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Diospyros lycioides Desf.: Review of its botany, medicinal uses, pharmacological activities and phytochemistry

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ABSTRACT

Diospyros lycioides Desf. (*D. lycioides*) is traditionally used as herbal medicine against various human and animal ailments in tropical Africa. The present paper reviewed information on botany, medicinal uses, phytochemistry and pharmacological activities of *D. lycioides*. This review was compiled using scientific literature from electronic search engine such as PubMed, Scopus, ScienceDirect, Springerlink, BioMed Central, Scielo, Medline and Science domain. Additional literatures were obtained from book chapters, books, dissertations, websites and other scientific publications. *D. lycioides* is used as traditional medicine in 50% of the countries where the species is native in tropical Africa. This study recorded 22 medicinal uses of *D. lycioides* which included abdominal pains, infertility in women, sexually transmitted infections, and used as chewing sticks (or mouthwash), toothbrushes and ethnoveterinary medicine. *D. lycioides* extracts demonstrated anti-adhesive, anti-inflammatory, antimetastatic, antioxidant, antifungal, antiproliferative, mutagenicity and antibacterial activities. Future research should focus on the pharmacological properties, phytochemistry, clinical trials and pharmacokinetics of *D. lycioides* which will enhance the therapeutic potential of the species.

1. Introduction

Diospyros lycioides Desf. (*D. lycioides*) is a member of the Ebenaceae or ebony family. Ebenaceae family includes fruit trees such as the persimmons [*Diospyros discolor* Willd., *Diospyros kaki* L. f., *Diospyros virginiana* L., *Diospyros lotus* L., *Diospyros nigra* (J. F. Gmel.) Perrier and *Diospyros texana* Scheele] and several species which yield ebony. Ebenaceae family is pantropical in distribution and encompasses four genera namely *Diospyros* L., *Euclea* L., *Lissocarpa* Benth. and *Royena* L.[1-3]. The genus *Diospyros* is characterized by about 500 species and has been classified as the most important genus of the Ebanaceae family due to its economic and medicinal uses[1]. Several phytochemical constituents have been isolated from the genus *Diospyros* and these include ursanes, terpenoids, lupanes, tannins, polyphenols, hydrocarbons, lipids, naphthoquinones, benzopyrones, taraxeranes and oleananes[4].

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Some pharmacological properties, clinical tests, *in vitro* and *in vivo* activities of *Diospyros* species including antioxidant, antiprotozoal, antipyretic, cardioprotective, anthelmintic, cosmeceutical, cytotoxicity, hypnotic-sedative, insecticidal, multidrug resistance reversal and neuroprotective have been attributed to the phytochemical compounds associated with different species of *Diospyros*[4]. *D. lycioides* is an important medicinal plant in tropical Africa, with the roots and stems widely sold as herbal medicines in informal medicinal markets throughout Namibia[5], Gauteng and Mpumalanga provinces in South Africa[6]. The fruits of *D. lycioides* are eaten by both humans and animals in Namibia[7], South Africa[8-11], Swaziland[12] and Zimbabwe[11,13]. The fruits of *D. lycioides* are sometimes used to brew alcoholic drinks, roasted and ground seeds of the species which were traditionally used as a coffee substitute in southern Africa[14]. Therefore, in this study, the ethnopharmacological review of *D. lycioides* was carried out aimed at providing a detailed summary of the botany, ethnomedicinal uses, pharmacological activities and chemical composition of the species.

2. Research methodology

The following: biological activities, ethnomedicinal uses, ethnopharmacoly, medicinal uses, phytochemistry, pharmacological activities, therapeutic value, *D. lycioides* subsp. *guerkei* (Kuntze) De Wint., *D. lycioides* subsp. *lycioides*, *D. lycioides* subsp. *nitens* (Harv. ex Hiern) De Wint. and *D. lycioides* subsp. *sericea* (Bernh.) De Wint. were the keywords which were used to search electronic search engine such as PubMed, Scopus, ScienceDirect, Springerlink, BioMed Central, Scielo, Medline and Science domain. Common names such as "African persimmon", "bluebush", "bluebush star-apple", "monkey plum", "red star-apple" and "star-apple" were also used for literature search. Additional literatures were obtained from book chapters, books, theses, websites and conference proceedings.

3. Taxonomy, distribution and description of *D. lycioides*

The generic name *Diospyros* is based on the Greek words, "dios" which means "divine" and "pyros" meaning "pear", referring to the good flavour of some species and their resemblance to a pear[8]. The specific name *lycioides* means "resembling *Lycium*", in reference to *D. lycioides* which has leaf shape or growth form resembling members of the genus *Lycium* L.[8,9]. Four subspecies are recognized differently mainly in distribution, leaf shape, size and the degree of hairiness and the appearance of leaf nerves[8]. These subspecies include subsp. *guerkei*, *lycioides*, *nitens* and *sericea*[8,9]. *D. lycioides* is indigenous to Malawi, the Democratic Republic of Congo, Lesotho, Namibia, South Africa, Mozambique, Swaziland, Zambia, Botswana, Tanzania, Zimbabwe and Angola[15-19]. *D. lycioides* is naturalized in Australia where it is categorized as a weed and importation of the species into the country, it is prohibited by the government except for the subspecies *sericea* which is allowed to be imported under very strict conditions[14]. The species has been recorded in rocky habitats, well-drained soils and along rivers and stream banks.

D. lycioides differs in appearance in various parts of its distributional range, ranging from a small deciduous shrub about 1 m tall to a small or medium tree up to 8 m tall[8]. All the four subspecies of *D. lycioides* have open crown and drooping branches. The leaves are blue-green in colour, simple, arranged spirally at the ends of the tree branches, leathery and alternate in arrangement. The bark of *D. lycioides* is dark grey to brown and smooth on older tree branches and stems, but covered with long hairs on young branches[9]. The flowers are bell-shaped, white to yellow, calyx with five deeply divided, hairy lobes that enlarge with age and curl strongly backwards and five petals that are reflexed. The flowers are sweet-scented, pendulous, long-stalked and borne singly in the terminal axils of the leaves. Fruits are roundish to oblong in shape, up to 2 cm long, often bright red and fleshy when ripe[9]. The seeds are oblong and smooth with a grooved line around them[8].

4. Ethnomedicinal uses of D. lycioides

Several plant parts of *D. lycioides* are used as herbal medicines for various diseases. *D. lycioides* is used as herbal medicine for 3 and 22 animal and human diseases and ailments, respectively. Ethnomedicinal information has been found in Zimbabwe, Malawi, South Africa, Namibia, Botswana and Swaziland, representing 50% of the countries where *D. lycioides* is indigenous. Several similarities were noted in terms of ethnomedicinal uses of *D. lycioides* across different ethnic groups in Africa. For example, use of *D. lycioides* as chewing sticks (or mouthwash), toothbrush and herbal medicine for sexually transmitted infections was recorded in four countries, while application of the species as ethnoveterinary medicine, herbal medicine for infertility in women and abdominal pains was recorded in three countries.

D. lycioides is widely known and used as a chewing stick, mouthwash or toothbrush in Botswana, Namibia, South Africa, Swaziland and Zimbabwe[5-7,10-12,20-22,23-25,26]. The root or twig of *D. lycioides* is peeled and the end is chewed to a fibrous brush, with the root changing in colour from white to yellow as it is chewed, imparting a pungent and refreshing taste to the mouth. In Namibia, bark, leaf or root decoction is applied topically as remedy for tooth decay or toothache[7,20-22,27,28] and stem decoction against oral candidiasis[29]. Root decoction of *D. lycioides* is widely used as traditional medicine for sexually transmitted diseases including gonorrhoea in Botswana, Namibia and Zambia[28,30,31], sexually transmitted diseases in South Africa[32] and syphilis in Namibia and Zambia[28,31]. Root decoction of *D. lycioides* is taken orally or powdered root is mixed with animal fat and applied topically for abdominal pain or general body pain in Malawi, South Africa and Zimbabwe[8,33]. In Botswana, South Africa and Zimbabwe, root

infusion of *D. lycioides* is used as herbal medicine for infertility in women[27,30,33,34,35]. Root infusion of *D. lycioides* is used as an emetic in South Africa[8] and root infusion of the species is mixed with the tuber of *Dicoma anomala* as an emetic in Malawi[33]. Root infusion of *D. lycioides* is used as traditional medicine for epilepsy in South Africa[9] and Zimbabwe[33]. Root infusion of *D. lycioides* is mixed with *Senna petersiana* and *Euclea natalensis* as herbal medicine for epilepsy in South Africa[36]. The root extract and powdered root of *D. lycioides* is used as herbal medicine for eye problems in Namibia and South Africa[8,20]. In Namibia and Zimbabwe, leaf, root or stem infusion of *D. lycioides* is used as remedy for menstrual problems[20,33]. Root infusion of *D. lycioides* is regarded as a purgative in South Africa and Namibia[8,23]. In Malawi and Zimbabwe, root pieces of *D. lycioides* are buried within the house to protect members of the household from witchcraft[33]. According to Hedberg and Staugard[30], women in Botswana use root decoction of *D. lycioides* during pregnancy and also use the decoction as remedy for pains in the womb. In Namibia, bark, leaf or root decoction are used as remedy for bleeding, fever, intestinal worms, oral candidiasis[21,22,27,28] and abortifacient[20]. In South Africa, bark and root infusion of *D. lycioides* is used as herbal medicine for blood in faeces, dysentery and inflammation[23,36,37]. In Swaziland, leaf decoction of *D. lycioides* is taken orally as remedy for HIV or AIDS opportunistic diseases or leaf decoction is applied on pubic hair as lice repellent[38]. In Zimbabwe, the root infusion of *D. lycioides* is applied topically as snake antidote, as remedy for heart problems, pneumonia and sore throat[33]. In Botswana, South Africa and Zimbabwe, *D. lycioides* is used as ethnoveterinary medicine[33,39,40].

5. Phytochemical and nutritional constituents of *D. lycioides*

The nutritional composition of *D. lycioides* fruits and leaves was shown in Table 1. *D. lycioides* is a source of important elements such as phosphorus, iron, magnesium, potassium, sodium, copper, zinc and calcium[41]. Phytochemical screening of leaves, roots, stems and twigs of *D. lycioides* revealed the presence of alkaloids, anthraquinones, cardenolides, carotenoids, flavonoids, naphthoquinone, phenolics, polyphenols, saponins, steroids, tannins and terpenoids[21,42–45]. Ferreira *et al*[46] isolated naphthoquinone constituents from the bark of the roots of *D. lycioides* which included isodisopyrin, 7-methyljuglone and 8.8-dihydroxy-4,4-dimethoxy-6,6-dimethyl-2,2-bisnaphtyl1,1-quinone. Dehmlow *et al*[47] isolated triterpenoids, namely lupeol and ursolic acid from leaf and young twig extracts of *D. lycioides*. Li *et al*[48] isolated two binaphathalenone glycosides, namely 1'2-binaphthalen-4-one-2',3-dimethyl-1,8'-epoxy-1,4',5,5',8,8'-hexahydroxy-8-O- β -glucopyranosyl-5'-O- β -xylopyranosyl(1→6)- β -glucopyranoside and 1',2-binaphthalen-4-one-2',3-dimethyl-1,8'-epoxy-1,4',5,5',8,8'-hexahydroxy-5',8-di-O- β -xylopyranosyl(1→6)- β -glucopyranoside from *D. lycioides* methanol twig extract. Cai *et al*[24] analysed extracts of the twigs from *D. lycioides* and isolated six chemical compounds which included juglones, 7-methyljuglone and diospyroside A, B, C and D. Some of these phytochemical compounds may be responsible for the pharmacological properties of *D. lycioides*. For example, Li *et al*[48] evaluated antibacterial activities of the compounds 1'2-binaphthalen-4-one-2',3-dimethyl-1,8'-epoxy-1,4',5,5',8,8'-hexahydroxy-8-O- β -glucopyranosyl-5'-O- β -xylopyranosyl(1→6)- β -glucopyranoside and 1',2-binaphthalen-4-one-2',3-dimethyl-1,8'-epoxy-1,4',5,5',8,8'-hexahydroxy-5',8-di-O- β -xylopyranosyl(1→6)- β -glucopyranoside against *Porphyromonas gingivalis* (*P. gingivalis*), *Streptococcus mutans* (*S. mutans*) and *Streptococcus sanguinis* (*S. sanguinis*). These two compounds exhibited some activities and demonstrated marginal growth inhibition against *S. sanguinis* and *S. mutans*. Similarly, Cai *et al*[24] evaluated antibacterial activities of 7-methyljuglone, juglone, diospyrosides A, diospyrosides B, diospyrosides C, and diospyrosides D against oral pathogens, *S. sanguinis*, *Prevotella intermedia*, *P. gingivalis* and *S. mutans*. These compounds isolated from *D. lycioides* showed activities against the tested pathogens with minimum inhibitory concentration (MIC) values of 0.019 mg/mL to 1.250 mg/mL[24].

Table 1

Nutrient composition of *D. lycioides* fruits and leaves per 100 g.

Caloric, nutritional and phytochemical	Plant part	Value	References
Ascorbic acid	Drupe	45.20 mg	[41]
Calcium (Ca)	Drupe	66.80 mg	[41]
Calcium (Ca)	Leaves	1.10 mg	[49]
Carbohydrates	Drupe	16.50 g	[41]
Condensed tannins	Leaves	1.80%	[42]
Condensed tannins	Stem	0.20%	[42]
Copper (Cu)	Drupe	0.23 mg	[41]
Crude fibre	Drupe	3.50 g	[41]
Energy	Drupe	70.70 kcal	[41]
Fat	Drupe	0.10 g	[41]
Flavonoids	Leaves	0.50 mg catechin equivalent/g	[42]
Flavonoids	Twigs	0.50 mg catechin equivalent/g	[42]
Gallotannins	Leaf	9.50 μg GAE/g	[42]
Gallotannins	Stem	0.50 μg GAE/g	[42]
Iron (Fe)	Fruit	1.00 mg	[41]
Magnesium (Mg)	Fruit	39.70 mg	[41]
Niacin	Fruit	0.17 mg	[41]
Phosphorus (P)	Fruit	13.70 mg	[41]
Phosphorus (P)	Leaf	0.10 mg	[49]
Potassium (K)	Fruit	271.00 mg	[41]
Protein	Fruit	0.90 g	[41]
Protein	Leaf	9.10 g	[49]
Riboflavin	Fruit	0.09 mg	[41]
Sodium (Na)	Fruit	16.30 mg	[41]
Thiamin	Fruit	0.11 mg	[41]
Total phenolic	Leaf	40.00 mgGAE/g	[42]
Total phenolic	Stem	6.30 mgGAE/g	[42]
Vitamin C	Fruit	45.20 mg	[41]
Water	Fruit	78.00 g	[41]
Zinc (Zn)	Fruit	0.30 mg	[41]

6. Biological activities

A wide range of biological activities have been documented from extracts and compounds isolated from *D. lycioides* including anti-adhesive[13], antibacterial[20,24,25,44,48,50], antifungal[50], anti-inflammatory[42], antimetastatic[44], antioxidant[43,44], antiproliferative[43] and mutagenicity[50].

6.1. Anti-adhesive

Nyambe[20] evaluated anti-adhesive activities of the leaf, root and twig fractions of *D. lycioides* on the attachment of oral pathogens to tooth surface using saliva-coated hydroxyapatite beads (S-HA) as a model. The leaf extract did not prevent the growth of any of the pathogens, it was able to inhibit the attachment of *S. sanguinis* to glass by 45% and 24% in the case of *S. mutans*[20]. The root extract was very weak on *S. mutans*, inhibiting its attachment by 10%, but very high on *S. sanguinis*, inhibiting its attachment by 77%. The ability of the leaf, root and twig fractions of *D. lycioides* which prevent formation of biofilm on teeth surface was tested using a 96 well polystyrene microtiter plate as a model. All crude extracts displayed inhibition of cell attachment of both organisms by over 80% at concentrations tested, ranging from 0.16 mg/mL to 10.00 mg/mL[20]. The crude root extract showed the highest inhibition activity since it prevented attachment of cells for both organisms by 88% at a concentration of 0.31 mg/mL against *S. mutans* and 0.16 mg/mL against *S. sanguinis*[20]. Since root and twig fractions inhibited the growth of bacteria and reduced attachment to S-HA, it indicates that *D. lycioides* has potential as a source of antibacterial and anti-adhesive agents and their use should be encouraged.

6.2. Antibacterial

Li *et al*[48] assessed antibacterial activities of methanol extract from the twigs of *D. lycioides* against common oral pathogens *S. sanguinis*, *S. mutans* and *P. gingivalis*. The extracts demonstrated antibacterial activities against *P. gingivalis* and *S. mutans* with MIC values of 0.16 mg/mL and 2.50 mg/mL[48]. Cai *et al*[24] assessed antibacterial properties of *D. lycioides* twig methanol extracts against oral pathogens, *S. sanguinis*, *Prevotella intermedia*, *S. mutans* and *P. gingivalis*. The methanol extracts inhibited the growth of oral pathogens showing MIC values ranging from 0.019 mg/mL to 1.300 mg/mL[27]. Fawole *et al*[50] assessed antibacterial properties of dichloromethane, petroleum ether, ethanol and water extracts of leaves and stems of *D. lycioides* against *Bacillus subtilis*, *Escherichia coli* and *Staphylococcus aureus* using microdilution assay with neomycin as positive control. Petroleum ether, ethanol and dichloromethane extracts showed activities with MIC values against tested pathogens ranging from 0.59 mg/mL to 6.30 mg/mL[50]. Mbanga *et al*[25] assessed antimicrobial activities of aqueous, methanol, acetone and diethyl ether extracts of *D. lycioides* stems and roots against *S. mutans* using disc diffusion and broth macro-dilution assays with ampicillin as control. The extracts exhibited some activities with inhibition zones ranging from 1 mm to 54 mm, against a range of 6 mm to 25 mm demonstrated by ampicillin control. The MIC and minimum bactericidal concentration (MBC) values of aqueous, methanol and acetone extracts ranged from 0.39 mg/mL to 2.80 mg/mL and 0.49 mg/mL to 5.00 mg/mL, respectively[25]. Nyambe[20] evaluated antibacterial activities of the crude root and twig extracts and fractions of *D. lycioides* using the agar overlay, disc diffusion and agar dilution methods against *S. mutans* and *S. sanguinis*. At 20 mg/mL the extracts exhibited varying degrees of activity with zones of inhibition from 8 mm to 25 mm[20]. The root fraction displayed the MIC values of 0.63 mg/mL and 1.30 mg/mL against *S. sanguinis* and *S. mutans*, respectively. Bagla *et al*[44] assessed antibacterial properties of hexane, ethyl acetate, acetone, and methanol extracts of *D. lycioides* using bioautography against *Escherichia coli*, *Enterococcus faecalis*, *Staphylococcus aureus* and *Pseudomonas aeruginosa*. All tested extracts were unable to inhibit the growth of *Escherichia coli* while the acetone and ethyl acetate extracts inhibited the growth of *Enterococcus faecalis*, *Staphylococcus aureus* and *Pseudomonas aeruginosa*[44]. These antibacterial activities demonstrated the species support the use of *D. lycioides* against dysentery in South Africa[23,36,37], dental caries and toothache in Botswana, South Africa, Swaziland and Zimbabwe[6,7,10-12,20-23,25-27] and sexually transmitted infections in Botswana, Namibia, South Africa and Zambia[28,30-32].

6.3. Antifungal

Fawole *et al*[50] assessed antifungal properties of dichloromethane, petroleum ether, ethanol and water leaf and stem extracts of *D. lycioides* against *Candida albicans* using microdilution assay with amphotericin as positive control. Dichloromethane, ethanol and petroleum ether showed some activity against *Candida albicans* with MIC and minimum fungicidal concentration values of 3.1 mg/mL to 6.3 mg/mL and 3.1 mg/mL to 8.3 mg/mL, respectively[50]. These findings corroborated the use of *D. lycioides* as herbal medicine for oral candidiasis in Namibia[28,29].

6.4. Anti-inflammatory

Fawole *et al*[50] evaluated anti-inflammatory activities of *D. lycioides* by assessing the ability of dichloromethane, ethanol, petroleum ether and water leaf and stem extracts of the species to inhibit cyclooxygenase 2 and 1 (COX 2 and COX 1) enzymes. All dichloromethane and petroleum ether extracts showed good activities against both COX 2 and COX 1 enzymes with inhibition of prostaglandin synthesis of (65.9±1.7)% to (94.0±5.7)% at the highest test concentration of 250 μg/mL[50]. Generally, ethanol and water extracts exhibited weak activity with inhibition < 50% against COX

2 enzyme[50]. These findings corroborated the use of *D. lycioides* against abdominal pains in Malawi and Zimbabwe[33], general body pains in South Africa and Zimbabwe[8,20] and inflammation and wounds in South Africa[37,40].

6.5. Antimetastatic

Bagla *et al*[44] evaluated antimetastatic effects of acetone extracts of *D. lycioides* on BUD-8 cells using the real-time xCELLigence system, and its activities on metastatic cervical cancer (HeLa) cells using wound healing migration and invasion assays. Acetone extract was found to be toxic to BUD-8 cell at concentrations of 500 μg/mL and 1 000 μg/mL[44]. Concentration ranges of 5 μg/mL to 100 μg/mL were not shown to be toxic at 18 h of exposure, with decrease in cell viability (index) during prolonged exposure time beyond 18 h, with the cells exhibiting a similar trend (decrease in viability) beyond 18 h. Bagla *et al*[44] found that the cytotoxicity activities of acetone extract was concentration-dependent in real-time xCELLigence system, with potential to suppress the migration and invasion of cervical cancer (HeLa) cells. The indication of the presence of chemical constituents in the acetone extracts that can suppress HeLa cell migration and invasion makes it a potential source of drug candidates that can interfere with the metastatic process[44].

6.6. Antioxidant

Pilane *et al*[43] assessed antioxidant activities of acetone leaf extract of *D. lycioides* using nitric oxide radical scavenging and 2, 2-diphenyl-1-picrylhydrazyl (DPPH) assays. It appeared that the acetone leaf extract of *D. lycioides* possessed constituents with hydrogen donating abilities, indicative of their antioxidant properties in a concentration-dependent activity with concentrations of 250 μg/mL and above exhibiting more than 50% free radical scavenging activity[43]. Bagla *et al*[44] assessed antioxidant activities of hexane, ethyl acetate, acetone, and methanol extracts of *D. lycioides* using the DPPH assay. All extracts showed the presence of antioxidant constituents with hexane extract showing the least antioxidant active compounds while ethyl acetate and acetone showed more active compounds, especially in the intermediate mobile system[44]. Most of the antioxidant compounds in ethyl acetate, acetone, and methanol could not move from the base of thin layer chromatography plates when they were eluted in benzene, ethanol and ammonia hydroxide (nonpolar) solvent system, suggestive of the high polar nature of the constituent compounds[44].

6.7. Antiproliferative

Pilane *et al*[43] assessed cytotoxicity properties of acetone leaf extract of *D. lycioides* by determining viability of MCF-7 cells with the MTT assay. The nuclear morphological changes of apoptotic cells were assessed by staining the cells with DNA-binding Hoechst 335258 dye, detecting and measuring the overall percentage of apoptotic cells by the annexin V-FITC staining and flow cytometry[43]. The mRNA expression levels of the apoptotic genes were evaluated by the quantification of the real-time PC, while the deferential protein expression levels were evaluated by using the 2D gel electrophoresis and the mass spectrometry techniques. Inhibition of the proliferation of MCF-7 cells by the acetone extract was demonstrated to be more or less concentration-dependent at the various time intervals tested with prolonged exposure time of 72 h, the extracts at 50 μg/mL were shown to inhibit the viability of cells by about 50%. Cells exposed for 48 h at the highest concentration of 500 μg/mL were shown to inhibit their viability at about 50%. Pilane *et al*[43] determined the IC_{50} of the extract to be 65 μg/mL following 48 h of exposure. The morphological changes of cells were evident by the presence of condensed chromatin and fragmented nuclei which embodies the early phase of apoptosis[43]. A small percentage of untreated cells were annexin Ⅴ-FITC positive after 24 h and 48 h of incubation. In contrast, the percentage of annexin Ⅴ-FITC positive cells increased after treatment with 65 μg/mL of the extract after incubation of 24 h and 48 h[43]. These results showed that the extract induced apoptosis of MCF-7 cells in a more or less time-dependent activity. The exposure of the MCF-7 cells to the extract downregulated *bcl–2* mRNA levels in a more or less time-dependent and dose-dependent way, and upregulated the bax mRNA expression level.

6.8. Mutagenicity

Fawole *et al*[50] evaluated mutagenicity of dichloromethane stem extracts of *D. lycioides* using the Ames assay by the use of the plate incorporation technique with *Salmonella typhimurium* strain T98. The total number of revertant colonies demonstrated no mutagenic activities of *D. lycioides* extracts and dense concentration of the agar plates after 48 h when compared with the negative control demonstrated that *D. lycioides* extracts are non-toxic to *Salmonella typhimurium*. These results which demonstrated lack of mutagenicity of dichloromethane stem extracts of *D. lycioides* suggest that the species is probably safe for consumption.

7. Conclusion

The biological activities of *D. lycioides* demonstrated in this study may be due to the phytochemical constituents of the species such as alkaloids, anthraquinones, cardenolides, carotenoids, flavonoids, naphthoquinone, phenolics, polyphenols, saponins, steroids, tannins and terpenoids that have been isolated from the species. Ethnopharmacological research on *D. lycioides* is encouraging as phytochemical profiling, nutritional and biological activities of the

species could support the documented medicinal uses, nutritional and nutraceutical properties of *D. lycioides*. Detailed research on phytochemical properties, biological activities, pharmacokinetics and clinical trials of *D. lycioides* is required as this will provide further evidence for the nutritional, ethnopharmacology and nutraceutical potential of *D. lycioides*. Further research should focus on experimental *in vitro*, *in vivo* studies and toxicological evaluation of *D. lycioides* and its phytochemical compounds.

Conflict of interest statement

The author declares that he has no conflict of interest.

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