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Review of the Multifaceted Therapeutic Potential of *Kigelia africana*: Medicinal, Pharmacological, and Economic Perspectives in Prevention and Treatment of Diseases

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Abstractd

Our world harbours a rich source of medicinal plants that are used in treating a wide range of diseases that have become a serious trait to mankind. Medicinal plants play a key role in the management of various diseases. Kigelia africana (K. africana), popularly known as the Sausage tree, is a multipurpose medicinal plant with many attributes and considerable potential. In African folklore and traditional medicine, the mysterious sausage tree, K. africana, has long been revered. Native American societies have long used this plant's unusual fruit, bark, and leaves as cultural artifacts and treatments for a wide range of illnesses. This extraordinary plant species has gained more attention recently, though not just as a representation of Africa's vast botanical diversity, but also as a reservoir of potential with a variety of uses that is just waiting to be discovered and realized. This has interested scientists, who have examined K. africana plant parts for their bioactivity, especially in developing nations where orthodox medicine are meager, expensive, or inaccessible. The various chemical constituents such as the naphthaquinones, iridoids, fatty acids, norviburtinal, sterols, lignans, terpenoids, and flavonoids are the essential building blocks responsible for its wide range of activities. Ethno-medicinal plant-use data in many forms has been heavily utilized in the development of formularies and pharmacopoeias, providing a major focus in global healthcare and contributing substantially to the drug development process. This review provides an insightful understanding on the ethnobotany, phytochemistry, medicinal uses, chemical constituents, pharmacological properties, and economic importance of K. africana in Africa specifically Nigeria. This plant has great potential to be developed as a drug by pharmaceutical industries but before recommending its use in modern systems of medicine, clinical trials are to be done.

Keywords: Kigelia africana, chemical constituents, medicinal properties, and pharmacological properties.

Introduction

Research has shown that 70 to 80% of the world population uses plants for their primary healthcare. Medicinal plants are globally valuable sources of herbal products, meaning that people are worldwide using them both in folk medicine and pharmacological studies leading to various discoveries on their properties but many wild populations where plants are harvested are under threat and some are disappearing at a high speed (Van *et al.,* 2016).

Medicinal plants play a very significant role in indigenous healthcare systems for humans, especially in developing countries where access to allopathic medicines and practitioners is limited (Yaduma *et al*., 2018). Throughout Africa, communities have relied on medicinal plants for centuries because they are easy to access, culturally appropriate, and considered safe (Tabuti *et al.,* 2012). Due to the importance of medicinal plants to human life, it is necessary to investigate the ethnobotanical knowledge related to the medicinal and medico magic utilization of plant species. (Dossou *et al.,* 2017). Research has shown that 70 to 80% of the world population uses plants for their primary healthcare. Furthermore, plant species harvested from wild populations serve as raw materials for commercial pharmaceutical factories and for local informal trade (Chen *et al.,* 2016). Medicinal plants are globally valuable sources of herbal products, meaning that people are worldwide using them both in folk medicine and pharmacological studies leading to various discoveries on their properties but many wild populations where plants are harvested are under threat and some are disappearing at a high speed (Van *et al.,* 2016). In turn, this has threatened the plant species from which such materials are sourced. Furthermore, most of the plant resources are threatened by unsustainable harvesting, habitat modification and conversion (Chen *et al.,* 2016).

Kigelia africana (Lam.) Benth is one of those tree species that have been heavily exploited for their medicinal, religious and cultural values (Yaduma *et al.,* 2018; Komakech *et al.,* 2020). It belongs to the family of Bignoniaceae and is the only species in the genus *Kigelia. Bignoniaceae* is the trumpet creeper or catalpa family of the mint order of flowering plants (Lamiales). It contains about 110 genera and more than 800 species of trees, shrubs and, most commonly, vines, chiefly of tropical America, tropical Africa and the Indo-Malayan region. *Kigelia africana* is endemic to Africa and distributed throughout the continent (Pariya *et al.,* 2013).

K. africana has been used in the management of human ailments since time immemorial, ethnobotanists have documented the traditional uses of *K. africana*, which include treatment of anticancer, antiulcer, anti-aging, antioxidant, and anti-malaria drugs. It is also widely applied in the treatment of infections, gynaecological disorders, hepato-renal disorders, sickle-cell anaemia, central nervous system depression, respiratory ailment, skin diseases, body weakness, leprosy, impetigo, worm infestation, scalp, athlete's foot, tumours, etc. The basic aim of the review is to accumulate information on the traditional use of *K. africana* relevant to the control of diabetes, cancer and hepatic disease, with *K. africana*, plants part, so as to enable researchers to unveil and confirm the presence of those therapeutic properties in the plant species. Diabetes prevalence is on the rise worldwide as a result of accumulating risk factors well pronounced in economically growing nations. An estimated 69% rise is observed in the prevalence of the disease in adults in developing countries versus 20% for adults in developed countries (Shaw *et al.,* 2010). A complex mechanism involving enzymes and other factors influences the action of insulin in the management of hyperglycemia (Elkanah *et al.,* 2022). Mainstream drugs that are used to control diabetes fall into three main categories. The first category of drugs aims to enhance endogenous insulin availability and includes agents that act on the sulfonyl urea receptors in the pancreas to promote insulin secretion and others that have an impact on the small intestinal mucosal epithelium. Medicines categorized as group two are directed topotentiate the response to insulin, among them being thiazoline, which is ine of the chemical constituents of *K. africana.* This group of drugs seems to act as initiator of peroxisomal receptors responsible for regulation of metabolism of carbohydrates, lipids and proteins. The drugs categorized as group three are represented by α-glucosdiase inhibitors and are targeted at reducing the metabolism of complex sugars (Thompson *et al.,* 2017). A number of reviews from different countries have highlighted the significance of *K. africana* application for the control of diabetes. Despite the wide-spread traditional use of these plants for diabetes management in Africa, scientific support for the safe and effective use of such plants is insufficient (Ezuruike *et al.,* 2014; Yaduma *et al*., 2018).

Cancer is a disease characterized by abnormal cell division and proliferation that result from disruption of molecular signals that control these processes (Hejmadi *et al.,* 2009). In the year 2000, lung (12.3%), breast (10.4%) and colorectum (9.4%) were the most prevalent forms of cancer worldwide (Ferlay *et al*., 2001). By the year 2015, cancer was the second leading cause of death globally resulting to 8.8 million deaths (WHO 2018). One in six deaths globally is caused by cancer with 70% prevalence in developing countries. Incidences in these countries account for more than half of all new cancer cases globally and will represent more than 80% of global

cancer burden by 2030 (Farmer *et al.,* 2010). About 80% of the human population depends on plants for their primary health care (Aung *et al.,* 2017). As many as 35000 plant species have been screened for anti-cancer activities previously, leading to the discovery of clinically important anti-cancer drugs such as Vincristine, Vinblastine, Taxol, Indicine–N-oxide, Etoposides and Camptothecin, with ability to inhibit growth of cancer cells by controlling apoptosis and autophagic pathways (Shaikh *et al.*, 2016). However, due to multidrug resistance and toxic effects of current chemotherapeutic drugs to other non-target tissues, development of new bioactive molecules with fewer side effects and greater efficacy is essential (Kanase *et al.*, 2018). The plant is used in many traditional medicine systems to control various diseases including cancer, research by Chinsembu *et al*., 2019 on the *in-vitro* activities of dichloromethane and methanol extracts of *K. africana* against the breast cancer cell line (HCC-1937) shows that the plants exhibit high *in-vitro* anti-cancer activity against the human breast cancer cell line HCC (Houghton *et al.,* 2010). In Africa stem bark of *K. africana* is boiled and taken orally in one glass (300 ml) twice a day for three months to cure breast, lung, and skin cancers (Ochwang'i *et al.,* 2014). In Malawi and Nigeria, boiling water extract of *K. africana* is used to treat stomach cancer and urinary tract infections (Oyelami *et al.,* 2012).

The liver is a glandular organ that acts like a factory for the production of substances that break down fats, produce urea, convert glucose to glycogen, make certain amino acids and many other functions. The hepatic protective substance is a substance that inhibits oxidation to protect body cells from the damaging effects of oxidation. It can bind to free oxygen radicals preventing these radicals from damaging healthy cells (Moss, 2000). The bark of *K. africana* Lam. (Benth.) as a powder is used in traditional medicine for ulcers treatment, and other hepato related disease. The methanol extract of *K. africana* revealed marked antipyretic activity based on the pyrogen induced fever reduction in rabbits. Although the aqueous extract effect was not statistically significant. In other hand the ethanolic stem bark extract of the plant can stimulate Central Nervous System in which by this property the plant can be explored for therapeutic advantage (Owolabi *et al.*, 2008). Furthermore, the stem bark of *K. africana* revealed that the crude ethanol extract has some activities such as antibacterial and antifungal, the aqueous extract showed no antibacterial or antifungal activity (Omonkhelin *et al.,* 2007). *Kigelia africana* has several synonyms, some of which include: *Kigelia pinnata* (Jacq.) DC., Bignonia africana Lam., *Crescentia pinnata* Jacq., *Kigelia abyssinica* A. Rich., Kigelia aethiopica Decne., Kigelia aethiopum (Fenzl) Dandy, Kigelia erytraeae Mattei, Kigelia ikbaliae De Wild., Kigelia somalensis Mattei, Kigelia acutifolia Engl. ex Sprague, *Kigelia elliotii Sprague*, *Kigelia elliptica*

Sprague, Kigelia impressa Sprague, Kigelia spragueana Wernham, Kigelia talbotii Hutch. & Dalziel, Tanaecium pinnatum (Jacq.) Willd. and *Tecoma africana* (Lam.) G. Don). The common name of *K. africana* is "sausage tree", which is derived from the shape of its fruits, which look like a sausage (Singh *et al.,* 2018).

The local names of *K. africana* vary throughout Africa due to the ethnic and cultural diversity on the continent. The many dialects reflect *K. africana's* ethnobotanical significance among several African communities (Arbonnier, 2022). Some of *K. africana's* local African names include: Nufuten, Nanaberetee (Ashanti and Akwapem), Etua (Fante), Blimmo (Baule), Akpele (Ga), Lele (Adanme), Nyakpe (Ewe), Rawuya (Hausa), Jilahi (Fulani), Bulungu (Kanuri), Bechi (Nupe), Pandoro (Yoruba), Ugbongbon (Bini), Uturubein (Ibo), Abu Shutor, Abu Sidra, Um Shutur, Umm Hashatur (Arabic), Rangbarabgbo (Zande), muVeve (Tonga), muVumati (Ndau), muZunguru (KalanBa), mPolota (Lozi), umBvewe, iPfungwani, muBvee (Shona, Zezuru, Manyika), Mufungufungu (Bemba and Lozi), ~lunguli (Lozi) Muzungule (Lozi and Tonga), Kufungule (Kaonde) Ifungufungu, Mufunofuno (Lunda), Chizutu, Mvula, Mvunguti (Nyanja). Muratina, (Kikuyu and Meru), Muatini, Kiatine (Kamba), Hwasini, Mvongonia (Teita), Ol-Suguroi, Ol-Darpoi (Masai), Yago (Luo), Morabe (Kakamega), Mvungunya, Mvungavunga, Hwegea, Mwicha, Mranaa (Swahili), Muratini (Gitiama), Mukisha (Taveta), Ratiunet (Nandi), Ratiunet (Kipsigi), Sheole (Boni), Modukguhlu (Sepedi), Muvevha (Venda), Worsboom (Afrikaans), Hantsar giiwaa (Hausa), Yago (Acholi), Edodoi (Ateso), Sifungu (Lugisu), Naizungwe (Lusoga), Omusa (Luganda), Roti (Pokot) and Bukuraal (Somalia) (Arbonnier, 2022). The many traditional medicinal uses of *K. africana* have attracted significant scientific interest in the species' pharmacological activity.

Scientific classification

Kingdom:Plantae

Clade:Tracheophytes

Clade:Angiosperms

Clade:Eudicots

Clade:Asterids

Order:Lamiales

Family:Bignoniaceae

Clade:Crescentiina

Clade:Paleotropical clade

Genus:Kigelia DC.

Species: K. africana

Binomial name: Kigelia africana (Lam.) Benth.

Botanical Description

Kigelia is a genus of flowering plants in the family Bignoniaceae. The genus consists of only one species, *Kigelia africana,* which occurs throughout tropical Africa. *Kigelia africana* (Lam.) Benth. syn. *Kigelia pinnata* belongs to the family Bignoniaceae and is the only species in the genus *Kigelia* (Nsubuga 2020). The generic name *Kigelia* comes from the Mozambican name for sausage tree, "kigeli-keia". Kigelia africana is native to Africa, thus the derivation of the species name "africana". The tree is deciduous, with a rounded crown, thick trunk, dark-grey to light-brown, scaly slash creamy-white with a green edge, low-branching, branches and branchlets spreading and lenticellate. The tree reaches maturity within four to six years, with a height of up to 24 meters. (Dhungana *et al.,* 2017). The leaves are alternate, pinnate and stipules absent; rachis up to 50 cm long; leaflets three to six opposite pairs, usually with a terminal leaflet, elliptic to elongated lanceolate, 7–20 cm long, 4–12 cm wide, apex abruptly to gradually shortly acuminate, base slightly asymmetrical, rounded to cuneate, margins entire or sometimes slightly toothed, coriaceous or papyraceous, shiny green and usually scab rid above, dull green and glabrous to tomentose below; midrib impressed above, major lateral veins 7–12 pairs and prominent below (Hussain *et al.,* 2016).

The flowers of *K. africana* are hermaphrodite, zygomorphic and five-merous. The calyx is campanulate approximately 1–4-cm-long, 1–2-cm-wide, fleshy, irregularly five-lobed, the lower lobes generally longer at maturity and the calyx mouth thus oblique. The corolla is greenish-yellow to purplish-red or bright claret, 5–12-cm-long, the throat rather abruptly expanded, limb 9–18 across with the two upper lobes smaller than the three lower and velvety inside; stamens four fertile and one staminode about half the fertile stamens. The ovary is conical, tapering into a slender style subequalling the stamens (Sidjui *et al.,* 2014). They possess a very unpleasant scent, which is most notable at night, indicating their reliance on pollination by bats, which visit them for pollen and nectar. The fruits are indehiscent, woody, greyish-brown, sausage-shaped and

pendulous, up to 50-cm-long and 15 cm in diameter, with elongated pedicels. The seeds are numerous, unwinged, obovate and 1.25-cm-long (Adam *et al.,* 2015). The fruits usually weigh 10 kg. The mature fruits can be found on trees throughout the year, although not eaten by humans, they find wide applications in traditional medicine (Singh *et al.,* 2018). Due to the unusual fruits and large attractive flowers, *K. africana* is considered a striking ornamental plant, and the fruits are used as florists' materials. The thick stem is an attractive feature for bonsai. The tree is sometimes planted as a boundary marker but usually at roadsides and for shade. Due to its occurrence along watercourses, it is suitable for erosion control and riverbank stabilization. (Dhungana *et al.,* 2017).

Ecology

K. africana occurs along watercourses, in riverine fringes, alluvial and open woodland, high-rainfall savanna, shrubland, and in rain forest. It occurs on loamy red clay soils, sometimes rocky, damp or peaty, from sea level up to 3000 m altitude. (Schumann *et al.,* 2013).

Propagation and planting

K. africana is readily propagated by seed vegetative propagation using cuttings is possible but success rates are generally low. It is best grown in warm areas, due to cold intolerance. It is not frost-resistant, but young plants will survive if protected for the first three years. In southern Africa, it is reputedly quick-growing from seed. In other areas germination rate is poor. It is also propagated by wildings, and hardwood cuttings have been used successfully in experiments. It may be competitive to crops in arid areas where water is limited (Shisanya *et al.,* 2011). *Kigelia africana* is not a prolific seeder, number of viable seeds per kg fibrous fruit pulp is between 3400 and 9700. Although it is sometimes advised that seed should not be stored, dry seeds store well under cool conditions. Seed storage behaviour is orthodox; viability is maintained for more than 3 years in airtight storage at ambient temperature with 11–15% humidity. Although pre-treatment is not essential, seeds may be soaked in hot or boiling water for 1 minute prior to sowing. Seeds are pressed into seedling trays filled with pure river sand, covered with a shallow layer of sand or compost, and kept moist. Germination commences within 10–25 days (Rocky *et al.,* 2012).

Ethnobotany

Plant species in the *Bignoniaceae* family play a central role in medication systems and *K. africana* is no exception. (Fitriyani *et al.,* 2020). The preparation and use of *K. africana* plant parts in medication differs across and within communities. Despite the differences in preparation and application, there is still a lot of overlap, viz., similar uses in different regions or countries. *K. africana* has interested many ethnobotanists and cultural anthropologists across the world who have intensively engaged in documenting its uses in several communities. The fruits are used in ethnoveterinary medicine to treat digestive system disorders, leg edemas, dermal irritations and infections, mastitis, retained placenta, brucellosis and Newcastle disease. The tree provides a nutritious food source during times of famine: the hard seeds are roasted and eaten. The fruit pulp, however, is said to be inedible and toxic, may have intoxicant or purgative effects and may cause blistering of the tongue and skin. However, fallen fruits, along with leaves and flowers, are browsed or foraged by livestock and game (Nsubuga *et al.,* 2020). *K. africana* is regarded as sacred in several regions and the flowers and fruits are regarded as a fetish. Fruits are commonly sold in markets as charms to promote wealth and prosperity, to impart strength and courage on warriors prior to, to increase crop yields and as a fetish for fecundity or to avert whirlwinds. The fruits and bark of *K. africana* are collected and traded locally in marketplaces. (Dhungana *et al.,* 2016)

Fruits are the most frequently used plant part in medication preparations, followed by the stem bark, roots, and leaves (Olubunmi *et al.,* 2014). Flowers are quite infamous and rarely used as medicine because they are seasonal, and when they bloom, within 14 days, they fall off the tree and dry. Thus, seasonality affects their wide application in medicine preparations, coupled with the short life cycle. The fruits are never consumed fresh, because they are said to be very poisonous, especially when young (Kakembo *et al.,* 2017). Whereas *K. africana* is traditionally considered potent, its pharmacological activity cannot be attributed to it as a single species, in some cases. The table below shows that some traditional medicine preparations involve using *K. africana* in combination with other medicinal plants or mollusks, like snails, or other foods, like porridge. This implies that these factors should be taken into consideration when examining its pharmacological activity. Unfortunately, the traditional uses of *K. africana* have threatened its existence on the African continent.

The medicinal uses of *K. africana* in different African communities, regions and countries, together with the plant part used, are summarized in the table below.

Table 1: Medicinal/Traditional uses of *Kigelia africana* (Lam.) Benth. in Africa.

REGION/COUNTRY	PLANTS PART\ PREPARATION	MEDICINAL USE
South Africa	Fruit	Solar keratosis, malignant melanoma, dysentery, worm infestations, pneumonia, toothache, malaria, diabetes, venereal diseases, convulsions, antidote for snakebite, postparturition hemorrhage, solar keratoses and skin cancer (Oyelami *et al.*, 2012)
	Roasted Seed	Pneumonia, fungal infections, eczema, malaria, diabetes and waist pain. (Singh *et al.*, 2018).
	Stem and root bark	Ulcers, pneumonia and toothache (Van *et al.*, 2015).
South Africa and Zimbabwe	Fruit	Crude fruit creams for freckles
South Africa and Ethiopia	Hot root Macrete	Gynecological complaints, constipation and tapeworm infections (Wicken *et al.*, 2007).
	Root bark	Uterine cancer, venereal diseases, hemorrhoids and rheumatism (Singh *et al.*, 2018).
	Stem bark	Rheumatism, dysentery, venereal diseases, gynecological conditions, hemorrhages, epilepsy, wounds, sores, abscesses, diarrhea and edema
South Africa and Cameron	Stem back decoction mixed in porridge	Infertility
South Africa and Nambia	Stem and leaves decoction	Eczema and herpes (Olufemi *et al.*, 2018).
	Fruits and stem bark decoction	Worm infections in children
Zambezi Valley	Fruits Crude fruit cosmetic preparation used by Tsonga women,	Dressing for ulcers, purgative and galactagogue
Zambia	Bark	Syphilis and gonorrhea
Botswana	Fruits boiled with milk	Sexually transmitted Disease.
West Africa (General)	Leaves	Gastrointestinal ailments
	Bark Water Macrete	Antidote for snakebite, sores, skin fungal infections, dysentery and syphilis
	Ground bark and fruit infusion	Stomach problems in children
	Root and bark	Pneumonia, tapeworms, ulcers and gynecological complaints
	Fruits	Wounds, abscesses, antimalaria, febrile jaundice and menorrhagia
	Aqueous bark extract	Backache, stomach pains and dysentery
	Leaves and twigs	Constipation, gynecological disorders, hemorrhoids, lumbago, dysentery, wounds kidney disorders, snakebite and rheumatism
	Leaves	Stomach and kidney ailments, antidote for snakebites and wounds
	Fruits, roots and leaves	Sexual complaints, viz., poor libido, sexual asthenia and impotence

	Fruits	Dermatitis—fruit ointment, constipation, gynecological disorders, hemorrhoids, psoriasis, eczema, diarrhea, malaria, rheumatism, retained placenta, dressing for wounds, purgative, galactagogue and dizziness
	Bark	Antimicrobial, cytotoxicity and anti-implantation activities (Agyare *et al.*, 2013).
Cameroon	Stem bark decoction	Abortifacient, filariasis and cataract
Ghana	Bark	Dysentery and rheumatism
Togo	Fruits	Cancer
Ivory coast	Fruit infusion	Rheumatism and back pains
Benin Ivory Coast and South Africa	Leaf decoction	Jaundice
Nigeria	Bark	Anti-inflammatory, dysentery and anticancer
	Fruits	Psoriasis, eczema, leprosy, rheumatism, snakebites, syphilis and chronic abdominal pain.
	Root decoction	Ante and postnatal disorders, fibroid and conception
	Fruit and flower mixed with water or alcohol	Fertility treatment among women and men of childbearing age
	Leaves	Diarrhea, abortifacient, aphrodisiac, tonic and impotence (Akintunde *et al.*, 2016).
Central Africa	Unripe Fruit	Dressing for wounds, hemorrhoids and rheumatism
Kenya	Roasted seeds mixed with beer	Enlargement of sexual organs
Tanzania	Stem bark infusion	Hyperpyrexia and gonorrhea
	Fruit boiled	Anemia, especially in pregnant women (Houghton *et al.*, 2016)
East and West Africa	Bark	Convulsions
Tanzania and Nigeria	Hot decoction of stem bark	Galactagogue
Africa (General)	Bark decoction	Laxative
	Ash leaves mixed with honey	High blood pressure
	Fruits	Mature fruit is used for treating wounds, abscesses, dressing wounds, skin cancer, reducing breast metastasis, ulcers, syphilis, rheumatism, fungal infections, boils, psoriasis, leprosy, venereal diseases and acne
	Leaves	Malaria, rheumatism, wounds, ulcers, retained placenta, venereal diseases and diarrhea.
	Fruit and bark (lesser extent) extracts	Dysentery, hemorrhoids, constipation, wounds, ulcers, boils, abscesses, rheumatism, syphilis and gonorrhea
	Fruit and root decoction	Postparturition hemorrhage
	Stem bark decoction of K. africana and the leaves of Irvingia gabonensi	Spleen infection.
	Powdered fruit mixed with palm oil	Dizziness
	Leaves and stem bark decoction	Malaria
	Decoction (stem bark of K. africana and leaves of Cassia	Gonorrhea and syphilis

occidentalis and potash)	
Mixture of ground K. africana young fruit and snails rolled into balls and allowed to dry is eaten with a cup of tea every day	Infertility
Bark	Rheumatism, regularizing menstrual flow, epilepsy and dysentery. (Oyebanji *et al.*, 2015).

Phytochemistry of Various Parts of *K. africana*

The occurrence of secondary metabolites in different parts of *K. africana* is responsible for its several medicinal applications. These compounds include naphtha quinones, iridoids, sterols, coumarins, flavonoids and alkaloids among others (Atolani *et al.,* 2010).

Chemical Constituents of *Kigelia africana* Fruit

Sidjui and colleagues reported that a new furanone derivative formulated as 3- (2'hydroxyethyl) – 5 - (2" hydroxypropyl) dihydrofuran – 2 - (3H)one and four new iridoids named: 7-hydroxyviteoid II, 7-hydroxyeucommic acid, 7 - hydroxy-10-deoxyeucommiol and 10 deoxyeucommiol have been isolated from the fruits in addition to seven known iridoids namely, jiofuran, jioglutolide, 1-dehydroxy - 3, 4 - dihydroaucubigenin, des – p – hydroxy benzoyl kisasagenol B, ajugol, verminoside and 6- transcaffeoyl ajugol (Sidjui *et al.*, 2016). Further phytochemical investigation of the fruits of *Kigelia Africana* yielded a new phenylpropanoid derivative identified as 6-p-coumaroylsucrose together with ten known phenylpropanoid and phenylethanoid derivatives and a flavonoid glycoside (Binutu *et al.,* 2006). A biologically monitored fractionation of the fruit led to the isolation and identification of the naphthoquinones, kigelinone, isopinnatal, dehydro-alpha lapachol and the phenylpropanoids p-coumaric acid and ferulic acid.

Chemical constituents of *K. africana* stem

A study of the antimicrobial properties of the aqueous stem bark extract of *K. africana* revealed the presence of two naphtha quinones kigelinone and isopinnatal (Dorcas *et al.,* 2018). Three known iridoids: specioside, verminoside and minecoside have also been isolated from the stem bark. The dichloromethane extract of the stem bark contain naphthoquinones which possess anti

trypanosomal properties while kigelin, β- sitosterol, 1, 3-dimethylkigelin and ferulic acid have been isolated from the bark, while the isolation of kigelinol from the wood and balaphonin from the stem bark have been reported. (Dhungana *et al.,* 2017).

Chemical Constituents of *K. africana* Root

Research reported the isolation and identification of the naphthoquinones, kigelinone, isopinnatal, dehydro-alpha-lapachol and the phenylpropanoids p-coumaric acid and ferulic acid from the root of *Kigelia africana*. Steroids, iridoids and coumarins have been isolated from the root bark as well as three isocoumarins: 6-methoxymellein, kigelin and 6-demethylkigelin (Gouda *et al.,* 2003). The isolation of kiglin and 6 methoxymellein together with two known compounds, stigmasterol and lapachol from the root has also been reported Naphthoquinones that possess anti-trypanosomal and antiprotozoal properties have been reported in the dichloromethane extract of the root while two non-quinonoid aldehydes, norviburtinaland pinnatal have been obtained from the root bark (Sidjui *et al.,* 2016).

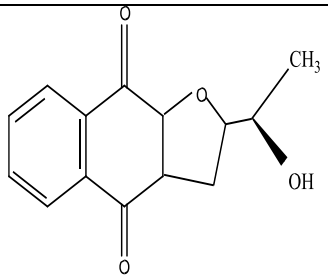
Chemical constituents of *K. africana* leaf

The hexane extract of the leaf of *K. africana* has been reported to be rich in hydrocarbons and some volatile compounds. In a study that qualitatively and quantitatively analyzed the hexane extract for various chemical compositions, it was revealed to contain twelve compounds with the major ones identified as nhentriacontane,1-tricosene, 11- (2, 2dimethylpropylheneicosane, 2, 6, 10-trimethyldodecane, penta fluoroheptadecyl ester, 2ethylhexyloctadecyl sulfurous acid ester, heneicosane and hexyloctylsulfurous acid ester (Idris *et al.,* 2018). Others are 4, 4-dimethylundecane, methyl-12-methyltetradecanoate, 1iodohexadecane and 1-iododecane. Hentriacontane have been reported to have a possible antitumor activity while methyl-12-methyltetradecanoate has also been reported for its inhibition capacity on the development of coneal angiogenesis, which is responsible for blindness and other infections. Flavonoids and iridoids and a 7- O- glucoside have also been found in the leaves (Atolani *et al.,* 2012).

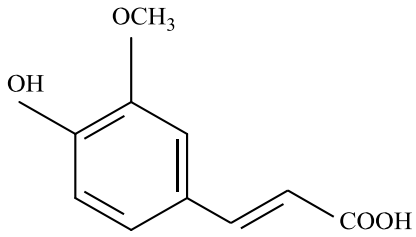
Table 2: Phytochemicals in *K. africana* (Lam.) Benth. responsible for its pharmacological activity.

S/No	Compound	Plant Part	Bioactivity
1.	Kigelinone	Stem bark	Antibacterial, Antifungal
2.	Isopinnatal	Stem bark	Antibacterial, Antifungal, Anti-malaria
3.	Kigelinol	Stem bark	Anti-malaria
4.	Isokigelinol	Stem bark	Anti-malaria
5.	Lapachol		Anti-cancer
6.	Dehydro-alpha-lapachone	Stem bark	
7.	2-(1-hydroxyethyl)naphtha [2,3-b] furan-4,9- quinine Kigeliol Balaphonin B-Sitosterol	Stem bark Wood Stem bark Bark	Anti-trypanosoma
8.	Caffeic acid	Bark	Cytotoxicity
9.	Specioside	Stem bark	Antibacterial, Antifungal
10.	Verminoside	Stem bark	
11.	Minecoside	Stem bark	
12.	Carbohydrates, alkaloids, tannins, saponins and glycosides	Fruit	
13.	7-Hydroxyviteoid II	Fruit	
14.	7-Hydroxyeucommic acid	Fruit	
15.	7-Hydroxy-10-deoxyeucomiol	Fruit	
16.	10-Deoxyeucommiol	Fruit	
17.	Jiofuran	Fruit	
18.	Jioglutolide	Fruit	
19.	1-Dehydroxy-3,4-dihydroxy-3,4-dihydroaucubigenin	Fruit	
20.	des-p-hydroxybenzoyl kisasagenol B	Fruit	
21.	Ajugol	Fruit	
22.	6-trans caffeoyl ajugol	Fruit	
23.	6-p-Coumaroyl sucrose	Fruit	
24.	β-Sitosterol	Fruit	
25.	Quercetin	Fruit	
26.	Luteolin	Fruit	
27.	3-(2'-hydroxyethyl)-5-(2"-hydroxypropyl) Dihydrofuran-2-(3H) one Isocoumarins	Fruit	
28.	6-Methoxymellein	Root	
29.	Kigelin	Root	
30.	6-Demethylkigelin	Root	
31.	3-Dimethylkigelin	Root	
32.	Phenylpropanoids p-Coumaric acid	Root bark	Antibacterial, Antifungal

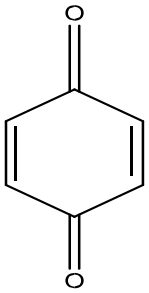
33.	Ferulic acid	Root bark	
34.	Stigma sterol	Root bark	
35.	Non-quinonoid aldehydes Norviburtinal	Root bark	
36.	Pinnatal	Root bark	
37.	Hydrocarbons n-Hentriacontane	Leaf	Antitumor
38.	1-Tricosene	Leaf	
39.	11-(2,2-Dimethylpropyl)heneicosane	Leaf	
40.	2,6,10-Trimethyldodecane	Leaf	
41.	Heneicosane	Leaf	
42.	4,4-Dimethylundecane	Leaf	
43.	Pentafluoroheptadecyl ester	Leaf	
44.	2-ethylhexyloctadecyl sulphurous acid ester	Leaf	
45.	Hexyloctyl sulphurous acid Ester	Leaf	
46.	Methyl-12- methyltetradecanoate	Leaf	Inhibition of corneal angiogenesis
47.	1-Iododecane	Leaf	
48.	11-Iodohexadecane	Leaf	



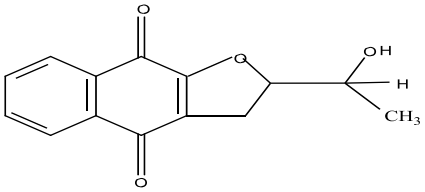
2-acetylnaphthao [2, 3-b] furan-4, 9-quinone



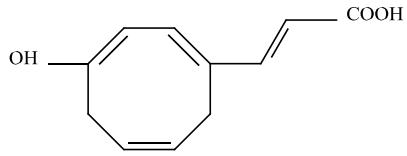
Caffeic acid



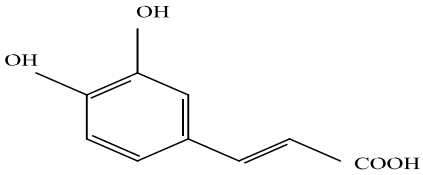
1, 4 Benzoquinone



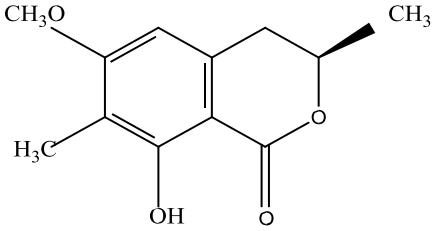
2-(1-Hydroxyethyl)-2-acetylnaptho-[2, 3-b]-furan-4,9-dione



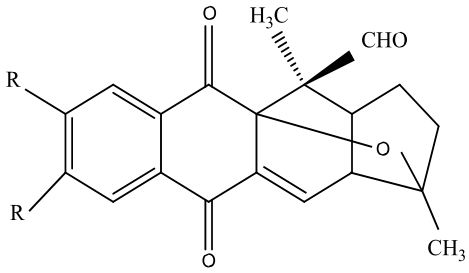
Coumaric acid



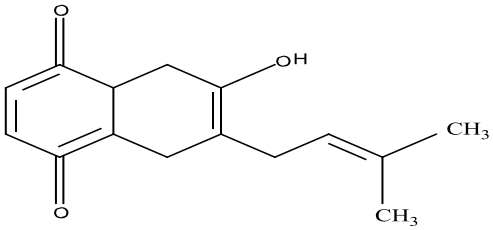
Ferulic acid



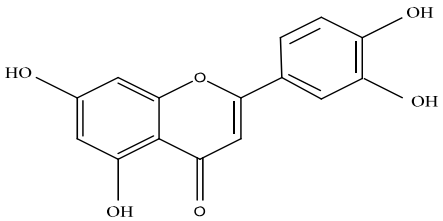
KIgelin



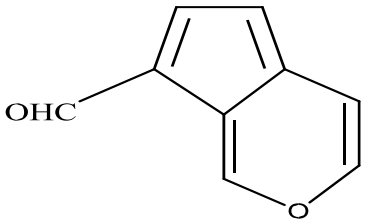
Kigelinol Isokigelinol



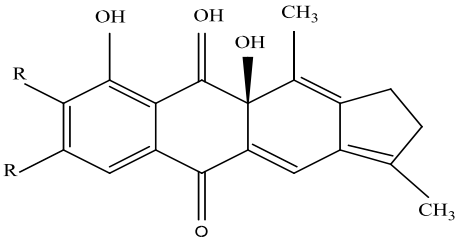
Lapachol



Luteolin

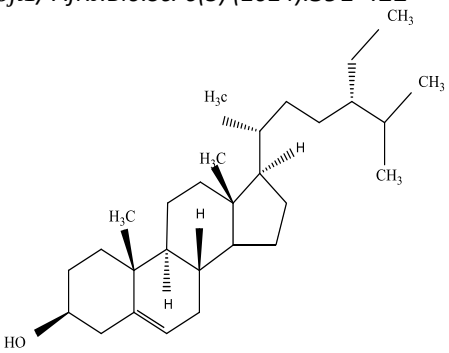


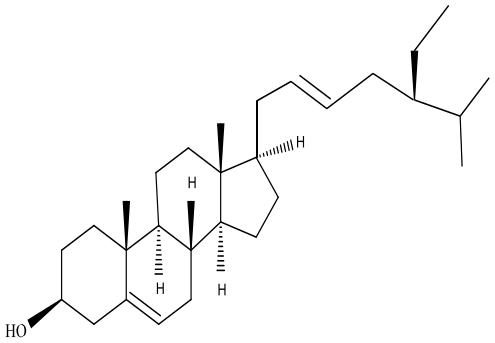
Norviburtinal R=H, R' =OH



Pinnatal

Isopinnatal R=OH, R"=H





Sitosterol Stigmaste

Structural formulae of some compounds found in *K. africana*

Table 3: Phytochemicals in *Kigelia africana* (Lam.) Benth, and their source in the plant part

Classification	Phytochemicals	Plant Part
Phenolic Compounds	p-Coumaric acid	Stem bark, fruits, roots
	Caffeic acid	Stem bark, fruits, roots
	Ferulic acid	Stem bark, fruits
	Atranorin	Stem bark
	Nonacosanoic acid, 2-(4-hydroxyphenyl) ethyl ester	Stem bark
	Luteolin	Roots, leaves, wood
	Luteolin 7-O-glucoside	Leaves
	6-p-coumaroyl-sucrose	Fruits
	Kigeliol.	Roots, leaves, wood
	Balaphonin	Stem bark
Coumarins.	Kigelin	Roots, stem bark, leaves, wood
	8-hydroxy-6, 7-dimethoxy-3-methyl-3, 4-dihydroisocoumarin	Root
	Isokigelin	Stem bark
	6-Demethylkigelin	Roots, stem bark
	1,3-dimethylkigelin	Stem bark
Sterols β-Sitosterol	Stem bark, fruits, heartwood, roots	6-Methoxymellein
	Stigmasterol	Stem bark, roots, heartwood
	γ-sitosterol	Stem bark, fruits
Triterpenes	Oleanolic acid	Stem bark
Diterpenes	Phytol	Leaves
	3-Hydro-4,8-phytene	
Unsaturated Fatty acids	(9Z,12Z)-Methyl octadeca-9,12-dienoate	Leaves
	Vernolic acid	Stem bark, roots, leaves, heartwood
	Methyl-12-methyltetradecanoate	Leaves
	Palmitic acid or hexadecanoic acid	Leaves, flowers
Quinones	Lapachol	Stem bark, fruits, roots, heartwood

	Dehydro α-lapachone	Stem bark, fruits, roots, heartwood
	2-acetylfuro-1,4-naphthoquinone	Stem bark
	Kigelinol	Stem bark, roots, fruits
	Kigelinone	Stem bark
	Isokigelinol	Roots, stem bark, roots, fruits
	Pinnatal	Roots, fruits, stem bark
	Isopinatal	Roots and fruits, stem bark
	Sonovoburtinal	Root bark
	2-(1-Hydroxyethyl)-naphtho[2,3-b] furan-4,9-quinone	Roots, stem bark
	2-acetylnaphtho[2,3-b] furan-4,9-quinone	Stem bark, roots
	2-(1-hydroxyethyl) naphtho [2,3-b] furan-4,9-dione	Stem bark, roots
	Tecomaquinone-I	Heartwood
	Kojic acid	Stem bark
Iridoids	7-Hydroxyviteoid II	Fruits
Jiofuran	3-(2-hydroxyethyl)-5-(2-hydroxypropyl)-4,5-dihydrofuran-2(3H)-one	Twig, roots, leaves, wood
	7-hydroxyeucommic acid	
Jioglutolide	7-hydroxy eucommiol	Leaves
	Verminoside	Stem bark, fruits, twigs leaves, roots
	Specioside	Stem bark
	Minecoside	Stem bark
	Alkanes n-hentriacontane	Leaves
Esters	Pentafluoro-N-heptadecyl	Leaves
	2-ethylhexyloctadecyl sulfurous acid	Leaves
	2-(4-hydroxyphenyl) ethyl ester	Bark
	Ethyl linoleoate	Leaves, flowers

Pharmacological activity of *K. africana*

Many researchers who have investigated the pharmacological activity of *K. africana* have relied on a known traditional use or ethnobotanical application (Adam *et al.,* 2013). On the other hand, some pharmacological uses have been serendipitously discovered in laboratories. While many traditional uses have not been substantiated in the laboratory, quite a number have proven positive through comprehensive clinical trials. In turn, products or drug leads have been discovered.

Antibacterial and antifungal activity

Roasted seeds, bark and fruit extracts of *K. africana* are traditionally used to treat fungal and bacterial infections. Out of the three plant parts, fruit extracts have found the widest applications in the treatment of fungal and bacterial skin infections. This may justify their wider usage in skin care formulations. In clinical microbiology, bacterial and fungal susceptibility tests are of paramount importance, as they help detect possible efficacy or resistance of common pathogens to the drug being tested (Reller *et al.*, 2010). Thus, the results of susceptibility tests are not an end and should always be followed by *in vivo* studies. This review reported susceptibility tests by Hussain *et al.*, 2016 and Arkhipov *et al*., 2014 The in vitro antibacterial activity of *K. africana* ethanolic, n-hexane and aqueous leaf, fruit and bark extracts against *Staphylococcus aureus*, *Proteus vulgaris*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae* and *Citrobacter amalonaticus* using the agar disc diffusion method has been investigated (Hussain *et al.*, 2016).

Analgesic and anti-Inflammatory activity

For centuries, medicinal plants have been used to manage inflammation among several indigenous communities. The roasted seeds, fruit infusion and bark of *K. africana* are traditionally used in the treatment of waist pain, back pain and inflammation. Many conventional anti-inflammatory drugs work by inhibiting cyclooxygenase (COX), the enzyme that makes prostaglandins (PGs) (Maroon *et al.*, 2010). However, herbal medicines act via different pathways, one of which is by inhibiting nuclear factor-kB (NF-kB) inflammatory pathways. NF-kB can detect noxious stimuli, such as infectious agents, cellular injuries and free radicals, and then promotes the synthesis of inflammatory cytokines. Inhibition of NF-kB leads to the management of inflammation (Matuschek. *et al.*, 2014).

Antidiabetic activity

The use of *K. africana* fruit extracts as a treatment for diabetes is commonest among South African indigenous communities, notwithstanding other parts of Africa and the world at large. (Njogu *et al*, 2018). Karau investigated the antidiabetic activity of *K. africana* aqueous and ethyl acetate extracts using male Swiss albino mice. Hyperglycemia was induced experimentally by a single-dose intraperitoneal administration of 186.9 mg/kg body weight of a freshly prepared 10% alloxan monohydrate (Karau *et al.*, 2012). The result of the study shows that, the aqueous and ethyl acetate leaf extracts of *K. africana* showed a blood glucose-lowering effect when

administered intraperitoneally and orally, an indication that they contained hypoglycemic constituents.

Antiprotozoal activity

The wood extract of *K. africana* has been reported to possess antimalarial activity against drug-resistant strains of Plasmodium falciparum superior to that of chloroquine and quinine (Atawodi *et al*, 2014). Atawodi and Olowoniyi reported the efficacy of hexane, dichloromethane, ethyl acetate and ethanol extracts of *K. africana* root bark against P. falciparum and Trypanosoma brucei and Trypanosoma brucei rhodesiense, the causative organisms for malaria and sleeping sickness, respectively. (Bharti *et al.,* 2010). Bharti et al, also reported that the growth of Entamoeba histolytica was inhibited by the stem bark butanol extract of *K. africana.*

Antiurolithiatic activity.

The third-most common disorder of the urinary tract is urolithiasis after urinary tract infections and benign prostatic hyperplasia. The worldwide incidence of urolithiasis is quite high, and despite tremendous advances in the field of medicine, there is no truly satisfactory drug for the treatment of renal calculi (Road *et al.,* 2013). Most patients still must undergo surgery to get rid of this painful disease. Hyperoxaluria is the main initiating factor for urolithiasis, and most calculi in the urinary system arise from a common component in urine, e.g., calcium-oxalate (CaOx), representing up to 80% of analyzed stones. In West Africa, *K. africana* leaves are used in the treatment of kidney ailments (Hussain *et al.,* 2016). This has been proven in various studies that *aqueous K. africana* fruit extract can alkalinize urine, making it less acidic. It has shown significant antiurolithiatic activity in the dissolution of generated calcium oxalate crystals. Gupta et al, reported that the antiurolithiatic activity of *K. africana* fruit extract may possibly be mediated through the inhibition of calcium oxalate crystallization, making the extract curative, as well as having prophylactic uses in urolithiasis (Gupta *et al.,* 2011).

Anticonvulsant activity

K. africana aqueous and methanolic bark extracts were investigated for anticonvulsant activity in Wistar rats using pentylenetetrazol (PTZ) and maximal electroshock (MES)-induced convulsions method. Both the extracts demonstrated potent anticonvulsant activity, which is due to the presence of linoleic and cinnamic acid. Doses of 250 mg/kg and 500 mg/kg of methanolic

and aqueous extracts were administered to the rats intraperitoneally. The extracts gave significant protection against the PTZ and MES-induced convulsions (Abhishek *et al.,* 2010).

Antidiarrheal activity

Indigenous knowledge of the use of bark, leaves and fruits of *K. africana* as a remedy for diarrhea among African communities has been documented by several researchers. Owolabi and Omogbai (Owolabi *et al.*, 2010), investigated the antidiarrheal properties of *K. africana* ethanolic bark extracts using Swiss albino mice. hThe result of the study shows that, *Kigelia africana* ethanolic bark extracts significantly inhibited the small intestinal motility in mice, with the 500 mg/kg dose giving the highest effect in both castor oil-induced diarrhea and small intestinal motility. When compared with the positive control, atropine, the antidiarrheal effect of *K. africana* ethanolic bark extracts at 500 mg/kg was 82% and 62.7%, respectively, on castor oil-induced diarrhea and small intestinal motility.

Treatment of sexually transmitted diseases

Traditional healers in the Igbo tribe in South-Eastern Nigeria use an aqueous or dilute alcohol extract of *K. africana* rootbark as a treatment for sexually transmitted diseases. Root extracts equivalent to those used in traditional preparations were found to contain the iridoids specioside and minecoside as major constituents. The root extracts, as well as two of the isolated iridoids, were tested, and their 1/10 and 1/100 dilutions were tested against four bacteria species, which are, *Staphylococcus aureus, Bacillus subtilis, Escherichia coli and Pseudomonas aeruginosa* and the yeast *Candida albicans*, both in the absence and presence of the enzyme emulsin. Emulsin enzyme converts catalpol-type iridoids to their more antimicrobially active non-sugar-containing aglycones. The growth of the organisms in culture broth was assessed by measuring the turbidity of the solution (Road *et al.*, 2013). The results showed that the aqueous extract had strong activity, even in the absence of emulsin, against all the bacteria tested but, especially, against the yeast *C. albicans*. Candida infections are common opportunistic infections of the genito-urinary tract, and the traditional use of this plant extract might alleviate this in sexually transmitted diseases. (Akunyili *et al.,* 1991). *K. africana* root extracts were reported as an effective treatment for sexually transmitted diseases, and this was concluded from a broth dilution susceptibility study against *C. albicans* (Omonkhelin *et al.,* 2007).

Diuretic activity

Investigation on the diuretic activity of *K. africana* aqueous bark extract by determining the urine volume, electrolyte concentration and diuretic potency in male albino rats. Different concentrations of the extract, 250 and 500 mg/kg were orally administered to hydrated rats, and their urine output was immediately measured after five hours of treatment. (Sharma *et al*, 2010). Furosemide (10 mg/kg) was used as the reference drug, while normal saline (0.9%) solution was used as the control. The result showed that the bark extract exhibited a dose-dependent diuretic property. The onset of diuretic action was within one hour and lasted up to five hours, with 500 mg/kg displaying more activity than 250 mg/kg. The extract also caused a marked increase in Na+, K+ and Cl− labels (Owolabi *et al.*, 2010).

Antioxidant activity

According to Ponnan and his colleague's, antioxidant compounds are abundantly available in plants and play an important role in scavenging free radicals, thus providing protection to humans against oxidative DNA damage (Ponnan *et al.,* 2006). An excess of reactive oxygen species (ROS) can result in noncontrolled oxidation (oxidative stress) and damage of cellular structures, such as DNA, protein and membrane lipids. It is believed that the presence of ROS is essential in cells, as they can act as key signaling molecules for the activation of the stress responses and defense pathways (Emeka *et al.,* 2014). According to Olubunmi and his colleagues, the free radical scavenging activities of *K. africana* root extract through the spectrophotometric assay on the reduction of DPPH compared favorably with α-tocopherol (standard antioxidant) at high concentrations. Scavenging activity was observed for the root extract at all concentrations (100, 250, 500 and 1000 μg/mL) assayed, with 250 μg/mL having the lowest activity, while the highest antioxidant capacity was observed at 1000 μg/mL. (Olubunmi *et al.,* 2010). Dhungana and his colleagues reported the antioxidant activity of the methanolic leaf and fruit extracts of *K. africana.* *Kigelia africana* extracts showed a significant reduction in free radical-related complications, lipid peroxidation, blood cholesterol and low-density lipoproteins (Dhungana *et al.,* 2016).

Anticancer activity

According to Khan and Mlungwana the anticancer potential of *K. africana* has been indicated by cytotoxicity of the root and bark materials in the brine shrimp bioassay against Artemia salina. Houghton and colleagues reported significant inhibitory activity of stem bark extracts against four melanoma cell lines and a renal carcinoma cell line and slight activity by fruit extracts. The

root bark had activity against KB cells. Inhibitory effects of *K. africana* fruit extracts on induced tumors and inflammation in mice have been reported. (Momekov *et al.,* 2014). Momekov and colleagues investigated the anticancer activity of *K. africana* methanolic stem bark extract. The powdered (1 mm) stem bark was refluxed with methanol (1: 20) for 1 h at 80 °C. After cooling at room temperature, the extract was filtered, and the residue was subject to the same extraction process twice. Thereafter, the filtrates were gathered, and the solvent was evaporated in vacuo to dryness. The methanolic extract of *K. africana* stem bark had significant cytotoxicity against human tumor cell lines, with IC50 values µg/mL against T-cell leukemia (a KE-37 derivative), acute lymphoid leukemia, acute myeloid leukemia, chronic myeloid leukemia, non-Hodgkin's lymphoma, Hodgkin's lymphoma, breast cancer and murine lung cancer cell line, respectively. These results compared with the vincristine-positive control (IC50 µg/mL) against T-cell leukemia (a KE-37 derivative), acute lymphoid leukemia, acute myeloid leukemia, chronic myeloid leukemia, non-Hodgkin's lymphoma, Hodgkin's lymphoma, breast cancer and murine lung cancer cell line, respectively (Momekov *et al.,* 2014).

In another study, the antitumor activity of *K. africana* methanolic leaf extracts of 100 and 200 mg/kg were evaluated against the Ehrlich ascites carcinoma (EAC) tumor induced into mammary glands of mice The result of the study shows that the methanolic extracts of *K. africana* resulted in a decrease in the tumor size and improved average body weihght and mean survival time, thereby increasing the life span of EAC tumor-bearing mice (Sainadh *et al.,* 2013). Higgins and colleagues investigated the cytotoxic activity for *K. africana* fruit extracts against melanoma and two breast cancer cell lines. They used a bioactivity-driven separation approach to identify demethylkigelin, kigelin, ferulic acid and 2-(1-hydroxyethyl)-naphtho[2,3-b] furan-4,9-dione as the compounds thought to be responsible for the cytotoxicity. Of these, 2-(1-hydroxyethyl)-naphtho[2,3-b] furan-4,9-dione was a particularly potent cytotoxic agent. Potent antiproliferative activity against the Caco-2 and HeLa carcinoma cell lines was noted for *K. africana* methanolic fruit extracts. (Higgins *et al.,* 2010)

Toxicological evidence

Sharma and colleagues went further to investigate the toxicity of the aqueous bark extract using experimental rats and found that it was safe up to 5 g/kg (Sharma *et al.,* 2010). The acute toxicity of the *Kigelia* methanolic fruit extract was investigated using male Sprague–Dawley rats. In this study, the extract was well-tolerated by the animals, as there were no observable signs of acute toxicity like restiveness, seizure or dizziness after the administration of 400 mg/kg. However, at

6400 mg/kg, the animals showed signs of toxicity like jerks and writhes with 60% death. At 12,800 mg/kg, there was 80% death of the animals. The LD50 was estimated from a log dose curve to be 3981.07 mg/kg (Azu *et al.,* 2010). Gaiuson, and colleagues conducted a comparative study of Hepatorenal Protective Potentials of Kigelia africana Ethanolic Leaf Extract on Carbon Tetrachloride Induced Toxicity in Adult Male Wistar Rats and find out that *K. africana* ethanolic leaf extract mitigates the toxic effect of CCl4 on hepatorenal functions. (Wandiahyel *et al*, 2018; Gaiuson *et al.,* 2020). In another study, 100 mg/kg aqueous extract was administered to rats induced with acetaminophen liver toxicity. The extract countered the effect of acetaminophen on the activities of aspartate transaminase (AST), alanine transaminase (ALT), superoxide dismutase (SOD), catalase (CAT), gluthathione peroxidase (GPx) and δ- amino levulinate dehydrogenase (δ-ALAD) (Olaleye *et al.*, 2007)

The protective effect of the methanol extract of the *K. africana* fruit extract against cisplatin-induced renal toxicity in male rats was investigated by Zofou and his colleagues (Zofou *et al.*, 2011). The rats treated with cisplatin for 28 days suffered a loss in body weight, elevation in blood urea nitrogen and serum creatinine levels, as well as tubular necrosis. Pretreatment with the *K. africana* fruit methanol extract at 100 mg/kg as a prophylaxis significantly prevented these changes. Though the posttreatment of animals with the extract after a cisplatin treatment did not completely restore the serum catalase activity, it caused some alleviating effects, suggesting that the *K. africana* fruit extract may protect against cisplatin-induced renal toxicity and, hence, might serve as a novel agent to limit renal injury.

Economic and non-medicinal benefits of *K. africana*

Fruits and bark of *K. africana*, are used in the brewing process to aid fermentation and enhance the flavor of traditional beers. *K. africana* wood is considered excellent for dugout canoes, planks, and fenceposts. It is also used for making boxes, drums, stools, yokes, tool handles, mortars, and large bowls for watering cattle. Weapon bows are made from branches, and smaller branches are hollowed to administer enemas to children (Burkill *et al*., 1985). Wood and fruits are carved into mousetraps, dolls, and various items of crockery and cutlery. Wood is used as fuel, black dye is obtained from the tannin-rich fruit pulp, while baboons are known to eat the fruits, the pulp of unripe fruits are said to be posionous to humans. However, slices of mature baked fruits are used to ferment and flavor traditional African beer (Chivandi *et al.,* 2011). The seeds of ripe fruits can also be roasted in warm ash and consumed and are reported to be energy-rich, with significant amounts of phosphorous, protein, and lipids. In turn, the seed oil is rich in

oleic acid and essential fatty acids and has potential to be an important nutritional resource. (Glew *et al.,* 2010).

Additionally, the leaves of *K. africana*, have been positioned as an important nutritional resource, comparable to other green leafy vegetables such as spinach. They are consumed by lactating women in various parts of sub-Saharan Africa as they are thought to enhance the volume and quality of breastmilk. The dried leaves contain levels of essential amino acids that may provide beneficial health benefits as well as other minerals and nutrients including calcium, magnesium, and iron. (Alam *et al.,* 2011).

The flowers are eaten by domestic stock and game, kudu, nyala, impala, and grey duiker. Leaves are consumed by elephants and kudu. The tree produces good quality timber and the wood is reported to be easy to work with. People living along large rivers, especially the Chobe and Zambezi, make their dugout canoes from the tree (Venter *et al.,* 2007). The boiled fruits are also used to produce a red dye and the roots are reported to produce a yellow dye.5 Much of the traditional use of *K. africana*, surrounds topical application to the skin. It is reported that the Tonga women of the Zambezi Valley regularly apply cosmetic preparations of the fruits to their faces to maintain a blemish-free complexion.5 Although not fully identified, this traditional use, like many others, is linked to the bioactive components of *K. africana* (Choudhury *et al.,* 2011)

Conclusions

K. africana is an interesting example of a plant used in medication locally for many years, but it is now attracting interest and use far beyond its original geographical range (Gaiuson *et al*, 2018). Experiments into the effect of *Kigelia africana* extracts and some of the pure compounds contained therein on microorganisms, cancer cells, debetes, and hepatic disease have shown that the use of this plant is given considerable justification (Yaduma *et al*., 2020). The chemical constituents of the plant provide molecules, which could be of immense medicinal applications. Despite efforts by several researchers to document the traditional uses of *K. africana*, a lot of information has been lost, owing to the death of custodians commonly known as living libraries. In addition, many traditional uses have not been scientifically validated; thus, they are simply claims. Thus, the gap to completely profile the ethnobotanical knowledge and phytochemistry and pharmacological activity of *K. africana* is still wide, and more research needs to be conducted to discover the unknowns and confirm the knowns. This will increase the significance of this species at the international level, as compared to the community level. *Kigelia africana*

contains many phytochemicals that have already been identified, isolated and their pharmacological activity validated. Nonetheless, the mechanism of action for pure compounds has not been studied for the majority. As per the reviewed studies, most pharmacological studies that have been carried out on *K. africana* plant parts have been based on traditional uses. Fruits have received more attention from researchers regarding their bioactivity compared to other plant parts. This has left little scientific basis for the bioactivity of the leaves, flowers, stems and roots. Therefore, other plant parts need to be given similar attention, since they may have unique and highly potent phytochemicals.

Despite the norms surrounding herbal medicine preparations as being safe with fewer side effects, this is completely wrong, except when proven in the laboratory. Many herbal medicine preparations have caused life-threatening side effects and death in the worse scenarios. Although many such cases have not been documented, some cases of poisoning have been reported in the literature. Therefore, quality, efficacy and safety are key elements to consider before using any herbal product or making it commercially available. Unfortunately, several products have been formulated from *K. africana* and are available on the market, yet they do not meet international quality standards. This implies that most of these product formulations have no standard dose and are of uncertain quality, efficacy and safety. Thus, if the availability and acceptance of *K. africana* products on international markets is to be increased, programs to promote training on efficacy, safety, international quality standards, sustainable use and conservation of the natural resource base need to be established. For a brighter future of medicinal plant research, researchers should embrace a high-throughput analysis before coming to conclusions concerning the biological activity of medicinal plants. This is because a high-throughput analysis combines genomics, proteomics and chemical and ultrastructural data. Additionally, all in vitro studies need to be followed by clinical trials to demonstrate the safety and efficacy of traditional treatments in biological systems, and all experiments must comply with international scientific standards and guidelines. There is also a need to add more information to the basic pharmacological assays and aim for clinical trials by focusing on molecular drug and disease targets. The quest for control of diabetes has led to increasing research on different fronts, among which is medicinal plants. Given the observation of an increasing use of medicinal plants for diabetes in Sudan, this necessitates validation of efficacy and safety. *In vitro* experiments are carried out to ascertain the mechanism of action of medicinal plants. The hypoglycemic effect of certain plants arises as a side effect of their in vivo toxicity (Marles and Farnsworth., 1995).

However, a risk may be posed by the fact that such hypoglycemic effect is probably partially exhibited via an unfavourable physical mechanism overriding a physiological one. As for the validation of experiments, ethical considerations concerning animal use are increased and therefore the use of non-animal models should be seriously considered (Festing and Wilkinson, 2007). A number of standardization measures such as reference pharmacopoeial monographs are necessary to assert the medicinal value of these herbal medicines as reliable and therapeutically effective. Case studies involving standardized medicinal plant products should be carried out in order to validate the usefulness of plant preparations in diabetes management, which will give support to the pre-clinical results. *K. africana* dichloromethane and methanol extracts exhibits high in-vitro anti-cancer activity against the human breast cancer cell line HCC. In general, the anti-cancer activities of the methanol and dichloromethane extracts can be attributed to the presence of flavonoids, triterpenes and phenolic constituents of the two extracts revealed on the TLC, as well as other constituents reported in the review (furanonaphthoquinones and norviburtinal). The findings for this study provide a scientific rationale for using the plant to control breast cancer in traditional medicine. More validation studies are important to determine cytotoxicity of the extracts and optimal dosage of application in traditional medicine (Yaduma *et al*., 2020).

Traditional medicine (TM) is strongly embedded in indigenous systems that are rooted within local communities and are very strong. Despite the strong roots of TM, there is a huge stumbling block to its development, and this is ignoring the capacity and roles of TM practitioners in national and international policies. Additionally, physicians and other health professionals are also not exposed to TM in their training, leading to a wide gap between conventional and TM practice and a disconnect between professional health groups and patients who choose to continue TM use. Another stumbling block to TM development is the failure of researchers to guard the intellectual property of local communities where they collect indigenous knowledge (IK) for their research. These two stumbling blocks are of regional, national and international importance. Interestingly, intellectual property rights frameworks such as the access to genetic resources and benefit sharing exist, but they are not fully operational, presenting a bottleneck for equitable benefit sharing, which is a prerequisite in fostering partnerships.

Thus to conclude by considering all the scientific reports from previous researchers, the present review has given an insight information about *K. africana,* because of its various pharmacological application like analgesic, anti-diabetic, anti-cancer, wound healing, antioxidant

and anti-hepatic disease. The therapies which are adapted from the allopathy are limited due to its efficacy, serious adverse effects and costly preparations. Therefore, researchers should take on the mantle and jealously guard the intellectual property (IP) of indigenous communities through inclusive patenting procedures. Similarly, the principle of prior informed consent as enshrined in the Convention for Biological Diversity needs to be enforced while collecting ethnomedical information.

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