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Role of Anthraquinonesin the *Aloe*-Mediated Nanotechnology

Research Article

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Abstract

The development of nanotechnology is a modern multidisciplinary science involving the fields of chemistry, physics, biology, and engineering, the production of nanoparticles (NPs), both in nature and by humans. Nowadays, biogenic or green synthesis of (NPs) using bacteria, fungi, actinomycetes, algae, and higher plants have emerged as potential nano-factories and their applications are based on the phytochemicals of these living things. Out of various biomaterials employed for these purposes, plant extracts have attracted much attention due to their effectiveness, availability, and green characteristics. Aloe species can store water and important chemical constituents in their swollen and succulent leaves because of their ability to survive in conditions such as hot and dry, which makes them a unique source of phytochemicals. Among the mostly known phytochemical from the genus anthraqunoines are the top valuable compounds chemicals for many activities. Anthraquinones are a class of natural compounds that consists of several hundreds of compounds that differ in the nature and positions of substituent groups. Recently, Aloe-based nanoparticles have been utilized for their wide applications. The fabrication of NPs by using Aloe species is due to chemical compounds present in the Aloe genus. It has been described that the plant chemical compositions are used for the NPs synthesis because they act as reducing, capping, and/or stabilizing agents. The influence of additional particles of Aloe phytochemicals attached to the nanoparticle can change its overall properties. Aloeanthraquinones have a great role in the formation and applications of Aloe-based NPs.

Keywords: Nanotechnology; Aloe; Role; Anthraquinones; Synthesis; and Applications.

Introduction

The development of nanotechnology is a modern multidisciplinary science involving the fields of chemistry, physics, biology, and engineering, the production of nanoparticles (NPs), both in nature and by humans [1]. The area of nanotechnology is one of the most dynamic views in current-day material science [2]. The word "nanotechnology" refers to the use of matter with dimensions ranging from one to a hundred nanometers at the molecular or atomic level [3]. “Nano” is a Greek word. “Nanos”, means “dwarf, tiny, or very small”. Nowadays, the terms like “creation,” “exploitation,” and “synthesis” are associated with nanotechnology [4]. A nanoparticle is characterized as a little item that acts in the general unit as far as its transport and properties in nanotechnology [5]. There are various chemical and physical methods to synthesize nanoparticles (NPs). Among them, the sol-gel process, chemical precipitation, chemical vapor deposition, hydrothermal, and microwave methods have been reported mostly [6]. However, these methods are not effective in many aspects. Therefore, currently, green synthesis, single-pot biomimetic, and/or biological methods of synthesis are preferred over chemical and physical methods due to their rapidity, eco-friendliness, non-pathogenic, and economical attributes. Besides, these biosynthesis methods exclude the use of high temperature, energy, pressure, and toxic chemicals [7]. Therefore, nowadays, biogenic or green synthesis of (NPs) using bacteria, fungi, actinomycetes, algae, and higher plants have emerged as potential nano-factories [8-10] and their applications are based on the phytoconstituents of these living things. Through biosynthesis methods, nanotechnology is related to biotechnology. This has been advanced in nanobiotechnology which is the development of eco-friendliness and biosynthetic nanomaterials/nanoparticles [11].

The green synthesis of nanomaterials such as silver [12], zinc oxide [13], magnesium oxide [14], gold [15], cerium oxide [16], copper oxide [17], titanium dioxide [18], activated carbon [19],

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palladium [20] and tin oxide [21] has been conducted extensively in recent years. The reasons that make green synthesis very important are due to the simple work-up procedure, environmentally benign nature, reusable, low cost, and ease of isolation [22]. Nanoparticles have a novel or superior behavior with defined shape and size. This is because of the high surface area to volume ratio. The physicochemical parameters of nanoparticles (NPs) are different from that of bulk or large material and single atom and molecule [23, 24]. The size of nanoparticles (NPs) is 1-100 nm with their unique surface, optical, electrical, magnetic, and biological properties [25].

Out of various biomaterials employed for these purposes, plant extracts have attracted much attention due to their effectiveness, availability, and green characteristics [26, 27]. Additionally, it has been noticed that the NPs prepared using plant extracts are more stable, cheap, monodispersed, and take less time to reduce [28]. The influence of the added particles like phytocomponents such as polysaccharides, flavanones, terpenoids, etc. attached to the nanoparticle can change its overall properties, especially the antimicrobial property [29]. In addition to plant extracts have an intense array of antioxidants such as polyphenols [30, 31], reducing sugars [32], nitrogenous bases, and amino acids [33], which can produce nanoparticles of metal and metal oxide from metal ions [34]. Aloe species can store water and important chemical constituents in their swollen and succulent leaves because of their ability to survive in conditions such as hot and dry, which makes them a unique source of phytochemicals [35]. Aloe plants have been widely known and used for centuries as topical and oral therapeutic agents due to their health, beauty, medicinal, and skin care properties [36]. The range of chemical constituents of the Aloe species can be used in preparing beauty and cosmetics, medicinal and pharmaceutical, personal care and toiletry products, and bittering agents in alcoholic drinks, and they are also grown as ornamental plants [38]. The phytoconstituents and bioactivity of Aloe spp. have attracted research interest since the trade in 'drug aloes', prepared from the leaf exudate, expanded rapidly in the 19th century [38]. But nowadays, the applications of Aloe plants do not limed to the Aloe alone; it is incorporated into different substances to give novel ideas such as chemical synthesis and drug delivery [39]. Currently, many researchers are focused on the incorporation of Aloe extracts into substances such as metal/metal oxides at the nanoscale. This is due to the Aloe species having a variety of phytocomponents responsible for the target application. The biological properties of Aloe such as anti-inflammatory, antimicrobial, antitumoral, and antioxidant are due to various compounds of Aloe extracts. These properties and activities are synergistic rather than one single class of compounds [40]. Among the mostly known phytochemical from the genus anthraqunoines are the top valuable compounds chemicals for many activities. Anthraquinones are a class of natural compounds that consists of several hundreds of compounds that differ inthe nature and positions of substituent groups. This class of compoundscontains derivatives that consist of the basic structure of 9, 10 anthraquinone [41]. However, due to several complexities in the identification of exact chemical components responsible for the synthesis and applications of nanoparticles, the green synthesis of nanoparticles becomes challenging. Moreover, there is a lack of a comprehensive review that presents a general idea about the roles of phytochemicals in both synthesis and applications of Aloe-mediated NPs. Herein; the review summarizes the recent update on these ideas somewhat. Although in all kinds of literature, the synthesized NPs were from leaves of Aloe, other parts of the plants like flowers and roots are also rich in bioactive compounds. Therefore, it is very important to synthesize NPs from other than leaves of Aloes and identify the roles of responsible phytochemicals in them.

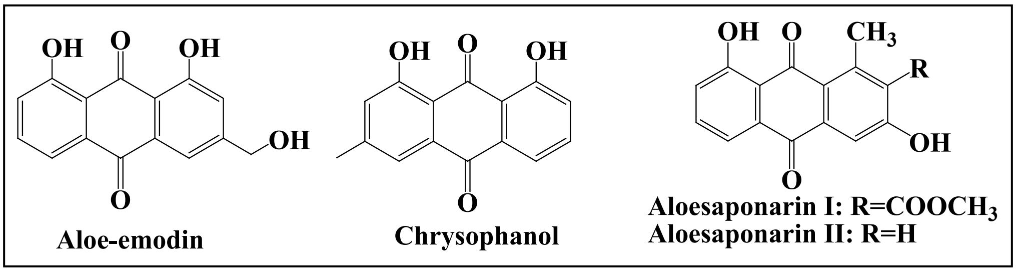
Anthrauinones of *Aloe*

The parts of Aloe species such as leaf, root, flower, and etc have various types of types of anthraquinones. Among these anthraquinonesaloesaponarin, chrysophanol, and its progenitor pre-chrysophanol, desoxyerythrolaccin, 1,5-dihydroxy-3-hydroxy methylanthraquinone, helminthosporin, 7-hydroxyaloe emodin, isoxanthorin, laccaicacid-D-methyl ester, nataloeemodin, and its ester nataloe emodin-8-methyl ester, aloechrysone,and aloesaponol have been reported. Structurally, Aloeanthraquinones are often present as O-glycosides, such as aloeemodin-11-O-rhamnoside, aloesaponol-6-O-glucoside, nataloe emodin-2-O-glucoside, aloesaponol-8-O-glucoside, and aloesaponol-O-methyl-4-O-glucoside. The hydroxylated derivatives of aloin, such as 5-hydroxyaloin A, 7-hydroxyaloin,and 10-hydroxyaloin B, as well as their acetate derivatives, 5-hydroxyaloin A 6'-O-acetate,7-hydroxyaloin-6'-O-monoacetate, and 10-hydroxyaloin-6-O-acetate have also been identified [36, 42]. Since A.vera is the mostly studied species, approximately 32 anthraquinones and their glycoside derivatives were isolated and identified from A.vera. The isomers of aloin A, and aloin B, two anthraquinone glucosides, are the most abundant active constituents. However, aloe-emodin, emodin, chrysophanol, and physcione are the four major anthraquinoneaglycones.Athraquinones have carbonyl groups and OH groups which are responsible for the properties of the compounds. The repeatedly identified *Aloe* anthraquinones are the one in Figure 1 [43, 44].

Aloe-Mediated Nanoparticles

Recently, Aloe-based nanoparticles have been utilized for their wide applications. The fabrication of NPs by using Aloe species is due to chemical compounds present in the Aloe genus [45]. In

Figure 1. Some anthraquinones isolated from *Aloe* species.



works of literature, numerous Aloe-mediated NPs have been fabricated along with their various applications. In Aloe-based NPs the leaf gel [46], leaf skin (peel) [47], whole leaves [48], and/or flower [49] of Aloe species with metal/ metal oxide have been conducted. the metal and metal oxide of Aloe based NPs such as silver NPs, gold NPs, selenium NPs, copper NPs, iron NPs, iron oxide NPs, silver oxide NPs, zinc oxide NPs, magnesium oxide NPs, titanium oxide NPs, and indium oxide NPs with various applications such as cytotoxicity, UV protection, antibacterial activity, catalytic activity, antibiofilm potential, photocatalytic activity, antifungal, and antioxidant activities have been described. Aloe-based NPs fabrication is affected by various factors such as type of metal, different Aloe spp., method of NPs formation, temperature, pH, and type of solvent used [28]. In addition to that, the part of the Aloe plant such as leaf skin, leaf gel, leaf latex, whole leaf, root, and flower is also a great factor to make difference in the fabrication of Aloe-based NPs due to the phytochemicals present in each part are different.

In the synthesis of Aloe mediated NPs, Aloe extract is prepared separately before being added to precursors. The extracts can be prepared from different parts of the plant such as the leaf, flower, and root. The mature, healthy, and fresh Aloe parts are used to utilize for this purpose. The selected part of the plant is washed with distilled water to remove any dirt or debris on the surface [50]. If the synthesis of NPs is based on whole leaf, the leaf extract is prepared by cutting it finely, if the skin of the plant the is targeted, the extract is prepared by peeling off the leaf carefully using a sharp knife and if the gel is needed, the leaf is slit longitudinally into half, the skin is discarded, the gel is scraped off by sharp-edged spoon/knife from the inner leaf into a container. If the latex/sap part of the Aloe is the target extract, the cut leaf is kept 45° to obtain latex. Flower and root parts of the plant are also used to prepare Aloe extract. The identified Aloe extracts are ground to be kept for the next steps. In the literature, there are different methods to make extracts to store for further use. Among the different methods, boiling the prepared extract with distilled water for certain minutes is the common method [48-51].

Role of Anthraquinones In *Aloe*-Mediated Nano-Technology

Role in synthesis

It has been described that the plant chemical compositions are used for the NPs fabrication because they act as reducing, capping, and/or stabilizing agents [52]. Some of these bioactive molecules act as electron shuttles in metal reduction, while other constituents are responsible for the capping of resulting NPs, which not only controls the aggregation of NPs but also results in post-surface modification of NPs [53]. Hydroxyl and carboxylic groups present may act as reducing agents and stabilizing agents in the synthesis of nanoparticles [54]. The functional groups are responsible for capping and stabilizing nanoparticles reduced [55]. The size and stability of the formed nanostructure are also controlled by the reduction mechanism. The stability of nanoparticles can be attributed to the formation of stable bonding between metallic nanoparticles and phytochemicals present in the Aloe extract [56]. There are various roles of Aloe phytochemicals in the formation of Aloe-mediatednanotechnology. However, roles such as reducing, capping, and stabilizing agents are very important in the synthesis and applications of Aloe-based NPs. These three properties are interrelated to one another. If the formed NPs are reduced or capped to precursor, then it stays stable. The stable NPs can be applied to the target applications.There is the presence of a -OH group in most phytochemicals obtained from Aloe spp. and this -OH served as a reducing agent, converting metal ions into metal/metal oxide NPs. Also, carbonyl functional groups are present in the phytochemical of Aloe spp. play a significant role in NPs synthesis [28]. In another study, the production of silver nanoparticles is demonstrated by the sharp peak around 400 nm for aloin-mediated silver nanoparticles in the UV–Vis spectrum, which indicates the availability of reducing functional groups in aloin [52]. The aloin (Figure 2) is an anthraquinone which has OH groups which are responsible for the formation of Ag-aloin complex. Figure 3 illustrates the formation of complexes with the biomolecules, (aromatichydroxyl groups and aloin) present in A.vera extract. The ZnO-biomolecule complex formation is due to the linkage between the Z^{n+2} ions and the functional group hydroxyl that present in the biomolecules like aromatic compounds like aloin (polyphenol) present in A. vera extract acts as the reducing agent for the ZnO NP synthesis [57].

Role in application

Researchers have demonstrated the possible mechanisms of action of medicinal plants and their active ingredients or active compounds, which may exert these mechanisms individually or in combination with other compounds present in the plants [58]. The influence of additional particles of Aloe phytochemicals attached to the nanoparticle can change its overall properties, especially in medical applications such as antimicrobial, antican-

Figure 2. Mechanism of formation of Ag-NP from *A. vera* anthraquinone.

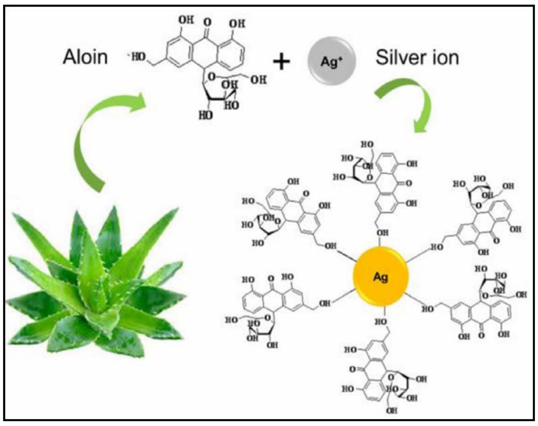


Figure 3. Zn^{2+} complex formations with the biomolecules (aromatic hydroxyl groups and aloin) present in *A. vera* extract.

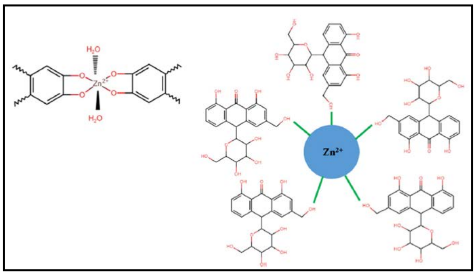


Table 1. Anthraquinones and other phytochemicals inthe applications of *Aloe*-mediated nanotechnology.

Precursors	*Aloe* spp.	Part of Aloe	Applications	Responsible phytochemicals and functional groups	Ref.
Se	*A.vera*	Leaf	Antioxidant activity	Hydroxyl groups and other functional groups	[60]
ZnO	*A.vera*	Leaf (skin)	Antibacterial Activity	Phenolic compounds and other phytochemicals	[53]
ZnO	*A.socotrina*	Leaf	Antibacterial activity	Hydroxyl groups and other functional groups	[39]
CuO	*A.vera*	Leaf	Antibacterial activity	Hydroxyl groups and other functional groups	[61]
Se	*A.vera*	Leaf	Antibacterial and antifungalactivities	Hydroxyl groups and other functional groups	[62]
Fe_3O_4	*A.vera*	Leaf (gel)	Cytotoxicity assessment	Phenolic compounds and other phytochemicals	[63]

cer, antioxidant, etc. [29]. In study, the addition of A.vera in the nanofiber membranes (NFMs) can increase the antibacterial effect of the NFMs. This is assumed to be due to the presence of substances such as anthraquinones in Aloe, resulting in its better antimicrobial activity [59]. Table 1 indicates the combination of anthraquinones with other phytochemicals as well as functional groups in the applications of Aloe-based NPs. In this case, the idea of responsible phytochemicals shows the role of these phytochemicals in investigated applications.

From the Table 1, the hydroxyl (OH) functional group shows the presence of anthraquinones phytochemicals. Note that the hydroxyl (OH) functional groups present not only in anthraquinones but also in many Aloe phytochemicals. Anthraquinones are one of the phenolic compounds although phenolic compounds are not limited to them. Generally, the anthraquinones in these plants incorporated to other substances in order to apply for various applications.

Conclusion

Due to the reason the unique nature of Aloe plants, Aloe-mediated nanoparticles are very important in a broad area of study. They have a variety of chemical compositions with chemical and biological properties. Therefore, the incorporation of the Aloe phytochemicals such as anthraquinones into another substance like metal or metal oxides make the biosynthesis of NPs which are very necessary for all aspects than other means of NPs syntheses. In addition to unique nature of Aloe plants, the second idea that brings the importance of Aloe-mediated nanoparticles is the new idea of nanotechnology. The combination of these points forms what is known as Aloe-based nanobiotechnology. Although the combination of Aloe phytochemicals and precursors is known, Aloeanthraquinones have a great role in the formation and applications of Aloe-mediated nanotechnology. Nowadays; this science has wide applications in medicine, food, environmental protection, material preparations, etc.

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