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Kirkia wilmsii Engl.: A review of its botany, medicinal uses, phytochemistry and biological activities

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Abstract

Kirkia wilmsii is a small-sized deciduous tree widely used as herbal medicine in South Africa. This study is aimed at providing a critical review of the botany, biological activities, phytochemistry and medicinal uses of *K. wilmsii*. Documented information on the botany, biological activities, medicinal uses and phytochemistry of *K. wilmsii* 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, biological activities, phytochemistry and medicinal uses of *K. wilmsii* was gathered from pre-electronic sources such as book chapters, books, journal articles and scientific publications sourced from the University library. This study showed that the bark, leaves, rootbark and tubers of *K. wilmsii* are used as herbal medicine for arthritis, asthma, diabetes mellitus, diarrhoea, high blood pressure, hypertension, malaria, nasal congestion, respiratory infections, ringworm and tuberculosis. Phytochemical analyses revealed that the leaves, tubers and twigs of *K. wilmsii* are characterized by caffeic acid, cardenolide deoxy sugars, cardiac glycosides, ellagic acid, flavonoids, gallic acid, isocoumarin, neo-lignan, nor-carotenoids, phenolics, phlobatannins, quercetin, reducing sugars, saponins, steroids, tannins and terpenoids. Pharmacological research revealed that *K. wilmsii* crude extracts have antimicrobial, antioxidant, antiplasmodial, antiplatelet and cytotoxicity activities. Future ethnopharmacological research should focus on correlating ethnomedicinal uses of the species with its pharmacological properties.

Keywords: Ethnopharmacology, herbal medicine, indigenous pharmacopeia, *Kirkia wilmsii*, Kirkiaceae, Simaroubaceae

INTRODUCTION

Kirkia wilmsii Engl. is a small-sized deciduous tree belonging to the *Kirkia* Oliver genus. The genus *Kirkia* is a member of the dicotyledonous family Kirkiaceae Takhtajan which consists of six species distributed in Madagascar, South Africa and tropical Africa.[1,2] The family Kirkiaceae was formerly placed as Kirkioideae (Sapindales) in the family Simaroubaceae, but recent molecular phylogenetic results showed that this is a separate family and a sister taxon to the clade of Anacardiaceae and Burseraceae.[1,2] *Kirkia* species are widely used as herbal medicines in tropical Africa.[3-5] The bark, fruits, leaves and roots of *K. acuminata* Oliver, *K. tenuifolia* Engl. and *K. wilmsii* are used as traditional medicines for abdominal pain, cholera, cough, snake bites and toothache in East, Central and Southern Africa.[3-5] The crude extracts and compounds isolated from these species are characterized by antimicrobial, antioxidant, antiplasmodial and antiplatelet activities. The swollen tuberous roots of *K. acuminata* and *K. wilmsii* are chewed to quench thirst in times of drought.[3,6-9] *Kirkia wilmsii* is managed in home gardens in the Limpopo province in South Africa as medicinal plant.[9,10] *Kirkia wilmsii* is also sold as herbal medicine in the informal herbal medicine markets in the Limpopo province in South Africa.[7,11-14] It is within this context that this review was undertaken aimed at reviewing the botany, medicinal uses, phytochemical and biological activities of *K. wilmsii* so as to provide baseline data required for evaluating the therapeutic potential of the species.

Botanical description of *Kirkia wilmsii*

Kirkia wilmsii is a small-sized tree with a rounded crown growing up to 8 metres in height.[15-18] *Kirkia wilmsii* has been recorded in various types of biomes, often on granite and dolomitic soils in dry bushveld areas or on rocky slopes at an altitude ranging from 365 m to 1495 m above sea level in Gauteng, Limpopo, Mpumalanga and the North West provinces.[16,18-20] The genus name *Kirkia* is in honour of Sir John Kirk (1832-1922), a Scottish physician, naturalist, plant collector and companion of explorer Dr David Livingstone and British administrator in Zanzibar.[19] The specific name "*wilmsii*" is in honour of a German apothecary, botanical collector and traveller, Dr Friedrich Wilms (1848-1919), who worked in Lydenburg in South Africa and collected the type specimen of the species in the neighbourhood.[19] *Kirkia wilmsii* is commonly referred to as mountain kirkia, mountain seringa and wild pepper tree in English.[16,19] The roots of *K. wilmsii* sometimes produces shoots as they sprawl among rocks. The bark of *K. wilmsii* is grey and smooth with branchlets marked with conspicuous leaf scars of old leaves and have noticeably stubby tips. The leaves are alternate, hairless, with minutely crenate or smooth margins and crowded at the ends of branchlets. Flowers are greenish white in colour and occurring as branched auxillary sprays. The fruit is a capsule, splitting into four valves which may remain joined at the apex.[16,19,20]

Medicinal uses of *Kirkia wilmsii*

The bark, leaves, rootbark and tubers of *K. wilmsii* are used as herbal medicine for arthritis, asthma, diabetes mellitus, diarrhoea, high blood pressure, hypertension, malaria, nasal congestion, respiratory infections, ringworm and tuberculosis (Table 1). In the Limpopo province in South Africa, the leaves, tubers and twigs of *K. wilmsii* are mixed with roots of *Drimia elata* Jacq., *Sarcostemma viminale* (L.) R. Br. and *Vahlia capensis* (L. f.) Thunb. to produce a commercial herbal concoction known as "tšhikwana" or "morotwa tšhwene".[21-23] The twigs of *K. wilmsii* are mixed with bulbs of *D. elata*, with leaves and corms of *Hypoxis hemerocallidea* Fisch., C. A. Mey. & Avé-Lall., *Monsonia angustifolia* E. Mey. ex A. Rich., *Sarcostemma viminale* (L.) Br. and *V. capensis* as antidiarrheal and aphrodisiac, and as herbal medicine for blood purification and pain.[22,24]

Table 1: Medicinal uses of *Kirkia wilmsii* in South Africa

Medicinal use	Plant parts used	References
Antidiarrheal	Twigs mixed with bulbs of *Drimia elata* Jacq., with leaves and roots of *Hypoxis hemerocallidea* Fisch., C. A. Mey. & Avé-Lall., *Monsonia angustifolia* E. Mey. ex A. Rich., *Sarcostemma viminale* (L.) Br. and *Vahlia capensis* (L. f.) Thunb.	Matotoka and Masoko[22]; Maroyi[24]
Aphrodisiac	Twigs mixed with bulbs of *D. elata*, with leaves and roots of *H. hemerocallidea*, *M. angustifolia*, *S. viminale* and *V. capensis*	Matotoka and Masoko[22]; Maroyi[24]
Arthritis	Tuber	Rasethe et al.[7]
Asthma	Bark	Semenya and Maroyi[25,26]
Blood purification	Twigs mixed with bulbs of *D. elata*, with leaves and roots of *H. hemerocallidea*, *M. angustifolia*, *S. viminale* and *V. capensis*	Matotoka and Masoko[22]; Maroyi[24]
Diabetes mellitus	Tuber	Rasethe et al.[7]; Semenya et al.[27]
Diarrhoea	Rootbark	Adebayo and Amoo[28]
High blood pressure and hypertension	Tuber	Mogale et al.[6]; Rasethe et al.[7]; Semenya and Potgieter[14]; Semenya et al.[29]; Semenya and Potgieter[30]; Semenya and Wadesango[31]
Malaria	Bark and leaves	Maroyi and Mosina[9]; Clarkson et al.[32]
Nasal congestion	Bark	Semenya and Maroyi[25,26]
Pain	Twigs mixed with bulbs of *D. elata*, with leaves and roots of *H. hemerocallidea*, *M. angustifolia*, *S. viminale* and *V. capensis*	Matotoka and Masoko[22]; Maroyi[24]; Hulley and Van Wyk[33]
Respiratory infections	Tuber	Semenya and Maroyi[34]
Ringworm	Bark	Rankoana et al.[35]
Tuberculosis	Bark	Semenya and Maroyi[26,36]

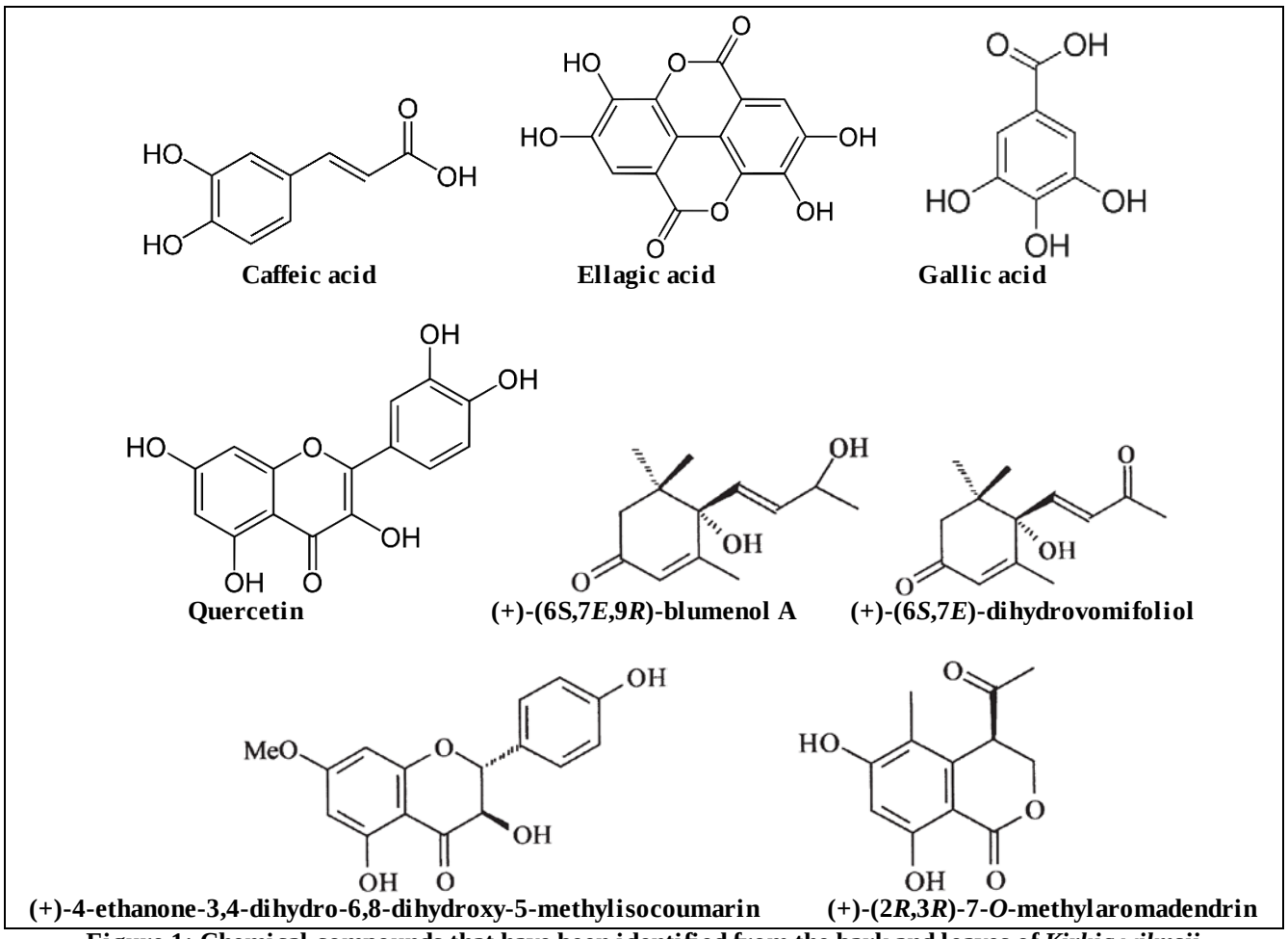

Figure 1: Chemical compounds that have been identified from the bark and leaves of *Kirkia wilmsii*

Phytochemistry

Chigayo et al.[37] and Matotoka and Masoko[21,23] identified cardenolide deoxy sugars, cardiac glycosides, flavonoids, phenolics, phlobatannins, reducing sugars, saponins, steroids, tannins and terpenoids from the leaves, tubers and twigs of *K. wilmsii*. The total flavonoids content of *K. wilmsii* leaves, tubers and twigs ranged from 1.5 to 917.0 mg quercetin equivalents (QE) per gram, total phenolic content ranged from 10.4 to 122.8 mg gallic acid equivalents (GAE) per gram and tannin content ranged from 6.9 to 22.8 mg gallic acid equivalents (GAE) per gram.[23,37,38]. Nooteboom[39] identified caffeic acid, ellagic acid, gallic acid and quercetin from the leaves of *K. wilmsii* (Figure 1). Mulholland et al.[40] identified (+)-(6S,7*E*,9*R*)-blumenol A, (+)-(6*S*,7*E*)-dihydrovomifoliol, (+)-4-ethanone-3,4-dihydro-6,8-dihydroxy-5-methylisocoumarin and (+)-(2*R*,3*R*)-7-*O*-methylaromadendrin from the bark of *K. wilmsii* (Figure 1).

Biological activities of *Kirkia wilmsii*

Biological activities of *K. wilmsii* leaf, rootbark and tuber extracts include: antimicrobial,[21,23,41-45] antioxidant,[21,23,37,38,42,46] antiplasmodial,[32] antiplatelet[41,46] and cytotoxicity[41,46] activities.

Antimicrobial activities

Suleiman[41] and Suleiman et al.[42,43] evaluated the antimicrobial activities of the hexane, acetone, dichloromethane and methanol leaf extracts of *K. wilmsii* against *Enterococcus faecalis*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Aspergillus fumigatus*, *Candida albicans*, *Cryptococcus neoformans*, *Microsporum canis* and *Sporothrix schenckii* using the bioautographic procedure. The extracts exhibited activities against the tested pathogens.[41-43]. Suleiman et al.[44] evaluated the antimicrobial activities of the hexane, dichloromethane, acetone and methanol leaf extracts of *K. wilmsii* against *Aspergillus fumigatus, Candida albicans, Candida neoformans, Microsporum canis, Sporothrix schenckii, Staphylococcus aureus, Enterococcus faecalis, Escherichia coli* and *Pseudomonas aeruginosa* using a two-fold serial microdilution method with amphotericin B (0.16 mg/ml) and gentamicin (0.1 mg/ml) as positive controls. The extracts exhibited activities with minimum inhibitory concentration (MIC) values ranging from 0.1 mg/ml to 2.5 mg/ml and total activities ranged from 13 ml/g to 863 ml/g.[44] Chigayo et al.[45] evaluated the antimicrobial activities of separated high-performance liquid chromatography (HPLC) aqueous components of *K. wilmsii* tuberous roots against *Escherichia coli, Proteus mirabilis, Salmonella typhi, Shigella dysenteriae, Staphylococcus aureus, Vibrio cholerae, Aeromonas hydrophilia, Candida albicans* and *Enterobacter aerogenes*. The extracts exhibited activities against *Shigella dysenteriae, Aeromonas hydrophilia, Salmonella typhi, Proteus mirabilis, Escherichia coli* and *Staphylococcus aureus* with MIC values ranging from 0.1 mg/ml to 3.4 mg/ml.[45] Matotoka and Masoko[21] evaluated the antimicrobial activities of the acetone and hexane tuber extracts of *K. wilmsii* against *Staphylococcus aureus, Enterococcus faecalis, Escherichia coli, Pseudomonas aeruginosa* and *Candida albicans* using the microdilution assay and bioautography technique. The extracts exhibited activities against all the tested pathogens with the exception of *Candida albicans* with MIC values ranging from 0.3 mg/mL to 2.5 mg/mL and total activities of the extracts ranging from 3.6 mL/g to 27.0 mL/g.[21] Matotoka and Masoko[23] evaluated antimicrobial activities of methanol leaves, tubers and twigs of *K. wilmsii* against *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Enterococcus faecalis* and *Candida albicans* using the micro-broth dilution assay with amphotericin B as a positive control. The extracts exhibited activities with MIC values ranging from 0.2 µg/mL to 2.5 µg/mL.[23]

Antioxidant activities

Suleiman[41] and Suleiman et al.[46] evaluated the antioxidant activities of methanol leaf extracts of *K. wilmsii* using 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging and 2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) assays with L-ascorbic acid as a positive control. The extracts exhibited activities with half maximal effective concentration (EC_{50}) value of 3.6 µg/mL in the DPPH assay, which was comparable to EC_{50} value of 1.6 µg/mL exhibited by the positive control. In the ABTS assay, the extract exhibited Trolox equivalent antioxidant capacity (TEAC) value 0.7.[41,46]. Chigayo et al.[37] evaluated the antioxidant activities of methanol, 60% methanol, 80% methanol, water and methanol/chloroform/water (12:5:3) tuber extract of *K. wilmsii* using the DPPH free radical scavenging assay with ascorbic acid as the positive control. The extracts exhibited activities with half maximal inhibitory concentration (IC_{50}) values ranging from 129.9 µg/g to 225.0 µg/g which were higher than IC_{50} value of 56.5 µg/g exhibited by the positive control.[37] Makhafola et al.[38] evaluated the antioxidant activities of methanolic leaf extracts of *K. wilmsii*, using the DPPH free radical scavenging assay with ascorbic acid as the positive control. The extract exhibited activities with EC_{50} value of 1.9 µg/ml, which was comparable to EC50 value of 2.3 µg/mL exhibited by ascorbic acid, the positive control.[38] Matotoka and Masoko[21] evaluated the antioxidant activities of the acetone and hexane tuber extracts of *K. wilmsii* using the DPPH free radical scavenging assay on thin layer chromatography (TLC) plates. The acetone extract exhibited antioxidant activities.[21] Matotoka and Masoko[23] evaluated antioxidant activities of methanol leaves, tuber and twigs of *K. wilmsii* using the DPPH free radical scavenging assay and ferric reducing power with L-ascorbic acid as a positive control. The extract exhibited activities with EC_{50} values ranging from 15.7 µg/mL to 34.5 µg/mL in DPPH assay. In the reducing power assay, the extracts showed activities with concentration-dependent relationship.[23]

Antiplasmodial activities

Clarkson et al.[32] evaluated antiplasmodial activities of *K. wilmsii* aqueous, dichloromethane, dichloromethane and methanol (1:1) leaf extracts against *Plasmodium falciparum* using the parasite lactate dehydrogenase (pLDH) assay. The dichloromethane and methanol (1:1) extract showed moderate activities with IC_{50} value of 3.7 µg/ml.[32]

Antiplatelet activities

Suleiman[41] and Suleiman et al.[46] evaluated the antiplatelet activities of methanol leaf extracts of *K. wilmsii* using the *in vitro* platelet aggregation assay with aspirin as a positive control. The extract exhibited activities with EC_{50} value of 0.2 µg/mL which was higher than the EC_{50} value of 0.04 µg/mL exhibited by the positive control.[41,46]

Cytotoxicity activities

Suleiman[41] and Suleiman et al.[46] evaluated the cytotoxicity activities of methanol leaf extracts of *K. wilmsii* against the Vero monkey kidney cell line using the 3-(4,5-dimethylthiazolyl-2)-2,5-diphenyltetrazolium bromide (MTT) assay with berberine chloride as a positive control and hemagglutination assay. The agglutination occurred at 1.3 mg/mL and the extract exhibited hemagglutination assay titer value of 0.8 implying low toxicity.[41,46].

CONCLUSION

The present review summarizes the botany, medicinal uses, phytochemistry and pharmacological properties *K. wilmsii*. At the present moment there is no data correlating the ethnomedicinal uses of *K. wilmsii* with its phytochemical and pharmacological properties. Therefore, future studies should focus on detailed chemical, pharmacological, pharmacokinetics, *in vivo* and clinical research involving both extracts and compounds isolated from the species. Future research should also focus on clinical significance of the pharmacological properties, cytotoxicity and toxicity of the species using *in vivo* models.

Conflict of interest

The author declares that he has no conflict of interest.

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