Review of Pharmacological Properties, Phytochemistry and Medicinal Uses of *Baccharoides adoensis*

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Abstract: *Baccharoides adoensis* is a shrub widely used as traditional medicine throughout its distributional range in tropical Africa. This study is aimed at providing a critical review of the pharmacological properties, phytochemistry, and medicinal uses of *B. adoensis*. Documented information on the pharmacological properties, phytochemistry, and medicinal uses of *B. adoensis* was collected from several online sources which included Scopus, Google Scholar, PubMed and Science Direct. Additional information on the pharmacological properties, phytochemistry, and medicinal uses of *B. adoensis* was gathered from pre-electronic sources such as book chapters, books, journal articles, and scientific publications sourced from the university library. The articles published between 1962 and 2020 were used in this study. This study showed that the roots, flowers, stems, and leaves of *B adoensis* are widely used as ethnoveterinary medicine and traditional medicines for backbone pain, reproductive problems, kidney diseases, fever and febrile complaints, wounds, ulcers, sexually transmitted infections, skin complaints, malaria, gastro-intestinal problems and respiratory problems. Phytochemical compounds identified from the species include alkaloids, carbohydrates, chondrillasterol, flavonoids, free sugars, glaucolides, glycosides, phenols, proanthocyanidin, saponins, steroids, tannins and terpenoids. Pharmacological research revealed that *B. adoensis* extracts and compounds isolated from the species have antimicrobial, antimycobacterial, anti-inflammatory, antioxidant, antiplasmodial, anti-pyretic, antitrypanosomal, antileishmanial, anti-ulcer and gastroprotective, immunomodulating, inhibition of *Helicobacter pylori* adhesion, larvicidal, cytotoxicity and toxicity activities. *Baccharoides adoensis* should be subjected to detailed phytochemical, pharmacological, and toxicological evaluations aimed at correlating its medicinal uses with its phytochemistry and pharmacological activities.

Keywords: Asteraceae, *Baccharoides adoensis,* Compositae, ethnopharmacology, herbal medicine, indigenous pharmacopeia, *Vernonia adoensis.*

INTRODUCTION

Baccharoides adoensis (Sch. Bip. ex Walp.) H. Rob. is a woody shrub belonging to the Asteraceae or Compositae family. This species was originally treated under the genus *Vernonia* Schreb. [1], a genus that is now known to be restricted to North America [1]. The genus name *Baccharoides* was first proposed by Moench in 1793 and remained unused until it was resurrected by Robinson in 1990 [1,2]. Synonyms associated with the name *B. adoensis* include *Ascaricida adoensis* Steetz, *A. richardii* Steetz, *Cacalia adoensis* Kuntze, *C. grantii* Kuntze, *C. tigrensis* Kuntze, *Candidea grantii* Stapf, *Stengelia adoensis* Sch. Bip., *Vernonia adoensis* Sch. Bip. ex Walp., *V. goetzei* Muschl., *V. grantii* Oliv., *V. integra* S. Moore, *V. kotschyana* Sch. Bip. ex Walp., *V. latisquama* Mattf., *V. macrocephala* A. Rich., *V. polymorpha* Vatke and *V. tigrensis* Oliv. & Hiern [3]. Two infraspecific taxa are recognized and these are *B. adoensis* var. *kotschyana* (Sch. Bip. ex Walp.) Isawumi, El-Ghazaly & B. Nord. and *B. adoensis* var. *mossambiquensis* (Steetz) Isawumi, El-Ghazaly & B. Nord. [4] *Baccharoides adoensis* is a woody shrub that can grow up to 3 metres in height [5]. The stems of the species are annual, with smooth brownish bark, and multi-stemmed growing from a woody rootstock. The leaves are alternate, ovate to elliptic in shape, with acute apex and serrate margins. The leaves of *B. adoensis* are silvery dark and dull green above and paler green below, both surfaces are rather rough, harsh or sandpapery. The flowers are white in colour forming dense heads, terminal, with open or tight clusters of large round flower heads surrounded by large leaf bracts. The fruit is a tiny dry nutlet achene with white hairs at one end. *Baccharoides adoensis* has been recorded in Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, the Democratic Republic of Congo (DRC), Eritrea, Eswatini, Ethiopia, Kenya, Nigeria, Rwanda, Senegal, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe [1,3-7]. It has been recorded in disturbed bushland, grassland, mixed woodland, savanna, montane forest, along forest edges, often along rivers or drainage lines at altitudes ranging from 550 m to 2150 m above sea level [4,6].

Baccharoides adoensis is an important traditional medicine in South Africa as the species is listed in the monograph of medicinal plants of the country [8]. The

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Table 1: Medicinal Uses of *Baccharoides adoensis*

Medicinal use	Parts used	Country	References
Arthritis	Leaves	Nigeria	[16-19]
Backbone pain	Leaves, roots and stems	Ethiopia and South Africa	[20-22]
Diabetes	Leaves	Eswatini	[23]
Ear infections	Leaves	Uganda	[15,24,25]
Evil eye	Roots mixed with those of *Capparis tomentosa* Lam., *Carissa spinarum* L., *Croton macrostachyus* Hochst. ex Delile and *Pterolobium stellatum* (Forssk.) Brenan	Ethiopia	[13]
Eye problems	Leaves and roots	Kenya	[24]
Fever and febrile complaints	Leaves	South Africa and Tanzania	[18,21,25,27-30]
Gall-bladder problems	Leaves	South Africa	[20,21,31]
Gangrene	Roots	Ethiopia	[13]
Gastritis	Roots	Mali	[10-12,18,19,32-40]
Gastro-intestinal problems (appetizer, diarrhoea, digestive problems, indigestion and stomach problems)	Leaves, roots and stems	Eswatini, Ethiopia, Mali, Nigeria, South Africa and Tanzania	[10,12,13,16-19,21,23,32,33,35,37,39-45]
Gingivitis	Leaves	Nigeria	[16-19]
Heart diseases	Leaves	Kenya	[29,30,46-48]
Herpes zoster	Roots	Kenya	[49]
Hypertension	Roots	Ethiopia	[13]
Inflammation	Roots	Nigeria	[50]
Kidney diseases	Leaves and roots	Ethiopia and Kenya	[29,30,46-48,51]
Madness	Roots	Zimbabwe	[52]
Malaria	Leaves	Ethiopia, Kenya, Mozambique, South Africa, Uganda and Zimbabwe	[18,25,29,30,45-48,53-57]
Malaria	Leaves mixed with *Aloe vera* (L.) Burm. f.	Uganda	[14,15]
Purgative	Leaves	Eswatini	[23]
Reproductive problems (infertility and sexual dysfunction)	Roots	Ethiopia and Zimbabwe	[22,51,52]
Respiratory problems (chest complaints, cough, flu and tuberculosis)	Leaves and roots	Eswatini, Ethiopia, Nigeria, South Africa, Tanzania and Uganda	[15-21,23,25,28-33,41,45,57-64]
Sexually transmitted infections (genital ulcers, gonorrhoea and human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS)	Leaves and roots	Kenya, Nigeria, Tanzania and Uganda	[16-19,25,29,30,41,45-49,57,65-67]
Skin complaints (blotches, head lice, rash and scabies)	Flowers, leaves and roots	Eswatini, Nigeria, South Africa, Tanzania, Uganda and Zimbabwe	[15,18,20,21,23-25,31,41,61,68]
Snake and scorpion bites	Leaves and roots	Ethiopia	[13,18,22,69,70]
Ulcers	Roots	Cameroon and Mali	[10-12,18,19,32-40,43,71]
Urinary problems	Leaves and stems	South Africa	[20,21]
Worms	Roots	Ethiopia	[13]
Wounds including circumcision wounds	Leaves and roots	Ethiopia and Mali	[10,12,18,19,22,25,35,39,40,43,45,69,72]
Ethnoveterinary medicine (tick-bite sores and worms)	Leaves	Kenya and Uganda	[7,18,41,73]

leaves, roots and stems of *B. adoensis* are sold as herbal medicines in Mali and South Africa [9,10]. The powdered roots of *B. adoensis* are commercially available in Malian pharmacies and other outlets selling pharmaceutical drugs and health products using the trade name gastrosedal. The pharmaceutical product gastrosedal is on the national list of essential drugs in Mali for treatment of gastritis and gastric ulcers [9]. As the roots of *B. adoensis* are used to produce gastrosedal, the wild populations of the species have decreased considerably over the years and the species is now cultivated in several areas and home gardens in Mali [11,12]. It is, therefore, within this background that the current study was undertaken aimed at documenting the pharmacological properties, phytochemistry, and medicinal uses of *B. adoensis.*

Medicinal Uses

The roots, flowers, stems and leaves of *B. adoensis* are widely used as ethnoveterinary medicine and traditional medicines for backbone pain, reproductive problems, kidney diseases, fever and febrile complaints, wounds, ulcers, sexually transmitted infections, skin complaints, malaria, gastro-intestinal problems and respiratory problems (Table **1**; Figure **1**). In Ethiopia, roots of B adoensis are mixed with those of *Capparis tomentosa* Lam., *Carissa spinarum* L., *Croton macrostachyus* Hochst. ex Delile and *Pterolobium stellatum* (Forssk.) Brenan and used as traditional medicine for evil eye [13]. In Uganda, the leaves of *B. adoensis* are mixed with those of *Aloe vera* (L.) Burm. f. as herbal medicine for malaria [14,15].

Phytochemistry

Bohlmann *et al.* [74] identified flavonoids and glaucolides, 14-hydroxy-8-desacyl-2,3-dehydrovernonataloide-8-O-methacrylate and 14-hydroxy-8-desacyl-2,3-dehydrovernonataloide-8-O-[2-methyl butyrate] from the aerial parts of *B. adoensis*. Sanogo *et al.* [33] isolated stigmastane-type steroidal glycosides, vernoniosides D1, D2, D3, F1 and F2, as well as androst-8-en glycoside from the root of *B. adoensis*. Nergard *et al.* [42] isolated two polysaccharides, a pectin and a pectic arabinogalactan from roots of *B. adoensis*. Austarheim *et al.* [10] and Inngjerdingen *et al*. [11] identified arabinose, rhamnose, galactose, galacturonic acid, glucuronic acid, 4-O-methyl glucuronic acid, glucose, mannose, fructose, and phenols from the roots of *B. adoensis*. Mozirandi *et al.* [30] identified the compound chondrillasterol from the leaves of *B. adoensis*. Several other researchers identified alkaloids, carbohydrates, flavonoids, free sugars, glycosides, phenols, proanthocyanidin, saponins, steroids, tannins and terpenoids from flowers, leaves, roots and root bark of *B. Adoensis* [12,17,28,48,55,64,67,75].

Pharmacological Properties

The following biological activities have been reported from the flower, leaf, root and stem bark extracts of *B. adoensis* and the compounds isolated from the species: antimicrobial, antimycobacterial, anti-inflammatory, antioxidant, antiplasmodial, anti-pyretic, antitrypanosomal, antileishmanial, anti-ulcer antiulcer

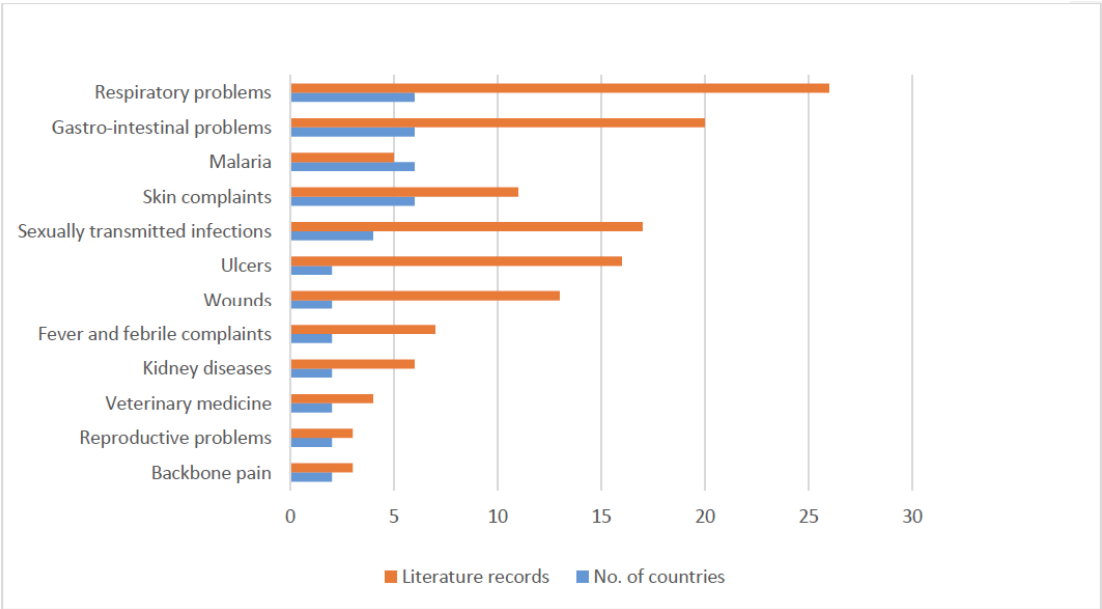

Figure 1: Medicinal applications of *Baccharoides adoensis* derived from literature records.

and gastroprotective, immunomodulating, inhibition of *Helicobacter pylori* adhesion, larvicidal, cytotoxicity and toxicity activities.

Antimicrobial Activities

Preliminary evaluations of antibacterial activities of *B. adoensis* leaf extracts revealed activities against both Gram-negative and Gram-positive bacteria [42]. Kisangau *et al.* [58] evaluated the antibacterial activities of petroleum ether, dichloromethane, and water extracts of *B. adoensis* leaves against *Staphylococcus aureus, Bacillus subtilis, Escherichia coli* and *Pseudomonas aeruginosa* using the agar well and disc diffusion assays with ampicillin (0.5mg/ml) and gentamicin (0.5mg/ml) as positive controls. The petroleum ether and dichloromethane extracts exhibited activities against Bacillus subtilis and Escherichia coli with zone of inhibition of 4.0 mm and 6.5 mm, respectively, while water extracts exhibited activities against *Staphylococcus aureus, Bacillus subtilis* and *Escherichia coli* with a zone of inhibition ranging from 10.0 mm to 46.0 mm [58]. Chitemerere and Mukanganyama [61] evaluated the antibacterial activities of ethanolic extracts of *B. adoensis* leaves against *Escherichia coli, Bacillus cereus, Bacillus subtilis, Staphylococcus aureus* and *Pseudomonas aeruginosa* using the agar diffusion assay and microplate method with ampicillin as a positive control. The extract exhibited activities with the zone of inhibition ranging from 15.0 mm to 25.0 mm, which was comparable to 21.0 mm to 45.0 mm exhibited by the positive control. The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values ranged from 94.0 µg/ml to 188.0 µg/ml, and 500.0 µg/ml to 1000.0 µg/ml, respectively [61]. Ibrahim and Ogaji [17] evaluated the antimicrobial activities of crude flavonoids isolated from *B. adoensis* leaves against *Staphylococcus aureus, Escherichia coli, Aspergillus niger* and *Candida albicans* using agar well diffusion and dilution methods with ofloxacin (20 µg/ml) and fluconazole (20 µg/ml) as positive controls. The flavonoids exhibited activities against the tested pathogens with the MIC values ranging from 12.5 mg/ml to 25.0 mg/ml [17]. Mutuku *et al.* [46] evaluated the antibacterial activities of the methanol : water (9:1) extract of *B. adoensis* leaves against *Salmonella typhi, Klebsiella* spp., *Klebsiella aerogenes, Bacillus cereus, Streptococcus pyogenes, Escherichia coli* and *Proteus vulgaris* using the agar well diffusion method with augmentin as a positive control. The extract exhibited activities against *Klebsiella* spp., *Bacillus cereus, Streptococcus pyogenes* and *Escherichia coli* with a zone of inhibition ranging from 11.7 mm to 20.2 mm in comparison to the zone of inhibition of 28.4 mm to 37.0 mm exhibited by the positive control [46]. Swamy *et al.* [47] evaluated the antibacterial activities of the methanol : water (9:1) extract of *B. adoensis* roots against *Salmonella typi, Klebsiella* spp., *Klebsiella aerogenes, Bacillus cereus, Streptococcus pyogenes, Escherichia coli* and *Proteus vulgaris* using the agar well diffusion method with augmentin as a positive control. The extract exhibited activities against *Bacillus cereus, Streptococcus pyogenes* and *Proteus vulgaris* with a zone of inhibition ranging from 10.0 mm to 15.7 mm in comparison to the zone of inhibition of 28.5 mm to 38.3 mm exhibited by the positive control [47]. Mabhiza *et al.* [28] evaluated the antibacterial activities of alkaloids isolated from *B. adoensis* leaves against *Staphylococcus aureus* and *Pseudomonas aeruginosa* using the broth microdilution assay with ampicillin as a positive control. The compound exhibited activities with the MIC values of 0.2 mg/mL and 0.4 mg/mL against *Staphylococcus aureus* and *Pseudomonas aeruginosa*, respectively, which were higher than the MIC value of 0.008 mg/mL exhibited by the positive control [28]. Muhindi *et al.* [75] evaluated the antibacterial activities of acetone and methanol extracts of *B. adoensis* stem bark against *Klebsiella aerogenes, Enterococcus faecalis, Staphylococcus epidermidis* and *Streptococcus pyogenes* using the disc diffusion method with penicillin as a positive control. The extracts exhibited activities against the tested pathogens with the exception of *Streptococcus pyogenes,* which was found to be resistant against the acetone extract. The zone of inhibition ranged from 9.0 mm to 16.0 mm against the zone of inhibition of 19.3 mm to 43.3 mm exhibited by the positive control [75]. Mozirandi and Mukanganyama [29] evaluated antibacterial activities of water, acetone, hexane, ethyl acetate, ethanol, methanol, and dichloromethane extracts of *B. adoensis* leaves against *Staphylococcus aureus* and *Pseudomonas aeruginosa* using the broth microdilution method and time kill assays. All the extracts had an inhibitory effect on the growth of tested pathogens with acetone extract exhibiting the best activities with the MIC value of 1.6 µg/ml and the MBC value of 6.3 µg/ml against *Pseudomonas aeruginosa*. In the time kill assay, the MBC concentration revealed bactericidal activities after 30 minutes of incubation with *Pseudomonas aeruginosa* [29]. Mozirandi *et al.* [30] evaluated the antibacterial activities of the compound chondrillasterol isolated from the leaves of *B. adoensis* against *Staphylococcus aureus, Klebsiella pneumoniae* and *Pseudomonas aeruginosa* using the broth microdilution assay with ciprofloxacin as a

positive control. The compound exhibited 25%, 38% and 65% inhibition of growth on *Staphylococcus aureus, Klebsiella pneumoniae* and *Pseudomonas aeruginosa*, respectively [30].

Antimycobacterial Activities

Chimponda and Mukanganyama [60] evaluated the antimycobacterial activities of ethanol extracts of *B. adoensis* flowers, leaves and roots against *Mycobacterium aurum* and *Corynebacterium glutamicum* using the agar disk diffusion method with rifampicin as a positive control. At 500 mg/disk, the extracts exhibited activities against the tested pathogens with a zone of inhibition of 28.0 mm, MIC value of 31.0 µg/disk and a MBC value of 250.0 µg/disk [60]. Mautsa and Mukanganyama [64] evaluated the antimycobacterial activities of ethyl acetate and hexane extracts as well as the compounds alkaloid and terpenoid isolated from *B. adoensis* flowers and leaves against *Mycobacterium tuberculosis* using the microbroth dilution method. The ethyl acetate extract was the most active with the MIC and the MBC values of 63.0 µg/ml and 250.0 µg/ml, respectively [64].

Anti-Inflammatory Activities

Ibrahim *et al.* [16] evaluated the anti-inflammatory activities of ethanol extracts of *B. adoensis* leaves using the carrageenan induced hind paw oedema in rats. The extract exhibited 45.5% carrageenan induced hind paw oedema in rats at 50 mg/kg i.p. [16].

Antioxidant Activities

Stangeland *et al.* [54] evaluated the antioxidant activities of acetone, dichloromethane, methanol, chlorine water, and methanol extracts of *B. adoensis* leaves using 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging and ferric reducing ability of plasma (FRAP) assays. The extracts exhibited activities with half maximal inhibitory concentration (IC_{50}) values in DPPH ranging from 33.3 µg/ml to >167.0 µg/ml while FRAP values ranged from 193.2 µmol/g to 2562.3 µmol/g [54]. Nethengwe *et al.* [55] evaluated the antioxidant activities of methanol extracts of *B. adoensis* leaves and roots using DPPH, 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid (ABTS) free radical scavenging, ferrous ion chelating activity assay, hydroxyl radicals (HO), nitric oxide (NO) and superoxide radicals (SO) scavenging ability, and the total antioxidant capacity with ascorbic acid, butylated hydroxy toluene (BHT), citric acid and ethylenediaminetetraacetic acid (EDTA) as positive controls. The extracts exhibited activities with the IC_{50} values ranging from 0.7 µg/ml to 5.2 µg/ml [55]. Vasincu *et al.* [12] evaluated the antioxidant activities of chloroform, ethyl acetate and ethanol extracts of *B. adoensis* roots using ABTS, SO, HO, NO, lipid peroxidation inhibition, ferrous ion chelating and cell-based antioxidant assays. The extracts exhibited varying degrees of activities with half maximal effective concentration (EC_{50}) values ranging from 0.2 µg/ml to 370.4 µg/ml [12] Mautsa and Mukanganyama [64] evaluated the antioxidant activities of ethyl acetate extract of *B. adoensis* leaves using the DPPH free radical scavenging assay with ascorbic acid as a positive control. The extract exhibited weak activities with IC_{50} value of 114.8 µg/ml, which was much higher than the IC_{50} value of 7.4 µg/ml exhibited by the positive control [64].

Antiplasmodial Activities

Stangeland *et al.* [54] evaluated the antiplasmodial activities of acetone, dichloromethane, methanol, chlorine water and methanol extracts of *B. adoensis* leaves using an enzyme-linked immunosorbent assay (ELISA) on *Plasmodium falciparum* chloroquine sensitive strain MRA-285 line with chloroquine as a positive control. All extracts exhibited activities with the IC_{50} values ranging from 2.1 µg/ml to 2.8 µg/ml in comparison to 8.0 µg/ml exhibited by the positive control [54]. Nethengwe *et al.* [55] evaluated the antiplasmodial activities of dichloromethane and methanol extracts of *B. adoensis* leaves and roots against chloroquine sensitive strain of *Plasmodium falciparum* using the parasite lactate dehydrogenase assay. The methanol extract of the leaves exhibited the best activities with the IC_{50} value of 2.9 µg/ml [55]. Zemicheal and Mekonnen [45] evaluated the antiplasmodial activities of the crude aqueous, methanol and chloroform extracts of the leaves of *B. adoensis* in *Plasmodium berghei* infected Swiss albino mice using Peters' 4-day suppressive test. The extracts demonstrated significant suppression of parasitaemia in the treated mice with inhibition ranging from 54.3% to 83.4% at an oral dose of 600 mg/kg body weight [45]. Obbo *et al.* [25] evaluated the antiplasmodial activities of petroleum ether, dichloromethane, methanol and water extracts of *B. adoensis* leaves against *Plasmodium falciparum* using a modified G-^{3}H-hypoxanthine incorporation assay in the chloroquine and pyrimethamine-resistant K1 strains with chloroquine and artemisinin as positive controls. The extracts exhibited activities with the IC_{50} values ranging from 1.0 µg/ml to >5.0 µg/ml [25].

Anti-Pyretic Activities

Nethengwe *et al.* [55] evaluated anti-pyretic activities of water and methanol extracts of *B. adoensis* leaves and roots using the brewer's yeast induced pyrexia model in Sprague-Dawley rats. The extracts exhibited the potential to reduce pyrexia in the induced rats exhibiting time and concentration-dependent activities with the extracts showing activities as from 30 minutes even at the lowest concentration of 100 mg/kg [55].

Antitrypanosomal Activities

Obbo *et al.* [25] evaluated the antitrypanosomal activities of petroleum ether, dichloromethane, methanol, and water extracts of B. adoensis leaves against *Trypanosoma brucei rhodesiense* and *Trypanosoma cruzi* using the Alamar Blue assay and assay for β-galactosidase, respectively, with melarsoprol as a positive control. The extracts exhibited activities against both pathogens with the IC_{50} values ranging from 1.6 µg/ml to >90.0 µg/ml in comparison to 0.007 µg/ml exhibited by the positive control [25].

Antileishmanial Activities

Obbo *et al.* [25] evaluated antileishmanial activities of petroleum ether, dichloromethane, methanol and water extracts of *B. adoensis* leaves against both extracellular promastigotes and intracellular amastigotes of *Leishmania donovani* with beznidazole as a positive control. The extracts exhibited activities with the IC_{50} values ranging from >3.3 µg/ml to >30.0 µg/ml in comparison to 0.3 µg/ml exhibited by the positive control [25].

Anti-Ulcer Antiulcer and Gastroprotective Activities

Germanò e*t al.* [32] evaluated the gastroprotective activities of aqueous extract of *B. adoensis* roots in ethanol-induced gastro-duodenal ulcer in male Swiss albino Sprague-Dawley rats. The extract caused a reduction in the number and severity of ethanol-induced ulcers and did not produce any changes in volume, pH and total acid output in pyloric-ligated rats [32]. Austarheim *et al.* [10] evaluated the anti-ulcer activities of inulin-rich fractions from *B. adoensis* roots by gastric lesion models in Swiss albino mice. The extract significantly inhibited the formation of gastric lesions in mice at 100 mg/kg [10]. Vasincu *et al.* [19] evaluated the antiulcer and gastroprotective activities of aqueous extract of *B. adoensis* roots on two mice models of gastric ulcer induced by indomethacin and absolute ethanol. The results of antiulcer activities showed that the extract exhibited activities with half maximal effective dose (ED_{50}) value of 557.1 mg/kg body weight while gastroprotective activities exhibited an ED_{50} value of 439.9 mg/kg body weight [19].

Immunomodulating Activities

Nergard *et al.* [35,43] evaluated the immunomodulating activities of acidic polysaccharides isolated from *B. adoensis* roots. The polysaccharides showed fixation activities and induced chemotaxis of human macrophages, T cells and NK cells [35,43].

Inhibition of *Helicobacter pylori* Adhesion Activities

Inngjerdingen *et al.* [38] evaluated the anti-adhesive activities of water extracts and polysaccharide fractions isolated from *B. adoensis* roots towards *Helicobacter pylori* using an *in vitro* flow cytometric assay on human gastric adenocarcinoma epithelial cells. The polysaccharide fractions caused approximately 30% inhibition of *Helicobacter pylori* adhesion to gastric adenocarcinoma epithelial cells [38].

Larvicidal Activities

Nethengwe *et al.* [55] evaluated the larvicidal activities of dichloromethane and methanol extracts of *B. adoensis* leaves and roots using the mosquito larvicidal assay. The dichloromethane and methanol extracts of the leaves caused 80.0% and 73.0% mortality of the fourth-instar larvae of *Culex quinquefascitus* [55].

Cytotoxicity and Toxicity Activities

Obbo *et al.* [25] evaluated cytotoxicity activities of dichloromethane extracts of *B. adoensis* leaves using the rat skeletal myoblast (L6) and murine macrophage (J774) cells. The extract exhibited activities with the IC_{50} values of 3.3 µg/ml and 10.0 µg/ml against L6 and J774 cells, respectively [25]. Vasincu *et al.* [40] evaluated the acute toxicity of ethyl acetate, ethanol and water extracts of *B. adoensis* roots in Swiss albino mice. The extracts were administered orally in doses of 800, 1600 and 3200 mg/kg body weight, and the mice monitored daily for 14 days. The ethyl acetate demonstrated slight toxicity with median lethal dose (LD_{50}) value within the range of 2021.1 ± 1484.2 mg/kg body weight while the other extracts were not found to be toxic [40].

CONCLUSION

The present review summarizes the medicinal uses, phytochemistry, and pharmacological properties of *B. adoensis*. Although *B. adoensis* has been the subject of phytochemical and pharmacological research, there is not yet enough data correlating the ethnomedicinal uses of the species with its phytochemical and pharmacological properties. Detailed studies on the pharmacokinetics, *in vivo* and clinical research involving both extracts and compounds isolated from the species are required. Therefore, future research should focus on the molecular modes or mechanisms of action, pharmacokinetics, and physiological pathways for specific extracts of the species including the identification of the bioactive compounds of the species and their associated pharmacological activities.

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