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Aloe Vera: A Valuable Ingredient for the Food, Pharmaceutical and Cosmetic Industries—A Review

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Scientific investigations on Aloe vera have gained more attention over the last several decades due to its reputable medicinal properties. Some publications have appeared in reputable Scientific Journals that have made appreciable contributions to the discovery of the functions and utilizations of Aloe—"nature's gift." Chemical analysis reveals that Aloe vera contains various carbohydrate polymers, notably glucomannans, along with a range of other organic and inorganic components. Although many physiological properties of Aloe vera have been described, it still remains uncertain as to which of the component(s) is responsible for these physiological properties. Further research needs to be done to unravel the myth surrounding the biological activities and the functional properties of A. vera. Appropriate processing techniques should be employed during the stabilization of the gel in order to affect and extend its field of utilization.

Keywords chemical composition, gel stabilization, biological activity

I. INTRODUCTION

Aloe is a tropical or subtropical plant characterized by lance-shaped leaves with jagged edges and sharp points. It has a history of use in folk medicine for skin and other disorders, which date back thousands of years.[1,2] Today, the processing of A. vera gel, derived from the leaf pulp of the plant for medicinal and cosmetic use, has become a big worldwide industry.

For centuries, this plant has been used for its medicinal and therapeutic properties without any clear understanding or scientific analysis of the basis for such properties.

In spite of the confusing scientific literature, together with a number of contradictory reports on this plant, it is still undoubtedly one of the few botanical medications with widespread domestic use in Western society. However, due to the lack of knowledge of the Aloe plant and its characteristics, most methods employed for the processing of the plant and its component result in end products that do not consistently achieve desired results.[4]

Generally, the production process of Aloe products involve crushing, grinding, or pressing of the entire leaf of the Aloe plant to produce an A. vera juice, followed by various steps of filtration and stabilization of the juice.[3,4] The resulting solution is then incorporated in or mixed with other solutions or agents to produce a pharmaceutical, cosmetic, or food product.[4]

In the food industry, A. vera has been utilized as a resource of functional food, especially for the preparation of health food drinks and other beverages, including tea. The amount of A. vera gel that finds its application in the pharmaceutical industry is not negligible as far as the manufacturing of topical ointments, gel preparations, and tablets and capsules are concerned. A. vera gel also finds its application in the cosmetic and toiletry industries, where it is used as a base material for the preparation of creams, lotions, soaps, shampoos, and facial cleansers.

Unfortunately, because of improper processing procedures, many of these so-called Aloe products contain very little or virtually no active ingredients, namely mucilaginous polysaccharides.

In view of the known wide spectrum of biological activities possessed by the leaves of the Aloe plant and its wide spread use, it has become imperative that the leaf be processed with the aim of retaining essentially every bioactive component.

For these reasons, scientists in the last several decades have begun to seriously probe Aloe chemistry for the following purposes:

1. To investigate the significant chemical ingredients which are responsible for the reported healing effects.[5–7]
2. To develop an effective method for the process of the A. vera leaf and, in the process, preserve and maintain almost all of

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the bioactive chemical entities naturally present in the Aloe leaf.[30–33]

This study aims to provide a succinct resume of information regarding A. vera to serve as a reference for further investigations about this potential ingredient. The analysis essentially deals with the botany, chemical properties, gel stabilization technique, biological functions, and current uses and applications of Aloe vera.

II. BOTANY OF ALOE VERA

Until recently, most sources placed Aloe in the Lily family (Liliaceae), but according to Reynolds,[8] it has now been designated its own family, known as Aloaceae. Nonetheless, it is related to the lily family and to plants, such as garlic, onion, and asparagus, all of which are known to have medicinal properties.[9,10] Reynolds[11,12] described 314 species in his classic monographs; there are now over 360 accepted species.[13]

Aloe is a xerophyte, therefore, it prefers very dried arid conditions, most of them originating in Africa.[9] Aloes vary in size beginning with the dwarf species, which is only a few centimeters in diameter, such as the popular house-plant Aloe variegata, and end with species as large as a small tree.

The nomenclature of A. vera has been very confusing, and the plant has been known under a variety of names.[12] There are at least four main species that have medicinal properties: Aloe barbadensis Miller, Aloe perryi Baker, Aloe ferox, and Aloe arborescens.[9,14] Most Aloe plants are non-toxic, but a few are extremely poisonous, containing a hemlock-like substance.[14] Aloe barbadensis Miller is considered to be medicinally the most potent and, therefore, is the most popular.

Aloe vera is a clump-forming, perennial succulent with basal rosettes of tapering thick leaves. In young plants, the leaves appear at ground level, but the stem can grow up to 25 cm long in older plants. There may be 12–16 leaves per plant, with the young leaves being more or less erect, while the older lower leaves are more wide spread. The plant matures when it is about 4 years old and has a life span of about 12 years. When fully grown, the individual leaves can reach a height of 60–90 cm long and 5–10 cm across the base, tapering to a point with saw-like teeth along their margins. A transverse section of the leaf reveals a slightly concave appearance on the adaxial surface, whereas the lower abaxial surface is markedly convex. In young plants and in the suckers or 'pups,' which grow from the plant base, the leaves are a bright green color with irregular whitish spots on both sides. As the rosettes mature, successive leaves have fewer spots, and fully mature leaves are a spotless grey-green color.

Although most Aloe species fit into the description given here, some, however, do not. Wood[15] has discussed the various varieties that have been described within the Aloe vera species.

The epidermis of the leaves has thick cuticles. Beneath the epidermis is the mesophyll, which is differentiated into chlorenchyma cells and thinner walled cells, known as parenchyma. The parenchyma cells harbor a transparent mucilaginous jelly. The vascular bundles with inner bundle sheath cells contain the yellow sap, which have laxative properties and are sandwiched between the two major cells. Aloe vera contains two major liquid sources, a yellow latex (exudate) and the clear gel (mucilage). The mucilaginous jelly from the parenchyma cells of the plant is referred to as Aloe vera gel. Thus, there are broadly three distinct portions of the A. vera leaves:

1. yellow sap, mainly anthraquinones;
2. internal gel matrix or the 'fillet;'
3. the 'rind,' which consists of outer rinds, tips, bases, and thorns.

III. CHEMICAL COMPOSITION OF ALOE VERA

Although the components of Aloe leaf exudates have been studied in some detail, the gel has received less intensive chemical investigation. While some reviews, such as Spoerke and Ekins[16] review make a clear distinction between the components found in the gel and those in the exudates, however, many do not [eg., Henry[6]].

An early chemical investigation by Rowe and Parks[17] distinguishing between the components of the leaf pulp and the rind indicated that the pulp contained 98.5% water, and its alcohol-insoluble portion was a mucilage, with a high content of uronic acid, fructose, and hydrolysable sugars. Enzymes, such as an oxidase, a catalase, and an amylase were reported to be present, but tannins, pectins, and vitamins A and D were absent, and there was only a small nitrogen content. The leaf pulp did not respond to tests for 'aloin.'

Waller et al.[18] analyzed an aqueous acetone extract of macerated whole leaves. Seventeen common amino acids were detected in the free state, with arginine being relatively abundant and representing approximately 20% of the total amino acids. Two monosaccharides, D-glucose and D-mannose were also identified, together with trace amounts of xylose, rhamnose, galactose, and either arabinose or fucose. Also present were lupeol(a triterpenoid), cholesterol, campestrol, and B-sitosterol.

The conventional cryodesiccation[19] technique to determine the water content of the homogenized A. vera gel revealed that the unpreserved, raw leaf mucilage, consists of about 99.5% water and has a pH of 4–5. Also, the protein content of a lyophilized product, as determined by the Kjeldahl method, indicates a level that corresponds to about 0.013% in commercial aloe gel products.[20]

Analysis of the A. vera gel by Meadows[21] indicated that at least four different partially acetylated glucomannans were thought to be responsible for producing the thick, stringy mucilage-like properties that are characteristic of the 'raw' aloe gel. The viscosity of the gel reduced when these sugars were subjected to hydrolysis. He also claimed that at least six enzymes are present in the A. vera gel: bradykinase, cellulase,

carboxypeptidase, catalase, amylase, and an oxidase. The bradykinase activity of an aloe extract has been reviewed by Fujita et al.[22]

Structural studies of polysaccharides found in A. vera gel by some researchers[23,24] supports the claim that the gel is composed of at least four different partially acetylated glucomannans, which are linear polymers with no branching and contain 1–4 glycosidic linkages in the ratio of glucose and mannose 1:2.8.

Ovodova et al.[25] reported that the presence of uronic acid, upon fermentative hydrolysis with pectinase,yields galacturonic acid and oligosaccharides. Gjerstad,[19] however, did not find uronic acids in the course of his analysis. He reported that A. vera gel carbohydrates consists of glucose and a polyuronide, consisting of a high molecular weight glucose-mannose polyose (MW up to about 2.75×10^5), and hexuronic acids, which upon hydrolysis yield glucose and mannose, as well as traces of galactose, arabinose, and xylose.

The presence of some vitamins has been reported. These include the important antioxidant vitamins A, C, E, B_1(thiamine), B_3(niacin), B_2(riboflavin), as well as choline and folic acid.[10,14] Some researchers suggest that there is also a trace of vitamin B_{12}, which is normally only available from an animal source.[9,10,14]

Mineral constituents of lyophilized A. barbadensis juice have been examined by some researchers.[26–28] It was concluded that the concentrations of chloride and potassium appeared to be excessive for most plant productions, whereas the sodium content was less than average. Calcium and magnesium were also found to be dominant cations. Leung[7] and Meadows[21] pointed out that the effects of seasonal, climatic, and soil variations should not be neglected, since they may strongly affect the composition of the gel. These factors could probably explain the differences in results obtained by the different experimental researchers.

Henry, however, reported that the different compositional and analytical results could be due to the different varieties of species of A. vera. In addition to the species, climatic and seasonal variations and the age of the plant are additional factors to be considered. The most significant increases in the components, eg., aloin, are found in plants 2–3 years old.[29]

IV. GEL STABILIZATION TECHNIQUE

As stated previously, A. vera gel is the mucilaginous jelly obtained from the parenchyma cells of the A. vera plant. When exposed to air, the gel rapidly oxidizes, decomposes, and looses much of its biological activities.[30] Different researchers have described different processing techniques of the gel with regard to its sterilization and stabilization, ie., cold processing or heat treatment. However, the fundamental principles underlying these processing techniques remains almost the same. Regardless of the relative quality of the plant, the best results are obtained when the leaves are processed immediately after harvesting. This is because degradative decomposition of the gel matrix begins cutting, due to natural enzymatic reactions, as well as the growth of bacteria within the gel, due to the presence of oxygen.

Typically, the entire process involves[31–33] washing the freshly harvested A. vera leaves in a suitable bactericide, followed by the processing of the leaves to mechanically separate the gel matrix from the outer cortex. The separation of the gel from the leaf could be facilitated by the addition of cellulose dissolving compounds, eg., cellulase. Thus, the aloe liquid obtained is treated with activated carbon to decolorize the liquid and remove aloin and anthraquinones, which have laxative effects. This is especially so if the stabilized gel is to be used as a drink formulation for internal use. The resultant liquid is then subjected to various steps of filtration, sterilization, and stabilization. The stabilized liquid, thus, obtained could be concentrated to reduce the amount of water or, alternatively, almost all of the water removed to yield a powder.

In the cold processing technique, the entire processing steps are accomplished without the application of heat. Coats[34] reported the use of enzymes, like glucose oxidase and catalase, to inhibit the growth of aerobic organisms within A. vera gel and, thereby, sterilize it. Other sterilization steps reported in the cold processing include exposing the gel to ultraviolet light,[34,35] followed by a micron filtration.[34]

In the heat treatment processing, sterilization is achieved by subjecting the aloe liquid obtained from the activated carbon treatment to pasteurization at high temperature.[3,31,32] Aloecorp[36] has reported that the biological activity of A. vera gel essentially remains intact when the gel is heated at 65°C for periods less than 15 minutes. Extended periods or higher temperatures have resulted in greatly reduced activity levels. They, however, suggested that the best method of pasteurization is HTST (high temperature short time), followed by flash cooling to 5°C or below.

In all the processing techniques, stabilization can be achieved by the addition of preservatives and other additives. The use of sodium benzoate, potassium sorbate, citric acid, vitamin E in synergism, and the resultant efficacy, has been reported by some researchers.[3,4]

V. BIOLOGICAL ACTIVITY OF ALOE VERA

The controversy over the identity of the active substance(s) in A. vera has not been settled. Also, various mechanisms have been proposed for the alleged healing properties of A. vera. Since no single definitive active ingredient has been found, it is commonly suggested that there may be some synergistic action between the polysaccharide base and other components.[6,37]

According to Mackee,[38] vitamin D was the healing agent, but Rowe[39] reported the absence of vitamin D. Morton[40] suggested a theory stating that the seeming efficacy of aloe pulp may be attributable to its high water content, ie., 96%+, providing a means of making water available to injured tissue without sealing it off from the air. This theory would explain the instant soothing effect A. vera gel has on burns, but would not account for the

long-term effects of healing. However, according to Spoerke and Ekins[16] and Meadows,[21] the action of A. vera is simply due to its moisturizing and emollient effects, hence, its use in cosmetics.

Some workers reported that the effective components for wound healing may be tannic acid[41] and a type of polysaccharide.[42] Other researchers have also reported anti-inflammatory effects of complex polysaccharides, glycoproteins, and sulfated polysaccharides. However, there are many examples in the literature indicating that polysaccharides can exhibit pharmacological and physiological activities without help from other components.

It is, therefore, logical that the mucilaginous gel of the A. vera plant, which is essentially a polysaccharide, holds the secret to A. vera's medicinal properties.

Many researchers, such as Collins and Collins,[43] Fine and Brown,[44] and Crew[45] have attributed pain-relieving properties to A. vera gel. Robson et al.[5] found salicylate, lactate, and magnesium in A. vera extract and suggested that the anaesthetic property could either be due to an aspirin-like effect or the high magnesium ion content, or possibly both acting synergistically. They further postulated that anthraquinone-type compounds, such as emodin and barbaloin could be broken down by the Kolbe reaction to salicylates.

It is virtually impossible to prevent contamination by the leaf exudates during commercial extraction of A. vera gel. It is also believed that in intact leaves anthraquinones and their derivatives may diffuse into the gel from the bundle sheath cells; this possibly supports the conclusion of Rowe et al.[46] who state that the healing agent is passed from the rind into the gel on standing.

Davis,[47] using the Conductor-Orchestra concept, explains the relationships that exists among over 200 biologically active compounds within A. vera. One of these molecules, a polysaccharide, acts as the conductor that leads a symphony composed of 200+ biologically active compounds. Davis concluded that, as the conductor, the polysaccharide modulates the biological activity between the surrounding orchestra molecules to work synergistically.

In view of these findings, it will seem presumptuous for any scientific researcher to consider or even to postulate that any one substance is responsible for the biological activity seen in the A. vera gel.

VI. USES AND APPLICATIONS

The use of A. vera could be dated as far back as the biblical times. Historically, A. vera has been known as a traditional folklore medicine for the treatment of many diseases and sicknesses. A. vera is a well-known anti-inflammatory and wound-healer, accelerating the rapid growth of epithelial tissue. Davis et al.[48] examined evidence that A. vera is effective in treating wounds and reducing inflammation by the action of mannose-6-phosphate(a major sugar in aloe gel), which they found to be an active growth substance.

Aloe vera is known to have a marked effect in the treatment of scar tissue and the prevention of scar formation following injury to the skin. This is because A. vera stimulates cell production through the activity of the amino acids, which are the basis for new cell formation, and also, due to the ability of its enzymes, promotes regeneration at the deepest layers of the skin.

Aloe vera has also been used in the treatment of burns. It is suggested that lectin may be responsible for the therapeutic effect of the gel on burns.[49] Aloe vera can be used successfully in the general treatment of skin ulcers, including mouth ulcers, cold sores (herpes simplex), and leg ulcers. This is possibly due to the anti-virucidal effect of the A. vera gel at concentrations of about 80%.[50]

Blitz et al.[51] reported the use of A. vera gel internally taken to treat peptic ulcers and disturbances of the gastrointestinal tract. They attributed the gel effect to coacervation of pepsin inhibition of hydrochloric acid secretion and a general detoxifying effect.

In the field of dentistry, aloe vera has been used to treat a variety of dental conditions and has been found to relieve pain and accelerate healing after periodontal flap surgery.[52]

The use of A. vera gel has also been described in veterinary medicines. The gel extract has been used in the treatment of a number of external conditions in many animals.[53,54] These conditions include ringworm, allergies, abscesses, fungal infections, various types of inflammation, pain, and itching.

Recent studies indicate that aloe vera can be used in the treatment of HIV-AIDS. This is attributed to the anti-viral and immuno-modulating properties of acemannan (a group of mucopolysaccharides found in aloe vera), which have direct effects on the cells of the immune system, activating and stimulating macrophages, monocytes, antibodies, and T-cells. The acemannan acts as a bridge between foreign proteins, such as virus particles macrophages, and facilitating phagocytosis[54,55] this is a key component in boosting cell-mediated immunity, which is deficient in HIV infection.

Aloe vera has also found its use in the treatment of cancer[56] and has been demonstrated to have a positive effect on the inhibition of tumour growth.

The A. vera gel has found an extensive application in the cosmetic and toiletry industries. This is principally due to its valuable moisturizing emollient effect.[19,57] A. vera gel has become an important selling point in cosmetic products. The cosmetic formulations available include a large range of moisturizing creams, cleansers, shampoos, and soaps. In the USA and Asia, aloe extracts have been incorporated into shaving creams and lotions to promote the healing of cuts.

Aloe vera's application in the pharmaceutical industry is also highly significant. Its used in the manufacture of medical products, such as burn treatments, ointments, and medicated creams and lotions for topical applications to fight various skin disorders. Bottled A. vera gel or juice is widely available in the USA for internal consumption as a tonic, and it has been claimed to cure many illness, such as gout, constipation, and arthritis.

Aloe vera also find its application in the food industry essentially in the formulation of health food drinks. Its also used in

the manufacture of yogurt and other beverages, including tea. In the USA, its becoming a common phenomenon for people to add the powdered extracts to their food or take one of the many flavored A. vera drinks. Because of these uses, it appears that aloe vera is tremendously beneficial and has a very wide range of utilization.

However, due to its increased popularity and application over the past several years, there is a bewildering variety of Aloe vera products available on the market today. The question often asked by consumers is "what is the best Aloe vera." This is quite vague and may depend on the purpose for which you need the Aloe vera product. In any case, the best Aloe vera is a preparation that maximizes the desired constituents, minimizes any ingredient with negative effects, maintains the constituents in an unaltered and active form, preserves the actions and benefits, and is present in the final product in amounts which, indeed, can bring about the desired result when the product is used as recommended.

Unfortunately it is not easy to differentiate between a good quality product and one that has been adulterated. Although price can be a guide—the more expensive the Aloe vera, the better the product—this does not always apply. In the end, the key to judging Aloe vera is by results. If there is no improvement in your condition, change the Aloe product and try another.

The things that happen to make Aloe products less desirable or cause it to become virtually non beneficial, stem from the harvesting of the leaves, processing and distribution. The freshly removed leafs must go directly into production or must be appropriately refrigerated to prevent a loss of biological activity, principally through the degradative decomposition of the gel matrix.[30] The value of Aloe further diminishes if the processing procedure applies too much heat for too long a time. Extended heating renders the product free from bacterial contamination, but effectively destroys Aloe's mucopolysaccharides and consequently reduces its efficacy.[10,36] For therapeutic purposes, the most efficacious Aloe vera is that derived from whole-leaf Aloe and cold-processed.[3,10,34]

Aloe is not just Aloe because the manufacturer says so. To assure yourself that you are purchasing an Aloe product at a price worth paying and to achieve the desired results, it is recommended to look for the International Aloe Science Council (IASC) Certification Seal on literature and packaging. Another way to ascertain whether an Aloe vera product has a high healing capacity is to find out the number of mucopolysaccharides (MPS) present. This is sometimes included on the labeling. The highest therapeutic value is found in products containing between 10,000 and 20,000 MPS per liter.[10]

CONCLUSION

A review of literature has revealed A. vera as a highly potential functional and valuable ingredient that exhibits relatively impressive biological functions of great interest in the cosmetic, pharmaceutical and food industries. Literature reviews show that there is scientific evidence for its beneficial properties. Therefore, it would be worthwhile embarking on an intensive scientific experimentation and investigation on this apparently valuable medicinal agent and to promote its large-scale utilization.

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