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Aloe vera applications and *Aloe vera* based nanomaterials

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Abstract
Three different formations of *Aloe vera* are frequently used in therapeutic applications, which are completely diverse in their biochemical content and beneficial characteristics, latex, gel, and extract. Recently, investigators have employed *Aloe vera* with new decomposable efficient biomaterials and nanostructures for targeting applications like tissue engineering, drug delivery systems, the remedy of various diseases, the food industry, and the removal of pollutants. Numerous different nanostructures made by *Aloe vera* for different applications are presented in this review.

Keywords: *Aloe vera*, Anti-inflammatory effect, Antioxidant
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Introduction

Three different formations of *Aloe vera* are frequently used in therapeutic applications, which are completely diverse in their biochemical content and beneficial characteristics, latex, gel, and extract. Aloe latex is a yellowish fluid derivative from the internal liner of the *Aloe vera* leaves and is administrated for its laxative effect. Aloe latex combinations have been considered and known so far as chromone, anthraquinone, or anthrone derivatives. Aloe gel is a transparent, gelatin-like compound from the adhesive cells form in the internal section of the leaves and is currently used for skin diseases and cosmetics, and inside by oral consumption in diabetic patients and to improve peptic ulcers and contain the polysaccharides glucomannan and acemannan. Other active identified components of Aloe gel include bradykinase, magnesium lactate, and salicylic acid. Aloe extract is possibly beneficial for cancer and AIDS (1). The biochemical compositions of *Aloe vera* and its applications are presented in Table 1.

Materials and Methods

In this review, we searched Google Scholar, Scopus, PubMed, EMBASE, EBSCO and Web of Science, by the following keywords of *Aloe vera*, anti-inflammatory effect and antioxidant. This study was conducted through searching the relevant articles published during 2006 to 2018.

Applications

Aloe vera can be used for different applications such as tissue engineering, the food industry, the remedy of different diseases, and the removal of pollutants, which are discussed in detail in the following.

Tissue engineering

Aloe vera is particularly noteworthy in tissue engineering due to its biodegradability and biocompatibility features, and it induces cell migration, regeneration, proliferation, and growth. Nevertheless, the biochemical properties of *Aloe vera* arise from a collective action of a variation of materials. Mannose-6-phosphate and acemannan cause the anti-inflammatory effect of *Aloe vera*. Glucomannan and acemannan have antimicrobial properties and are verified to quicken tissue transformation and trigger immune system cells. Acemannan improves cellular metabolism by normalizing cellular function and adjusting nutrients (e.g., oxygen) and wastes. Barbaloin behaves as an antioxidant to prevent free radicals. The anti-inflammatory effect of *Aloe vera* arises from mannose-6-phosphate and acemannan (2).

Skin

Effects of *Aloe vera* on the skin have been investigated, ranging from wound gel to moisturizing cream. Several constituents of *Aloe vera* (such as mannose-6-phosphate, anthraquinones, barbaloin, and saponin) are bioactive and associated with skin ailments by collagen formation and tissues replacement with collagen, promotion of blood circulation, and elimination of dead skin cells.

Aloe vera gel is very attractive in the cosmetic industry

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Implication for health policy/practice/research/ medical education

The extract of Aloe vera has been widely applied from ago times for its famous anti-inflammatory, antiviral and antimicrobial properties.

due to its moisturizing and skin-soothing effects. Goods, like soaps and cleaners, sun creams, face antiaging creams, creamy solutions, and coated tissue papers, comprise *Aloe vera* ranging from 1%-98% accompanied by other vital additives. Also, *Aloe vera* improves the injured tissue's collagen capacity, fibroblasts, stretchy intensity, degree of crosslinking, hyaluronic acid, and dermatan sulfate.

Dentistry

The antimicrobial activity of *Aloe vera* has been examined in contradiction of oral etiologic bacteria such as gram-negative bacteria; therefore, Aloe gel act like an antibiotic. In addition to *Aloe vera*'s antimicrobial activity, favorable interactions with dental cells make it promising for periodontal treatment (2).

Food industry

Aloe vera is used for the construction of natural edible coatings in the food industry and cause extends the shelf life of products in addition to their antimicrobial activity. Qualitative improvement of the low-meat beef burger is performed by the water preservation characteristic of *Aloe vera*, which usually needs customers' admission. Also, *Aloe vera* has been added to prepare ready-to-serve beverages and foods and acts as the prebiotic source to increase the nutritional value of the products.

Remedy of different diseases

Aloe vera leaves are administered extensively for the therapy of diabetes currently. The antidiabetic activity of *Aloe vera* is because of improving insulin secretion from pancreatic b-cells, its antioxidant and anti-inflammatory properties, and its inhibitor of pancreatic a-amylase activity, insulin sensitizer. This can be more elucidated by reducing serum malondialdehyde levels and increasing antioxidant enzymes such as superoxide dismutase and glutathione. Emodin and mannose-6-phosphate in *Aloe vera* increase insulin sensitivity due to their anti-inflammatory properties. Finally, *Aloe vera* extracts regulate the hyperglycemia state by preventing pancreatic alpha-amylase action (3,4).

A clinical follow-up confirmed that pain, wound healing, and hemorrhaging upon release of feces from the body were improved after a week of consumption of *Aloe vera*. The plant has also treated hemorrhoid surgery problems (5).

Responsible chemical compositions of *Aloe vera* for the remedy of different diseases are shown in Table 2.

Removal of pollutants

The capability of *Aloe vera* to progress the condition of household wastewater is examined by using biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, dissolved oxygen (DO), and conductivity parameters. Consequences displayed that *Aloe vera* lowered the almost 30% pollutants in the operated wastewater. *Aloe vera* excess biomass has been applied as an originator for the production of biosorbents. *Aloe vera* biosorbents were classified into five classes, based on the practical strategies, including non-reacted materials, air-dehydrated biosorbents, chemically reacted dehydrated powder with strong acids, thermally treated *Aloe vera* biomass and carbonized and functionalized materials using the magnetic property of additive inorganic phase. *Aloe vera* excess-biomass for eliminating contaminants, for example, metals, dyes, fluoride, aniline, and para-chlorophenols, are explored (6).

Aloe vera based nanomaterial

Nanotechnology has appeared as a reasonable method to construct materials with admirable physicochemical and biological properties. It has revealed extensive capability in researching new techniques and spreading its operation range. Recently, investigators have employed *Aloe vera* in association with new decomposable efficient nanostructures for targeting different uses, for instance, tissue engineering, drug delivery systems, and food industry. The extract of *Aloe vera* has been widely applied from ago times for its famous anti-inflammatory, antiviral and antimicrobial properties.

Aloe vera extracts have been recently established to

Table 1. Biochemical compositions of *Aloe vera* and its applications

Constituents	Applications
Sugars and amino acids	Anti-inflammatory, anti-cancer, antiallergic, antimicrobial, antitumor, and regeneration
Vital minerals	Antioxidant, antibacterial, antipruritic
Lipids and steroids	Anti-inflammatory, antiseptic, analgesic
Anthraquinones, including Aloins, glycoproteins, and Aloe emodin	Purgative, anti-cancer, antiviral, antibacterial
Active enzymes	Antibacterial, antifungal, antiviral, anti-inflammatory, analgesic
Salicylic acid and hormones	Anti-inflammatory, antibacterial
Essential vitamins	Antioxidant, anticancer

Table 2. Responsible chemical pieces of Aloe vera for remedy of different diseases and their functions

Different clinical efficacy	Components	Function
Burn wound healing effect	Mannose-6-phosphate	Wound reduction and collagen construction
	Polysaccharides	Stimulate the growth and the production of major components of the protein collagen in fibroblasts
	Acemannan	Promoting tissue repair, cell proliferation, activating macrophages
Hemorrhoid	Saponins, flavonoids, protein	Anti-inflammatory, anti-bleeding,
Anti-AIDS	Glucomannan (composed mainly of sugar mannose)	Inhibit HIV-1
	Acemannan	Antiviral and immunomodulating properties
Immunomodulatory effect	Polysaccharides	Weakening the brainy ischemia and reperfusion damage via preventing systemic inflammatory response
	Anthraquinones (aloin) and chromone (Aloesin)	Lessen inflammatory responses in inflammatory-related diseases
Antidiabetic effect	Aloe emodin-8-O-glycoside	Effect on glucose uptake and its conversion into glycogen
	Polysaccharides	Lower glucose and triglyceride levels in diabetic patients improve the characteristic of immune cells and remove waste and other toxins
	Emodin and mannose-6-phosphate	Anti-inflammatory
Antioxidant effect	Vitamin E, carotenoids, vitamin C, flavonoids, and tannins	Antioxidant
Anti-cancer activity	Aloin	Protective effects against preneoplastic lesions
	Aloe emodin	Antiproliferation effects of cancer cells
Antimicrobial activity	Anthraquinones	Inhibition of bacterial protein synthesis
	Polysaccharides	Prompt of phagocytic leucocytes to destroy bacteria
	Pyrocatechol	Antimicrobial
	Saponins	Antiseptic properties
Antiviral activity	Anthraquinone derivatives	Reducing the virus-induced cytopathic effect
Antihyperlipidemic activity	Phytosterols	Reduces visceral fat mass

have exceptional characteristics of producing metal nanoparticles. Despite many works, it is yet not apparent which particular constituents in *Aloe vera* extract cause the construction of nanostructures. *Aloe vera* extracts have been applied as reducing agents in synthesizing metal nanoparticles, as mentioned in Table 3.

Table 3. Different metal nanoparticles made by *Aloe vera* extract

Metal nanoparticles made by *Aloe vera* extract	References
Mg-Zn Nano ferrites	(7)
Silver nanoparticles	(8,9)
Indium oxide (In2O3) nanoparticles	(10)
Nano Tin (iv) oxide	(11,12)
Gold nanotriangles and silver nanoparticles	(13)
Iron and Fe3O4 nanoparticle nanoparticles	(14,15)
Copper nanoparticles	(16,17)
Nano-sized $Cu_{0.5}Ni_{0.5}Fe_2O_4$	(18)
Cadmium	(19)
Synthesize 5-fluorouracil (5-FU) nanoparticles	(20)
Nanocrystalline $CuFe_2O_4$, $NiFe_2O_4$, $ZnFe_2O_4$ powders	(21)
Nanocrystalline (MFe_2O_4, M = Ni, Co, Mn, Mg, Zn)	(22)

The produced 5-fluorouracil nanoparticles were described by various spectrophotometric techniques for anti-cancer activity (23). Solid lipid nanoparticles (SLNs) have been advanced as a moderately new form of drug delivery system which proposes collective qualities of liposomes and polymeric nanoparticles. The addition of *Aloe vera* for the construct of solid lipid nanoparticles enhanced the water absorption ability of lipid nanoparticles and thus enhanced the drug loading efficacy of lipid nanoparticles. *Aloe vera* could be added to various nanostructures like hydrogel, nanoparticles, nanocomposite film, nanofibers, scaffolds, and sponges. In all the studies, the accumulation of *Aloe vera* is supposed to positively change the properties of the materials (20). Aloe emodin-loaded solid lipid nanoparticles showed intense anti-cancer action (24). Numerous different nanostructures made by *Aloe vera* for different applications are presented in Table 4.

Conclusion

The extract of *Aloe vera* has been widely applied from ago times for its famous anti-inflammatory, antiviral and antimicrobial properties. *Aloe vera* could be added to various nanostructures like hydrogel, nanoparticles,

Table 4. Series of different nanostructures made by Aloe vera for different applications

	Nanostructure	Applications	Analysis method	References
Nanofibers	Nanofibrous scaffold by electrospinning of PCL–AV mixture	Wound healing	FTIR, XPS, XRD, FESEM, MTS assay, and TGA	20
	Electrospun nanofibrous mats made from a mixture of PVP, AV, and HPMC	Wound healing	FTIR, SEM	20
	PVA/PVP/PEG/AV/HPMC with the addition of PAA	Wound healing	SEM, DSC, and FTIR	20
	Four different nanofibrous scaffolds: PLACL, PLACL-SF, PLACL-SF-AV, and PLACL-CLG	Skin regeneration and wound healing applications	FTIR, SEM, FESEM, Contact angle studies	20
	Four different nanofibrous, for example, PCL, PCL-5% AV, PCL-10% AV and PCL/CLG.	Skin cell proliferation	Contact angle studies	20
	Precipitation of HA on assembled PCL-SF-AV nanofibrous scaffolds	Promoting osteoregeneration	FTIR, SEM	20
	Electrospun PLACL, PLACL/SF, and PLACL/SF/AV nanofibrous scaffolds	Vascular regeneration	FESEM and MTS assay	20
	Distinct electrospun systems such as PCL/AV, PCL/SF, PCL/AV/SF, and PCL/AV/SF/CU	Vascular and tissue regeneration	FTIR and SEM, MTS assay	20
	Distinct nanofibrous mats, for example, PCL, PCL/CU, PCL/AV, PCL/Neem, PCL/CU/AV, and PCL/CU/neem	Anti-cancer activities	SEM, MTT	20
	PVA mats and increased the surface area with the help of AV	Technical and functional textiles	FTIR, FESEM, DSC analysis	20
	PCL/AV/CT	Wound dressings	ATR-FTIR, SEM	25
	Starch Nanoparticle /SF/PVA/AV	Wound healing	SEM, TEM, IR	26
	(PLLA/COL) scaffold with sustained release of AV using a CT	Skin tissue engineering	SEM, UV–Vis	27
Nanoparticles	AV/AAN-based NPs	Drug delivery	FTIR, SEM, TEM, XRD, TGA and DTG	28
	zidovudine-loaded solid lipid nanoparticles	Drug delivery system	DLS, TEM	29
	AV extract functionalized ZnO NPs	Antibiotics	XRD, FTIR, SEM, EDX, TEM, and EM analyses	30
Nanocomposite	Nanocomposite of In2O3, ZnO, and AV powder	Antibacterial and antifungal properties	XRD, SEM, TEM and UV-Vis	31
	Nanocomposites sponges were prepared with AV extract	Wound dressing	UV–Vis, XRD, FTIR, SEM	32
	Nanosilver hydrogels of PMMA/AV/CU	Wound care dressings	EDX, FTIR, DLS, HRTEM, SEM	33
	Incorporation of AV extracts into nanocellulose	Tissue regeneration	XRD	34
Nanocapsules	triblock PEG/PBA/ AV extract	Treatment of ulcers and cancers	SEM and PSAR	20
Nanoencapsulation	Nanoencapsulation of AV in synthetic and naturally occurring polymers	Food industry	UV-Vis, FTIR	35
	Nanosuspension-based nanogel of SSD and AV	Wound healing		36

Aloe vera (AV), hydroxypropyl methylcellulose (HPMC), hydroxyapatite (HA), polybutylene adipate (PBA), poly (ethylene glycol) (PEG), poly (acrylic acid) (PAA), silk fibroin (SF), Polycaprolactone (PCL), Curcumin (CU), Collagen (CLG), poly (L-lactic acid)(PLLA), chitosan (CT), poly (methacrylic acid) (PMMA), polyvinyl polymers (PVP), acrylonitrile (AN), silver sulfadiazine (SSD), particle size analysis report (PSAR), Fourier-transform infrared (FTIR), Field emission scanning electron microscopes (FESEM), X-ray powder diffraction (XRD), Transmission electron microscopy (TEM), Ultraviolet-visible spectroscopy (UV-Vis), Differential scanning calorimetry (DSC). X-ray photoelectron spectroscopy (XPS), poly-L-lactic acid-silk fibroin (PLACL-SF), Infrared (IR), thermogravimetric analysis (TGA), Derivative thermogravimetry (DTG), electron microscopy (EM), high resolution transmission electron microscopy (HRTEM).
The MTT assay is a colorimetric analysis for measuring cell metabolic activity.
MTS is a 'one-step' MTT assay without solubilization of formazan crystals and cell viability assays.

nanocomposite film, nanofibers, scaffolds, and sponges. In all the studies, the accumulation of *Aloe vera* is supposed to positively change the properties of the materials. Soon, better approaches could be invented for constructing assembled nanostructures with *Aloe vera* resulting in bioactive components for practical biomedical applications.

Authors' contribution

Conceptualization, resources, visualization, supervision, project management: SN.
Validation: YR, ZR and SN.
Research: ZR and YR.
Data curation: ZR and SN.
Writing—original draft preparation: ZR.
Writing—reviewing and editing: AK and NCC.

Conflicts of interest

YR and ZR are staff at Nickan Research Institute; however the process of peer-review was conducted like others.

Ethical issues

Ethical issues (including plagiarism, data fabrication, double publication) have been completely observed by the authors.

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