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Medicinal Properties of Selected Asparagus Species: A Review

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Abstract

Asparagus species are naturally distributed along Asia, Africa, and Europe and are known to have numerous biological properties. This review article was aimed to provide an organized summary of current studies on the traditional uses, phytochemistry, and pharmacological and toxicological studies of *Asparagus laricinus* Burch., *Asparagus africanus* Lam., *Asparagus officinalis* L., *Asparagus racemosus* Willd., and *Asparagus densiflorus* (Kunth) Jessop to attain and establish new insights for further researches. Information used in this review was obtained from electronic database including PubMed central, Google scholars, Science direct, Scopus, and Sabinet. Based on the present findings, the existing literature still presents some breaches about the mechanism of action of various constituents of these plants, and their relation to other plant compounds in poly-herbal formulations, as well as their long-term use and safety. More in-depth studies are still needed for active compounds and biological activities of *Asparagus laricinus*, *Asparagus africanus*, and *Asparagus densiflorus*. Therefore, innumerable opportunities and possibilities for investigation are still available in novel areas of these plants for future research studies. It can be concluded that all selected Asparagus species have tremendous potential to improve human health and the pharmacological activities of these plants can be attributed to bioactive phytochemicals they possess.

Keywords: Asparagaceae, *Asparagus africanus lam.*, *Asparagus densiflorus (kunth)* Jessop, *Asparagus laricinus* Burch., *Asparagus officinalis* L., *Asparagus racemosus* Willd., pharmacological actions, phytochemistry

1. Introduction

Historically, plants were used for numerous purposes for mankind in general, inter alia, feeding and catering, culinary spices, medicine, various forms of cosmetics, symbols in worship and for a variety of ornamental goods. They are still being used for these purposes. The traditional medicines are sold in market places and prescribed by traditional healers at their home [1] particularly in the rural areas where herbal medicine is the main source of the healthcare system. South Africa is blessed with a vast variety of plants since it has such a large diversity of more than 20,000 types of species. The research and scientific community find this to be a great source of interest [2]. Since the 1990s, great interest is being shown in plants that can be used as important sources of new medicines and herbs, which have become mainstream throughout Africa [3].

It is estimated that three quarters of the world of mankind relies on herbal and traditional medicine as a basis for primary healthcare [4]. It was discovered that between 12 and 15 million South Africans still rely on more than 700 indigenous types of plants for the supply of their traditional herbal medicines [5]. Up to 60% of the South African population consults one of an estimated 200,000 traditional healers in rural areas [6]. These herbal medicines which are extracted from plants and used for medicinal purposes often result in acute toxicity. For example, it is estimated that between 8000 and 20,000 people die every year in South Africa due to the fact that these medicinal plants are used incorrectly [7, 8]. The Food and Drug Administration [FDA] indicates that both serious and moderate adverse events from many botanical and others traditional medicinal products are significantly underreported, and that the annual number of such cases is at least 50,000 each year [9, 10].

Different research studies to elucidate and validate the ethnobotanical value of medicinal plants have been conducted and reported by investigators world-wide, with findings that were established from the use of various methods, and also under diverse conditions.

In this review study, five native *Asparagus* species (namely *Asparagus laricinus* Burch., *Asparagus africanus* Lam., *Asparagus officinalis* L., *Asparagus racemosus* Willd. and *Asparagus densiflorus* Kunth) Jessop) were evaluated for their historical, etymological, morphological, phytochemical and pharmacological aspects. The findings of this review study are summarized, and the medicinal properties of the chosen *Asparagus* species are documented in this review study.

2. Methodology

2.1 Search criteria

Original articles, research papers published in journals and in PubMed central, Google scholars on plants of interest (*Asparagus laricinus* Burch., *Asparagus africanus* Lam., *Asparagus officinalis* L., *Asparagus racemosus* and *Asparagus densiflorus* (Kunth) Jessop), and medicinal uses were studied, and related articles and papers were also taken into consideration. The two species, *Asparagus laricinus* Burch. and *Asparagus africanus* Lam. were the first choice according to the research studies at the laboratory of authors for their pharmacological activities and toxicology. The other three species of interest were randomly selected from an enormous number of *Asparagus* species retrieved when the key words “*Asparagus* species with medicinal properties” were used in the search.

2.2 Data analysis

The available literature was especially studied for historical, etymological, morphological, phytochemical and pharmacological aspects of *Asparagus laricinus* Burch., *Asparagus africanus* Lam., *Asparagus officinalis* L., *Asparagus racemosus* and *Asparagus densiflorus* (Kunth) Jessop. Priority was given to ethnobotanical reports, laboratory work and clinical trials carried out on all five species. Finally, results were obtained from all collected data and literature studied.

3. *Asparagus* species with medicinal properties

The genus *Asparagus* is an herbaceous plant comprising approximately 150 species around the world which are comprised of herbs, shrubs and vines [11]. *Asparagus*

forms part of *Asparagaceae*, which is a monogeneric family and was formerly included in the *Liliaceae* family. *Asparagus* species are naturally distributed along Asia, Africa and Europe [12]. Most of these species have economic value as ornamental plants, such as *Asparagus plumosus*, and for their medicinal properties from plants such as *Asparagus laricinus* Burch. *Asparagus* species have numerous biological properties, such as being antioxidant, anti-inflammatory, antibacterial, antihepatotoxic, immunostimulant, and reproductive agents. Among large number of *asparagus* species that are used as medicine, five of them have been chosen as they have been investigated for their anticancer activity, namely: *Asparagus laricinus* Burch.; *Asparagus africanus* Lam.; *Asparagus officinalis* L.; *Asparagus racemosus*; and *Asparagus densiflorus* (Kunth) Jessop.

4. *Asparagus laricinus* Burch.

Vernacular names

English: Wild asparagus;

Afrikaans: Bergkatbos, Bergkatdoring, Fynkatbos, Katdoring, Langbeenkatdoring; Zulu: Ibutha, Setswana: Lesitwana [13].

Synonym: *Protasparagus laricinus* (Burch.) Oberm.

4.1 Historical aspects

Asparagus laricinus Burch. is a very hardy, evergreen, shrubby *Asparagus* with fine, feathery foliage and silvery, zigzag branchlets. It has myriads of tiny white, nectar-rich flowers that develop during spring and summer. These flowers are fragrant and attract insects and birds. Birds in the garden are attracted by its bright red and black berries. It may be grown in the sun or semi-shade and is a very useful plant for a security hedge as it is extremely spiny. It is fire-resistant and, if the stems burn, it shoots quickly from the base. The new shoots can be eaten as a vegetable. It grows in sun or shade and in all types of soil except water-logged soils. It can grow up to 1.5 m. *Asparagus laricinus* Burch. is native to Botswana and South Africa, Lesotho and Swaziland. They are used to treat tuberculosis, sores, red water, uterine infection, general alignments, umbilical cord inflammation, and serve as a diuretic.

4.2 Phytochemical active principals

Roots and leaves of *Asparagus laricinus* Burch. had tannins, saponins, terpenes, steroids. However, only roots showed the presence of alkaloids [14], while leaves are devoid of alkaloids [15]. The leaves further had flavonoids, glycosides, steroids and carbohydrates. The stems are rich in saponins, tannins, and flavonoids, with a lack of steroids, glycosides and carbohydrates [15]. The *Asparagus laricinus* Burch. aqueous roots extract contained 4.2 g/l GAE (Gallic acid equivalent) total phenolic content, while leaves and stem aqueous extract showed the phenolic concentration of 0.572 mg/GAE and 0.277 mg/GAE, respectively. It was apparent that leaves had more phenolic content than the stem, and this was supported by the number of active phytochemicals identified from both parts of the plant. Fuku et al. [14] isolated and identified three compounds from the *Asparagus laricinus* Burch. roots: indole-3-carbinol, α -sitosterol and ferulic acid.

4.3 Pharmacological actions

Secondary metabolites produced by plants for plant protection do not only benefit plants, but they also have health benefits for human beings. These compounds

result in antimicrobial medicines [16], anti-inflammatory drugs, anticancer drugs, and plant-based anti-oxidants. Phytochemical screening was performed on the leaves and roots of *Asparagus laricinus* Burch., and parts had tannins, saponins, terpenes, and steroids. However, only roots showed the presence of alkaloids. It was also shown that flavonoids which are known to have an ability to inhibit microbial growth also scavenge antioxidants. The leaf extract contained steroids, these being important compounds as sex hormones. Both leaves and stem extracts showed that they contain saponins, which ultimately has a suppressive effect on inflammation [17]. This is a main reason why *Asparagus laricinus* Burch. is used in traditional medicine. *In vivo* anti-inflammatory activity studies of this plant are being conducted in the Unit of Drug discovery, CUT [18].

Tannins are generally found in most plant parts: bark, wood, leaves, fruits and roots, and can have a toxic effect on filamentous fungi, yeasts and bacteria [19]. No alkaloids were found in this study. Leaf extracts further showed positive antibacterial activity on *S. aureus*, *S. saprophyticus*, *E. cloacae* and *B. subtilis*. Inhibition of *Staphylococcus aureus* by the *Asparagus laricinus* Burch. plant extract demonstrates huge potential for using this plant to extraction in the treatment of microbial infections, especially in the light of the growing antibiotic resistance in micro-organisms. The presence of phenols correlates with the antibacterial and antioxidant activities of the leaf extract of *Asparagus laricinus* Burch., as demonstrated by Ntsoelinyane and Mashele [15].

In recent times, there has been a growing interest in finding antioxidants which occur naturally to replace synthetic antioxidants, many of which are being restricted due to their carcinogenicity [20, 21]. Free radical scavenging molecules such as flavonoids, tannins, alkaloids, quinones, amines, vitamins and other metabolites have anti-inflammatory, anti-carcinogenic, antibacterial and antiviral activities [22]. *Asparagus laricinus* Burch. aqueous extracts of roots and leaves showed positive antioxidant activity with DPPH assay [15]. Flavonoids contain anion radicals and produce membrane bound enzymes [23]. This could be the reason for the mechanisms of antioxidative action of *Asparagus laricinus* Burch. leaf extract. The antioxidant that is found in the plant extract may also be due to polyphenols as phenolics being present [24]. The aqueous leaves extract of *Asparagus laricinus* Burch. produced significant activity as an antioxidant, and this could be due to the presence of ferulic acid; and as it is known to protect cells from oxidative stress.

Using the Ames test on *Salmonella typhimurium* strains: TA97, TA98, TA100 and TA102 without any metabolic activation, Mashele and Fuku [25] evaluated the mutagenic and antimutagenic properties of the aqueous root's extracts of this plant. The extract was non-mutagenic towards all strains, had moderate inhibitory effect on TA100, and had low inhibitory effects on TA102 and TA97 [7]. Root aqueous extract showed an indirect mutagenic effect toward TA102 after metabolic activation, but not in TA97, TA98 and TA100. However, it was found that the Ames test, without S9 (liver extract of a rat, hamster or human) metabolic activation, could only detect direct mutagens, while S9 metabolic activation allowed the detection of indirect mutagens which were mostly caused by conjugation reactions of metabolic oxidation systems. Cytotoxicity activity on Vero cells was also elucidated. The cytotoxicity tests indicated no cytotoxic effect below 500 µg/ml concentration of the *A. laricinus* Burch. aqueous extract [7].

The phytoconstituents detected from *Asparagus laricinus* Burch. may have caused the cytotoxic activity, although their precise mode of action is poorly understood. Only a few compounds were isolated from the roots of *Asparagus laricinus* Burch.: indole-3-carbinol, α -sitosterol and ferulic acid. β -Sitosterol have numerous therapeutic and chemo-preventive uses in the medical field [26, 27]. Prostate cancer is being treated by Indole-3-carbinol [28]. Anticancer activity on breast (MCF7), renal (TK10) and melanoma (UACC62) using roots aqueous and ethanol extracts was

shown by Mashele and Kolesnikova [29], who revealed that ethanol extracts were very active while aqueous extracts were weakly active. However, ethanol roots extract only showed the presence of tannins while the aqueous roots extract showed a number of active phytochemicals. These results should be investigated further to elucidate the aforementioned difference. It may be that the presence of other active compounds somehow affected the ability of tannins by neutralizing their activity in the aqueous root's extracts. Another possibility is that active compounds from the roots were present and these were missed during the phytochemical screening of this plant.

Mokgawa evaluated possible toxic effects of dried roots, stem and leaves of *Asparagus larycinus* Burch. extracts using Sprague Dawley rats as animal models [18]. Histological evaluation could not reveal any pathological changes in both aqueous and ethanolic extracts across all levels of dosages. Full blood count results could not point in the direction of toxicity, adverse effects or hazards as indicated by statistically similar results between the exposed and unexposed groups, using both aqueous and ethanol extracts at different concentrations [18]. According to results obtained by Mokgawa, histological assessment has proven that both aqueous and ethanolic extracts of *Asparagus larycinus* Burch. had no detrimental or adverse effects on vital organs of Sprague Dawley rats [18]. Tissue damage, lesions or inflammation were not observed on the kidney, liver or spleen of treatment groups in comparison to the control group. The pattern was observed across increasing doses of aqueous and ethanolic extracts. It was, therefore, concluded that toxicological evaluation of *Asparagus larycinus* Burch. extracts may be considered relatively free of toxicity when given orally, because it did not cause death, damage or inflammation to tissues, nor did it produce any remarkable biochemical and hematological adverse effects in both male and female Sprague Dawley rats [18]. Further studies may also be conducted to demonstrate *in vivo* efficacy against cancer as studies to date were done using cell lines (*in vitro* studies).

4.4 Reflections and future recommendations

Only preliminary screening of phytochemicals was done on crude extracts. Isolation of active pure compounds was only done on roots (3 compound identified) and not on leaves, even though leaves showed so much active compounds. This compound identification still needs to be done and testing of them has not been done either. Both leaves and roots extracts showed the presence of saponins. However, the identification and isolation of those specific saponins has not been done. Intensive work still needs to be performed regarding the mutagenicity or genotoxicity of the plant extracts for the confirmation of the safety of *Asparagus larycinus* Burch., as the root cytotoxicity results were promising, while the safety of the leaves also needs to be investigated. The toxicological study of the roots of *Asparagus larycinus* Burch. confirmed that the plant extract did not cause any harm *in vivo* and can thus be considered as non-toxic. However, the *in vivo* anticancer activity of the root extract has not been done in order to confirm or corroborate the results obtained in the screening study that was conducted. Both *in vitro* and *in vivo* anticancer, cytotoxicity and mutagenicity studies still need to be done on the leaf extract. The ability of the crude extract of this plant as an antibacterial agent was confirmed, and findings supported the use of this plant against infections. However, not all ethnobotanical claims of this plant have been confirmed as the anti-TB activity, anti-inflammatory activity and its ability as a diuretic still needs to be elucidated.

5. *Asparagus africanus* Lam.

Vernacular names

English: Wild Asparagus climbing asparagus fern, bush asparagus;

Afrikaans: Haakdoring, Katdoring Wag-'n-bietjie, Wag-n'-bietjie, Wag-'n-bietjie-doring; Xhosa: Ubulawu Ubumhlope, Umthunzi; Zulu: Isigoba, Isigobo; Sesotho: Lelala-tau-le-leholo, Leunyeli; Banda: ngorozo; Kirundi: imburabano, umunsabe; Maasai: embere e papa; Afeen Oromo: Seriti.

Synonym: *Protasparagus africanus* (Lam.) Oberm.

Scientific classification

Kingdom: plantae; **Subfamily:** asparagoideae; **Genus:** *Asparagus*—*asparagus*; **Order:** asparagales; **Species:** *Asparagus africanus* Lam.—African Asparagus; **Family:** Liliaceae.

5.1 Historical aspects

Asparagus africanus Lam., commonly known as African Asparagus, is a monocot. *Asparagus africanus* Lam (Liliaceae) is an erect armed herb that grows to a height of up to 6 m. The plant is found in many parts of tropical Africa and can grow between 700 and 3800 m above sea level. The fruit consists of a rounded berry which has a width of about 5–6 mm and it contains only one seed. It starts off as green colored but eventually becomes orange and somewhat shriveled as it matures. They grow during most parts of the year.

Their roots are traditionally used for: the relief of pain, rheumatism and chronic gout, hematuria, hemorrhoids, headache, backache, stomach pain, sore throat and otitis. It is also used to treat malaria, central nervous system related conditions, tuberculosis, venereal diseases and as an aid during childbirth [30].

5.2 Phytochemical active principals

The main contents of the plant are carbohydrates and saponins which have small quantities of flavonoids and tannins. Three steroidal saponins were isolated from the roots of *Asparagus africanus* Lam. [31]. Two compounds namely 2 beta-, 12 alpha-dihydroxy-(25R)-spirosta-4, 7-dien-3-one, lignan (+)-nyasol, and (Z)-(+)-4,4-(3-ethenyl-1-propene-1,3-diyl) bisphenol) were isolated by Oketch-Rabah et al. [32] from *Asparagus africanus* Lam roots.

5.3 Pharmacological actions

In traditional medicine, *Asparagus africanus* Lam. is used for treating headaches, backaches, and stomach pains and also is used to assist in childbirth and for hematuria, hemorrhoids, malaria, leishmaniasis, bilharziasis, syphilis, and gonorrhea [32, 33]. External application of the root is used for the relief of pain, rheumatism and chronic gout [34]. It is further used a diuretic, for sore throats and otitis [35]. The focus of many anti-infective drugs as well as alternative sources of antimalarial agents in various parts of the world has been on the use of medicinal plants [36–38]. During *in vitro* studies on extracts from the root of *Asparagus africanus* Lam., it has been found that they can be used as a counter activity against four different malaria schizont strains [32].

Oketch-Rabah et al. [32], were able to isolate two antiprotozoal compounds, a saponin (muzanzagenin) and lignan ((+) niasol), which they reported to be responsible for the antimalarial activity. Even though this plant has displayed promising antiplasmodial activities, no remarkable *in vivo* studies have been found up to now which can strengthen the preclinical study profile. There has been only one report by Dikasso et al. [39], on the *in vivo* anti-malarial activity of extracts of hydroalcoholic from *Asparagus africanus* Lam. in mice which have been infected with *Plasmodium berghei* [39]. The extract displayed parasite suppressive effects on

P. berghei infected rats in a dose dependent manner. However, the effects on Packed Cell Volume and body temperature observed were inconclusive [39].

Asparagus species are known to have steroidal saponins as their major bioactive constituents. The presence of saponins and carbohydrates from *Asparagus africanus* Lam. showed significant analgesic and anti-inflammatory activities as reported by Hassan et al. [30]. Saponins are also known to have broad spectrum of pharmacological and antimicrobial activities [40]. According to Madikizela et al. [41] *Asparagus africanus* Lam. leaves showed very active antimycobacterial activity on *Mycobacterium aurum* A+, with moderate antibacterial activity against *Klebsiella pneumonia* [41], due to the saponins present in this plant. The methanolic extract obtained from the roots of *Asparagus africanus* Lam. were considered to be none toxic as there was no mortality caused on rats after a dose of 5000 mg/kg was administered by mouth [42], and these findings were corroborated by Kedebe et al. [43], using hydro-alcoholic extracts of *Asparagus africanus* Lam.

Three steroidal saponins, which are the most probable components of estrogen, have been separated from the roots of *Asparagus africanus* Lam. [31], and *Asparagus officinalis* L. that was reported to have uterine contractile properties. Steroidal saponins have been found to be one of the active principles of the majority of anti-fertility agents [44, 45]. *In vitro* and *in vivo* studies of the extracts of ethanol of leaves and roots of *Asparagus africanus* Lam. displayed the ability of both extracts to have a potential acetylcholine effect on uterine contraction [46]. These results suggested the possibility of interaction of the extracts with endogenous acetylcholine to induce an abortifacient effect. Thus, this plant should not be used during pregnancy because of the possibility of unintentionally abortion.

Saponins isolated from this plant have displayed anti-inflammatory activities against several experimental types of inflammation in mice and rats [47]. During the initial inflammation process, histamine and serotonin are released resulting in inflammation signs such as edema, pain, redness and heat. In a study by Kebede et al. [43], rats were injected with edemagenic agents to trigger edema (sign of inflammation), root extracts of *Asparagus africanus* Lam. were administrated to the rats, and the expected edema was not observed as the plant inhibited an antihistaminic agent. The extract activity was then found to be more pronounced in the first phase of the rat edema (within 90 min), thus making it possible for the extract to contain antihistaminic activity [43].

5.4 Reflections and future recommendations

The roots of this plant are traditionally used for the relief of pain, rheumatism and chronic gout, hematuria, hemorrhoids, headache, backache, stomach pain, sore throat and otitis. In addition, they are used to treat malaria, central nervous system related conditions, tuberculosis, venereal diseases, and aid in childbirth. *In vitro* and *in vivo* studies performed on this plant confirmed the ethnobotanical claims of this plant and active compounds were isolated and identified. However, the mechanism of action of these compounds as anti-inflammatory, antimycobacterial, antiplasmodial and anti-infertility agent has not been performed to date. Toxicological studies showed that the plant was not toxic. However, its ability to induce mutagenicity was not determined.

6. *Asparagus officinalis* L.

Vernacular name

English: Asparagus, Garden asparagus, White asparagus, Sparrow grass and Common asparagus; **Arabic:** Ehlilaj aswad, Helion, Dhagboth, Akla, al theeb;

Chinese: Shi diao bai; **German:** Spargel; **French:** Asperge; **Italian:** Asparagio; **Japanese:** Oranda-kiji-kakushi; **Portuguese:** Espargo; **Spanish:** Espárrago, Esparraguera, and **Swedish:** Sparris.

Synonyms: *Asparagus caspius* Hohen.; *Asparagus longifolius* Fisch. ex Steud.; *Asparagus officinalis* var. *caspius* (Hohen.) Asch. & Graebn.; *Asparagus officinalis* subsp. *officinalis*; *Asparagus polyphyllus* Steven ex Ledeb.

Scientific classification

Kingdom: plantae; **Subfamily:** asparagoideae; **Clade:** Angiosperms; **Genus:** *Asparagus*—asparagus; **Order:** asparagales; **Species:** *Asparagus officinalis* L.—garden asparagus; **Family:** Asparagaceae.

6.1 Historical aspects

Asparagus officinalis L. is a perennial herb which grows to a height of between 60 and 150 cm. It has thick swollen root stock. Its stem is multi-branched, with 2–6 needle-like shoots in whorls. Flowers are wide (4–6 mm), 6-lobed, perianth regular with a whitish–greenish yellow. Leaves are rudimentary, scale-like and its axillary shoots are needle-like and whorled. Fruits are round, initially green and, when ripe, forms an orange, 6–10 mm wide berry [17, 49]. The plant was distributed in Central and Southern Europe, the Middle East, Western Siberia and Northern Africa. It was then cultivated in many places. It is now distributed in Eastern Africa, Asia, Europe, Northern and Southern America [48]. *Asparagus* stalks are commonly eaten as a vegetable. Roots and seeds have been used as a treatment for various illnesses and as a diuretic, despite the lack of clinical evidence.

6.2 Phytochemical active principals

Chemical constituents of *Asparagus officinalis* L. contain steroid saponins including asparagosides A, B, D, F, Ge3w2q H, I, the bitter steroid saponins, amino acids, fructans (asparagose and asparagosine), ferulic acid and flavonoids (quercetin, rutin, hyperoside, and isoquercitrin) [36, 49, 50]. Shao et al. [51], further isolated two oligofurostanosides *Asparagus officinalis* L. seeds, and their structures were identified as 3-O-[alpha-L-rhamnopyranosyl-(1→2)-(alpha-L-rhamnopyranosyl-(1→4))-beta-D-glucopyranosyl]-26-O-[beta-D-glucopyranosyl]-(25R)-22 alpha-methoxyfurost-5-ene-3 beta,26-diol (methyl protodioscin), and with the corresponding 22 alpha-hydroxy analogs (protodioscin). New asparagusic acid anti-S-oxide methyl ester (a new acetylenic compound) and asparagusic acid syn-S-oxide methyl ester, 2-hydroxyasparenyn {3,4"-trans-2-hydroxy-1-methoxy-4-[5-(4-methoxyphenoxy)-3-penten-1-ynyl]-benzene}, and eleven known compounds, [asparenyn, asparenynol, (±)-1-monopalmitin, ferulic acid, 1,3-O-di-p-coumaroylglycerol, 1-O-feruloyl-3-O-p-coumaroylglycerol, blumenol C, (±)-epipinoresinol, linoleic acid, 1,3-O-diferuloylglycerol, and 1,2-O-diferuloylglycerol, were separated from an ethyl acetate-soluble fraction of the methanol extract of the aerial parts of *Asparagus officinalis* L. [48]. Two major anthocyanins (A1 and A2) were also separated from peels of the spears of *Asparagus officinalis* L.. However, A1 was identified as cyanidin 3-[3"-(O-beta-D-glucopyranosyl)-6"-(O-alpha-L-rhamnopyranosyl)-O-beta-D-glucopyranoside], while A2 was recognized to be cyanidin 3-rutinoside, which was found to be in higher plants [48].

Sun et al. [52], recognized a new steroidal saponin, yamogenin II, with a unique aglycone moiety, and a structure of (25S)-spirostan-5-ene-3β-ol-3-O-α-L-rhamnopyranosyl-(1,2)-[α-L-rhamno pyranosyl-(1,4)]-β-D-glucopyranoside from the dried stems of *Asparagus officinalis* L.. Furthermore, more saponins

were isolated from the plant included (25R)-furost-5-en-3 β ,22,26-triol-3-O-[α -L-rhamnopyranosyl-(1 \rightarrow 4)- β -D-glucopyranoside]-26-O- β -D-glucopyranoside, (25R)-furostane-3 β ,22,26-triol-3-O-[α -L-rhamnopyranosyl-(1 \rightarrow 4)- β -D-glucopyranoside]-26-O- β -D-glucopyranoside, and (25S)-furostane-3 β ,22,26-triol-3-O-[α -L-rhamnopyranosyl-(1 \rightarrow 4)- β -D-glucopyranoside]-26-O- β -D-glucopyranoside, and 3-O-[α -L-rhamnopyranosyl-(1 \rightarrow 2)] { α -L-rhamnopyranosyl-(1 \rightarrow 4)}- β -D-glucopyranosyl]- (25S)-spirost-5-ene-3 β -ol [53]. Nutritional analysis showed that the plant contained water 93.5%, total protein 1.91%, fat 0.16%, carbohydrates 2.04%, total dietary fiber 1.31%, and total nitrogen 0.31% [54]. The amino acid and mineral contents were found to be much higher in the leaves than the shoots [54].

6.3 Pharmacological actions

Asparagus officinalis L. is believed to have laxative, diuretic and contraceptive effects, and as a remedy for neuritis, rheumatism, cancer, toothache relieve, face acne lesion, as well as to stimulate hair growth [55]. According to research findings, the aqueous extract of *Asparagus officinalis* L. showed some antidiabetic effect after diabetic rats were treated with the extract, and their elevated blood glucose was suppressed [56]. The extract further displayed dangerous antioxidant activity in *in vitro* and *in vivo* assays. *Asparagus officinalis* L. crude saponins from the shoots (edible part) of asparagus, were found to have antitumor activity as they promoted the growth of HepG2 cells, and of human leukemia HL-60 cells in a way which caused it to become dose-dependent.

Shao et al., separated two oligofurostanosides from the seeds of *Asparagus officinalis* L. with cytotoxic activity [51]. They repressed the growth of human leukemia HL-60 cells in culture and macromolecular synthesis in a manner which promoted dose-dependence. Saponins from old stems of asparagus (SSA) exerted potential repressive activity on tumor growth and metastasis of breast, colon and pancreatic cancer cells. Sakaguchi et al. [57], found that anthocyanins A1 and A2 separated from the spears of *Asparagus officinalis* L. were found to act as antioxidants. The saponin fraction of the *Asparagus officinalis* L. exerted antifungal activity [58, 59]. The intake of asparagus also improved antioxidant status (superoxide dismutase and catalase enzymes) and prevented lipid peroxidation [60]. This corroborated with the findings by Hafizur et al. [56]. The hypolipidemic effect of n-butanol extract from asparagus by-products was evaluated in mice fed a high-fat diet, and the results were positive [56].

The antibacterial potential of the ethanolic extracts was determined against *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Bacillus cereus*, and the activity was seen only on *Escherichia coli*, while there was no antimicrobial activity in the same concentration against other tested pathogenic bacteria [61]. The taking in of asparagus alleviated some clinical symptoms (stool consistency, stool blood, and spleen hypertrophy) during active colitis. Other pharmacological effects of *Asparagus officinalis* L. were anti-fatigue effects, enhanced anoxia tolerance, induced analgesia and improved memory, and decreased the prevalence of lipid peroxide in plasma, liver and brains of the rats [62].

Jang et al. examined *Asparagus officinalis* L. for its inhibitory effects against both cyclo-oxygenase-1 and -2, thus having anti-inflammatory potential [48], due to linoleic acid identified as the most active compound in the plant [48, 54]. Aqueous extract of *Asparagus officinalis* L. resulted in relaxation of spontaneous contractions of separated smooth muscle of rabbit jejunum [57]. *Asparagus officinalis* L. also induced diuretic effects [63].

6.4 Reflections and future recommendations

Roots and seeds have been used as a treatment for various illnesses and as a diuretic, despite the lack of clinical evidence. So many active chemical constituents were isolated and identified. However, not all pharmacological activity of those isolated compounds was done. *In vivo* anticancer activity is desirable to confirm the *in vitro* findings. Studies have claimed that *Asparagus officinalis* L. has other pharmacological effects which were not reported as ethnobotanical uses of this plant, such as anti-fatigue effects, enhanced anoxia tolerance, induced analgesia and improved memory, as well as the decreased contents of lipid peroxide in plasma, liver and brains of the rats. However, this was not linked to the active compound present from the plant that could be responsible for those pharmacological activities.

7. *Asparagus racemosus* Willd.

Vernacular names

English name: Wild Asparagus, Indian Asparagus, Hundred Roots, *Asparagus racemosus* Willd.; **Hindi:** Satavar.

Synonyms: Indeevari, Sukshamapatra, Bahusuta, Shatmooli, Narayani, Bhiru, Virya, Madabhanjani, Shatpadi, Shatvirya.

Scientific classification

Kingdom: Plantae; **Sub-family:** Asparagoideae; **Clade:** Angiosperms; **Genus:** *Asparagus*; **Order:** Asparagales; **Species:** *Asparagus racemosus* Willd.; **Family:** Asparagaceae.

7.1 Historical aspects

Asparagus racemosus Willd. has been used traditionally for ages as a female reproductive tonic as it prevents abortion and promotes the health of the mother and growing fetus when used in antenatal care. This plant also increases lactation and is useful for the treatment of gynecological diseases when used in postnatal care [64]. Research has supported other reported ethnobotanical uses of this plant for female reproductive system-related health issues. This plant can be described as a climbing shrub which is thorny and has woody stems. The leaves become minute scales and spines. Fruits are round and are a purple black color. Roots are succulent and tuberous and taper at both ends. It is distributed throughout India, and almost commonly found in areas up to an altitude of 4000 feet in the Himalayas and in Ceylon [64]. Tuberous roots of the plant are the parts used [65]. The tubers are eaten as a sweetmeat. The root contains juice which, when fresh used with honey as a demulcent in bilious dyspepsia or diarrhea. It is used in the preparation of medicated oils for external application to sufferers of nervous and rheumatic infections, and urinary tract infections [64].

7.2 Phytochemical active principals

The main active sections of *Asparagus racemosus* Willd. are steroidal saponins (Shatavarins I–IV), which are the phytoestrogen compounds which are present in the roots of this plant [66–69]. Shatavarin IV is a glycoside of sarsasapogenin having two molecules of rhamnose and one molecule of glucose. It also contains mucilage and starch. The 8-methoxy-5,6,4'-trihydroxyisoflavone, a new isoflavone, was separated from the roots of *Asparagus racemosus* Willd. by Saxena and Chaurasia [70]. A novel oligospirostanosid 1,3-O-[α -L-3-rhamnopyronosyl-(1 \rightarrow 2)- α -L-rhamnopyronosyl(1 \rightarrow 4)-O- β -D-glycopyranosyl]25(S)-5 β -Spirostan-3 β -ol also known

as immunoside was isolated, and it was biologically evaluated as an immunomodulatory agent [71]. Wiboonpun et al. [72], isolated a new antioxidant compound named Racemofuran, together with known compounds asparagine A and racemosol. Three steroidal saponins (Racemosides A, B and C) were also isolated from the methanolic extract of fruit of *Asparagus racemosus* Willd.. Polycyclic alkaloid like asparagine A, and disaccharide in roots are also reported in other research studies [73–75]. *Asparagus racemosus* Willd. is also reported to have alkaloids, proteins, starch, tannin, flavonoids, glycosides of quercetin, rutin and hyperoside in roots and flowers [76]. Quercetin 3-glucuronide is present in leaves [77]. There were few trace minerals like zinc (53.15), manganese (19.98), copper (5.29), and cobalt (22.00 microgram per gram) together with calcium, magnesium, potassium, zinc, and selenium [68, 78]. The callus culture of *Asparagus racemosus* Willd. has shown synthesis of sarsasapogenin [79]. However, no report has been received on the chemistry of the contents of its fruit.

7.3 Pharmacological actions

The healing qualities of *Asparagus racemosus* Willd. are useful to a wide array of ailments. Ayurvedic (Indian traditional medicines database) literature considers it a strong drug which can improve memory intelligence and physical strength and maintain youthfulness [48, 80]. *Asparagus racemosus* Willd. can also be used as a uterine sedative. In addition, a glycoside, Shatavarin 1, separated from the roots of *Asparagus racemosus* Willd. has been found to be responsible for the competitive blocking of oxytocin-induced contractions, *in vitro* as well as *in vivo* [19, 64]. In India, it is recognized as a female tonic. In spite of being a rejuvenating herb, it is recognized as being used in female infertility, as it increases libido, is able to cure inflammation of sexual organs, and can be used to moisten dry tissues of the sexual organs. It further enhances folliculogenesis and ovulation, prepares the womb for conception, prevents miscarriages, acts as post-partum tonic by increasing lactation, normalizing uterus and changing hormones. It is also used in leucorrhoea and menorrhagia [65, 81].

The roots of *Asparagus racemosus* Willd. have been described as bitter-sweet, emollient, cooling, nervine tonics, preventing constipation, and may be used as an aphrodisiac, diuretic, carminative and antiseptic [82]. The powdered dried root exhibits galactagogic properties as there was an increase in milk secretion during lactation [83]. While active it has resulted in the action of released corticosteroids or an increase in prolactin. The other study also agreed with the galactagogic effect of this plant, because an alcoholic extract of *Asparagus racemosus* Willd., increased the prolactin levels in female rats (Kumar et al., 2008). It served as a potential stimulator for early restoration of milk production without any adverse effects [84]. The juice of fresh roots of *Asparagus racemosus* Willd. is recommended for duodenal ulcers [85]. The plant can also be used to treat skin diseases, wounds and as a demulcent in dyspepsia [64]. The aqueous root extract possesses immunoadjuvant potential [37]. In the roots of *Asparagus racemosus* Willd. antioxidant and anti-ADH (Antidiuretic hormone) activity were found to be present [72, 86], and there was antitumor and anticancer activity [87, 88].

Asparagus racemosus Willd. displayed a preventative action on DMBA (-7,12-Dimethylbenz[a]anthracene) induced mammary carcinogenesis in rats. Rats which were fed on *Asparagus racemosus* Willd. diet displayed a decline in both tumor incidence and mean number of tumors per tumor bearing animal [76]. Studies also showed that the plant has anti-ulcerogenic activity [89], anti-inflammatory activity and antimicrobial activity [90]. Antimicrobial activity was used against *Escherichia coli*, *Shigella dysenteriae*, *Shigella sonnei*, *Shigella flexneri*, *Vibrio cholerae*, *Salmonella typhi*, *Salmonella typhimurium*, *Pseudomonas pectida*, *Bacillus subtilis* and *Staphylococcus aureus*, and sensitivity was observed in all strains under study [90]. As *Asparagus racemosus* Willd. is believed to have no antibacterial action, protection

offered by *Asparagus racemosus* Willd. against sepsis by altering function of macrophages, shows its potential immunomodulatory property [91, 92].

Methanolic extract of roots displayed important antitussive activity on sulfur dioxide-induced coughs in mice [93]. An aqueous solution of the crude alcoholic extract of the roots displayed significant antiprotozoal activity against *Entamoeba histolytica* *in vitro* [94]. An examination was made on rat liver mitochondria for the possible antioxidant effects of crude extract and purified aqueous fraction of *Asparagus racemosus* Willd. against membrane damage induced by the free radicals generated during gamma radiation [86, 95]. It also raised the urinary concentration of magnesium, which is considered as one of the suppressors of crystallization [96]. Aqueous and butanol fractions displayed less prominent effects on the release of, especially at lower glucose concentration [97]. *Asparagus racemosus* Willd. further showed the potential of anti-HIV, (Human immunodeficiency virus) and its active principles are being investigated [98].

It can be concluded that *Asparagus racemosus* Willd. has immense importance in the folk medicine. In Ayurveda, *Asparagus racemosus* Willd. has been described as perfectly safe for long term use, even during pregnancy and lactation. To support this theory, an *in vivo* study was conducted and the systemic administration of higher doses of all extracts did not display any abnormality behavioral patterns in mice and rats [99], neither did it produce mortality even up to higher oral dosages of 64 g/kg [100].

7.4 Reflections and future recommendations

Intensive research has been performed on the active compounds from this plant. The plant was reported to have anticancer activity. However, cell lines used, and solvents used were not mentioned. While antitumor activity was reported on the mammary carcinogenesis only, more research using other cell lines is required to explore the antitumor and anticancer activity of this plant root's extract. The potential of this plant as cancer inducing agent has not been thoroughly elucidated as *in vivo* studies showed the safety of this plant. However, the exposure duration was not long enough. It is well known that the process of carcinogenesis is very slow, thus the adverse effects after 10 years of using *Asparagus racemosus* Willd. has not been determined scientifically. It will, therefore, be important to understand the mutagenicity of the plant before we can conclude that it is hundred percent safe. Mechanism of action of the active compounds from this plant and human trials are required, as different metabolic reactions in humans may influence the activity of the compound.

8. *Asparagus densiflorus* (kunth) jessop

Vernacular names

Sprenger's asparagus fern, bushy asparagus, asparagus fern and smilax. Inwele in Zulu.

Synonyms: *Asparagopsis densiflora* Kunth, *Protasparagus densiflorus*.

Scientific classification

Kingdom: Plantae; **Subfamily:** Asparagoideae; **Clade:** Angiosperms; **Genus:** *Asparagus*; **Order:** Asparagales; **Species:** *A. densiflorus*; **Family:** Asparagaceae.

8.1 Historical aspects

South African asparagus was observed for the first time in an illustration from 1686, while plants from the 'Sprenger' group began to be cultivated as early as 1888. Today they are grown in all parts of the world, and are hardy, drought-tolerant and quite salt-tolerant plants which are used for plants foliage and as garden plants. The South

African *Asparagus* species and the European *Asparagus* species are related, and they display a very interesting structure botanically. They do not have true leaves at all, but these are actually cladodes which may actually be modified branches, while the spines are formed from modified branches or from modified leaves. The most popular forms form part of the emerald ferns of the *Asparagus densiflorus* (Kunth) Jessop ‘Sprengeri’ group [101]. They form large cushions which have long, arching stems more or less densely covered with dark green, leaves which have the appearance like needles. The plant appears fernlike, but its flowers and fruit clearly place it among the angiosperms.

Asparagus densiflorus (Kunth) Jessop is a delicate, fern-like perennial plant which has arching stems which grow up to 1 m long and have a scrambling habit. A large cushion of dark green needle-like leaves is formed by the plant. It is often proved to be of use for medicinal purposes and can also be used as ground cover in partial or light shade, but it flourishes in full sun if watered regularly. It has very small, hardly observable spines which is unlike most *Asparagus* fern species. It is also attractive as an indoor or patio plant in large containers or hanging baskets. Unlike most *Asparagus* fern species, it only has very small, hardly noticeable spines. The roots of the plants are extensive which contain numerous grape sized tubers. These provide food in nature for extensive periods of drought in summer. The root system is used extensively for binding soil on slopes [101].

8.2 Phytochemical active principals

The phytochemical analysis of the aqueous and ethanolic extracts was carried out for the presence of flavonoids, tannins, phenolics, saponins, cardiac glycosides, terpenoids, quinones, amino acids, carbohydrates and alkaloids [46]. Both extracts showed a lack of amino acids, and were found to contain flavonoids, tannins, phenolics, saponins, cardiac glycosides and carbohydrates. In addition, the ethanol extract was found to contain terpenoids and alkaloids, whereas the aqueous was found to contain quinones. Estimated flavonoid and phenolic content of *Asparagus densiflorus* (Kunth) Jessop aqueous plant extracts were 900 and 380 µg/ml [102].

8.3 Pharmacological actions

An infusion of the plants’ leaves may be used to treat pain in the abdomen, as a general tonic and to boost immunity. Further it may be used as a cleansing agent to rid the body of “poison” and “dirty blood”. Thrust and ulcers in the mouth associated with HIV may also be treated by this plant. According to Davids et al. [103], traditional health practitioners (THPs) reported that *Asparagus densiflorus* (Kunth) Jessop is one of the “strongest” plants used for HIV. Moreover, according to Singh et al. [102], *Asparagus densiflorus* (Kunth) Jessop is considered as one of the ethnomedicinal plants. However, its ethnomedicinal actions had never been discussed. No literature was found on the correlation or link of phytochemical active compounds and pharmacological activity of this particular plant. *Asparagus densiflorus* (Kunth) Jessop aqueous and ethanoic leaf structures were screened for their antibacterial activity against *Enterobacter aerogenes*, *Clostridium perfringens* and *Salmonella typhimurium*. However, it was found that the aqueous extract showed a potential to inhibit growth of all three selected micro-organisms, while the ethanol extract inhibited only the growth of *Enterobacter aerogenes* [46].

8.4 Reflections and future recommendations

Only the preliminary phytochemical screening was performed on the crude extract of this plant, but no deeper research has been done on the activity of this plant in order to confirm its ethnobotanical claims as a plant used to treat thrush,

ulcers in the mouth as well as for HIV. Thrush results from an overgrowth of normal flora in the mouth. The anti-fungal activity of this plant has not been studied yet, together with its anti-HIV activity, as the plant has been reported to be used ethnobotanically for HIV. Further studies to isolate the active compounds, elucidate the safety of this plant and to fully confirm its pharmacological activity are needed.

9. Conclusions

The genus *Asparagus* is an herbaceous plant comprising approximately 150 species around the world, and consisting of herbs, shrubs and vines. *Asparagus* species possess bioactive properties, such as: antioxidant, anti-inflammatory, antibacterial, antihepatotoxic, immunostimulant, and reproductive agents. In the present review study, five native *Asparagus* species (namely: *Asparagus larycinus*

Plant species	Active phytochemicals	Mode of Action	Beneficial role in human health
<i>Asparagus larycinus</i> Burch	<i>Asparagus larycinus</i> Burch roots and leaves have tannins, saponins, terpenes and steroids. The stems are rich in saponins, tannins, and flavonoids, with a lack of steroids, glycosides and carbohydrates. Only roots have alkaloids and indole-3-carbinol, α -sitosterol and ferulic acid were isolated from the roots	<i>Asparagus larycinus</i> Burch. has flavonoids that inhibited microbial growth and scavenged antioxidants. Both leaves and stem extracts showed that they contain saponins, which ultimately has a suppressive effect on inflammation. This plant was not toxic when administered orally to rats, it was non-mutagenic, however, root aqueous extract showed an indirect mutagenic effect toward <i>Salmonella typhimurium</i> TA102 strain after metabolic activation, but not in TA97, TA98 and TA100 strains. β -Sitosterol isolated from this plant is known for its therapeutic and chemopreventive uses in the medical field, while prostate cancer is being treated by Indole-3-carbinol. This plant had anticancer activity on breast (MCF7), renal (TK10) and melanoma (UACC62)	<i>Asparagus larycinus</i> Burch. is used to treat tuberculosis, sores, red water, uterine infection, general alignments, umbilical cord inflammation, and serve as a diuretic
<i>Asparagus africanus</i> Lam.	The main contents of the plant are carbohydrates, saponins, flavonoids and tannins. Two compounds namely; 2 beta-, 12 alpha-dihydroxy-(25R)-spirosta-4,7-dien-3-one, lignan (+)-nyasol, and (Z)-(+)-4,4-(3-ethenyl-1-propene-1,3-diyl) bisphenol) were isolated from <i>Asparagus africanus</i> Lam roots, but their mode of actions has not been documented	This plant has acetylcholine effect on uterine contraction and antiplasmodial activity. Two antiprotozoal compounds; a sapogenin (muzanzagenin) and lignan ((+) nyasol), which were reported to be responsible for the antimalarial activity, have been isolated from <i>Asparagus africanus</i> Lam. The presence of saponins and carbohydrates from <i>Asparagus africanus</i> Lam. showed significant analgesic, anti-inflammatory activities and antimicrobial activities	<i>Asparagus Africanus</i> Lam. is used for treating headaches, backaches, stomach pains, malaria, to treat sexual transmitted infections and also used to assist in childbirth. It is also used to treat central nervous system related conditions, tuberculosis, venereal diseases and as an aid during childbirth. External application of the root is used for rheumatism and chronic gout. It is further used a diuretic, for sore throats and otitis

Plant species	Active phytochemicals	Mode of Action	Beneficial role in human health
<i>Asparagus officinalis</i> L.	<i>Asparagus officinalis</i> L. contain steroid saponins, amino acids, fructans, ferulic acid and flavonoids (quercetin, rutin hyperoside, and isoquercitrin), oligofurostanosides, new isolated asparagusic acid, two major anthocyanins. Carbohydrates, proteins, dietary fiber and nitrogen where found in this plant.	<i>Asparagus officinalis</i> L. showed antidiabetic activity through the suppression of blood glucose levels. The saponins from this plant inhibits the growth of leukemic cells, had antifungal activity, and scavenged antioxidants. The extracts of this plant further displayed antibacterial, anti-inflammatory potential <i>in vitro</i> also induced diuretic effects <i>in vivo</i>	<i>Asparagus officinalis</i> L. is believed to have laxative, diuretic and contraceptive effects, and as a remedy for neuritis, rheumatism, cancer, toothache relieve, face acne lesion, as well as to stimulate hair growth
<i>Asparagus racemosus</i> Willd.	<i>Asparagus racemosus</i> Willd. is reported to have alkaloids, proteins, starch, tannin, flavonoids, glycosides of quercetin, rutin and hyperoside in roots and flowers. There were few trace minerals identified from this plant species such as zinc, manganese, copper, cobalt, calcium, magnesium, potassium, zinc and selenium. The main active sections of <i>Asparagus racemosus</i> Willd. are steroidal saponins, racemofuran, polycyclic alkaloid, together with known compounds asparagamine A and racemosol	The glycoside from <i>Asparagus racemosus</i> Willd. blocks the oxytocin-induced contractions and have galactagogic properties that leads to increase in milk secretion during lactation. The roots of <i>Asparagus racemosus</i> Willd. showed significant antioxidant, anticancer, anti-inflammatory, anti-ADH and antimicrobial activities Methanolic extract of roots displayed important antitussive activity and antiprotozoal activity against <i>Entamoeba histolytica</i> <i>in vitro</i>	<i>Asparagus racemosus</i> Willd. is used to improve memory intelligence, physical strength, as a uterine sedative, and to maintain youthfulness. It is used as a female tonic to prevent abortion, to promote the health of the mother and growing fetus when used in antenatal care and acts as post-partum tonic by normalizing uterus and changing hormones. Despite being a rejuvenating herb, it is used in female infertility, as it increases libido, ovulation, can be used to moisten dry tissues of the sexual organs and it's able to cure inflammation of sexual organs. This plant also increases lactation and is useful for the treatment of gynecological diseases when used in postnatal care. The juice of fresh roots is recommended for duodenal ulcers. The plant can also be used to treat urinary tract infections, skin diseases, and wounds, in preventing constipation, and as an aphrodisiac, diuretic, carminative, and antiseptic. It is also used for nervous and rheumatic infections

Plant species	Active phytochemicals	Mode of Action	Beneficial role in human health
<i>Asparagus densiflorus</i> (Kunth) Jessop	This plant has flavonoids, tannins, phenolics, saponins, cardiac glycosides, terpenoids, quinones, amino acids, carbohydrates and alkaloids. In addition, the aqueous extracts have quinones	<i>Asparagus densiflorus</i> (Kunth) Jessop aqueous and ethanolic leaves extracts can inhibit antibacterial activity against <i>Enterobacter aerogenes</i> , <i>Clostridium perfringens</i> and <i>Salmonella typhimurium</i> . However, other pharmacological activities of this plant have not been scientifically investigated and documented	An infusion of the plant leaves is used to treat thrush and ulcers in the mouth, for abdominal pains, as a tonic to boost immunity, as a cleansing agent to rid the body of “poison” and “dirty blood”

Table 1.
Summary of phytochemicals, mode of action and the role of selected asparagus species in human health.

Burch., *Asparagus africanus* Lam., *Asparagus officinalis* L., *Asparagus racemosus* Willd. and *Asparagus densiflorus* (Kunth) Jessop) were evaluated for their historical, etymological, morphological, phytochemical and pharmacological aspects. The phytochemicals, mode of action and the role of selected *Asparagus* species in human health have been summarized in **Table 1**.

Conflict of interest

“The authors declare no conflict of interest.”

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