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A review of medicinal uses, phytochemistry and biological activities of *Boscia angustifolia*

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Abstract

Boscia angustifolia is an evergreen shrub or small tree widely used as herbal medicine in the Sahel and sub-Saharan Africa. The current study critically reviewed the botany, medicinal uses, phytochemistry and biological activities of *B.* angustifolia. Literature on botany, medicinal uses, phytochemical and biological activities of *B.* angustifolia was collected from multiple internet sources including Elsevier, Google Scholar, SciFinder, Web of Science, Pubmed, BMC, Science Direct and Scopus. Complementary information was gathered from pre-electronic sources such as books, book chapters, theses, scientific reports and journal articles obtained from the University library. This study revealed that the species is used as cholagogue and purgative, and herbal medicine for bruises, sores and wounds, gastro-intestinal problems, eye problems and otitis, fever and typhoid fever, gonorrhoea and venereal diseases, malaria, respiratory infections, skin problems, swellings and swollen feet, ulcers and ethnoveterinary medicine. Ethnopharmacological research identified alkaloids, amino acid derivatives, carboxylic acids and their derivatives, saponins, sugars and their derivatives from the bark, fruits, leaves and roots of *B. angustifolia*. The crude extracts of the species and the compound 7,4'-dimethoxy quercetin isolated from the species exhibited antibacterial, antimycobacterial, antifungal, antiviral, antioxidant, antiplasmodial, antitrypanosomal, $GABA_A$–benzodiazepine receptor binding, larvicidal and cytotoxicity activities. *Boscia angustifolia* should be subjected to detailed phytochemical, pharmacological and toxicological evaluations aimed at correlating its medicinal uses with its phytochemistry and pharmacological activities.

Keywords: *Boscia angustifolia*, Capparaceae, herbal medicine, indigenous knowledge, Sahel, sub-Saharan Africa

INTRODUCTION

Boscia angustifolia A. Rich. is an evergreen shrub or small tree belonging to the Capparaceae or Capparidaceae or caper family. The Capparaceae family contains 33 genera and approximately 700 species distributed in tropical and subtropical regions of the world.[1-3] *Boscia* Lam. is a genus of shrubs or small trees consisting of 37 species, mostly in tropical and southern Africa, a few in Madagascar, one confined to Arabia, mostly in semi-arid or seasonally dry areas.[2,4,5] Several *Boscia* species are used as herbal medicines in tropical Africa and these include *B. albitrunca* (Burch.) Gilg & Gilg-Ben., *B. angustifolia*, *B. coriacea* Graells, *B. foetida* Schinz, *B. longifolia* Hadj-Moust., *B. madagascariensis* (DC.) Hadj-Moust., *B. mossambicensis* Klotzsch., *B. salicifolia* Oliv. and *B. senegalensis* Lam.[6-8] Iwu[6] argued that the medicinal properties of *Boscia* species could be attributed to alkaloids, flavonoids, sesquiterpenes and their glycosides, sulphur compounds and lipids that are associated with the genus. *Boscia angustifolia* is categorized as a multipurpose species in Burkina Faso, Ethiopia, Eritrea and Tanzania, used as a source of charcoal, cosmetics, dye or tannin, fodder, food, firewood, construction materials, ethnoveterinary medicines, herbal medicines, shade, fodder, source of bee forage, toothbrush, reclaiming degraded sites and source of timber for furniture and carvings.[9-27] The fruits of *B. angustifolia* are edible but bitter, however, seeds are cooked and then eaten.[28] The powdered seeds are mixed with millet (*Eleusine coracana* Gaertn.) flour and added to soups or cereals.[28] Boiled pieces of wood have been used to sweeten milk[7] and the bark of *B. angustifolia* has been used as tea in Kenya.[29] *Boscia angustifolia* appears to be an important source of herbal medicine within its distributional range in the Sahel and sub-Saharan Africa, and therefore, there is need for formal documentation and systematic research which is beneficial to indigenous and traditional systems of herbal medicine.[30,31] It is within this context that this review was undertaken aimed at reviewing the botany, medicinal uses and biological activities of *B. angustifolia* so as to provide baseline data required in evaluating the therapeutic potential of the species.

Botanical profile of *Boscia angustifolia*

The genus name *Boscia* is in honour of a French naturalist, botanist, zoologist and horticulturist Louis Auguste Guillaume Bosc (1759-1828).[32] The species name "*angustifolia*" means "narrow-leaved" in reference to narrow oblong and sometimes wider leaves.[4,33] Two infraspecies of *B. angustifolia* are recognized, namely *B. angustifolia* var. *angustifolia* with glabrous leaves occurring from Senegal to Somalia, Kenya and northern Tanzania and var. *corymbosa* (Gilg) DeWolf with short and hairy leaves below and occurring from Uganda and Kenya southward to northern South Africa.[7,34-40] However, most ethnobotanical and ethnopharmacological literature do not separate *B. angustifolia* into specific varieties, but rather to *B. angustifolia sensu lato*, and this is the approach that has been adopted in this study.

Boscia angustifolia is commonly referred to as "rough-leaved shepherd tree" in English. Synonyms associated with *B. angustifolia* include *B. caloneura* Gilg, *B. corymbosa* Gilg, *B. dawei* Sprague & M.L. Green, *B. engleri* Gilg & Gilg-Ben., *B. fischeri* Pax, *B. homblei* De Wild., *B. patens* Sprague & M.L. Green, *B. reticulata* Hochst. ex A. Rich. and *Boscia senegalensis* Hochst. ex Walp.[34-37,39,40] *Boscia angustifolia* is an evergreen shrub or

small tree with rigid and sometimes spiny branches growing up to 15 m in height.[7,38,41] The bole is often deeply and sinuously fluted and twisted with pale grey bark. The leaves are often spirally arranged or occur in groups of two to four on very dwarf spur-branchlets.[38] The leaves are elliptic to oblanceolate in shape, leathery, dark green in colour above, much paler and grey-green or bluish green below. The flowers are small, sweet-smelling and yellowish green in colour, occurring in dense clusters on short terminal lateral shoots. The fruit is a berry, which is spherical in shape, hairless and yellowish to almost black in colour with one to two seeds embedded in a sticky pulp.[36,38] *Boscia angustifolia* is widespread, from southern Arabia and Mauritania, Senegal and Gambia eastward to Somalia and southward to northern South Africa.[34,35,37,40,43-46] The species has been recorded in dry, open woodland, bushveld, wooded grassland, often on termitaria, also on hills, stony or rocky soils, laterite outcrops and cliffs, loamy soils, and sometimes dry riverbeds at an altitude up to 2000 m above sea level and in drier regions with rainfall ranging from 200 mm to 800 mm per annum.[7,24]

Medicinal uses of *Boscia angustifolia*

The bark, bark fibres, fruits, leaves, roots, stem bark and twigs of *B. angustifolia* are mainly used as cholagogue and purgative, and herbal medicine for bruises, sores and wounds, gastro-intestinal problems, eye problems and otitis, fever and typhoid fever, gonorrhoea and venereal diseases, malaria, respiratory infections, skin problems, swellings and swollen feet, ulcers and ethnoveterinary medicine (Table 1, Figure 1). In Zimbabwe, the roots of *B. angustifolia* are mixed with roots of Vernonia glabra (Steetz) Vatke as herbal medicine for constipation.[47] In Ethiopia, the twigs and roots of *B. angustifolia* are mixed with those of *Capparis tomentosa* Lam., *Carissa spinarum* L., *Croton macrostachyus* Hochst. ex Delile, *Phytolacca dodecandra* L'Hér., *Ruta chalepensis* L., *Securidaca longipedunculata* Fresen. and *Sida schimperiana* Hochst. ex A. Rich. and used against evil spirits and evil eye.[48-54]

Table 1: Medicinal applications of *Boscia angustifolia*

Medicinal use	Parts of the plant used	Country	References
Anthelmintic	Bark, leaves, roots and stem bark	Sudan	Elegami et al.[55]
Bruises, sores and wounds	Bark, leaves and roots	Kenya, Mali, Nigeria and Zambia	Keay et al.[56]; Diallo et al.[57]; Fowler[58]; Hassan et al.[59]; Cheruiyot et al.[60]; Chalo et al.[61]
Cholagogue	Leaves	Mali and Senegal	Chini et al.[62]; Diallo et al.[63]
Constipation	Roots mixed with roots of *Vernonia glabra* (Steetz) Vatke	Zimbabwe	Gelfand et al.[47]
Gastro-intestinal problems (diarrhoea, dysentery and intestinal disorder)	Bark, leaves, roots and stem bark	Ethiopia, Kenya, Mali, Nigeria and Tanzania	Gidey et al.[27]; Keay et al.[56]; Hassan et al.[59]; Chalo et al.[61]; Ahua et al.[64]; Maregesi et al.[65]; Omwenga et al.[66]; Mariita et al.[67]; Omwenga et al.[68]
Dislocated backbone	Roots	Ethiopia	Gidey et al.[27]
Magical purposes (evil spirits and evil eye)	Twigs and roots mixed with *Capparis tomentosa* Lam., *Carissa spinarum* L., *Croton macrostachyus* Hochst. ex Delile, *Phytolacca dodecandra* L'Hér., *Ruta chalepensis* L., *Securidaca longipedunculata* Fresen. and *Sida schimperiana* Hochst. ex A. Rich.	Ethiopia	Zenebe et al.[48]; Enyew et al.[49]; Chekole et al.[50]; Gidey and Asfaw[51]; Hishe and Asfaw[52]; Mekuanent et al.[53]; Fitsumbirhan et al.[54]
Eye problems and otitis	Bark and leaves	Ethiopia and Mali	Chini et al.[62]; Gebrezgabiher et al.[69]
Fertility	Roots	Zambia	Fowler[58]
Fever and typhoid fever	Bark, leaves, roots and twigs	Burkina Faso, Kenya and Nigeria	Keay et al.[56]; Hassan et al.[59]; Cheruiyot et al.[60]; Fowler[70]
Gonorrhoea and venereal diseases	Bark and stem bark	Kenya and Tanzania	Maregesi et al.[65]; Mariita et al.[67]; Omwenga et al.[68]
Headache	Bark	Mali	Diallo et al.[63]; Ahua et al.[64]
Human immunodeficiency virus (HIV)	Roots	Zambia	Chinsembu et al.[71]
Hypertension	Stem	Nigeria	Ajayi et al.[72]
Insanity	Bark and roots	Tanzania	Mathias[73]
Joint pains	Bark	Kenya	Chalo et al.[61]

Medicinal use	Parts of the plant used	Country	References
Malaria	Bark, bark fibres, leaves, stem bark and twigs	Kenya, Mali and Zambia	Fowler[70]; Koch et al.[74]; Bizimana et al.[75]; Kokwaro[76]; Chinsembu[77]; Diarra et al.[78]; Muthaura et al.[79]
Neuralgia	Bark	Mali	Chini et al.[62]
Pain	Leaves	Mali	Danton et al.[80]
Pesticide	Leaves and stems	Kenya	Menge et al.[81]; Karani et al.[82]
Purgative	Bark, fruits, leaves, roots and stem bark	Mali and Sudan	Elegami et al.[55]; Chini et al.[62]
Respiratory infections (chest pains, cough, pneumonia, throat infection and tuberculosis)	Bark, leaves and roots	Ethiopia, Kenya, Nigeria and Tanzania	Keay et al.[56]; Hassan et al.[59]; Cheruiyot et al.[60]; Mariita et al.[67]; Otieno et al.[83]; Legesse[84]
Retained after birth	Leaves and stems	Kenya	Kaingu et al.[85]
Snake bite	Roots and stem bark	Eritrea	Kaushik et al.[86]
Skin problems (boils and mumps)	Leaves, roots and stem bark	Nigeria and Tanzania	Keay et al.[56]; Hassan et al.[59]; Maregesi et al.[65]
Swellings and Swollen feet	Bark	Ethiopia, Kenya, Senegal and Sudan	Chalo et al.[61]; Diallo et al.[63]; Doka and Yagi[87]; Tefera and Kim[88]
Ulcers (gastric and genital)	Roots	Namibia and Zambia	Chinsembu et al.[71]; Chinsembu et al.[89]
Urinary infections	Leaves and roots	Nigeria	Keay et al.[56]; Hassan et al.[59]
Vomiting	Bark, leaves and stems	Kenya	Kaingu et al.[85]; Tsigemelak et al.[90]
Weight loss	Leaves	Burkina Faso	Pare et al.[91]
Ethnoveterinary medicine (ectoparasites, fever, gynaecological problems and wounds)	Bark, leaves and roots	Eritrea, Ethiopia, Kenya and Uganda	Bein et al.[14]; Zorloni[23]; Mekuanent et al.[52]; Gebrezgabiher et al.[69]; Byaruhanga et al.[92]; Kigen et al.[93]

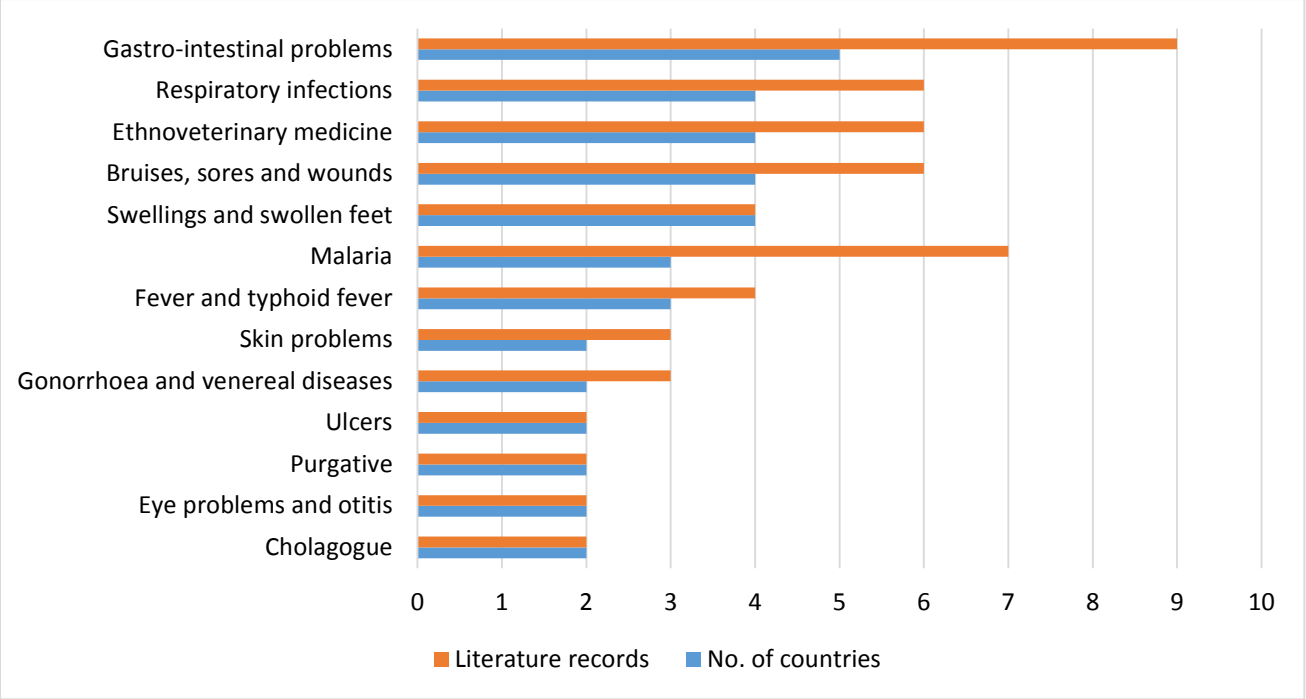

Figure 1. Medicinal applications of *Boscia angustifolia* derived from literature records

Phytochemical and nutritional composition of *Boscia angustifolia*

Several compounds which include alkaloids, amino acid derivatives, carboxylic acids and their derivatives, saponins, sugars and their derivatives (Table 2) have been identified from the bark, fruits, leaves and roots of *B. angustifolia*.[7,19,20,59,62,66,67,94,95] Some of the pharmacological activities associated with the species could be attributed to the documented phytochemical compounds.

Table 2: Phytochemical composition of *Boscia angustifolia*

Phytochemical and nutritional composition	Value	Plant part	Reference
1-Methyl imino thieno [3,4b] naphthalene (%)	10.0	Leaves	Salem et al.[94]
1, 2, 4-Trimethoxy-5,6-dihydrophenanthridin-6-one (%)	2.4	Leaves	Salem et al.[94]
1-H-9-methoxybenz [f] indole (%)	1.9	Leaves	Salem et al.[94]
1,5-Anhydro-d-sorbitol (%)	1.1	Leaves	Salem et al.[94]
2,3,4,5-Tetrahydroxypentanoic acid-1,4-lactone (%)	0.2	Leaves	Salem et al.[94]
2-Deoxy-erythro-pentonic acid (%)	0.3	Leaves	Salem et al.[94]
2-Hydroxy-4-methylpentanoic acid (%)	0.2	Leaves	Salem et al.[94]
4-hydroxystachydrine	-	Bark and leaves	Chini et al.[62]
4-N,N dimethylaminobutyric acid (%)	0.5	Leaves	Salem et al.[94]
7,4'-dimethoxy quercetin	-	Leaves	Salem et al.[94]
Acid detergent fibre (g/kg dry matter)	390.3	Leaves	Osuga et al.[20]
Acid detergent lignin (g/kg dry matter)	94.9	Leaves	Osuga et al.[20]
Allofuranose (%)	0.5	Leaves	Salem et al.[94]
Ash (g/100g of dry matter)	8.0	Fruits	Lemmens[7]
Ash (g/kg dry matter)	115.0	Leaves	Dereje and Udén[19]
Calcium (g/kg dry matter)	22.0	Leaves	Dereje and Udén[19]
Carbohydrates (g/100g of dry matter)	78.0	Fruits	Lemmens[7]
Condensed tannins (g/kg dry matter)	22.7	Leaves	Dereje and Udén[19]
Crude protein (g/kg dry matter)	149.4 – 206.0	Leaves	Dereje and Udén[19]; Osuga et al.[20]
Dry matter (g/kg dry matter)	405.0	Leaves	Dereje and Udén[19]
Energy (kj/100g)	78.0	Fruits	Lemmens[7]
Erythritol (%)	0.6	Leaves	Salem et al.[94]
Esculetin	-	Leaves	Salem et al.[95]
Esculetin 6,7 di-methylether	-	Leaves	Salem et al.[95]
Fat (g/100g of dry matter)	5.0	Fruits	Lemmens[7]
Fibre (g/100g of dry matter)	2.0	Fruits	Lemmens[7]
Fructofuranose (%)	5.8	Leaves	Salem et al.[94]
Glucopyranose (%)	0.3	Leaves	Salem et al.[94]
Glucuronic acid lactone (%)	0.3	Leaves	Salem et al.[94]
Glycerol (%)	2.5	Leaves	Salem et al.[94]
Glycolic acid (%)	0.4	Leaves	Salem et al.[94]
Gulonic acid lactone (%)	0.4	Leaves	Salem et al.[94]
Hexadecanoic acid (%)	0.7	Leaves	Salem et al.[94]
Hydracrylic acid (%)	0.5	Leaves	Salem et al.[94]
in vitro dry matter digestibility (IVDMD) (g/kg dry matter)	0.5	Leaves	Dereje and Udén[19]
Lactic acid (%)	18.1	Leaves	Salem et al.[94]
Lactulose (%)	1.8	Leaves	Salem et al.[94]
Malic acid (%)	1.0	Leaves	Salem et al.[94]
Maltose methyloxime (%)	15.2	Leaves	Salem et al.[94]
Mannitol (%)	1.6	Leaves	Salem et al.[94]
Methyl-3-H pyrrolo [1,2a] indole-9-carboxylate (%)	0.5	Leaves	Salem et al.[94]
Methyl-4-methoxy benzoate	-	Leaves	Salem et al.[95]
Methyl galactoside (%)	0.3	Leaves	Salem et al.[94]
Methyl leucine (%)	1.5	Leaves	Salem et al.[94]
Methyl mannofuranoside (%)	0.2	Leaves	Salem et al.[94]
Myo-inositol (%)	0.4	Leaves	Salem et al.[94]
Neutral detergent fibre (g/kg dry matter)	570.4	Leaves	Osuga et al.[20]
N, N-dimethyl lysine methyl ester (%)	0.2	Leaves	Salem et al.[94]
Organic matter (g/kg dry matter)	885.0 –	Leaves	Dereje and Udén[19];

Phytochemical and nutritional composition	Value	Plant part	Reference
	919.4		Osuga et al.[20]
Pentenal (%)	1.0	Leaves	Salem et al.[94]
Phosphorus (g/kg dry matter)	2.4	Leaves	Dereje and Udén[19]
Phthalic acid decyl octyl ester	-	Leaves	Salem et al.[95]
Proteins (g/100g of dry matter)	7.0	Fruits	Lemmens[7]
Quinic acid (%)	2.5	Leaves	Salem et al.[94]
Rhamnocitrin-4'-O-methylether	-	Leaves	Salem et al.[95]
Rhamnocitrin-3-O-β-glucopyranoside	-	Leaves	Salem et al.[95]
Rhamnocitrin-3-O-β-(6"-O-E-p-coumaroyl)-glucopyranoside	-	Leaves	Salem et al.[95]
Rhamnocitrin-3-O- β-sophoroside	-	Leaves	Salem et al.[95]
Ribitol (%)	1.1	Leaves	Salem et al.[94]
Ribofuranose (%)	0.8	Leaves	Salem et al.[94]
Ribono-1, 4-lactone (%)	0.5	Leaves	Salem et al.[94]
Soluble tannins (g/kg dry matter)	110.0	Leaves	Dereje and Udén[19]
Sorbose (%)	0.4	Leaves	Salem et al.[94]
Stachydrine	-	Bark and leaves	Chini et al.[62]
Sucrose (%)	5.2	Leaves	Salem et al.[94]
Talopyranose (%)	1.4	Leaves	Salem et al.[94]
Tamarixetin-7-O-methylether	-	Leaves	Salem et al.[95]
Tamarixetin-3-O-β-sophoroside-7-O-methylether	-	Leaves	Salem et al.[95]
Tetrahydroxy-2-furanacetaldehyde (%)	0.8	Leaves	Salem et al.[94]
Threonic acid (%)	0.6	Leaves	Salem et al.[94]
Total extractable phenolics (mg/g dry matter)	13.1	Leaves	Osuga et al.[20]
Total extractable tannins (mg/g dry matter)	1.5	Leaves	Osuga et al.[20]
Trehalose (%)	1.3	Leaves	Salem et al.[94]
Turanose (%)	11.9	Leaves	Salem et al.[94]
Water (g/100g)	81.5	Fruits	Lemmens[7]
Xylose, methyloxime (%)	0.5	Leaves	Salem et al.[94]

Biological activities of *Boscia angustifolia*

The following biological activities have been reported from the bark, inner bark, leaves, roots, stem bark, twig and whole plant part extracts and the compound 7,4'-dimethoxy quercetin isolated from *B. angustifolia*: antibacterial,[55,59,66,67,96,97] antimycobacterial,[67] antifungal,[67] antiviral,[94] antioxidant,[94] antiplasmodial,[74,79,98,99] antitrypanosomal,[75,100] $GABA_A$–benzodiazepine receptor binding,[98] larvicidal[100] and cytotoxicity[94,99,102] activities.

Antibacterial activities

Elegami et al.[55] evaluated antibacterial activities of aqueous, chloroform and methanol whole plant part extracts of *B. angustifolia* against *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa* using cup-plate agar diffusion method with ampicillin and neomycin as positive controls. The chloroform and methanol extracts exhibited activities with zone of inhibition ranging from 13 mm to 18 mm which was comparable to 11 mm to 23 mm exhibited by the positive controls.[55] Hassan et al.[59] evaluated antibacterial activities of aqueous, hexane, petroleum ether and chloroform root extracts of *B. angustifolia* against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Salmonella typhi* and *Streptococcus pneumoniae* using the micro dilution technique with tetracycline (10 mg/ml) as a positive control. The aqueous and chloroform extracts were active against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Streptococcus pneumoniae* but did not show activity against *Salmonella typhi* at concentrations ranging from 10 mg/ml to 120 mg/ml with minimum inhibitory concentration (MIC) values ranging from 10.0 mg/ml to 20.0 mg/ml.[59]. Similarly, Hassan et al.[96] evaluated antibacterial activities of chloroform root extracts of *B. angustifolia* against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Salmonella typhi* and *Streptococcus pneumoniae* using the micro dilution technique with tetracycline (10 mg/mL) as a positive control. The extract exhibited activities against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Streptococcus pneumoniae* but did not show activity against *Salmonella typhi* at concentrations of 5 mg/mL to 60 mg/mL with MIC values ranging from 0.6 mg/mL to 1.3 mg/mL.[96] Maregesi et al.[97] evaluated antibacterial activities of aqueous, n-hexane and methanol stem bark extracts of *B. angustifolia* against *Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae* and *Salmonella typhimurium* using a liquid dilution method with ampicillin and rifampicin as positive controls. The n-hexane extract exhibited activities against *Bacillus cereus* with MIC and minimum bactericidal concentration (MBC) value of 500 µg/mL while MIC value of 1000 µg/mL was exhibited against *Staphylococcus aureus*.[97] Omwenga et al.[66] evaluated antibacterial activities of methanol bark

extracts of *B. angustifolia* against *Staphylococcus aureus, Bacillus subtillis, Salmonella typhi, Escherichia coli* and *Pseudomonas aeruginosa* using disc diffusion and micro titre-dilution techniques with amoxicillin and cefrodoxima as positive controls. The extracts exhibited activities against tested pathogens with zone of inhibition ranging from 7.0 mm to 20.0 mm which was comparable to 17.1 mm to 24.2 mm exhibited by amoxicillin. The MIC value against the tested pathogens was 3.8 mg/50µl while the MBC values ranged from 3.8 mg/50µl to 7.5 mg/50µl.[66]. Mariita et al.[67] evaluated antibacterial activities of methanolic bark extracts of *B. angustifolia* against *Salmonella typhi, Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli* and *Klebsiella pneumoniae* using the agar disc diffusion method with amoxicillin and ciprofloxacin as positive controls. The extract exhibited activities against tested pathogens with zone of inhibition ranging from 6.7 mm to 9.0 mm which was lower than 13.0 mm to 21.3 mm exhibited by the positive controls. The MIC and MBC values exhibited against Staphylococcus aureus were 37.5 mg/mL and 75.0 mg/mL, respectively.[67]

Antimycobacterial activities

Mariita et al.[67] evaluated antimycobacterial activities of methanolic bark extracts of B. angustifolia against *Mycobacterium tuberculosis, Mycobacterium Kansasii, Mycobacterium fortuitum* and *Mycobacterium smegmatis* using the BACTEC MGIT 960 system with isoniazid as a positive control. At the highest concentration of 2.0 mg/mL, the extract exhibited activities against tested pathogens.[67]

Antifungal activities

Mariita et al.[67] evaluated antifungal activities of methanolic bark extracts of *B. angustifolia* against *Candida albicans*, using the agar disc diffusion method with fluconazole as a positive control. The extract exhibited activities against the tested pathogen with zone of inhibition of 6.0 mm which was lower than 13.0 mm exhibited by the positive control.[67]

Antiviral activities

Salem et al.[94] evaluated the antiviral activities of aqueous methanol leaf extracts of *B. angustifolia* and the compound 7,4'-dimethoxy quercetin isolated from the species against avian influenza virus (H5N1) using plaque reduction assay. Both the extract and the compound 7,4'-dimethoxy quercetin exhibited activities with a potential activity against H5N1 infection up to 63 and 68.5%, respectively, at concentration of 80 µg/µl.[94]

Antioxidant activities

Salem et al.[94] evaluated the antioxidant activities of aqueous methanol leaf extracts of *B. angustifolia* and the compound 7,4'-dimethoxy quercetin isolated from the species using 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay with ascorbic acid as a positive control. Both the extract and the compound 7,4'-dimethoxy quercetin exhibited activities with half maximal inhibitory concentration (IC_{50}) values of 41.2 µg/ml and 16.5 µg/ml, respectively which were higher that IC_{50} value of 1.9 µg/ml exhibited by the positive control, ascorbic acid.[94]

Antiplasmodial activities

Koch et al.[74] evaluated antiplasmodial activities of chloroform inner bark extracts of *B. angustifolia* against a chloroquine-sensitive (D6) strain of *Plasmodium falciparum* using a semiautomated microdilution technique. The extract showed activity with an IC_{50} value of >10.0 µg/ml.[74] Bah et al.[98] evaluated the antiplasmodial activities of dichloromethane and methanol bark and leaf extracts of *B. angustifolia* against the chloroquine sensitive strain of *Plasmodium falciparum* (3D7) using the parasite lactate dehydrogenase (pLDH) assay. The methanol leaf extract exhibited moderate activities with IC_{50} value of 37.6 µg/ml.[98] Muthaura et al.[79] and Muthaura et al.[99] evaluated antiplasmodial activities of aqueous and methanol stem bark extracts of *B. angustifolia* against chloroquine sensitive (D6) and resistant (W2) *Plasmodium falciparum* using the semi-automated micro-dilution technique that measures the ability of the extracts to inhibit the incorporation of (G-^{3}H) hypoxanthine into the malaria parasite. The aqueous and methanol extracts exhibited activities with IC_{50} values of 1.4 µg/ml and 7.4 µg/ml, respectively against D6, and 4.7 µg/ml and 35.9 µg/ml, respectively against W2.[79,99] Muthaura et al.[99] evaluated the *in vivo* antimalarial activities of aqueous and methanol stem bark extracts of *B. angustifolia* by using chloroquine sensitive *Plasmodium berghei* strain ANKA based on four-day suppressive test. The methanol extract was active in interperitonial injection treatment with chemo-suppression of 60.1% which was lower than 99.9% chemo-suppression of malaria parasites exhibited by the positive control, chloroquine.[99]

Antitrypanosomal activities

Bizimana et al.[75] evaluated the antitrypanosomal activities of water, methanol and dichloromethane leaf and twig extracts of *B. angustifolia* using the low inoculation long Incubation test (LILIT) with diminazene aceturate as a positive control. All the extracts exhibited activities with MIC value of 10.0 µg/ml while diminazene aceturate exhibited MIC value of 0.05 µg/ml.[75] Aderbauer et al.[100] evaluated antitrypanosomal activities of dichloromethane stem bark extracts of *B. angustifolia* using the long-term viability assay on *Trypanosoma brucei brucei*. The extracts exhibited activities with minimum toxic concentration (MTC) and MIC values of 100.0 µg/ml and 200.0 µg/ml, respectively.[100]

$GABA_A$–benzodiazepine receptor binding activities

Bah et al.[98] evaluated the $GABA_A$–benzodiazepine receptor binding activities of dichloromethane and methanol bark and leaf extracts of *B. angustifolia* using the GABAA–benzodiazepine receptor binding assay. A weak $GABA_A$-receptor complex binding activity was exhibited by dichloromethane leaf extract.[98]

Larvicidal activities

Cepleanu et al.[101] evaluated larvicidal activities of aqueous, dichloromethane and methanol root bark and stem bark extracts of *B. angustifolia* by assessing the effect of extracts at a concentration of 500 mg/ml on mortality of 2nd instar larvae of *Aedes aegypti* with diazinon as a positive control. Only dichloromethane root bark extract exhibited weak activities with LC_{100} value after 24 hours of 250.0 µg/ml which was higher than LC_{100} value of 0.1 µg/ml exhibited by the positive control.[101]

Cytotoxicity activities

Hassan et al.[102] evaluated the toxicological effects of the alkaloid and aqueous ethanol root extracts of *B. angustifolia* on biochemical indices of kidney and liver functions in Wister albino rats. The renal and liver indices were significantly altered at higher doses of alkaloidal extract at 703.6 mg/kg and 1125.7 mg/kg, and aqueous methanol extract at 839.3 mg/kg and 1342.8 mg/kg body weight. The extracts produced histopathological lesions of the liver and kidney such as perivascular cuffs, protein cast, infiltration, slight infiltration at higher doses. There was a significant dose dependent decrease in weight in the rats given higher doses of the extract.[102] Muthaura et al.[99] evaluated the cytotoxicity activities of aqueous and methanol stem bark extracts of *B. angustifolia* on Vero cells using the plaque reduction assay. The methanol and water extracts were non-toxic with CC_{50} value of 1000.0 µg/mL and 6720.0 µg/mL, respectively.[99] Salem et al.[94] evaluated cytotoxicity activities of aqueous methanol leaf extracts of *B. angustifolia* and the compound 7,4'-dimethoxy quercetin isolated from the species using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay. Both the extract and the compound 7,4'-dimethoxy quercetin exhibited activities with TC_{50} values of 151.0 µg/µl and 81.0 µg/µl, respectively.[94]

CONCLUSION

The present review summarizes the botany, medicinal uses, phytochemistry and pharmacological properties *B. angustifolia*. Based on presented information, 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 identification of the bioactive compounds of the species and their associated pharmacological activities.

Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this paper.

Figure legend

Figure 1. Medicinal applications of *Boscia angustifolia* derived from literature records

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