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A review of botany, medicinal uses, phytochemistry and biological activities of *Erythrophleum africanum*

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Abstract

Erythrophleum africanum is a medium-sized to large tree widely used as traditional medicine throughout its distributional range in tropical Africa. This study is aimed at providing a critical review of the botany, medicinal uses, phytochemistry and biological activities of *E. africanum*. Documented information on the botany, medicinal uses, phytochemistry and biological activities of *E. africanum* was collected from several online sources which included BMC, Scopus, SciFinder, Google Scholar, Science Direct, Elsevier, Pubmed and Web of Science. Additional information on the botany, medicinal uses, phytochemistry and biological activities of *E. africanum* was gathered from pre-electronic sources such as book chapters, books, journal articles and scientific publications obtained from the University library. This study showed that the bark, leaves, roots and stem bark of *E. africanum* are mainly used as analgesic and emetic, and traditional medicines for diabetes, epilepsy, gastro-intestinal problems, headache, menstrual problems, mental problems, rheumatism and arthritis, sexually transmitted diseases, skin diseases and toothache. The bark, leaves, seeds and stems of *E. africanum* contain alkaloids, cardiac glycosides, flavonoids, saponins, steroids, tannins and terpenoids. Pharmacological research revealed that the leaf and twig extracts of *E. africanum* exhibited antibacterial, antifungal, antidote, antioxidant and toxicity activities. There is need for clinical and toxicological evaluations of crude extracts and compounds isolated from the species since *E. africanum* contains potentially toxic compounds.

Keywords: Caesalpinioideae, ethnopharmacology, *Erythrophleum africanum*, Fabaceae, herbal medicine, indigenous pharmacopeia

INTRODUCTION

Erythrophleum africanum (Welw. ex Benth.) Harms is a medium-sized to large tree belonging to the subfamily Caesalpinioideaethe of the Fabaceae family. The bark, leaves and roots of *E. africanum* are considered to be poisonous.[1,2] Therefore, *E. africanum* is regarded as toxic and lethal to livestock throughout the distributional range of the species, particularly goats, sheep and cows.[1-8] Closely related species such as *E. chlorostachys* (F. Muell.) Baillon, *E. couminga* Baill., *E. ivorense* A. Chev., *E. lasicanthum* Corbishley and *E. suaveolens* (Guill. & Perr.) Brenan are also known to be poisonous.[8-19] *Erythrophleum africanum* is widely used as an ordeal poison throughout its distributional range for executing capital punishment for witches and enemies, and the species is also used as an insecticide.[1,8,9,15,20] In spite of literature reports emphasizing toxicological properties of the various parts and compounds isolated from the species, *E. africanum* is also a popular traditional medicine throughout its distributional range in tropical Africa. For example, in Côte d'Ivoire and Nigeria, the stem of *E. africanum* is widely used as mouth wash and toothpick.[4,8,21-23] The roots of *E. africanum* are sold in informal herbal medicine markets as traditional medicine in Belgium,[24] the Democratic Republic of Congo (DRC)[15] and Mozambique.[25] Moreover, *E. africanum* and other related species such as *E. couminga*, *E. ivorense*, *E. lasicanthum* and *E. suaveolens* are regarded as important sources of traditional medicines in tropical Africa, and these species are included in the book "Plant resources of tropical Africa 11: medicinal plants 1".This book is an encyclopaedic guide on plants widely used as traditional medicines in tropical Africa, including their medicinal applications, ethnopharmacological properties, description, geographical distribution, trade, management and ecology.[26] It is therefore, within this context that this review was undertaken aimed at reviewing the botany, medicinal uses, phytochemical and biological activities of *E. africanum* so as to provide baseline data required in evaluating the therapeutic potential of the species.

Botanical profile of *Erythrophleum africanum*

The genus *Erythrophleum* Afzel. ex G. Don consists of about 10 species distributed in continental Africa, Madagascar, eastern Asia and Australia.[17] The genus name is derived from the Greek words "*erythros*" meaning "red" and "*phloios*" meaning "bark of trees", that is, red bark in reference to red sap produced by some African tree species.[27] Several species of the genus are often called "redwater trees" because a red sap is exuded when the bark is cut and this colours water red.[1] The specific name "*africanum*" means "of Africa". Synonyms associated with this species include *Caesalpiniodes africanum* (Welw. ex Benth.) Kuntze, *Cordyla densiflora* Milne-Redh., *E. africanum* Harms, *E. africanum* (Welw. ex Benth.) Harms var. *stenocarpum* Harms, *E. africanum* var. *stenocarpum* Harms, *E. pubistamineum* Henn., *E. pubistamineum* Henn. var. *parvifolium* Schinz and *Gleditsia africana* Welw. ex Benth.[28-30] The English common name of *E. africanum* is "ordeal tree" since the bark of the tree has been used as an ordeal poison in several countries. *Erythrophleum africanum* is a medium-sized to large tree, growing to a height of 15 metres.[1,2] The bole is straight and cylindrical, up to 120 cm in diameter with a fairly dense and spreading crown.[15] The bark is grey in colour and smooth in young trees and becoming red-brown, rough and fissured with age. The leaves are alternate, egg-shaped to oblong, finely velvety, particularly when young and on the under surface. The apex of the leaf is broadly tapering to rounded or notched and the base is broadly tapering with entire margins. Flowers are cream to yellow in colour, sweetly scented,

occurring in more or less dense spikes and often grouped together in large heads. The fruit is a pod, splitting along both sides simultaneously and each section curving backwards. The species has been recorded in bushveld, riverine thickets, dry savanna of the Sahel and deciduous woodland in hot, dry, low-lying areas that are associated with sandy soils at an altitude ranging from 250 m to 1600 m above the sea level.[29,31] *Erythrophleum africanum* has been recorded in Angola, Benin, Botswana, Burkina Faso, Central African Republic, Chad, the DRC, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Malawi, Mali, Mozambique, Namibia, Nigeria, Rwanda, Senegal, South Sudan, Sudan, Tanzania, Togo, Zambia and Zimbabwe.[28-44]

Medicinal uses of *Erythrophleum africanum*

The bark, leaves, roots and stem bark of *E. africanum* are mainly used as analgesic and emetic, and traditional medicines for diabetes, epilepsy, gastro-intestinal problems, headache, menstrual problems, mental problems, rheumatism and arthritis, sexually transmitted diseases, skin diseases and toothache (Table 1; Figure 1). In Belgium, the bark of *E. africanum* is mixed with red earth and palm oil (*Elaeis guineensis* Jacq.) to rejuvenate the skin.[24] In Zambia, the leaves of *E. africanum* are mixed with roots of *Ximenia caffra* Sond. var. *natalensis* Sond. as traditional medicine for stomach problems.[45]

Table 1: Medicinal uses of *Erythrophleum africanum*

Medicinal use	Parts used	Country	References
Abortifacient	Leaves	Nigeria	Mohammed et al.[8]; Jinju[46]; Dalziel[47]; Alhaji[48]
Analgesic	Leaves and roots	Angola and Namibia	Mohammed et al.[8]; Kawanga[15]; Quattrocchi[27]; Alhaji[48]; Dushimemaria et al.[49]; Lautenschläger et al.[50]
Cancer	Leaves and stem bark	DRC	Mohammed et al.[8]; Amuri et al.[51]
Cough and respiratory problems	Roots	Angola	Catarino et al.[52]
Diabetes	Leaves and stem bark	DRC and Nigeria	Mohammed et al.[8]; Dalziel[47]; Alhaji[48]; Amuri et al.[51]
Diuretic	Stem bark	Côte d'Ivoire	Kadja et al.[21]
Emetic	Roots and stem bark	Côte d'Ivoire and Tanzania	Mohammed et al.[8]; Kawanga[15]; Kadja et al.[21]; Quattrocchi[27]; Alhaji[48]; Kokwaro[53]
Epilepsy	Leaves	Angola and Guinea-Bissau	Kawanga[15]; Alhaji[48]; Bossard[54]; Romeiras et al.[55]
Eye problems	Leaves	Angola	Bossard[54]
Fever and malaria	Roots	Angola	Catarino et al.[52]
Fish poison	Leaves	Angola	Bossard[54]
Fistula	Leaves	DRC	Gelfand et al.[56]
Gastro-intestinal problems (diarrhoea, dysentery, intestinal problems and stomach pains)	Bark, leaves and roots	Angola and Zimbabwe	Mohammed et al.[8]; Kawanga[15]; Quattrocchi[27]; Dalziel[47]; Alhaji[48]; Catarino et al.[52]; Gelfand et al.[56]
Goiter	Leaves	Nigeria	Mohammed et al.[8]; Dalziel[47]; Alhaji[48]
Haemorrhoids	Roots	Togo	Tchacondo et al.[57]
Headache	Leaves and roots	Angola and Namibia	Catarino et al.[52]; Hedimbi and Chinsembu[58]
Heart diseases	Roots	Angola	Mohammed et al.[8]; Kawanga[15]; Dalziel[47]; Alhaji[48]; Catarino et al.[52]
Hernia	Leaves	DRC	Gelfand et al.[56]
Intestinal parasites	Leaves	DRC	Gelfand et al.[56]
Magical purposes	Stem bark	Côte d'Ivoire	Kadja et al.[21]
Menstrual problems	Bark and roots	Angola and Zimbabwe	Kawanga[15]; Quattrocchi[27]; Alhaji[48]; Lautenschläger et al.[50]
Mental problems	Roots	Angola and Namibia	Mohammed et al.[8]; Kawanga[15]; Bulkill[20]; Junju[46]; Dalziel[47]; Alhaji[48]; Catarino et al.[52]; Cheikhyoussef et al.[59]
Nose bleeding	Roots	Angola	Lautenschläger et al.[50]
Rheumatism and arthritis	Leaves, roots and stem bark	Angola and DRC	Amuri et al.[51]; Catarino et al.[52]
Scoliosis	Roots	Angola	Lautenschläger et al.[50]
Sexually transmitted diseases and gonorrhoea	Leaves	Namibia and Nigeria	Mohammed et al.[8]; Jinju[46]; Alhaji[48]; Hedimbi and Chinsembu[58]; Cheikhyoussef et al.[59]
Skin diseases (chicken pox, leprosy and scabies)	Leaves and root bark	Namibia and Nigeria	Mohammed et al.[8]; Kawanga[15]; Burkill[20]; Quattrocchi[27]; Jinju[46]; Dalziel[47]; Alhaji[48]
Rejuvenate skin	Bark mixed with red earth and	Belgium	Van Andel and Fundiko[24]

Medicinal use	Parts used	Country	References
	palm oil (*Elaeis guineensis* Jacq.)		
Snakebite	Leaves	Togo	Tchacondo et al.[57]
Sores and wounds	Leaves	Nigeria	Mohammed et al.[8]; Dalziel[47]
Stomach problems	Leaves mixed with roots of *Ximenia caffra* Sond. var. *natalensis* Sond.	Zambia	Roodt[45]
Toothache	Bark, leaves, roots and stem bark	Angola, Côte d'Ivoire and Ghana	Kawanga[15]; Kadja et al.[21]; Quattrocchi[27]; Alhaji[48]; Lautenschläger et al.[50]; Catarino et al.[52]
Ethnoveterinary medicince (diarrhoea)	Leaves	Nigeria	Offiah et al.[60]

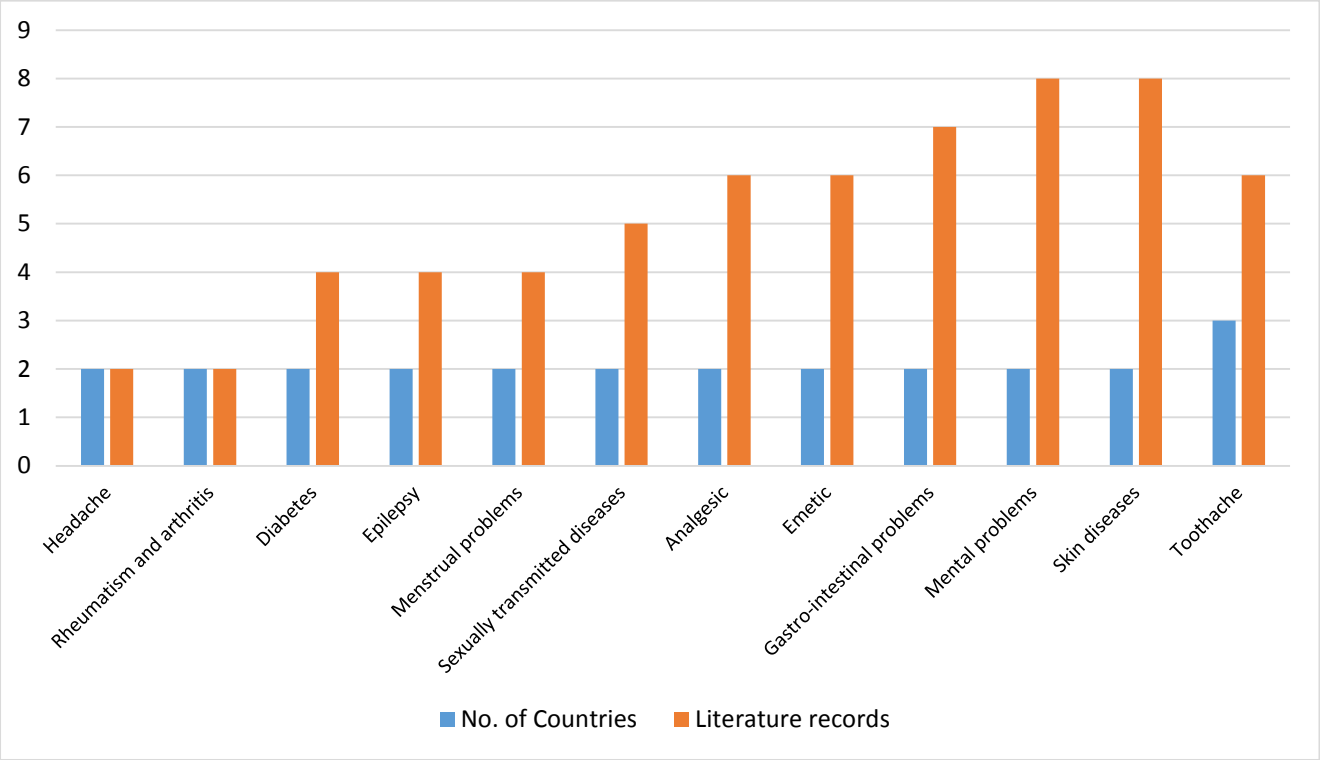

Figure 1. Medicinal applications of *Erythrophleum africanum* derived from literature records

Table 2: Phytochemical compounds and chemical elements identified from *Erythrophleum africanum*

Phytochemical compound or element	Value	Plant part	Reference
Aglycones (mg/g)	0.1	Stems	Kadja et al.[21]
Alkaloids (% w/v)	0.2	Leaves	Hassan et al.[62]
Alumunium (%)	0.6	Stems	Kadja et al.[23]
2-Amino-4-methylpentanedioic acid	-	Seed	Watson and Fowden[63]; Bisby et al.[64]
Anthocyanidins (mg/g)	1.8	Stems	Kadja et al.[21]
Baikiain (S)-form	-	Seeds	Watson and Fowden[63]; Bisby et al.[64]
Calcium (%)	12.0	Stems	Kadja et al.[23]
Cardiac glycosides (% w/v)	0.2 – 4.3	Leaves	Hassan et al.[62]
Cassamidine	-	Bark	Bisby et al.[64]; Jansson and Cronlund[65]
Dihydromyricetin	-	Leaves	Hänsel and Klaffenbach[66]
Epicatechin gallate	-	Stem	Kadja et al.[22]; Kadja et al.[23]
Epigallocatechin gallate	-	Stem	Kadja et al.[22]; Kadja et al.[23]
Erythrophlamine	-	Bark	Bisby et al.[64]; Jansson and Cronlund[65]
Erythrophleum alkaloid A	-	Bark	Bisby et al.[64]; Jansson and Cronlund[65]
Flavonoid glycosides (% w/v)	4.3	Leaves	Hassan et al.[62]
Free flavonoids (% w/v)	4.3	Leaves	Hassan et al.[62]
Gallic acid	-	Stems	Kadja et al.[22]; Kadja et al.[23]
Iron (%)	1.0	Stems	Kadja et al.[23]

Phytochemical compound or element	Value	Plant part	Reference
Magnesium (%)	6.0	Stems	Kadja et al.[23]
Manganese (%)	0.2	Stems	Kadja et al.[23]
Norerythrophlamide	-	Bark	Bisby et al.[64]; Jansson and Cronlund[65]
Norerythrostachamide	-	Bark	Bisby et al.[64]; Jansson and Cronlund[65]
Phosphorus (%)	4.5	Stems	Kadja et al.[23]
2-Piperidinecarboxylic acid (S)-form	-	Seeds	Watson and Fowden[63]; Bisby et al.[64]
Potassium (%)	21.0	Stems	Kadja et al.[23]
Pseudotannins (% w/v)	0.2	Leaves	Hassan et al.[62]
Saponin (% w/v)	1.2	Leaves	Hassan et al.[62]
Silicon (%)	1.5	Stems	Kadja et al.[23]
Sulfur (%)	1.0	Stems	Kadja et al.[23]
Tannin (% w/v)	0.2	Leaves	Hassan et al.[62]
Titanium (%)	0.05	Stems	Kadja et al.[23]
Total flavonoids (%)	0.05	Stems	Kadja et al.[21]
Zinc (%)	0.05	Stems	Kadja et al.[23]

Antibacterial activities

Mohammed et al.[8] evaluated antibacterial activities of n-hexane, chloroform, ethyl acetate, n-butanol and aqueous leaf extracts of *E. africanum* against *Staphylococcus aureaus, Streptococcus feacalis, Escherichia coli, Pseudomonas aeruginosa, Salmonella typhi* and *Proteus vulgaris* using the agar diffusion method and broth dilution techniques. The extracts exhibited activities against *Staphylococcus aureaus, Escherichia coli, Pseudomonas aeruginosa* and *Proteus vulgaris* with zone of inhibition ranging from 12.0 mm to 36.0 mm. The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) ranged from 3.3 mg/ml to 15.0 mg/ml and 3.3 mg/ml to 30.0 mg/ml, respectively.[8] Alhaji[48] evaluated antibacterial activities of ethanol leaf extracts of *E. africanum* against *Staphylococcus aureaus, Streptococcus feacalis, Corynebacterium ulcerans, Enterobacter cloacae, Escherichia coli, Pseudomonas aeruginosa* and *Proteus mirabilis* using agar well diffusion method and broth dilution techniques with sparfloxacin (2 mg/ml) as a positive control. The extract exhibited activities against *Staphylococcus aureaus, Streptococcus feacalis, Enterobacter cloacae* and *Proteus mirabilis* with zone of inhibition ranging from 22 mm to 29 mm which was comparable to 29 mm to 36 mm exhibited by the positive control. The MIC and MBC values were 1.3 mg/ml to 2.5 mg/ml and 1.3 mg/ml to 10.0 mg/ml, respectively.[48] Kadja et al.[23] evaluated antibacterial activities of hydroacetonic stem extract of *E. africanum* against *Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus* and *Micrococcus luteus* using the agar diffusion method and broth dilution techniques. The extract exhibited activities against *Staphylococcus aureaus* and *Micrococcus luteus* with zone of inhibition values of 10.0 mm and 19.0 mm, respectively. The MIC and MBC against *Staphylococcus aureaus* were 156.0 µg/mL and 312.0 µg/mL, respectively while MIC and MBC against *Micrococcus luteus* was 78.0 µg/mL.[23]

Antifungal activities

Mohammed et al.[8] evaluated antifungal activities of n-hexane, chloroform, ethyl acetate, n-butanol and aqueous leaf extract of *E. africanum* against *Candida albicans, Candida krusei* and *Candida tropicalis* using the agar diffusion method and broth dilution techniques. The extracts exhibited activities against *Candida albicans* and *Candida tropicalis* with zone of inhibition ranging from 17.0 mm to 25.0 mm. The MIC and minimum fungicidal concentration (MFC) values ranged from 3.3 mg/ml to 15.0 mg/ml and 3.3 mg/ml to 30.0 mg/ml, respectively.[8] Alhaji[48] evaluated antifungal activities of ethanol leaf extracts of *E. africanum* against *Candida albicans* and *Candida stellatoidea* using agar well diffusion method and broth dilution techniques with fluconazole (5 mg/ml) as a positive control. The extract exhibited activities against *Candida stellatoidea* with zone of inhibition of 24 mm which was lower than 32 mm to 39 mm exhibited by the positive control. The MIC and MFC values were 1.3 mg/ml to 2.5 mg/ml and 1.3 mg/ml to 5.0 mg/ml, respectively.[48]

Antidote activities

Zailani et al.[61] evaluated the antidote activities of aqueous leaf extract of *E. africanum* by administering 2000 mg/kg body weight of the extract on albino rats. The extract exhibited activities by raising the levels of aspartate transaminase, alanine transaminase and alkaline phosphatase, and also decreasing the levels of total protein.[61]

Antioxidant activities

Kadja et al.[21] evaluated the antioxidant activities of methanol stem extracts of *E. africanum* using the 2,2'-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging assay with vitamin C as a positive control. At concentrations ranging from 0.10 mg/ml to 0.48 mg/ml, the extracts exhibited percentage inhibition of the DPPH ranging from 65.0% to 67.0% which was comparable to 69.1% to 69.7% exhibited by vitamin C, the positive control.[21] Kadja et al.[23] evaluated the hydroacetonic activities of methanol stem extracts of *E. africanum* using the DPPH free radical scavenging assay with vitamin C and butylhydroxytoluene (BHT) as positive controls. At concentrations ranging from 0.25 mg/mL to 8.0 mg/mL, the extract exhibited percentage inhibition of the DPPH ranging from 38.0% to 92.2%.[23]

Toxicity activities

Hassan et al.[62] evaluated the acute and sub-acute toxicity activities of *E. africanum* aqueous leaf extracts by orally administering 1 mL of 1000 mg/kg, 2000 mg/kg and 3000 mg/kg body weight to Wister albino rats once daily for 28 days and toxicological effects were assessed. The lethal dose (LD_{50}) was greater than 3000 mg/kg and sub-acute administration of the extract resulted in some changes in renal and liver in the form of moderate and marked infiltration with necrosis and perivascular lymphocytic cuff.[62]

CONCLUSION

Erythrophleum africanum is a known poisonous plant[1,2] and there is need to strike a balance between the medicinal potential of the species on one hand and its adverse and toxic effects on the other. At the present moment there is very little ethnobotanical information on the poisonous properties of *E. africanum*, whether it causes superficial irritation or discomfort through its use as traditional medicine or contact with the skin during usage or collection or serious poisoning when ingested. Therefore, the widespread use of *E. africanum* in tropical Africa as traditional medicine suggest that the species is not taken at toxic dosages. But use of *E. africanum* for the treatment of human diseases and ailments should be treated with caution and rigorous toxicological and clinical studies on the bark, leaves, roots, stems and compounds isolated from the species are necessary.

Conflict of interest

The author declares that he has no conflict of interest.

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