Phytochemical and Pharmacological Values of Two Major Constituents of Asparagus Species and their Nanoformulations: A Review

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Abstract

Objectives: This review article highlights two of the major chemical classes and their derivatives frequently isolated from different species of genus Asparagus and the diversity of their biological activities in addition to different applications of genus Asparagus in nanoformulation. The species belonging to this genus are well known for their nutritional and medicinal benefits and are considered one of the promising sources of biologically active natural compounds. Among the major constituent detected in the genus Asparagus are saponins and flavonoids to which most of the biological activities are attributed. Methods: This review includes a collection of articles between 2000 to 2022, reviewed by internationally accepted databases and scientific journals. Results: This review demonstrates the structural and biological diversities of fifty-three saponin aglycones and glycosides and nineteen flavonoids and flavonoid glycosides isolated from different Asparagus species highlighting their structural diversity along with the biological activities of the reviewed species highlighting their structural diversity along with the biological activities of the reviewed species. Moreover, the application of Asparagus extracts for green synthesis of metal-based nanoparticles to minimize the hazardous effect on the environment and humans observed with metal-based nanoparticles chemically synthesized. Conclusion: The structural and biological diversities and potency of the reviewed saponins and flavonoids isolated from Asparagus along with their use in the production of stable nanoformulations made them a perfect candidate for future drug discovery of new pharmaceutically active agents.

Keywords: Asparagus, Saponins, Polyphenols, Nanoformula

Introduction

Plants are considered the major source of powerful drugs that have been used either for medical treatment or used as a precursor for semi-synthesis of effective analogs against several diseases. The Asparagaceae family is a large group of herbaceous plants including around 114 genera, and the most famous one is Asparagus, including other several genera, genus Asparagus is one of its well-known plant genera, it comprises about 300 species of herbaceous perennials and woody shrubs all over the world such as Asparagus...
INTRODUCTION

Plants are considered the major source of powerful drugs that have been used either for medical treatment or used as a precursor for semi-synthesis of effective analogs against several diseases. The Asparagaceae family is a large group of herbaceous plants including around 114 genera, and the most famous one is Asparagus, including other several genera, genus Asparagus is one of its well-known plant genera, it comprises about 300 species of herbaceous perennials and woody shrubs all over the world 1 such as Asparagus plumosus, A. asparagoides, A. officinalis, A. racemosus, and A. falcatus 2. Based on the color difference, the genus Asparagus is classified into green, white, purple-green, purple-blue, and pink Asparagus 3. Asparagus has been used as a food material for a long time for its nutritional benefits and also used for its medicinal properties 4. The nutritive benefits of the genus Asparagus over other vegetables are due to the presence of higher content of proteins, fats, vitamins, and minerals 5. Asparagus species are naturally located mainly in three continents, Asia, Africa, and Europe and many of them have established economic value as ornamental shrubs i.e. A. plumosus and A. virgatus or for their pharmacological importance i.e. A. racemosus, and A. adscendens 6. Several studies were conducted to evaluate the phytochemical and pharmacological value of Asparagus species, with findings that highlighted their chemical diversity which justified their medicinal importance as well. Asparagus species have numerous biological properties, such as antioxidant 6, 7, antihepatotoxic 8, anti-inflammatory 9, antibacterial 10, and immunostimulant activities 11. Phytochemical studies of the genus Asparagus extensively highlighted the prominent content of steroidal saponins and phenolics 3. Among the chemical profile of the genus Asparagus, steroidal saponins are the main group of phytochemicals isolated and identified 12. Moreover, green Asparagus is a rich source of phenolic compounds 13 which justify the reported potent antioxidant and cytotoxic activities 14. Nanotechnology has greatly impacted the field of pharmaceuticals and drug delivery. Nanomedicine is the branch of medicine that use particles sized from 1 to 1,000 nm for either therapeutic or diagnostic purposes 15-18. Nanomedicine as a drug delivery system was used to target the drug to a specific site and consequently overcome drug accumulation at off-target tissues and consequently side effects associated with drug administration 19-23. This made nanomedicines to be able to overcome the limitations of conventional therapy 24 such as high frequency of drug administration 25 improve the delivery of a hydrophilic drug into cells 26 improve the bioavailability of poorly soluble drugs, control/sustain drug release 26, 27 and aid crossing the blood-brain barrier 28, 29.

Nanoparticles (NPs) have been applied previously for diagnosis, prevention, and treatment of several diseases such as viral infections with promising results 27, 30-33, and and also, they demonstrated a good antibacterial activity against multidrug resistant bacteria 17, 34-39 and for treatment of cancer, Alzheimer's, tuberculosis, wound healing repairing damaged tissue 40-42, and inflammation 43.

Literatures reported nano formulations of natural products were characterized by a remarkable improvement of the stability of the prepared formula (due to protection of active ingredients from physical and chemical degradation), solubility, bioavailability, and thus biological activity, as well as reduction of toxicity 15, 44. Metal-based nanoparticles such as gold and silver were extensively studied due to their unique physicochemical properties rendering them massively applied in different disciplines including chemistry, biology, and biochemical 17. Silver nanoparticles are considered one of the most formulated nanoparticles for various biomedical applications 45. However, they were commonly synthesized by a chemical method, which includes the administration of toxic chemicals, high energy, and pressure for successful production of nanomaterials. Toxic materials are hazardous to the surrounding environment and Humans 46. Thus, researchers adopted other strategies for green synthesis of metal-based nanoparticles including silver nanoparticles to make benefit of unique properties of nanomaterials as well as minimize any harmful or toxic effects on the environment and humans 17. Several researchers have reported the use of plant extracts for the green synthesis of nanoparticles 47 and among its best strategies are either nano-suspension or nano-emulsion of plant extracts 48, 49.

This review study covering a period of 22 years, aims to evaluate the content of different species of the genus Asparagus of saponins and phenolic compounds and their pharmacological effect along with the reported nanoformulations prepared with their extracts. The findings of this review study are categorized into different subclasses of the studied compounds as well as the collection of the reported biological activities of Asparagus species and its nano-applications.

MATERIAL AND METHODS

Search criteria

Original articles, research papers published in journals and PubMed Central, Google scholars on Asparagus species, and medicinal uses were collected and studied. The recorded collected data were selected when the keywords “Phytochemical, pharmacological significance, nanoformulations, Asparagus species” were typed in the search engines.
RESULTS AND DISCUSSION

Several reports indicated that saponins especially those with steroidal nucleus, flavonoid, and phenols are among the major constituents isolated from the genus *Asparagus*. Several other minor classes such as alkaloids, tannins, minerals, and amino acids were also reported from *Asparagus* species.

Steroidal saponin isolated from genus *Asparagus*

The main saponin of *A. officinalis* L., and some other *Asparagus* species, is protodioscin (C_{51}H_{84}O_{22}), which is a derivative of diosgenin of the spirostane, and furostanoid type (Figure 1) in a glycoside form. Structural activity relationships (SAR) of the steroidal saponins were extensively studied and the reports indicated that structural diversity of the saponin glycoside leads to functional alterations. The SAR of steroidal saponins were found to be due to the monosaccharide’s residues constituting the sugar part and their sequences, as well as to the structures of the aglycones. According to previous reports, saponins identified from *Asparagus* species, have different substitutions in the sapogenin (Aglycone part) as well as differences in their types, linkage, and the number of sugar residues. This tremendous structural variability opens the gate for diverse bioactivities. Table 1-6 illustrates the steroidal saponin of the spirostane and the furostane type and their derivatives isolated from *Asparagus* species (Figure 1-2). We noticed that they are dominated by the hexacyclic spirostane nucleus. The chemical structure of this group of compounds has a perhydrocyclopentanophenanthrene nucleus. Most of the natural spirostane saponins have the R configuration at C-22. The spirostanes also differ in the configuration at C-25 and 27-Me which can acquire an R/S configuration.

![Figure 1. Spirostanol (left) and furostanol (right) saponins](image1)

![Figure 2. Spirostanoid, and furostanoid steroidal saponin isolated from Asparagus species.](image2)
Table 1. Spirostan saponin derivatives isolated from *Asparagus* species

<table>
<thead>
<tr>
<th>Species(s)</th>
<th>Compound</th>
<th>R</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. racemosus</em></td>
<td>Diosgenin (25R) (1)</td>
<td>H</td>
<td>58</td>
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<tr>
<td><em>A. officinalis</em></td>
<td>Yamogenin (25S) (2)</td>
<td></td>
<td>59</td>
</tr>
<tr>
<td><em>A. adscendens</em></td>
<td>Adscendin A (3)</td>
<td>β-D-Glu(1→6)α-L-Rha</td>
<td>60, 61</td>
</tr>
<tr>
<td><em>A. cochinchinensis</em></td>
<td>Asparagusoside C (4)</td>
<td>α-L-Rha(1→2)-{α-L-Rha(1→4)}β-D-Glu</td>
<td>62</td>
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<tr>
<td></td>
<td>Asparagusoside D (5)</td>
<td>α-L-Rha(1→4)-β-D-Glu</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Spirostan saponin derivatives isolated from *Asparagus* species

<table>
<thead>
<tr>
<th>Species(s)</th>
<th>Compound</th>
<th>R</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. cochinchinensis</em></td>
<td>(25S)-5β-spirostan-3β-ol-3- D-β-D-glucopyranoside (6)</td>
<td>β-D-Glu</td>
<td>63</td>
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<tr>
<td><em>A. racemosus</em></td>
<td>Shatavarin IV</td>
<td>β-D-Glu(1→2)β-D-Glu (1→4)α-L-Rha</td>
<td>64</td>
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<tr>
<td><em>A. adscendens</em></td>
<td>(Asparanin B, Curillin H) (7)</td>
<td>β-D-Glu(1→2)β-D-Glu</td>
<td>1, 58, 65</td>
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<tr>
<td><em>A. racemosus</em></td>
<td>Asparanin A (8)</td>
<td>β-D-Glu(1→2)β-D-Glu</td>
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<td>Shatavarin V (9)</td>
<td>β-D-Glu(1→2)α-L-Rha(1→4)β-D-Glu</td>
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<td>Shatavarin VI (10)</td>
<td>β-D-Glu(1→2)β-D-Glu(1→4)α-L-Rha</td>
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<td></td>
<td>Shatavarin VIII (11)</td>
<td>β-D-Glu(1→2)β-D-GluGlu(1→4)α-L-Ara(1→6)β-D-Glu</td>
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<td>Shatavarin IX (12)</td>
<td>β-D-Glu(1→2)β-D-Glu(1→4)β-D-Glu</td>
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<td>Shatavarin X (13)</td>
<td>β-D-Glu (1→2)α-L-Rha(1→4)β-D-6-acetylglu</td>
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<td>Shatavaroside A (14)</td>
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<td>Shatavaroside B (15)</td>
<td>β-D-Glu(1→2)β-D-Glu(1→4)α-L-Xyl(1→6)α-L-Rha</td>
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<tr>
<td></td>
<td>Immunoside (16)</td>
<td>β-D-Glu(1→2)α-L-Rha(1→4)α-L-Rha</td>
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<td><em>A. filicinus</em></td>
<td>Filicinin A (17)</td>
<td>β-D-Glu(1→4)β-D-Glu(1→4)β-D-Gal(1→6)-β-D-Xyl</td>
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<td>Filicinin B (18)</td>
<td>β-D-Glu(1→4)β-D-Glu(1→2)β-D-Glu(1→4)β-D-Gal(1→6)-β-D-Xyl</td>
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</tr>
<tr>
<td><em>A. racemosus</em></td>
<td>Filiasparoside C (19)</td>
<td>β-D-Glu(1→2)β-D-Xyl(1→4)α-L-Rha</td>
<td>1, 67, 68</td>
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<tr>
<td><em>A. filicinus</em></td>
<td>Filiasparoside D (20)</td>
<td>β-D-Glu (1→6)α-L-Ara</td>
<td>68</td>
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<td></td>
<td>Aspafiloside A (21)</td>
<td>β-D-Glu (1→4)β-D-Xyl</td>
<td>69, 70</td>
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<tr>
<td></td>
<td>Aspafiloside B (22)</td>
<td>β-D-Glu(1→4)β-D-Xyl(1→6)α-L-Rha</td>
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<tr>
<td><em>A. racemosus</em></td>
<td>Curillin H (23)</td>
<td>β-D-Glu (1→2)α-L-Rha(1→6)-β-D-Glu</td>
<td></td>
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<tr>
<td><em>A. curillus</em></td>
<td>Racemoside A (24)</td>
<td>β-D-Glu(1→4)α-L-Rha(1→6)-β-D-Glu</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Racemoside B (25)</td>
<td>β-D-Glu (1→6)-α-L-Rha(1→6)-β-D-Glu</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Racemoside C (26)</td>
<td>β-D-Glu (1→4)α-L-Rha(1→6)-β-D-Glu</td>
<td></td>
</tr>
<tr>
<td><em>A. acutifolius</em></td>
<td>(25S)-5β-spirostan-3β-ol-3-D-β-D-xylopyranosyl(1→2)-{β-D-xylopyranosyl(1→4)}β-D-glucopyranoside (27)</td>
<td>β-D-Glu(1→2)β-D-Xyl (1→4)-β-D-Xyl</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>(25R)-5β-spirostan-3β-ol-3-D-β-D-glucopyranoside (27)</td>
<td>β-D-Glu(1→2)β-D-Glu(1→6)-α-L-Ara</td>
<td>74</td>
</tr>
<tr>
<td><em>A. africana</em></td>
<td>(25S)-5β-spirostan-3β-ol-3-D-β-D-glucopyranoside (27)</td>
<td>β-D-Glu(1→2)β-D-Glu(1→6)-α-L-Ara</td>
<td></td>
</tr>
</tbody>
</table>
### Table 3. Spirostan-12-one saponin derivatives isolated from *Asparagus* species

<table>
<thead>
<tr>
<th>Species(s)</th>
<th>Compound</th>
<th>R</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td><em>A. filicinus</em></td>
<td>Filiasparsoside A (29)</td>
<td>α-Glu(1→4)α-L-Xyl(1→6)R-Ara</td>
<td>69, 70</td>
</tr>
<tr>
<td><em>A. filicinus</em></td>
<td>Filiasparsoside B (30)</td>
<td>α-Glu(1→6)R-Ara</td>
<td></td>
</tr>
<tr>
<td><em>A. africana</em></td>
<td>(25R)-3β-hydroxy-5β-spirostan-12-one 3-O-[β-D-glucopyranosyl(1→2)-O-L-arabinopyranosyl(1→6)]-β-D-glucopyranosyl (31)</td>
<td>β-D-Glu(1→2)β-D-Glu(1→6)</td>
<td>74</td>
</tr>
</tbody>
</table>

### Table 4. Saponins with furostan nucleus isolated from *Asparagus* species

<table>
<thead>
<tr>
<th>Species(s)</th>
<th>Compound</th>
<th>R</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. racemosus</em></td>
<td>Shatavarin I (32)</td>
<td>β-D-Glu(1→2)β-D-Glu(1→6)α-L-Rha</td>
<td>1, 58</td>
</tr>
<tr>
<td><em>A. curillus</em></td>
<td>Curilloside G (33)</td>
<td>β-D-Glu(1→2)α-L-Rha (1→4)β-D-Glu</td>
<td>71</td>
</tr>
<tr>
<td><em>A. filicinus</em></td>
<td>Aspafilioside C (34)</td>
<td>β-D-Glu (1→2)-β-D-Xyl (1→4)</td>
<td>79</td>
</tr>
<tr>
<td><em>A. acutifolius</em></td>
<td>(25S)-3β,5β,22α-furostan-3,22,26-triol-3-O-[β-D-xylopyranosyl(1→2)]-β-D-xylopyranosyl(1→4)-β-D-glucopyranosyl-26-O-β-D-glucopyranoside (35)</td>
<td>β-D-Glu (1→2)-β-D-Xyl (1→4)</td>
<td>73</td>
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<tr>
<td><em>A. cochinchinensis</em></td>
<td>(25S)-26-O-β-D-glucopyranosyl-5β-furostan-3β,22α,26-triol-3-O-β-D-glucopyranoside (36)</td>
<td>β-D-Glu</td>
<td>63</td>
</tr>
<tr>
<td><em>A. racemosus</em></td>
<td>(25S)-26-O-β-D-glucopyranosyl-5β-furostan-3β,22α,26-triol-3-O-α-L-rhamnopyranosyl(1,4)-β-D-glucopyranoside (37)</td>
<td>β-D-Glu(1→4)α-L-Rha</td>
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</tr>
<tr>
<td><em>A. curillus</em></td>
<td>Curilloside H (38)</td>
<td>β-D-Glu(1→2)α-L-Rha (1→6)β-D-Glu</td>
<td>71</td>
</tr>
<tr>
<td><em>A. racemosus</em></td>
<td>Asparoside A (39)</td>
<td>β-D-Glu(1→2)β-D-Glu(1→4)α-L-Rha</td>
<td>74</td>
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<tr>
<td><em>A. africana</em></td>
<td>26-O-β-D-glucopyranosyl-22α-methoxy-(25R)-furostan-3β,26-diol-3-O-[β-D-glucopyranosyl(1→2)]-β-D-glucopyranoside (40)</td>
<td>β-D-Glu(1→2)-β-D-Glu</td>
<td>74</td>
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<tr>
<td><em>A. acutifolius</em></td>
<td>(25R)-3β,5β,22α-22-methoxyfurostan-3,26-diol-3-O-[β-D-xylopyranosyl(1→2)]-β-D-xylopyranosyl(1→4)-β-D-glucopyranosyl-26-O-β-D-glucopyranoside (41)</td>
<td>β-D-Glu(1→2)-β-D-Xyl (1→4)</td>
<td>73</td>
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<tr>
<td><em>A. acutifolius</em></td>
<td>(25R)-3β,5β,22α-22-methoxyfurostan-3,26-diol-3-O-[β-D-xylopyranosyl(1→2)]-β-D-xylopyranosyl-26-O-β-D-glucopyranoside (42)</td>
<td>β-D-Glu(1→2)-β-D-Xyl</td>
<td>73</td>
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### Table 5. Furostanone saponin derivative isolated from *Asparagus* species

<table>
<thead>
<tr>
<th>Species(s)</th>
<th>Compound</th>
<th>R</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. filicinus</em></td>
<td>Filiasparsoside G (43)</td>
<td>β-D-Glu(1→4)β-D-Xyl(1→6)α-L-Ara</td>
<td>69</td>
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### Table 6. Furostan-12-one saponin derivative isolated from *Asparagus* species

<table>
<thead>
<tr>
<th>Species(s)</th>
<th>Compound</th>
<th>R</th>
<th>Reference</th>
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<tbody>
<tr>
<td><em>A. cochinchinensis</em></td>
<td>(25S)-26-O-β-D-glucopyranosyl-5β-furostan-3β,22α,26-triol-12-one-3-O-β-D-glucopyranoside (44)</td>
<td>β-D-Glu</td>
<td>65</td>
</tr>
<tr>
<td><em>A. cochinchinensis</em></td>
<td>(25S)-26-O-β-D-glucopyranosyl-22α-methoxy-5β-furostan-3β,26-diol-12-one-3-O-β-D-glucopyranoside (45)</td>
<td>β-D-Glu</td>
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Table 7. Other steroidal compounds from Asparagus species

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<tr>
<th>Species(s)</th>
<th>Compound</th>
<th>Structure</th>
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<td>A. filicinus</td>
<td>Asparilisine (46)</td>
<td><img src="image1" alt="Structure" /></td>
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<td>A. Officinalis</td>
<td>β-Sitosterol (47)</td>
<td><img src="image2" alt="Structure" /></td>
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<td>A. filicinus</td>
<td>Ecdysterone [stachyostereone-α-20,22-acetonide] (47)</td>
<td><img src="image3" alt="Structure" /></td>
<td>60, 61</td>
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<td>A. dumosus</td>
<td>Calonysterone (48)</td>
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<td>Blechnoside (49)</td>
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<td>Dumoside I (50)</td>
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<td>Dumoside II (51)</td>
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<td></td>
<td>Dumoside IV (53)</td>
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### Flavonoids reported from different species of the genus Asparagus

Several reports have demonstrated scarce information regarding the genus Asparagus flavonoids and phenolic investigations. Fuentes et al. 2007 investigated the phenolic content of both white and green varieties of the genus Asparagus, and reported that white Asparagus contained hydroxycinnamic acid derivatives, on the other hand, flavonoids were the major phenolics in green Asparagus.<ref>. Table 8 and Figure 3 are illustrating different flavonoid classes identified from Asparagus species including classes such as flavones (e.g., luteolin), flavanols (e.g., quercetin, kaempferol), flavanones (e.g., naringenin), and others.

### Pharmacological studies

Several therapeutic potentials of Asparagus are well documented in the literature. The therapeutic activity is due to the possession of significant pharmacological activities such as antioxidant, anti-inflammatory, analgesic, antiulcer anti-aging, antifungal, and antimicrobial properties. Table 9 describes the reported pharmacological activities of genus Asparagus.

http://aprh.journals.ekb.eg/
Table 8. Flavonoids reported from different *Asparagus* species

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rutin (54)</td>
<td>1, 3, 78, 79</td>
</tr>
<tr>
<td>Kaempferol-3-O-rutinoside (55)</td>
<td>78</td>
</tr>
<tr>
<td>Isorhamnetin-3-O-rutinoside (56)</td>
<td>78</td>
</tr>
<tr>
<td>Quercetin-3-rhamnosyl-rutinoside (57)</td>
<td>79, 80</td>
</tr>
<tr>
<td>Isorhamnetin-3-rhamnosyl-rutinoside (58)</td>
<td>80</td>
</tr>
<tr>
<td>Isorhamnetin-3-glucosyl-rutinoside (59)</td>
<td>79, 80</td>
</tr>
<tr>
<td>Isorhamnetin-3-O-glucoside (60)</td>
<td>79, 80</td>
</tr>
<tr>
<td>Naringin (61), Vitexin (62)</td>
<td>81</td>
</tr>
<tr>
<td>8-Methoxy-5,6,4-trihydroxy isoflavone-7- O-β-glucopyranoside (63)</td>
<td>1</td>
</tr>
<tr>
<td>Genistin (64), Daidzein (65)</td>
<td>81</td>
</tr>
<tr>
<td>Quercetin (66)</td>
<td>1, 58, 78, 80</td>
</tr>
<tr>
<td>Kaempferol (67)</td>
<td>1, 78, 80, 81</td>
</tr>
<tr>
<td>Kaempferide (68), Luteolin (69)</td>
<td>81</td>
</tr>
<tr>
<td>Rhamnetin (70)</td>
<td>78</td>
</tr>
<tr>
<td>Isorhamnetin (71)</td>
<td>78, 79</td>
</tr>
<tr>
<td>Chrysin (72)</td>
<td>81</td>
</tr>
</tbody>
</table>

Figure 3. Flavonoids isolated from *Asparagus* species.

Nanoparticle formulation from extracts of genus *Asparagus*

Several reports have demonstrated the usage of the extracts of different species of the genus *Asparagus* in the synthesis of several metal-based nanoparticles due to the oxidative or reducing potential of active ingredients in the plant extracts. Moreover, the plant extract enriched with biologically active macromolecules (e.g. saponin, flavonoids, etc) was also encapsulated into nanoformulations such as liposomes, suspension, or alternatively adsorbed onto the surface of metal-based nanoparticles to act as a targeted drug delivery system to target the plant extract to diseased organ. Nanoformulations of plant extracts as previously discussed had superior advantages over conventional plant extract and it includes increasing the solubility, enhancing the bioavailability, reducing toxicity, and increasing the biological activity of the drug, in addition to increasing the sustainability and the protection against physical and chemical degradation. However, literature reported that nanoparticles formulated using plant extracts for preparation are most likely to have biological activities similar to that of the original plant extracts but with the added benefit of optimizing the biological activity of the secondary metabolites. Different nanoformulations prepared from extracts of different species of genus *Asparagus* and their biological activities were presented in Table 10.
Table 10. Biological activities of extracts of genus *Asparagus*

<table>
<thead>
<tr>
<th>Biological activity</th>
<th>Species</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antioxidant</td>
<td><em>A. racemosus</em></td>
<td>82-84</td>
</tr>
<tr>
<td></td>
<td><em>A. cochinchenlss</em></td>
<td>85</td>
</tr>
<tr>
<td></td>
<td><em>A. albus</em></td>
<td>86</td>
</tr>
<tr>
<td></td>
<td><em>A. suaveolens</em></td>
<td>87</td>
</tr>
<tr>
<td></td>
<td><em>A. stipularis</em></td>
<td>88</td>
</tr>
<tr>
<td>Anti-aging</td>
<td><em>A. cochinchenlss</em></td>
<td>85</td>
</tr>
<tr>
<td>Anti-inflammatory</td>
<td><em>A. racemosus</em></td>
<td>58</td>
</tr>
<tr>
<td></td>
<td><em>A. pubescens</em></td>
<td>89</td>
</tr>
<tr>
<td></td>
<td><em>A. cochinchenlss</em></td>
<td>90, 91</td>
</tr>
<tr>
<td></td>
<td><em>A. africanus</em></td>
<td>92</td>
</tr>
<tr>
<td></td>
<td><em>A. laricinus</em></td>
<td>92</td>
</tr>
<tr>
<td>Anti-microbial</td>
<td><em>A. racemosus</em></td>
<td>93-95</td>
</tr>
<tr>
<td></td>
<td><em>A. laricinus</em></td>
<td>92</td>
</tr>
<tr>
<td></td>
<td><em>A. albus</em></td>
<td>86</td>
</tr>
<tr>
<td>Anti-fungal</td>
<td><em>A. retrofractus</em></td>
<td>73, 96</td>
</tr>
<tr>
<td></td>
<td><em>A. acutifolius</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>A. setaceous</em></td>
<td></td>
</tr>
<tr>
<td>Anti-bacterial</td>
<td><em>A. suaveolens</em></td>
<td>87, 97</td>
</tr>
<tr>
<td></td>
<td><em>A. racemosus</em></td>
<td></td>
</tr>
<tr>
<td>Anti-ulcer</td>
<td><em>A. pubescens</em></td>
<td>98, 99</td>
</tr>
<tr>
<td></td>
<td><em>A. racemosus</em></td>
<td>58, 98</td>
</tr>
<tr>
<td>Analgesic</td>
<td><em>A. africannus</em></td>
<td>92</td>
</tr>
</tbody>
</table>

Table 11. Nano formulations and biological significance of extracts of genus *Asparagus*

<table>
<thead>
<tr>
<th>Species</th>
<th>Nanoformulation</th>
<th>Biological significance</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. racemosus</em></td>
<td>Silver nanoparticles</td>
<td>Antibacterial activity</td>
<td>103</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bactericidal and Cytotoxic</td>
<td>104, 105</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antibacterial and Immnonomodulatory Potentials</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Gold nanoparticles</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ant mycobactericidal and Cytotoxicity</td>
<td>106</td>
</tr>
<tr>
<td></td>
<td>Silver nanoparticles</td>
<td>Anti-diabetic activity</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antibacterial activity</td>
<td>108</td>
</tr>
<tr>
<td><em>A. officinalis</em></td>
<td>Silver nanoparticles</td>
<td>Bactericidal and Cytotoxic</td>
<td>109</td>
</tr>
<tr>
<td><em>A. adscendens</em></td>
<td>Copper Nano-Particles</td>
<td>Antmicrobial Activities</td>
<td>110-112</td>
</tr>
<tr>
<td><em>A. racemosus</em></td>
<td>Liposomes</td>
<td>Anti-inflammatory activity</td>
<td>113</td>
</tr>
<tr>
<td><em>A. stipularis</em></td>
<td>Nanoencapsulation</td>
<td>Antioxidant</td>
<td>114</td>
</tr>
</tbody>
</table>

CONCLUSION

This review illustrated the structural diversity of two of the major classes of secondary metabolites separated from the genus *Asparagus*, including saponins and flavonoids. It also describes the diversity of their biological activities in addition to all nanof ormulation application trials applied to different *Asparagus* extracts. The efficient comprehension of *Asparagus*’s steroidal saponins/flavonoids structural diversity and their biosynthetic pathways has scientific importance for further future studies of the possible use of the naturally occurring saponins and flavonoids as a chemical structural entity to prepare a library of semisynthetic derivatives for optimization of their biological activity and drug design research. Phytochemicals reported in *Asparagus* extracts were shown to be efficient in green synthesis of metal-based nanoparticles, where they can reserve the biological activity of these nanoparticles but with no harmful effect on the environment and humans that was previously identified with metal-based nanoparticles synthesized chemically. In addition, nanoencapsulation of *Asparagus* extracts into one of the promising drug delivery systems e.g. liposomes, suspension, emulsion, etc was shown to have various merits compared to conventional *Asparagus* extracts such as improving solubility, stability, bioavailability, and hence, pharmacological activity.

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Conflict of interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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