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ELEPHANTORRHIZA BURKEI BENTH. (FABACEAE): REVIEW OF ITS MEDICINAL USES, PHYTOCHEMISTRY AND BIOLOGICAL ACTIVITIES

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Abstract
*Elephantorrhizaburkei*Benth. is a shrub or small tree widely used as traditional medicine in southern Africa.The current study critically reviewed the medicinal uses, phytochemistry and biological activities of *E. burkei*. Results of the current study are based on literature survey conducted using various search engines such as Web of Science, Elsevier, Pubmed, Google scholar, Springer, Science Direct, Scopus, Taylor and Francis, and pre-electronic sources such as books, book chapters, scientific journals and other grey literature obtained from the University library. This study revealed that *E. burkei*is used mainly as anti-emetic, and traditional medicine for gastro-intestinal problems, anaemia, blood circulation problems, infertility in women, miscarriage, postpartum and prenatal problems. Pharmacological research identified alkaloids, cardiac glycosides, entagenic acid, flavonoids, phenolics, saponins and tanninsfrom the bark, rhizomes and roots of *E. burkei*. The crude extracts of *E. burkei* exhibited antibacterial, antimycobacterial, antigonococcal, antifungal, anti-HIV, anti-diabetic, anti-inflammatory, antioxidant, trypsin and chymotrypsin inhibition, cytotoxicity and mutagenicity activities.*Elephantorrhizaburkei*should be subjected to detailed phytochemical, pharmacological and toxicological evaluations aimed at correlating its medicinal uses with its phytochemistry and biological activities.

Keywords:*Elephantorrhizaburkei*, Fabaceae, herbal medicine, indigenous knowledge, Leguminosae,southern Africa

1. Introduction

*Elephantorrhizaburkei*Benth. (Figure 1) is a shrub or small tree belonging to the Fabaceae, Leguminosae, legume, bean or pea family. *Elephantorrhiza*Benth. is a genus with eight species endemic to Africa, south of the equator [1]. The majority of *Elephantorrhiza* species have been recorded in grassland and savanna with the highest species diversity in the central to eastern region of South Africa [1]. *Elephantorrhizagoetzei* (Harms) Harms is widespread, recorded in Angola, Botswana, Malawi, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe while *E. elephantina* (Burch.) Skeelshas been recorded in Botswana, Eswatini, Lesotho, Mozambique, Namibia, South Africa and Zimbabwe [2-4]. *Elephantorrhizaburkei*has been recorded in Botswana, Mozambique, South Africa and Zimbabwe while *E. suffruticosa*Schinz has been recorded in Angola, Mozambique, Namibia and Zimbabwe [1]. *Elephantorrhizawoodii* E. Phillips has been recorded in Lesotho and South Africa while three species are endemics, *E. obliqua*Burtt Davy and *E.praetermissa*J.H.Ross are confined to South Africa and *E.schinziana*Dinter is confined to Namibia [2,5,6]. The genus name *Elephantorrhiza* is derived from a Greek word meaning “elephant root” in reference to large underground stem which is characteristic of some members of the genus [5,7,8]. The species name *burkei* is in honour of Joseph Burke (1812-1873), a collector of plant and animal specimens in the 19th century [5,7,8]. The English common names of *E. burkei* include “sumach bean”, “elephant-root”, “broad-pod elephant root” and “sumach elephant root” [9,10].

Figure 1: *Elephantorrhizaburkei*: branch showing leaves and flowers (photo: M Coates Palgrave)

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Elephantorrhizaburkei is a deciduous, multi-stemmed shrub or small tree growing up to 6 metres in height with a dense roundish to elongated crown [7,10]. Bark of *E. burkei* on young branches is smooth and grey-green in colour, but dark brown to blackish brown and rough on older branches and stems [9]. The leaves of *E. burkei* are blue-green in colour and hairless with slender leaflets with sharply pointed apex and symmetric bases. The flowers of *E. burkei* are small, fragrant with small reddish glands at the base of individual flowers, creamy white in colour becoming yellow with age and borne in axils of leaves. The fruit of *E. burkei* is a flat brown to reddish brown pod with pod margins remaining after the seeds have broken loose with pieces of the pod. *Elephantorrhizaburkei*has been recorded on rocky ridges and on slopes in woodland, grassland and scrubveld at an altitude ranging from 350 m to 1500 m above sea level [11]. *Elephantorrhizaburkei*is a valuable medicinal plant in southern Africa and an overview of its botanical description, active ingredients, pharmacological effects and distribution are outlined in the monograph "medicinal plants of South Africa" [12]. Moreover, the root bark is used for tanning leather [7,8]. The roots of *E. burkei*are sold in informal herbal medicine markets in Gaborone, Botswana [13]. In South Africa, *E.burkei* is a component of a commercial herbal mixture or traditional herbal tonic known as "sejeso"made from a mixture of five plant species which include *E. burkei, Senegaliacaffra* (Thunb.) P.J.H. Hurter and Mabb. (familyFabaceae), *Peltophorumafricanum*Sond. (Fabaceae), *Alepideaamatymbica*Eckl. &Zeyh. (Apiaceae) and *Hypoxisobtusa*Burch. ex Ker Gawl. (Hypoxidaceae) [14]. The "sejeso" herbal mixture is a multipurpose traditional medicine sold in informal street herbal medicine markets, herbal medicine shops, supermarkets and pharmacies used against heartburn, stomachache, stomach cramps and indigestion[14]. It is therefore, within this context that this study was undertaken aimed at reviewing the medicinal uses, phytochemistry and biological activities of *E. burkei*.

2. Materials and methods

Several electronic databases were searched which included Web of Science, Elsevier, Pubmed, Google scholar, Springer, Science Direct, Scopus, Taylor and Francis. Additional information was obtained from pre-electronic sources such as books, book chapters, scientific journals and other grey literature obtained from the University library. The relevant terms *Elephantorrhizaburkei*was paired with keywords such as "medicinal uses of *Elephantorrhizaburkei"*, "phytochemicals of *Elephantorrhizaburkei"*, "biological activities of *Elephantorrhizaburkei"*, "pharmacological properties of *Elephantorrhizaburkei",* "ethnobotany of *Elephantorrhizaburkei",* and various other synonyms and common names of the plant species. The ultimate goal of this search was to explore articles that investigated the medicinal uses, phytochemical and biological activities of *E. burkei.*

3. Results and discussion

3.1 Medicinal uses of *Elephantorrhizaburkei*

The rhizome and root decoctions or infusions of *E. burkei*are mainly used as anti-emetic, and traditional medicine for gastro-intestinal problems, anaemia, blood circulation problems, infertility in women, miscarriage, postpartum and prenatal problems (Table 1; Figure 2). Other medicinal applications of the rhizome and root decoctions or infusions of *E. burkei*supported by at least five literature records include abortifacient [15-20], aphrodisiac [17,19-23], menstrual problems [17,19,21,24,25], respiratory problems [24,26-29] and sexually transmitted infections [17,19-21,24,25,30-34]. *Elephantorrhizaburkei*is also used in combination with roots of *Adeniaspinosa*Burtt Davy and *Peltophorumafricanum*Sond.as remedy for asthma and fatigue [29,35] while roots of *E. burkei* are mixed with *P. africanum* (stem bark), *Cassia abbreviata*Oliv. (stem bark) and *Cissusquadrangularis* L. (stems) as remedy for sexually transmitted infections [32,36]. Similarly, roots of *E. burkei*are mixed with *Blepharisdiversispina* (Nees) C.B. Clarke (roots), *Jatropha zeyheri*Sond. (roots), *P. africanum* (stem bark), *C. abbreviata* (stem bark) and *C. quadrangularis* (stems) and *Catharanthusroseus* (L.) G. Don (roots) as remedy for sexually transmitted infection known as dropsy [32].

Table 1: Medicinal uses of *Elephantorrhizaburkei*

Medicinal uses	Parts used and preparation	Country	Reference
Abortifacient	Roots	South Africa	[15-20]
Anaemia and blood circulation problems	Rhizome and roots	Botswana, South Africa and Zimbabwe	[17,19,21,24,32,36-38]
Anti-emetic	Roots	South Africa and Zimbabwe	[7,8,37]
Aphrodisiac	Roots	South Africa	[17,19-23]
Arthritis	Bark	South Africa	[39]
Astringent	Roots	Botswana	[1,15]

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Candidal infections	Bark	South Africa	[20,25]
Convalescent	Roots	South Africa	[21]
Diabetes mellitus	Bark and roots	South Africa	[39-41]
Eye infections	Roots	South Africa	[32]
Fatigue	Roots mixed with those of *Adeniaspinosa*Burtt Davy and *Peltophorumafricanum*Sond.	South Africa	[29,35]
Fever	Rhizome and roots	South Africa	[24,27]
Gastro-intestinal problems (abdominal pains, constipation, diarrhoea, dysentery andstomach problems)	Rhizome, roots, seeds and stem rhizome	South Africa and Zimbabwe	[7,8,16,24,25,30,37,38,42]
Haemorrhoids	Rhizome and roots	South Africa	[24]
Headache	Twigs	South Africa	[30]
Human immunodeficiency virus and acquired immunodeficiency syndrome (HIV and AIDS) opportunistic infections	Rhizome and roots	South Africa	[24]
Hypertension	Rhizome and roots	South Africa	[24]
Infertility in women	Rhizomes and roots	South Africa and Zimbabwe	[24,37]
Massaging muscles	Roots	Botswana	[13]
Menstrual problems	Roots	South Africa	[17,19,21,24,25]
Miscarriage	Rhizome and roots	Botswana and South Africa	[16,19,21,43]
Postpartum and prenatal	Roots	Botswana and Zimbabwe	[13,37,44]
Respiratory problems (asthma, chest pains, cough, pneumonia and tuberculosis)	Rhizome and roots	South Africa	[24,26-29]
Asthma	Roots mixed with those of *A.spinosa* and *P. africanum*	South Africa	[29,35]
Sexually transmitted infections (chlamydia, syphilis and venereal diseases)	Roots	South Africa	[17,19-21,24,25,30-34]
Sexually transmitted infections	Roots mixed with *P.africanum* (stem bark), *Cassia abbreviata*Oliv. (stem bark) and *Cissusquadrangularis*L. (stems)	South Africa	[32,36]
Dropsy	Roots mixed with *Blepharisdiversispina*(Nees) C.B. Clarke (roots), *Jatropha zeyheri*Sond. (roots), *P.africanum* (stem bark), *C.abbreviata* (stem bark) and *C.quadrangularis* (stems) and*Catharanthusroseus*(L.) G. Don (roots)	South Africa	[32]
Sores	Rhizomes and roots	Botswana	[38]
Swollen legs	Roots	South Africa	[16,38]
Toothache	Seeds	South Africa	[30]
Ulcers	Rhizome and roots	South Africa	[24]
Vomiting	Rhizome	Botswana	[43]
Ethnoveterinary medicine (diarrhoea in cattle)	Bark and roots	South Africa	[32,45]

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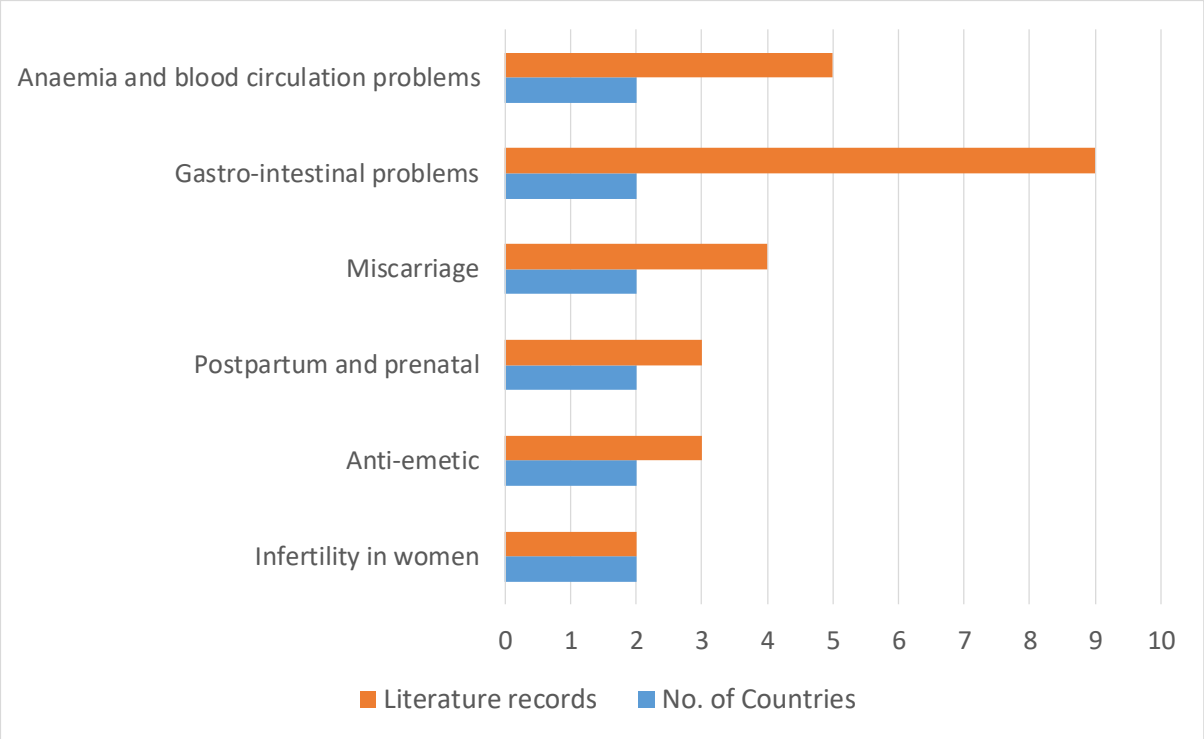

Figure 2: Medicinal uses of *Elephantorrhizaburkei*in southern Africa

3.2 Phytochemistry of *Elephantorrhizaburkei*

A variety of chemical compounds have been isolated and identified from *E. burkei*(Table 2). These phytochemical compounds identified from the bark, rhizomes and roots of *E. burkei* alkaloids, cardiac glycosides, entagenic acid, flavonoids, phenolics, saponins and tannins (Table 2).

Table 2: Phytochemical compounds isolated from *Elephantorrhizaburkei*

Phytochemical compound	Value	Plant part	Reference
Alkaloids	-	Bark	[39]
Cardiac glycosides	-	Bark and roots	[36,39]
Condensed tannins (% LCE)[a]	0.4	Roots	[19,21]
Entagenic acid	-	Roots	[30]
Flavonoids (µg CAE/g)[b]	3.7	Bark and roots	[19,21,36,39]
Gallotannin (µg GAE/g)[c]	31.6	Roots	[19,21]
Saponins	-	Bark and roots	[36,39]
Tannin	-	Rhizomes and roots	[36,46]
Total phenolics (mg GAE/g)	12.0	Roots	[19,21]

[a]Values expressed as percentage leucocyanidin equivalents (LCE) per gram plant extracts
[b]Values expressed as catechin equivalents (CTE) per gram of plant extracts.
[c]Values expressed as gallic acid equivalent (GAE) per gram of plant extracts.

3.3 Biological activities of *Elephantorrhizaburkei*

The following biological activities have been reported from the leaves, rhizomes and roots of *E. burkei*: antibacterial [19,21,24,30,31,36,42,44], antimycobacterial[44], antigonococcal[19,21], antifungal [19,21,44], anti-HIV [19,21], anti-diabetic [39], anti-inflammatory [19,39,47], antioxidant [36,39], trypsin and chymotrypsin inhibition [48], cytotoxicity [24,39] and mutagenicity [19,47] activities.

3.3.1 Antibacterial activities

Tshikalange[30] and Tshikalange et al. [31] evaluated the antibacterial activities of aqueous and chloroform extracts of *A. burkei* roots against *Bacillus cereus, Bacillus pumilus, Bacillus subtilis, Staphylococcus aureus, Enterobacter cloacae, Escherichia coli, Klebsiellapneumoniae, Pseudomonas aeruginosa, Serratiamarcescens*and *Enterobacteraerogenes*using the agar dilution method. The aqueous extract exhibited activities against *Bacillus pumilus, Bacillus subtilis* and *Staphylococcus aureus* with the minimum inhibitory concentration (MIC) value of 60.0 mg/ml [30,31]. Mathabe et al. [42] evaluated the antibacterial activities of

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water, ethanol, acetone and methanol extracts of *E. burkei*stem rhizome against *Shigellaflexneri*, Escherichia coli, *Staphylococcus aureus*, *Shigellaboydii*, *Vibrio cholerae*, *Shigellasonnei, Salomonellatyphi*and*Shigella dysentery*using the a*gar-well diffusion* and *serial dilution assays with* contrimoxazole (25.0 µg), erythromycin (15.0 µg) and nalidixic acid (10.0 µg) as positive controls. The extracts exhibited activities against *Shigellaflexneri*, *Staphylococcus aureus*, *Shigellaboydii*, *Vibrio cholerae*and*Shigella dysentery* with zone of inhibition ranging from 10.0 mm to 23.3 mm and the MIC values ranged from 0.08 mg/ml to 0.6 mg/ml [42].Mukanganyama et al. [44] evaluated antibacterial activities of ethanol extracts of *E. burkei*roots against *Bacillus cereus*, *Bacillus subtilis*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* using the disk agar diffusion method with ampicillin as a positive control. The extracts exhibited activities against *Bacillus cereus*, *Bacillus subtilis*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* with zone of inhibition values ranging from 2.5 mm to 3.5 mm [44]. Mulaudzi[19] and Mulaudzi et al. [21]evaluated the antibacterial activities of ethanol, dichloromethane, water and petroleum ether extracts of *E. burkei* roots against *Escherichia coli, Staphylococcus aureus, Klebsiellapneumoniae* and *Bacillus subtilis* using the microdilution method with neomycin (0.1 mg/ml) as a positive control. The extracts exhibited activities against the tested pathogens with the MIC values ranging from 0.03 mg/ml to 12.0 mg/ml [19,21].Mongalo[36] evaluated the antibacterial activities of aqueous, methanol, acetone, ethanol and ethyl acetate extracts of *E. burkei* roots against *Escherichia coli*, *Pseudomonas aeruginosa*, *Enterobacter cloacae*, *Klebsiellapneumoniae*, *Klebsiella spp.*, *Serratiamarscens*, *Acinetobactercalcaoceticusanitratus,Shigellaflexineri,Samonella spp.Staphylococcus aureus*, Streptococccusviridans, *Bacillus cereus*, *Bacillus pumilus*, *Enterococcus faecalis*, *Staphylococcus epididirmis*and *Bacillus subtilis* using disc diffusion method with penicillin (10.0 µg/disc), streptomycin (10.0 µg/disc) and neomycin (10.0 µg/disc) as positive controls. The extracts exhibited activities against the majority of tested pathogens with the exception of *Klebsiellapneumoniae*, *Staphylococcus epididirmis,* Streptococccusviridans and *Enterococcus faecalis*with zone of inhibition ranging from 7.0 mm to 15.7 mm and MIC values ranging from 0.8 mg/ml to >10.0 mg/ml [36]. Madikizela et al. [24] evaluated the antibacterial activities of aqueous and 70% acetone extracts of *E. burkei* roots against *Shigellaflexneri, Campylobacter jejuni, Staphylococcus aureus* and *Escherichia coli* using the microtitre plate method with streptomycin and neomycin as positive controls. The extracts exhibited activities against tested pathogens with the MIC values ranging from 0.2 mg/ml to 6.3 mg/ml [24].

3.3.2 Antimycobacterial activities

Mukanganyama et al. [44] evaluated the antimycobacterial activities of ethanol extracts of *E. burkei*roots against *Mycobacterium aurum*using the disk agar diffusion method with ampicillin as a positive control. The extract exhibited activities against the tested pathogen with the MIC and minimum bactericidal concentration (MBC) value of 0.04 mg/ml [44].

3.3.3 Antigonococcal activities

Mulaudzi[19] and Mulaudzi et al. [21] evaluated the antigonococcal activities of ethanol, dichloromethane, water and petroleum ether extracts of *E. burkei* roots against *Neisseria gonorrhoeae* through determination of clear zones of inhibition with ciprofloxacin as a positive controls. The extracts exhibited moderate activities with percentage inhibition ranging from 44.0% to 51.0% [19,21].

3.3.4 Antifungal activities

Mukanganyama et al. [44] evaluated the antifungal activities of ethanol extracts of *E. burkei*roots against *Candida mycoderma*and *Candida albicans*using the disk agar diffusion method with fungazole as a positive control. The extracts exhibited activities against *Candida mycoderma*and *Candida albicans*with zone of inhibition values ranging from 3.0 mm to 3.5 mm, MIC and minimum fungicidal concentration (MFC) value of 0.08 mg/ml [44]. Mulaudzi[19] and Mulaudzi et al. [21]evaluated the antifungal activities of ethanol, dichloromethane, water and petroleum ether extracts of *E. burkei* roots against *Candida albicans* using the microdilution method with amphotericin B as a positive control. The extracts exhibited activities against the tested pathogen with MIC and MFC values ranging from 1.6 mg/ml to 6.3 mg/ml and 3.1 mg/ml to 6.3 mg/ml, respectively [19,21].

3.3.5 Anti-HIV activities

Mulaudzi[19] and Mulaudzi et al. [21] evaluated the anti-HIV activities of methanol and water extracts of *E. burkei* roots against a non-radioactive HIV-1 reverse transcriptase colorimetric ELISA kit with combivir and kaletra as positive controls. The extracts exhibited activities with inhibition percentage of 65.0% at 1.0 mg/ml and half maximal inhibitory concentration (IC_{50}) values ranging from 0.4 mg/ml to 0.5 mg/ml, which were comparable to IC_{50} values of 0.06 mg/ml to 0.3 mg/ml exhibited by the positive control [19,21].

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3.3.6 Anti-diabetic activities

Tshidzamba[39] evaluated the anti-diabetic activities of aqueous, ethyl acetate, ethanol and hydro-ethanol extracts of *E. burkei* leaves by assessing the α-amylase and α-glucosidase inhibition activities using Michaelis-Menten kinetics. The extracts exhibited activities with IC_{50} values ranging from 52.2 mg/ml to 1996.4 mg/ml [39].

3.3.7 Anti-inflammatory activities

Mulaudzi[19] and Mulaudzi et al. [47] evaluated the anti-inflammatory activities of aqueous, dichloromethane, 80% ethanol and petroleum ether extracts of *E. burkei* roots against the cyclooxygenase (COX-1 and COX-2) enzymes. The extracts exhibited activities towards COX-1 with percentage inhibition of at least 90.0% [19,47]. Similarly, Tshidzamba[39] evaluated the anti-inflammatory activities of ethyl acetate, ethanol and acetone extracts of *E. burkei*leaves against RAW 264.7 cells and inhibition of nitric oxide (NO) production with quercetin as a positive control. The extracts exhibited NO production in a concentration dependent manner with more than 60.0% cell viability [39].

3.3.8 Antioxidant activities

Mongalo[36] evaluated the antioxidant activities of methanol extracts of *E. burkei* roots using the 2,2-azinobis-3-ethylbenzithiazoline-6-sulfonic acid (ABTS) and 2, 2-diphenyl-1-picryl-hydrazyl (DPPH) free radical scavenging assays with ascorbic acid as positive control. The extracts exhibited activities with IC_{50} values of 0.1 mg/ml and 0.5 mg/ml against DPPH and ABTS, respectively in comparison to IC_{50} values of 0.5 mg/ml and 0.8 mg/ml exhibited by the positive control [36]. Similarly, Tshidzamba[39] evaluated the antioxidant activities of ethyl acetate, ethanol and acetone extracts of *E. burkei*leaves using the DPPH free radical assay with ascorbic acid and trolox as positive controls. The extracts showed activities with half maximal lethal concentration (LC_{50}) values ranging from 0.5 µg/ml to 2.5 µg/ml in comparison to LC_{50} value of 0.1 µg/ml exhibited by the positive controls [39].

3.3.9 Trypsin and chymotrypsin inhibition activities

Weder[48] evaluated the trypsin and chymotrypsin inhibition activities of seeds of *E. burkei* using the casein method. The trypsin and chymotrypsin inhibition activities were 25.2 mg trypsin-inhibited by 1.0 g of bruised grain and 7.1 mg chymotrypsin-inhibited by 1.0 g of bruised grain, respectively [48].

3.3.10 Cytotoxicity activities

Madikizela et al. [24] evaluated the cytotoxicity activities of aqueous and 70% acetone extracts of *E. burkei* roots against the African green monkey kidney (Vero) cell line using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) colorimetric technique with doxorubicin hydrochloride as positive control. The 70% acetone extract exhibited activities with LC_{50} value of 0.2 mg/ml in comparison to LC_{50} value of 10.0 µM exhibited by the positive control [24].Tshidzamba[39] evaluated the cytotoxicity activities of ethyl acetate, ethanol and acetone extracts of *E. burkei*leaves against African green monkey kidney (Vero) and bovine dermis cell lines using the MTT colorimetric technique with doxorubicin as a positive control. The extracts exhibited activities with LC_{50} values ranging from 0.05 mg/ml to 1.0 mg/ml [39].

3.3.11 Mutagenicity activities

Mulaudzi[19] and Mulaudzi et al. [47] evaluated the mutagenicity activities of aqueous, dichloromethane, 80% ethanol and petroleum ether extracts of *E. burkei* roots using the Ames test, with and without S9 (metabolic activation) against *Salmonellatyphimurium*tester strain TA98 with 4-nitroquinoline-N-oxide (4NQO) (2.0 µg/plate) as a positive control. The Ames test revealed that the extracts induced 50.0 revertant colonies at 500 µg/ml and 50.0 µg/ml and therefore, the extract could be classified as a weak mutagen [19,47].

Conclusion

The present review summarizes the medicinal uses, phytochemistry and biological activities of *E. burkei*. Based on presented information, there is not yet enough data correlating the medicinal uses of the species with its phytochemical and biological activities. Detailed studies on phytochemical, biological activities, toxicological properties, *in vivo* and clinical research involving both extracts and compounds isolated from the species are required.

Conflict of interest

No conflict of interest is associated with this work.

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