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Review Article

Beyond the Leaf: Unlocking the Hidden Power of Aloe vera Flowers

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ABSTRACT

Aloe Vera is globally recognized for its therapeutic properties, primarily attributed to its succulent leaves; however, its flowers remain an underexplored botanical resource with remarkable pharmacological potential. Recent scientific attention has shifted toward these vibrant inflorescences, revealing a diverse phytochemical profile including flavonoids, phenolic acids, Anthraquinones, alkaloids, terpenoids, sterols, and essential glycosides. These compounds collectively contribute to potent antioxidant, anti-inflammatory, antimicrobial, Immunomodulatory, and wound-healing activities, positioning Aloe Vera flowers as a promising natural candidate for future medicinal, cosmetic, and nutraceutical innovations. Their strong free-radical scavenging abilities demonstrate significant potential in mitigating oxidative stress—an underlying cause of chronic conditions such as cancer, neurodegenerative disorders, diabetes, and cardiovascular diseases. Moreover, emerging studies highlight the flowers' capacity to enhance cellular defense pathways, inhibit lipid peroxidation, and modulate immune responses, offering new avenues in preventive and therapeutic strategies. The presence of bioactive pigments, including carotenoids and anthocyanins, further supports their use in skincare formulations due to photo protective and anti-aging mechanisms. Despite these promising findings, research remains limited compared to Aloe Vera leaves, underscoring the need for comprehensive pharmacological, toxicological, and clinical investigations. This review compiles and analyzes current evidence on the phoytochemistry, biological activities, extraction methods, and potential industrial applications of Aloe Vera flowers. It also highlights research gaps, future prospects, and formulation challenges, aiming to encourage scientific exploration and commercial utilization. Unlocking the hidden potential of Aloe Vera flowers could inspire novel therapeutic discoveries, promote sustainable plant use, and widen global phytopharmaceutical resources.

INTRODUCTION

Aloe Vera is known by the nickname "Gwarpatta" (1). The Arabic term Alloeh, which means

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"shining bitter substances," is the source of the aloe's name (2). Aloe Vera is a succulent, drought-resistant, perennial plant without stems that has purportedly been used medicinally from ancient times (3).Aloe Vera (Aloe Barbadensis Miller) is a succulent perennial plant of family Aloeaceae and Has been used for centuries for its medicinal properties. Of the plant parts of the Aloe Vera, Gel is being widely were investigated for their biological activity. We found that the Aloe Vera Gel, leaf and flowers exhibited strong anti-oxidant activity.(4)

Fig No.1 Aloe vera flower(17)

All Aloe species possess the added allure of year-round mass flower production. The Flower, however, among all the parts of the Aloe, has rarely been investigated and the biological constituents are largely uncharacterized. Diurnal and tubular nectar-rich brightly Colored flowers are produced by most Aloe species, often red or yellow (5).The consumption of edible flowers has become more common, as found in European and Asian foods, with a variety of natural antioxidants. An antioxidant-rich diet can lower the risk of cardiovascular and chronic diseases, and cancer (6). There is adequate evidence for the protective effect of vitamin E against cardiovascular diseases, free radical-induced DNA damage and oxidation, and skin diseases.(7)

Artificial medications used for antioxidant purposes often include rutin, butylated hydroxyl Toluene, and butylated hydroxyl anisole. Nevertheless, these medications have harmful Side effects include toxicity, cell damage, inflammation, and atherosclerosis in mammals . (8)As a result of these issues, there is a growing global trend toward the use of natural .Therapeutic antioxidant compounds found in medicinal plants and herbs. Researchers have recently discovered that several plant ingredients, including terpenes, flavonoids, and Polyphenols, have antioxidant properties .(9) Researchers are more likely to discover natural Antioxidants with high activity and low cytotoxicity based on these components' Antioxidant role .(10)

Aloesin, aloeemodin, acemannan, aloeride, methylchromones, flavonoids, Saponins, amino Acids, vitamins, and minerals from the inner gel of leaves are among the more than 75 Active constituents in aloe vera. It is a miracle cure for heart attacks, strokes, leukaemia, Anaemia, hypertension, AIDS, radiation burns, digestive disorders, and more because of its Anti-inflammatory, antioxidant, antibacterial, anticancer, antidiabetic, immune-boosting, And hypoglycemic qualities.(11)

For thousands of years, people have utilized aloe vera for its therapeutic qualities to heal a variety of human illnesses and ailments (12). Numerous investigations have Identified various bioactive substances in aloe vera leaves and gel, including Minerals, vitamins A, B, C, and E, enzymes, carbohydrates, polyphenols, amino acids, and anthraquinones .(13,14,15,16) Some of the health benefits that these bioactive Compounds offer include anti-ulcer, anti-hypercholesterolemic, antioxidant, antibacterial, antiviral, antifungal, anti-acne, nutraceutical, humectant, skin Protection against UV-A and UV-B, wound

healing, preventing type II diabetes and Cancer, cardiovascular diseases, and antibody production .(16,18) The use of aloe vera has recently spread to the food industry with the creation of beverages and food Supplements made from aloe vera.(19,20)

Table No: 1 Taxonomical properties (20)

Common Name	Aloe Vera (Barbadensis Miller), Barbados Aloe, Aloe Arborescence, Aloe Blossom, Aloe Flower.
Scientific Name	Aloe barbadensis Mill.
Kingdom	Plantae
Order	Asparaguses
Division	Spermatophyte
Subdivision	Angiospermae
Class	Monocotyledoneae
Family	Liliaceae
Genus	Aloe
Species	Barbadensis Mill

History :

Among the more than 300 species in the genus Aloe, Aloe vera (Barbadensis Miller) is the most well-known worldwide. This tropical plant is a member of the Asphodelaceae family. The use of aloe flowers and aloe vera gel dates to 1500 B.C., and it is further corroborated by the discovery of ancient Mesopotamian tablets expressing how aloe was being used for medical purposes. Through both human activity and natural processes, aloe barbadensis expanded throughout the world from its initial habitat in Africa.(21)

This medicinal plant is currently grown all over the world and may be found in warm-climate regions of America, Asia, and Europe because of its healing properties. Aloe vera is mainly produced in South America.

Aloe flower has nutritional value and possible applications in the food, pharmaceutical, and cosmetic industries. Aloe barbadensis Mill is known as Kumari in Ayurveda. Kaumarya, which means “princess” in Sanskrit, is where the word Kumari originates.(22)

Morphological characteristics:

Aloe vera is a plant with short or no stems that can reach heights of 60 to 100 cm. In the second year of the winter season, it produces upright, unbranched blooming stalks that grow 90-150 cm tall. The blooms are grouped in supplementary spikes and are vivid yellow and orange. (23)During the summer, aloe plants grow spikes up to 90 cm tall with pendulous blooms that have tubular yellow corollas. The number of aloe flowers within the raceme ranged from 20 to 64, and in another report, there were 20 to 94 flowers per raceme in aloe(24).

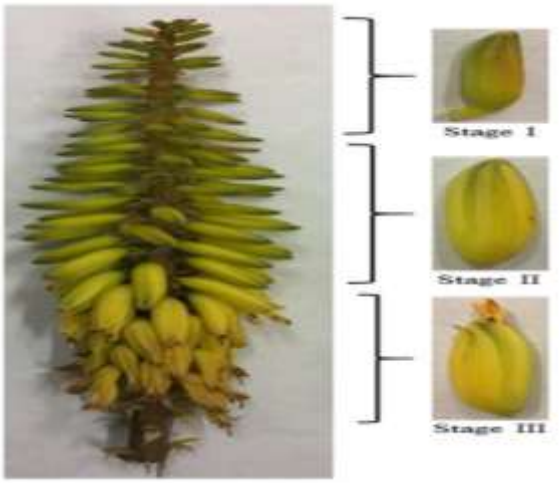

Fig No:2 Classification of Aloe vera flowers according their development stages (125)

The flowers were categorized based on length at three distinct developmental stages:

- Stage I, which consisted of young flowers measuring 2 cm;
- Stage II, which included mature flowers with closed flower buds measuring between 2 and 4 cm;
- Stage III, which included mature flowers with opening flower buds measuring 4 cm(25).

These yellow-colored tubular blooms are gradually maturing from the bottom to the top, suggesting both quantitative and qualitative variations in the bioactive substances the flowers contain. Its rosette of thick, meaty leaves gives it a unique look. On the top and bottom stem surfaces of certain varieties, there are white specks. While the leaves range in color from Green to gray-green. The leaf's edge features tiny white teeth and is serrated. (26)

Bioactive compounds:

Bioactive Substances Natural antioxidants can be found in aloe flower. Compared to the aloe vera leaf gel, the antioxidant activity in the flower is four to eight times higher. According to a 2018 study, the eleven constituents are coumarin, gallic acid, caffeic acid, D-catechin, vanillic acid, nariqenin, resveratrol, cinnamic acid, thymol, quercetin, and naringin. Vanillic acid had the highest content of any phenolic component examined here, which may be related to its potent antioxidant properties. Another study conducted in 2013 found that the most common phenolic compounds found in the blossoms were quercetin, epicatechin, and gentisic acid. (27)

Phytochemicals constituent:

Table No 2 phytochemicals constituent (30)

Compounds	Pharmacological activities
Anthraquinone	Anti-inflammatory Antibacterial Wound healing Antioxidant Laxative Immunomodulatory Anti-diabetic Skin protective Anti-Hyperlipidemic Gastroprotective Antifungal Anticancer Antiviral
Polysaccharides	Immune-modulating Anti-inflammatory
Phytosterol	Cholesterol-lowering Anti-inflammatory
Saponins	Antimicrobial Anti-inflammatory
Flavonoids	Antioxidant Anti-inflammatory Anticancer
Enzymes	Anti-inflammatory
Vitamins	Nutritional support

Vitamin: The antioxidant vitamins A, C, and E are among the many vitamins found in the plant. There are also thiamine, niacin, riboflavin, vitamin B12, choline, and folic acid .Antioxidants neutralize free radicals.(28)

Enzyme: To help with digestion, enzymes such as amylases, lipases, alkaline phosphatases, celluloses, catalases, and peroxidases break down sugars and fats. Bradykinases and carboxypeptidases decrease inflammation by deactivating bradykinins. Lectins exhibit anti-tumor properties (29)

Minerals: Numerous minerals, such as sodium, potassium, calcium, magnesium, selenium, manganese, copper, zinc, chromium, and iron, are found in aloe plants. The correct functioning of enzymes involved in various metabolic pathways depends on these minerals. Numerous of these possess antioxidant qualities (30)

Sugers: The mucilaginous layer of the plant, which lies beneath the leaf rind, contains sugars. It has both monosaccharides (glucomannose and polymannose) and polysaccharides (fructose and glucose). The immune system is modulated by the polysaccharides. Glutamannan is used in cosmetics and is a great moisturizer.(31)

Anthraquinones: The bitter reddish yellow exudates that are located behind the outer green rind contain anthraquinones and their derivatives, including barbaloin, aloeemodin-9-anthrone, lsobarbaloin, anthrone-C-glycosides, and chromones. These are phenolic compounds, which have been utilized as laxatives for a long time. These substances have a strong purgative effect when present in high concentrations, but they also seem to improve gastrointestinal absorption, function as strong antibacterial agents, and produce strong analgesic effects when present in lower concentrations. (28)

Sterols: Examples of sterols include campesterol, cholesterol, sitosterol, and luteol. Numerous of them have anti-inflammatory properties, and lupeol also has analgesic and antibacterial properties (32).

Hormone: Auxins and gibberellins have anti-inflammatory and wound-healing effects.

Salicylic acid: Salicylic acid is a chemical with antibacterial and anti-inflammatory qualities that is comparable to aspirin.

Amino acid: Aloe vera gel provides the amino acids required for growth and healing. Twenty of the twenty-two non-essential amino acids and seven of the eight essential amino acids are present in it (29)

Lignin: When added to topical treatments, lignin, an inert chemical, improves the other compounds' skin penetration (30).

Saponins : Saponins are substances that resemble soap and have antiseptic and cleaning qualities(30).

Antioxidant Mechanisms :-

Table No :3 Types of Antioxidants and their mechanisms (33)

Types of Antioxidants	Example	Function
Free Radical scavengers	*Synthetic antioxidants*: BHA (Butylated hydroxyanisole) BHT (Butylated hydroxytoluene) TBHQ (tert-Butylhydroquinone) Propyl gallate *Natural antioxidants:* Tocopherols Aromatic amines Phenolic antioxidants (extracts from aloe, spices and herbs)	Block of the radicals by reducing a hydrogen atom
Oxygen scavengers and Reducing agents	Ascorbic acid Erythorbic acid Ascorbates Sulphites, bisulphites Ascorbic palmitate Amino acids	React with oxygen
Cheating Agents	Citric acid EDTA (Ethylene diamine tetra acetic acid) Phosphates	Chelate metal ions in their structure in the form of stable complexes to reduce the catalytic oxidation activity

1. Free radical-scavenging: the flower/leaf extracts donate electrons/hydrogen atoms to neutralize reactive oxygen species (ROS) and nitrogen-centered radicals such as ABTS$^{\bullet+}$ and DPPH.(34)

2. Metal-ion chelation: Some flavonoids and phenolic in Aloe vera bind transition metal ions (e.g., Fe^{2+}/Fe^{3+}) thus inhibiting Fenton-type reactions that generate hydroxyl radicals.(36)

3. Enhancement of endogenous antioxidant enzymes: The extracts up-regulate or preserve activity of enzyme systems like superoxide dismutase (SOD), catalase, glutathione peroxidase (GPx) and increase levels of reduced glutathione (GSH). For example, in diabetic rats treated with Aloe vera leaf gel extract showed improved SOD, catalase, GPx in the pancreas.(35)

4. Reduction of lipid peroxidation: The extracts reduce formation of lipid peroxidation products like malondialdehyde (MDA) indicating less oxidative damage to lipids in biological systems.(34)

5. Synergistic actions: Polysaccharides, phenolic, flavonoids, vitamins (C & E) operate together. Aloe vera polysaccharides may help regeneration of other antioxidants and stimulate enzyme activity.

Pharmacological potential:-

1. Antioxidant property

Aloe Vera flower extract exhibited antioxidant properties.[37,38] Additionally, it demonstrates the protective effect against gentamicin-induced nephrotoxicity.(39) It lessens the carcinogenic effect that inhaling cigarette smoke causes in pulmonary tissue.[40] Additionally, it lessens oxidative stress brought on by diabetes.[41] A. vera (A. barbadensis) gel demonstrated antioxidant properties both in vitro and in vivo.[42,43] Aloe saponaria demonstrated antioxidant activity in sunburns caused by UVB rays.[44] A. vera gel shields the liver from harm brought on by oxidative stress.[45] A. Vera's polysaccharides and phenolic components both exhibited antimycoplasmic and antioxidant properties.[46] Both folate and barbaloin demonstrated pharmacological potential.[47] In rowers, extract from A. arborescens Mill. Stimulates cytokine synthesis and prooxidant–antioxidant balance.[48] irritable bowel syndrome is less likely when A. vera and Matricaria recutita are combined because of their antioxidant and spasmolytic properties.[49,50]

2. Anti-Cancer property

Aloe emodin, which has antitumor properties, is found in A. vera. [51] Aloe emodin also prevents high metastatic breast cancer MDA-MB-231 cells from invading and spreading. [52] Solid lipid nanoparticles loaded with aloe emodin demonstrated potent chemotherapeutic anticancer activity in vitro. [53, 54] In vitro, A. vera gel demonstrated a protective effect on the permeability transition pore in the rat liver mitochondria's inner membrane. [55] Products from A. vera slow the spread of cancer, lower inflammation, and repair other signal pathways. [56,57] It has broader clinical uses as well. [53] Components of A. vera that inhibit tyrosinase exhibited antiviral properties. [58] In B6C3F1 mice and F344/N rats, a non-colorized whole leaf extract of A. barbadensis Miller (A. vera) was found to be effective [59]. Mice given a high-fat diet supplemented with A. vera gel extract demonstrated a decrease in the development of intestinal polyps. [60]

3. Antiparasitic Property

Aloe vera natural products, like aloe-emodin, have antitumor properties. [61] Both in vitro and in vivo, it may prevent angiogenesis and the growth of human colorectal cancer. [62]. On the other hand, rats exposed to Aloe barbadensis miller leaf extract exhibit carcinogenic activity. [63] The antiplasmodial potential of decolorized low anthraquinones whole leaf Aloe vera was lower than that of crude extracts. [64] Aloe pulcherrima leaf latex contains chemical constituents that exhibit antiplasmodial properties. [65]

4. Antidiabetic Property

In animal models, A. vera exhibits nutritional and metabolic effects. [66] Because local healers use its extract to treat diabetes mellitus, it has significant ethnomedical value. [67,6i] Among the natural treatments for diabetes and its complications, it works well. [69] Aloe is well-known for being used in herbal self-care treatments for people with type 2 diabetes and obese people who are at risk for the disease. [70,71] In streptozotocin-induced diabetic rats, its fibroin/aloe gel film was found to be effective in wound healing. It can also be used as a dietary supplement to help diabetic wounds heal. [72] It is an effective nutraceutical for naturally managing diabetes. [73] In rats with type 2 diabetes induced by streptozotocin, extracts from A. barbadensis Miller demonstrated antidiabetic effects. [74]

5. Antimicrobial Property

Traditional medicinal soft soaps contain antimicrobial agents made from A. vera gel, which exhibits antimicrobial qualities [75]. [76] The plant is used to make eye drops that contain neomycin sulfate and aloe. [77] A. vera is also used to check for primary microbiological infections in a variety of root canal filling materials. [78] In comparison to fungal strains, the extracts exhibit superior antimicrobial activity against bacterial strains. [79] A. arborescens Mill. crude extract was found to be effective against Salmonella enteric server Typhimurium, an enter pathogen that causes diarrhea. [80] Lupeol, salicylic acid, urea nitrogen, cinnamic acid, phenols, and sulfur are the six antiseptic agents found in A. vera. All of them have the ability to inhibit viruses, bacteria, and fungi.

Immunomodulatory Property

Impact on Immunomodulation A. vera exhibits immunomodulatory qualities, and its fractions influence macrophages' reaction to Candida albicans. [81] Gel made from A. vera exhibits both immunostimulatory and immunomodulatory qualities. [82] A. barbadensis Mill. Extract (AVH200®) has the ability to lower healthy human blood T-cell activation, proliferation, and cytokine secretion. In vitro, AVH200® suppresses human blood T cells. [82] Components of A. vera function as immunostimulants or antioxidants and demonstrated dose-dependent immunomodulatory effects on leukocytes stimulated by phorbol myristate acetate ($P \leq 0.05$). [83] In a mouse model, probiotic lassi supplemented with A. vera (A. barbadensis Miller) stops Shigella from penetrating the epithelial barrier and entering the systemic blood flow. [84]

6. Wounds Healing Property

Healing of Wounds Collagenase activity and corneal wound closure are impacted by A. vera. [85] Its nutritional supplements aid in the healing of diabetic wounds. [86] Burn wounds are treated topically with polymeric films containing vitamin E and vitamin A. vera. [87,88] Aloe vera polysaccharides stimulate the expression of the MMP-3 and TIMP-2 genes in rats undergoing skin wound healing. [89] During wound healing, A. vera gel is also used as a decontaminating agent.

[90,91] A. vera affects alginate hydrogel film enzymatic breakdown and water absorption. A. vera exhibits pharmacological properties and effectively cleanses pressure ulcer wounds. [92] They are applied as hydrating creams to shield the skin while receiving radiation treatment for breast cancer. [93]

7. Burn Property

In Ayurveda, A. vera crude gel is a well-known burn treatment. Burn wounds are treated topically with polymeric films containing vitamin E and vitamin A. vera. [94] Second-degree burn wounds were found to respond well to A. vera gel. [95,96,97] It keeps burn injuries from getting infected. [98,99] It promotes wound healing and lessens the effects of inflammation brought on by heat damage [100]. [101] Both acute and chronic wounds can be treated with A. vera. [102] Additionally, it promotes better burn skin healing and prevents the growth of infectious microorganisms on injury sites [103]. [104] A. vera gel protects the skin from radiation damage. [105,106]

8. Psoriasis treatment Property

Topical treatment of psoriasis involves the use of A. vera leaf extract. [107] Better skin care is demonstrated by the bioactive natural ingredients it contains. [108] The plant extract of A. vera is very good for skin and skin conditions. [109] It can be applied to alternative treatments for common skin conditions. [109] Plaque psoriasis is treated topically with A. vera and 0.1% triamcinolone acetonide. [110,111] Its mineralized cream protected human skin from UVB-induced stress. [112] For dermatological use, A. vera gel is a good topical herbal product that is safe and clinically effective. It contains anthraquinone, a naturally occurring substance with laxative properties. [113]

9. Constipation treatment Property

In rats with constipation, aqueous leaf extract of A. ferox Mill improves intestinal motility, increases fecal volume, and returns body weight to normal. [114] It lowers the risk of colorectal cancer. [115] It has been discovered that A. vera gel is effective against strains of H. pylori. [116] Latex contains anthraquinones, which have strong laxative properties. It raises intestinal peristalsis, mucus secretion, and intestinal water content. [116]

10. Ulcerative colitis therapy

Herbal therapy for inflammatory bowel disease uses A. vera as a complementary and alternative medicine [117–118]. [119] Another herbal remedy for ulcerative colitis is A. vera gel. [120,121] In vitro, A. vera gel also demonstrated anti-inflammatory properties in human colorectal mucosa. [122] In a rat model of colitis, dietary aloin, aloesin, or aloe-gel exhibit anti-inflammatory properties. [122] A. vera gel taken orally has been shown to be effective in ulcerative colitis. [123] Additionally, it demonstrates the healing and protective effects against ulcerative colitis in rats induced by dextran sulfate. [124]

CONCLUSION

Aloe vera flowers represent a valuable but largely overlooked component of a widely celebrated medicinal plant. Their diverse bioactive constituents demonstrate promising antioxidant, anti-inflammatory, antimicrobial, and dermatoprotective properties, offering new opportunities for pharmaceutical, cosmetic, and nutraceutical development. However, limited scientific inquiry restricts their clinical validation and commercial utilization. Future studies focusing on standardized extraction, molecular mechanisms, and human trials are essential to fully harness their therapeutic benefits. Exploring Aloe

vera flowers not only enhances botanical drug discovery but also supports sustainable resource utilization—truly extending Aloe Vera's legacy beyond the leaf.

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