undeclared maltodextrin or sucrose has also been reported.[6,24-27] (R. Gallego [Aloecorp] email to S. Gafner, April 2, 2019) The AOAC Standard Method Performance Requirements (SMPR)® document for identification of *Aloe vera* in dietary supplements and dietary ingredients requires analysis for presence of undeclared carrageenan, gum arabic (*Acacia senegal* and other *Acacia* spp., Fabaceae), and locust bean gum (*Ceratonia siliqua*, Fabaceae) in addition to maltodextrin. Despite their listing in the SMPR, the use of thickeners like carrageenan, gum arabic, or locust bean gum as aloe vera adulterants has limited evidence in the literature.[28]

According to IASC labeling guidelines, products labeled "aloe vera inner leaf juice" should consist solely of the liquid from the inner leaf from which the aloe exudate (latex) has been removed. Further, IASC proposes that the concentration of aloins A and B (the primary aloe vera anthrones) in aloe leaf dry juice be reduced to less than 10 ppm (parts per million).[2] Isocitrate (isocitric acid), which is more abundant in the aloe rind than the inner leaf, was established by IASC as a negative marker for the inner leaf. IASC also states that aloe vera leaf juice products that contain more than 5% dry weight of isocitric acid should be labeled as "aloe vera leaf juice," not "aloe vera inner leaf juice".[1,6] While IASC has proposed definitions and guidance for how aloe vera leaf-derived products should be described and labeled, not all products claim compliance with IASC. IASC also is not a regulatory body and so compliance with IASC guidelines is voluntary.

A number of other *Aloe* species are traded commercially and are sometimes not accurately declared as to proper species. Aloe species traded include *A. ferox, A. arborescens,* and *A. perryi* according to the American Herbal Pharmacopoeia (AHP) monograph on aloe.[6] The *American Herbal Products Association's Herbs of Commerce*, 2nd edition,[7] provides clear differentiation of common names used for these species and include cape aloe (*A. ferox*), *Aloe littoralis* (*A. littoralis*), Perry's aloe (*A. perryi*), *Aloe spicata* (*A. spicata*), and aloe vera (*A. vera*) as the aloes in trade.

**3.2 Additional IASC quality parameters:** Low quality aloe vera leaf and inner leaf juice ingredients may be due to decomposition or dilution with water. IASC has established specific standards of product strength. The minimum requirement for an aloe vera juice is 1% total aloe solids in aloe vera leaf juice and 0.5% total aloe solids for inner leaf juice ingredients.[6,29] The soluble solids value is an important quality indicator, because low values for solids suggest adulteration by dilution with water.[24] In addition, bulk aloe vera ingredients need to contain a minimum of 5% acemannan calculated by dry weight.[27]

The presence of acetic acid is indicative of the degradation of acetylated polysaccharides. Lactic acid levels of more than 10% are indicators of bacterial activity, likely due to contamination with *Lactobacillus* species. The presence of succinic and fumaric acids indicates enzymatic degradation of the polysaccharides.[27]

**3.3 Sources of information supporting confirmation of adulteration:** In the 1990s, spray-dried aloe vera juice with maltodextrin was sold as 100% aloe vera juice, constituting a fraudulent misrepresentation. This fraud was possible because many members of the industry promoted an analytical method for aloe quality termed the Methanol Precipitable Solids (MPS) test despite all scientific evidence that the test is not useful.[24] (See section 3.7)

In the early 1990's IASC started channeling efforts to protect both the industry and the consumer with the focus on the development of an aloe standard produced by the Aloe Research Foundation (ARF), an industry-sponsored organization with the goal to further research on aloe vera's biological activities. Analysis of commercial aloe vera ingredients was compared to the aloe vera ARF standard using a chromatographic procedure developed by Pelley et al. in 1993.[30] The first analysis indicated that the quality of commercial aloe vera ingredients was variable and not always accurately represented on the label or the certificate of analysis. Although no details of the number of samples tested and degree of adulteration were provided, the conclusion was that many commercial aloe ingredients in the marketplace were adulterated with undeclared maltodextrin.[24,30,31]

In 1998, 18 commercially available aloe vera samples in the US marketplace were analyzed at the University of Mississippi, School of Pharmacy, using size exclusion chromatography. Half of the samples contained no or only trace amounts of the main polysaccharide component in aloe vera.[32]

The same year, Kim et al, analyzed 21 commercial aloe vera ingredients in Korea, also confirming adulteration with undisclosed maltodextrin in over 30% of the samples.[25]

An investigative report, published in 2003 by *Nutraceuticals World*, concluded that adulteration was a serious problem in the aloe vera business, detailing how adulteration of aloe vera ingredients occurs and the economic incentive for such adulteration.[18]

In Europe, aloe vera samples, obtained from pharmacies and other commercial venues, were analyzed by the German Federal State of Baden-Württemberg's food control office.[33] Their report confirmed that 17 out of 24 high-priced aloe vera products contained no significant amount of aloe vera ingredients and were adulterated with large amounts of undisclosed sorbic and benzoic acids while being marketed as "aloe juices and gels" dietary supplements.

An analysis of 3 commercial aloe vera leaf solid raw materials and 12 commercial aloe vera products, with a newly developed spectrophotometric method to assess polysaccharide content, showed that 6 out of 12 commercial aloe vera products contained less than 20% (range 0.58-18.83%) of the active original aloe vera polysaccharide found in fresh whole aloe vera leaf.[28]

In another study conducted in Switzerland, nine aloe vera ingredient samples of leading international suppliers were examined by nuclear magnetic resonance (NMR) and compared with fresh aloe vera leaf gel. Only three samples were found to have acceptable levels of acemannan, the main aloe vera leaf polysaccharide.[34]

In another NMR study, the authors commented on the large percentage of aloe vera products adulterated with maltodextrin and suggested that NMR should be the method of choice to assess quality control (QC) of the samples.[35]

The International Agency for Research on Cancer (IARC) aloe vera monograph and the AHP *Aloe vera* leaf, *Aloe vera* leaf juice, *Aloe vera* inner leaf juice standards of identity, analysis, and QC monograph describe the use of maltodextrin in the manufacturing process and state that it is added to artificially enhance polysaccharide content. They also state that this has historically been one of the most common adulterants in aloe vera inner leaf juice products.[6,36]

In an article published by Nutraingredients-USA on November 12, 2012, and updated on September 26, 2016, Roy Upton (AHP) indicated in reference to aloe vera products in the marketplace that: "results that come back from analytical labs show that a number of 'aloe' products on the market contain little (in some case, none) of the actual plant."[22]

A *Bloomberg News* report of November 22, 2016 mentioned four samples of store-brand aloe gel purchased at national retailers showed no indication of the presence of aloe vera compounds in various lab tests. All products listed aloe barbadensis leaf juice — another name for aloe vera — as either the No. 1 or No. 2 ingredient (on the label) after water.[37] Aloe vera's three inner leaf chemical markers — acemannan, malic acid, and glucose — were absent in three

products based on NMR tests conducted by an anonymous lab hired by *Bloomberg News*. The three samples analyzed contained maltodextrin. The fourth aloe gel contained malic acid, but not acemannan and glucose.[37]

After this report, several law firms filed lawsuits against four retailers after separate testing failed to find aloe vera chemical marker compounds in the companies' private-label products. The plaintiffs are seeking class-action status and (asking for) restitution for all the customers who they say were misled.[37,38] One of the cases was dismissed at least in part based on the argument that acemannan levels can decrease depending on the storage conditions, which may not be under full control by the companies selling the aloe vera products.[39]

Alkemist Labs, a third-party contract analytical laboratory, shared a summary of their thin-layer chromatography (TLC) reports of 2015-2017, indicating they have "failed" samples because they contained a high content of maltodextrin. Sidney Sudberg, president and CSO of Alkemist Labs, said "Most of the time, we do not get any indication of whether the manufacturers use maltodextrin as an undeclared excipient, so we may be failing samples when the maltodextrin appears to exceed the aloe (content), chromatographically speaking." (S. Sudberg [Alkemist Labs] email, June 29, 2017)

IASC tests every aloe vera ingredient sold by an IASC member to ensure it has a minimum of 5% acemannan content by dry weight, as well as the presence of markers glucose and malic acid. A spokesperson states that IASC has not seen an adulteration issue recently, but the problem seems to be frequent on products from companies that are not IASC certified. (J. Wilson [IASC] email, June 28, 2017).

IASC Executive Director Jane Wilson added: "I am not aware of any recent reporting of adulteration with other aloe species. The responsible industry continues to be concerned with suppliers marketing aloe raw materials containing undeclared maltodextrin, as well as the use of poor quality aloe and "fairy-dusting" in aloe finished products. IASC conducts its certification program, and we have not had any products fail due to a documented case of adulteration, but of course this may not be representative of the market as a whole. Obviously companies who may want to cheat are not the ones that subject themselves to outside scrutiny." (J. Wilson [IASC] email, April 23, 2019)

**Aloe** *Aloe vera*
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**3.4 Accidental or intentional adulteration:** Both types (or means) of adulteration, accidental and intentional, are known to occur in the marketplace. The use of undeclared maltodextrin and preservatives is clearly intentional. Intentional adulteration is also easily carried out through the addition of excess water to juices or powders. The reasons for economically motivated adulteration are clearly stated in the German report from 2003: "High quality *Aloe vera* gel, containing 0.5-1.3% solid material, currently sells for $1.25 – $1.95 per kg (wholesale price) as non-concentrated pure juice. Whole leaf extract (0.95-2.0% solid matter) is available for $2.00 – $4.00 per kg. Usually, 10x to 40x concentrated gel is supplied. Powder (200x concentrate) sells for $225 – $305 per kg for IASC-certified material. However, aloe vera juice powder can be purchased for as little as $60, but it is likely to contain up to 60% maltodextrin, which is acceptable as long as it is appropriately labeled."[18] High quality 1x (single strength - neither diluted nor concentrated) aloe vera juice sold for approximately $1.45 – $2.00 per kg in 2018. Based on an informal investigation by this author, the spray-dried powders coming from inner aloe juice are running from $235 per kg for small amounts to about $140 for over 500 kg orders. Costs of (whole) aloe vera leaf juice ingredients fluctuate greatly. Spray-dried aloe

vera leaf juices range from $90 – $160 and unconcentrated decolorized aloe leaf juice can be priced as low as $18.

**3.5 Frequency of occurrence:** Several investigations from 1998 to 2016 in different countries suggest that adulteration of aloe vera inner leaf juice is very frequent.[25,28,32,33] The quality of the products varied, with some studies reporting that up to 50% of the commercial products tested are adulterated.[32] However, recent results from testing 361 powdered aloe vera leaf juice products by high-performance liquid chromatography (HPTLC) at Alkemist Labs, found that only 11 products (3%) were clearly adulterated with maltodextrin, meaning that they consisted solely of maltodextrin, or maltodextrin was present in amounts that made an accurate identity determination impossible. (S. Sudberg [Alkemist labs] email, June 29, 2017 and January 7, 2019)

**3.6 Possible safety/therapeutic issues:** Although anthrones from aloe vera latex found in the rind of the aloe vera leaf or other aloe species have a history of use for medicinal purposes, mainly as a laxative, their presence at relatively high concentrations in aloe vera food and supplement products may be responsible for some reported adverse effects.[36,40,41] The main adverse effect is diarrhea with consequent loss of fluid and electrolytes, but impacts on microbiota and mucosa architecture due to the cytotoxicity, mutagenicity, and carcinogenicity of anthrones after prolonged exposure have been observed in *in vitro* and animal studies.[40] The European Food Safety Authority (EFSA) published a safety assessment of hydroxyanthracene derivatives, including anthrones from aloe vera, used in food supplements in 2018, and based on limited data collected and reviewed, the EFSA Panel on Food Additives and Nutrition Sources Added to Food concluded no safe intake levels can be established.[42] While insufficient data are available to assess the carcinogenicity of non-decolorized aloe vera leaf juice in humans, IARC has classified non-decolorized aloe vera whole leaf extract as a possible human carcinogen.[36]

In the United States, aloe vera in food and supplement products is either derived from inner leaf or decolorized leaf preparations in which anthrones are largely removed. It is crucial to monitor the content of these compounds in aloe vera leaf juice ingredients.[40,43] The IASC standard suggests a maximum allowable aloin content in aloe vera-derived material for oral consumption of less than 10 ppm; for non-medical use, the recommended limit is 50 ppm or lower.[2,29]

No safety issues are known from adulteration of aloe vera with maltodextrin, glucose, sucrose, glycerin, and/or malic acid or after decomposition of aloe vera ingredients producing acetic, succinic, and/or lactic acids. However, some of the purported benefits of aloe vera may be diminished by excessive dilution of aloe vera polysaccharides with water, or the replacement of aloe vera polysaccharides with maltodextrin.

**3.7 Analytical methods to detect adulteration:** Several *Aloe* species including *A. ferox*, *A. arborescens*, and *A. perryi* are traded commercially and sometimes they are marketed as *A. vera*. The various species of aloe that appear in trade are readily differentiated by the morphology of the leaf and the color, size and location, of the "teeth," and can be authenticated macroscopically.[6] In addition, the presence of maltodextrin is readily detected by microscopic means. In cases where macro- or microanatomical features are lacking, chemical and genetic testing methods may be used to authenticate ingredients derived from aloe vera leaf (see below).

***Ionic strength***

A quick test to assess the adulteration of an aloe vera juice ingredient is to measure its ionic strength (conductivity). There is a direct correlation of the sum of the sodium, potassium, calcium, and magnesium cations per mg/L and the ingredient's conductivity. Maltodextrin has a much lower conductivity than spray-dried aloe vera powders.[24] Therefore, conductivity measurements provide a low-cost and rapid substitute for the analysis of the individual ions, e.g., by atomic absorption spectroscopy or inductively coupled plasma-mass spectrometry (ICP-MS).[24,30]

***Colorimetric assays***

A colorimetric assay can be used as an initial screening tool for identifying potentially adulterated aloe vera juice ingredients with maltodextrin. This is a method commonly known as starch detection method using an iodine/potassium iodide reagent. Depending on the amount of maltodextrin present, the solution will turn medium to dark brown or purple to black.[6] Another quick quantitative colorimetric assay was developed for the determination of acemannan in aloe vera ingredients and products based on formation of a complex between β-glucans and the azo dye Congo red. The reaction between the dye and aloe acemannan leads to a substantially more intense color reaction than with adulterating materials such as maltodextrin, locust gum, or gum arabic.[28] However, the method may be fooled by addition of undeclared β-glucans from other sources.

A different colorimetric approach takes advantage of the formation of a ferric-acetohydroxamic complex after reaction of the aloe acemannan with hydroxylamine and subsequent complex formation with ferric chloride. The submission of a validation report enabled it to achieve AOAC Official Method First Action status with the proviso that its use is limited to the analysis of processed raw materials and not finished products.[44] As with other colorimetric methods, the hydroxylamine/ferric chloride method lacks specificity. The color reaction is not only obtained with aloe acemannan, but also with other acetylated substances, which could be used to manipulate the results.

***Chromatographic assays***

AHP and the HPTLC Association provide details of an HPTLC method to distinguish *A. vera* leaf from leaves of *A. ferox* and *A. arborescens*.[6,45] In addition, the AHP monograph includes fingerprints for aloe vera leaf, outer leaf, inner leaf, and various IASC-certified commercial aloe vera ingredients.[6] TLC methods to authenticate aloe vera leaf

juice and 'gel,' and to detect adulteration in commercial products have also been published by Kim et al. and Lachmeier et al.[25,33]

High-performance liquid chromatography (HPLC) is most often used to quantify aloins A and B in aloe vera leaf juice products. Two HPLC methods were subjected to a single-laboratory validation according to guidelines of AOAC International, one of which was approved as an AOAC Official Method First Action status.[6,46,47] These methods allow to evaluate compliance of aloe vera products with the IASC for anthrone content. Kim et al. published an HPLC-refractive index (RI) method to determine maltodextrin in 21 aloe leaf 'gel' products, and found undeclared maltodextrin (45.0-94.6%) in eight samples.[25] However, since the maltodextrin peaks elute over a time span of about 16 minutes, the accurate quantification of maltodextrin in aloe vera leaf samples using this method by HPLC remains challenging. The determination of the isocitric acid contents can be used to distinguish products made with aloe rind or whole leaf from those made solely from the inner leaf.[48]

Another approach to determine the presence of maltodextrin in aloe vera leaf ingredient samples is the quantification of glucose, galactose, and mannose by gas chromatography (GC) after hydrolysis of larger polysaccharides (separated using a molecular weight filter of 5000 Da) and subsequent silylation.[25] Large amounts of glucose (relative to mannose) and absence of galactose are indications of materials that contain large amounts of maltodextrin. A headspace-SPME-GC/MS method developed by researchers in Germany has been used to evaluate 24 aloe vera beverages. The report explains how to determine authenticity (identity, adulteration, excessive dilution with water) undeclared preservatives, and quantify aloin in aloe vera beverages.[33]

Two publications have detailed methods to measure aloe vera polysaccharides in commercial preparations using size exclusion chromatography (SEC) with refractive index detection or multi-angle laser light scattering detection (MALLS).[32,49] The peak distribution from the analysis of commercial aloe vera liquids and powders provided highly variable results.[49,50] Therefore, it is unclear if the published methods are useful for the distinction among *Aloe* spp., or for the detection of undeclared maltodextrin.

### *Methanol precipitable solids*

The MPS test measures polysaccharides plus a complex of alcohol insoluble salts and organic acids in aloe vera leaf juices gravimetrically after precipitation and subsequent evaporation of the solvent. The values for "polysaccharide" generated by this test are substantially higher than the actual levels measured by other tests. Since the assay measures every molecule that is precipitated with methanol, it is easily fooled by the addition of extraneous materials, in particular other polysaccharides such as maltodextrin.[24] Despite these limitations, many companies may still rely on MPS values for quality control and even suggest their products are better than others when their MPS value is higher.

### *Spectroscopic assays*

Diehl and Teichmüller were the first to suggest $^{1}$H NMR as a tool to assess identity and quality of aloe vera leaf preparations.[31] A single-laboratory validation of an NMR method for the determination of aloe vera polysaccharides was published in 2009.[35] In 2010, an $^{1}$H NMR method for quality control of aloe vera products was developed and validated by research groups from industry and academia.[51] The procedure allows quantifying acetylated polysaccharides, glucose, malic acid, lactic acid, and acetic acid in aloe vera products to meet quality control specifications per IASC requirements. The presence of degradation products (e.g., lactic acid, succinic acid, fumaric acid, acetic acid, formic acid, and ethanol), preservatives (potassium sorbate, sodium benzoate, and citric acid/citrate), and other atypical impurities, additives, or adulterants (e.g., methanol, glycine, glycerol, sucrose, maltodextrin, propylene glycol, ethanol) can also be evaluated.

The method published by Jiao et al.[51] was expanded by adding cesium-EDTA, which allows the determination of magnesium, calcium, and fructose in addition to the compounds mentioned above.[52] Most recently, the AOAC SMPRs for identification of *Aloe vera* in dietary supplements and dietary ingredients specifically listed four potential aloe vera adulterants: maltodextrin, carrageenan, gum arabic, and locust gum.[53] Using $^{1}$H NMR, all four potential adulterants were detected at levels of 10% and above in decolorized aloe vera leaf extract.[54]

NMR provides advantages over separation-based test methods in that it is rapid, allows for specific recognition of molecules, and requires minimal sample preparation.[51] The disadvantage is that it is not a testing platform that is integrated into most commercial laboratories.

An authoritative reference for authentication and detection of adulterants of aloe vera leaf derived ingredients, with a specific emphasis on aloe vera leaf juice products that are compliant with IASC standards was produced by AHP in 2012. The AHP Aloe monograph details a variety of analytical methods and standards to authenticate ingredients made from aloe vera leaf, and to detect the most common adulterants.[6]

### *Genetic Methods*

Some preliminary attempts are being made to develop DNA methodologies to detect aloe vera adulteration. A test for identification of eight *Aloe* species, including *A. vera, A. arborescens*, and *A ferox*, was developed using the Random Amplified Polymorphic DNA (RAPD) technique.[55] Using this technique may be useful in combination with other analytical methods to help identify aloe samples containing DNA, but may not be a solution for the evaluation of processed aloe vera leaf ingredients if there is no DNA of sufficient quality to allow unambiguous authentication.[55]

## 4. Conclusions

Aloe vera leaf and inner leaf juice ingredient products are widely used for their healing properties, both for internal

use and in a wide array of topical products. There is significant nomenclatural confusion among different aloe vera derived materials. The IASC has attempted to establish a clear distinction between unfiltered anthrone-rich aloe vera leaf products and those that are decolorized to contain less than 10 ppm of aloins.[21,22] The marketplace importance of aloe vera products rich in aloins is low in the United States and internationally.

The main motivation for aloe vera adulteration is economic, i.e., the dilution of leaf and inner leaf powder with undeclared maltodextrin or sucrose, or of liquids with excessive amounts of water. Also observed is the substitution/admixture of aloe vera inner leaf with aloe vera (whole) leaf. Companies and individuals involved in the purchase, trade, or quality control of aloe vera leaf ingredients should be aware of the quality requirements and of existing adulteration issues, and take the necessary precautionary measures to avoid purchasing, selling, or manufacturing products made with adulterated aloe vera leaf materials.

## 5. References


1. IASC Labeling Guidance. The International Aloe Science Council (IASC); 2009. http://www.iasc.org/Portals/19/Documents/Members/10_0405_IASC_Labeling_Guidance_Definitions.pdf. Accessed May 4, 2018.
2. The International Aloe Science Council presents: An aloe scientific primer. The International Aloe Science Council (IASC); 2009. http://www.iasc.org/Portals/19/Documents/Scientific/IASC_Aloe_vera_A_Scientific_Primer.pdf. Accessed February 13, 2019.
3. Aloe vera and aloe gel. *WHO Monographs on Selected Medicinal Plants.* Vol 1. Geneva, Switzerland: World Health Organization; 1999.
4. Youngken HW. *Textbook of Pharmacognosy,* 6th ed. Philadelphia, PA: The Blakiston Company; 1948.
5. Blumenthal M, Busse WR, Goldberg A, Gruenwald J, Hall T, Riggins CW, Rister RS, eds. Klein S, Rister RS, trans. *The Complete German Commission E. Monographs—Therapeutic Guide to Herbal Medicines.* Austin, TX: American Botanical Council; Boston: Integrative Medicine Communication; 1998.
6. Upton R, Axentiev P, Swisher D. *American Herbal Pharmacopoeia and Therapeutic Compendium: Aloe Vera Leaf, Aloe Vera Leaf Juice, Aloe Vera Inner Leaf Juice,* Aloe vera *(L.) Burm. f. Standards of Identity, Analysis, and Quality Control.* Scotts Valley, CA: American Herbal Pharmacopoeia; 2012.
7. McGuffin M, Kartesz JT, Leung AY, Tucker AO. *Herbs of Commerce.* 2nd ed. Silver Spring, MD: American Herbal Products Association; 2000.
8. Tropicos.org. Missouri Botanical Garden. https://www.tropicos.org/Name/34000217. Accessed January 17, 2019.
9. Olwen MG, Ronell RR, Figueiredo E, Smith GF. *The Aloe Names Book.* Pretoria, South Africa: National Biodiversity Institute, S A N B I; 2011.
10. Melzig MF, Hiller K, Loew D. *Aloe barbadensis*. In: Blaschek W, ed. *Wichtl — Teedrogen und Phytopharmaka*. Stuttgart, Germany: Wissenschaftliche Verlagsgesellschaft mbH; 2016:63-66.
11. Mills S, Bone K. *Principles and Practice of Phytotherapy: Modern Herbal Medicine.* Edinburgh, Scotland: Churchill Livingstone; 2000.
12. Aguilar A, Camacho JR, Chino S, Jácquez P, López ME. *Herbario medicinal del Instituto Mexicano del Seguro Social.* Mexico City, Mexico: Instituto Mexicano del Seguro Social; 1994.
13. *Aloe vera* (L.) Burm.f. The Plant List. Version 1.1. http://www.theplantlist.org/tpl1.1/record/kew-298116. Accessed June 12, 2017.
14. Engels G. Aloe. *HerbalGram.* 2010;87:1-5.
15. Medel Zavala AE, Ortiz-Velazquez JR. *Estudio de factibilidad para el cultivo de sabila (*Aloe vera*) en San Luis Potosí*. San Luis Potosí, Mexico: Facultad de Economía, Universidad Autonoma de San Luis Potosí; 2006.
16. Aloe. *USP 42-NF 37*. Rockville, MD: United States Pharmacopeial Convention; 2019:140-141.
17. European Medicines Agency. Community herbal monograph on *Aloe barbadensis* Miller and on *Aloe* (various species, mainly *Aloe ferox* Miller and its hybrids). London, United Kingdom: European Medicines Agency Committee on Herbal Medicinal Products (HMPC); 2006:1-9.
18. Herzberg F, Gruenwald J. *Aloe vera*: An international success story. A glimpse of the international aloe market. *Nutraceuticals World [online]*: Rodman Media; 2003.
19. Aloe vera gel market: Global industry trends, share, size, growth, opportunity and forecast 2018-2022 [press release]. Arlington, VA: IMARC Group; 2018.
20. IMARC, 2017 Aloe vera gel market: Global industry trends, share, size, growth, opportunity and forecast 2017-2022. International Market Analysis Research and Consulting Group; 2017:1-48.
21. Global demand for *Aloe vera* extracts to reach 60,720 tonnes in 2016; Emergence of innovative, high-quality and cost-effective products ramping up adoption. 2016; http://www.futuremarketinsights.com/press-release/aloe-vera-extracts-market. Accessed January 10, 2018.
22. Schultz H. Global aloe market estimated at 13 billion. *Nutraingredients USA [online]*: William Reed Business Media, Inc.; 2012.
23. Watson E. Improve USA: Aloe is already the biggest botanical on the planet but it's about to get even bigger. *Nutraingredients [online]*: William Reed Business Media, Inc.; 2012.
24. Waller TA, Pelley RP, Strickland FM. Industrial processing and quality control of *Aloe barbadensis* In: Reynolds T, ed. *Aloes, The Genus* Aloe. Boca Raton, FL: CRC Press LLC; 2004:139-205.
25. Kim KH, Lee JG, Kim DG, et al. The development of a new method to detect the adulteration of commercial aloe gel powders. *Arch Pharm Res.* 1998;21(5):514-520.
26. Yaron A. Characterization of *Aloe vera* gel before and after autodegradation, and stabilization of the natural fresh gel. *Phytother Res.* 1993;7(7):S11-S13.
27. Certification Program Policies & Operational Procedures. The International Aloe Science Council (IASC); 2012. http://www.iasc.org/Portals/19/Documents/Certification/12_0312_IASC%20Certification%20Program_SOP_EDIT.pdf?ver=2016-06-30-215036-090. Accessed May 8, 2018.
28. Eberendu AR, Luta G, Edwards JA, et al. Quantitative colorimetric analysis of aloe polysaccharides as a measure of *Aloe vera* quality in commercial products. *J AOAC Int.* 2005;88(3):684-691.
29. *Aloe vera* Quality Standard The International Aloe Science Council (IASC); 2015. http://www.iasc.org/Portals/19/Documents/Certification/AloeVeraQualityStandard.pdf?ver=2015-09-01-113340-987. Accessed May 8, 2018.
30. Pelley RP, Wang Y-T, Waller TA. Current status of the quality control of *Aloe barbadensis* extracts. *SÖFW Journal* 1993;119(5):255-268.
31. Diehl B, Teichmüller EE. Aloe vera, quality inspection and identification. *Agro Food Ind Hi-Tech.* 1998;9(1):14-16.
32. Ross SA, ElSohly MA, Wilkins SP. Quantitative analysis of *Aloe vera* mucilaginous polysaccharide in commercial *Aloe vera* products. *J AOAC Int.* 1997;80(2):455-457.

33. Lachenmeier K, Kuepper U, Musshoff F, Madea B, Reusch H, Lachenmeier DW. Quality control of *Aloe vera* beverages. *Electron J Environ Agric Food Chem.* 2005;4(4):1033-1042.
34. Bozzi A, Perrin C, Austin S, Arce Vera F. Quality and authenticity of commercial aloe vera gel powders. *Food Chem.* 2007;103(1):22-30.
35. Davis B, Goux WJ. Single-laboratory validation of an NMR method for the determination of *Aloe vera* polysaccharide in pharmaceutical formulations. *J AOAC Int.* 2009;92(6):1607-1616.
36. *Aloe Vera. Some drugs and herbal products: IARC monographs on the evaluation of carcinogenic risks to humans.* Vol 108. Lyon, France: International Agency for Research on Cancer (IARC); 2016:37-71.
37. Mulvany L, Faux Z. No evidence of *Aloe vera* found in the *Aloe vera* at Wal-Mart, CVS. Wal-Mart, Target, CVS sell aloe without appearance of plant. *Bloomberg News [online]*. New York, NY: Bloomberg L.P.; 2016.
38. *Patricia Bordenet vs CVS Health Corporation. Case: 1:16-cv-06103*, June 10, 2016 (Illinois Northern District Court).
39. Family Dollar aloe vera false advertising class action tossed, for now. Top Class Actions, LLC; 2018. https://topclassactions.com/lawsuit-settlements/lawsuit-news/845951-family-dollar-aloe-vera-false-advertising-class-action-tossed-now/. Accessed February 20, 2019.
40. Boudreau MD, Olson GR, Tryndyak VP, Bryant MS, Felton RP, Beland FA. From the cover: Aloin, a component of the *Aloe vera* plant leaf, induces pathological changes and modulates the composition of microbiota in the large intestines of F344/N male rats. *Toxicol Sci.* 2017;158(2):302-318.
41. Gardner Z, McGuffin M. *American Herbal Products Association's Botanical Safety Handbook.* 2nd ed. Boca Raton, FL: CRC Press; 2013.
42. Younes M, Aggett P, Aguilar F, et al. Scientific opinion on the safety of hydroxyanthracene derivatives for use in food. *EFSA Journal.* 2018;16(1):5090-5187.
43. Shao A, Broadmeadow A, Goddard G, Bejar E, Frankos V. Safety of purified decolorized (low anthraquinone) whole leaf *Aloe vera* (L) Burm. f. juice in a 3-month drinking water toxicity study in F344 rats. *Food Chem Toxicol.* 2013;57:21-31.
44. Metcalfe C. Quantitation of *Aloe vera* polysaccharides by O-acetyl and UV-Vis spectrophotometry: First action 2018.14. *J AOAC Int.* 2019.
45. Barbados aloes (*Aloe barbadensis*). HPTLC Association. Aloe_barbadensis_Barbados_Aloes_HPTLC_Association_31_Aug_17.pdf. Accessed January 8, 2019.
46. Brown PN, Yu R, Kuan CH, Finley J, Mudge EM, Dentali S. Determination of aloin A and aloin B in *Aloe vera* raw materials and finished products by high-performance liquid chromatography: Single-laboratory validation. *J AOAC Int.* 2014;97(5):1323-1328.
47. Kline D, Ritruthai V, Babajanian S, et al. Quantitative analysis of aloins and aloin-emodin in *Aloe vera* raw materials and finished products using high-performance liquid chromatography: single-laboratory validation, first action 2016.09. *J AOAC Int.* 2017;100(3):661-670.
48. Zhang Y, Bao Z, Ye X, et al. Chemical investigation of major constituents in *Aloe vera* leaves and several commercial aloe juice powders. *J AOAC Int.* 2018;101(6):1741-1751.
49. Turner CE, Williamson DA, Stroud PA, Talley DJ. Evaluation and comparison of commercially available *Aloe vera* L. products using size exclusion chromatography with refractive index and multi-angle laser light scattering detection. *Int Immunopharmacol.* 2004;4(14):1727-1737.
50. He K, Mergens B, Yatcilla M, et al. Molecular weight determination of aloe polysaccharides using size exclusion chromatography coupled with multi-angle laser light scattering and refractive index detectors. *J AOAC Int.* 2018;101(6):1729-1740.
51. Jiao P, Jia Q, Randel G, Diehl B, Weaver S, Milligan G. Quantitative 1H-NMR spectrometry method for quality control of *Aloe vera* products. *J AOAC Int.* 2010;93(3):842-848.
52. Monakhova YB, Randel G, Diehl BWK. Automated control of the organic and inorganic composition of *Aloe vera* extracts using 1H NMR spectroscopy. *J AOAC Int.* 2016;99(5):1213-1218.
53. Ingle P, Barrett B, Betz JM, et al. AOAC SMPR® 2017.010. *J AOAC Int.* 2017;100(4):1187-1188.
54. Lee I, Vo J, Ma H, et al. Detection and determination of adulterants in *Aloe vera* using NMR and FTIR techniques. 132nd AOAC International Annual Meeting & Exposition; 2018; Toronto, ON, Canada.
55. Ezzat SM, El Sayed AM, Salama MM. Use of random amplified polymorphic DNA (RAPD) technique to study the genetic diversity of eight *Aloe* species. *Planta Med.* 2016;82(15):1381-1386.

## REVISION SUMMARY

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