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Review Article

LANNEA SCHIMPERI: REVIEW OF ITS BOTANY, MEDICINAL USES, PHYTOCHEMISTRY, AND BIOLOGICAL ACTIVITIES

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ABSTRACT

Lannea schimperi is a well-known fruit tree and medicinal plant in tropical Africa. The current study critically reviewed the botany, medicinal uses, phytochemistry, and pharmacological activities of *L. schimperi*. Literature on botany, medicinal uses, phytochemical and biological activities of *L. schimperi* were collected from multiple internet sources including Elsevier, Google Scholar, SciFinder, Web of Science, PubMed, BMC, ScienceDirect, and Scopus. Complementary information was gathered from pre-electronic sources such as books, book chapters, theses, scientific reports, and journal articles obtained from the University Library. This study revealed that the species is used as a source of fiber, edible fruits, and herbal medicine. Phytochemical compounds identified from the species include cyclohexenones, cardanols, alkaloids, anthocyanins, anthracene glycosides, carbohydrates, cardiac glycosides, carotenoids, condensed tannins, coumarins, flavonoids, phenolic glycosides, phenols, polyoses, polyuronoids, reducing sugars, saponins, steroids, tannins, triterpenoids, and volatile compounds. Pharmacological research revealed that extracts and phytochemical constituents isolated from *L. schimperi* have anesthetic, antibacterial, antifungal, anticoccidial, anti-inflammatory, antinociceptive, antioxidant, anti-trypanosoma, antiulcerogenic, cytotoxicity, and toxicity activities. *L. schimperi* should be subjected to detailed phytochemical, pharmacological, and toxicological evaluations aimed at correlating its medicinal uses with its phytochemistry and pharmacological activities of the species.

Keywords: Anacardiaceae, *Lannea schimperi*, Herbal medicine, Tropical Africa.

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INTRODUCTION

Lannea schimperi (Hochst. ex A. Rich.) Engl. is categorized by Brink and Achigan-Dako [1] as an important source of fiber in tropical Africa. *L. schimperi* is among some plant species that are used locally for making tying material and clothes, packing and for the production of baskets, mats, and brooms [1]. Van Wyk and Gericke [2] argued that many different items made from fibers, fibrous stems or bark are used by rural people in their daily lives, such as rope or code for tying, baskets for carrying and storing food and for catching fish, beer strainers, sitting mats and sleeping mats, hand brooms for sweeping, and clothing items such as hats. The fruits of *L. schimperi* are edible in several countries including Ethiopia [3-6], Nigeria [7,8], Rwanda [9], and Tanzania [10]. The bark of *L. schimperi* is also chewed to quench thirst in Tanzania [10]. *L. schimperi* is also an important medicinal plant species in tropical Africa [11-17], not only used for human health care but also applied as veterinary medicine [18-21]. Traditional medicines are an important component of the daily lives of many people in tropical Africa as part of their cultural heritage [22-27]. The species is among the herbal medicines that have been used in the continent for centuries [11-15,17], and this form of complementary and alternative medicine and health-care system is still the most affordable and accessible health-care system in the continent. However, there is a dearth of information on the medicinal uses and phytochemical and pharmacological activities of *L. schimperi*. Despite considerable efforts over the past decades to document the medicinal uses and active ingredients of medicinal plants [24], there is still a lack of detailed documentation on the medicinal uses and phytochemical and pharmacological properties of many medicinal uses in tropical Africa [28-54]. This is an urgent priority in view of the fragility of oral-indigenous knowledge and the rapid rate of urbanization and acculturation in the continent [22-24]. It is within this context that this review was undertaken aimed at summarizing the botany, medicinal uses, and phytochemical and biological activities of *L. schimperi* so as to provide baseline data required in evaluating the therapeutic potential of the species.

BOTANICAL PROFILE OF *L. SCHIMPERI*

L. schimperi is a member of the cashew or sumac or Anacardiaceae family. The Anacardiaceae family includes economically important genera such as sumac (*Rhus* L.), mango (*Mangifera* L.), cashew (*Anacardium* L.), and marula (*Sclerocarya* Hochst.), and the family is made up of approximately 800 species in 82 genera [55]. The name of the genus, "*Lannea*," is based on a Latin word "lana" which translates to "wool" in reference to young plant parts which are densely hairy or possibly to the wool on the roots of some *Lannea* species [56,57]. The specific name "*schimperi*" probably honors Wilhelm Schimper (1804–1878), a German botanist, naturalist and traveler in North Africa or possibly after other members of his family who were also botanical collectors [58]. The genus *Lannea* consists of approximately 40 species which are usually trees, shrubs, or suffrutices, occupying different habitats in sub-Saharan Africa, Arabia, and tropical Asia [56,59,60]. The synonyms of *L. schimperi* are *L. schimperi* (Hochst. ex A. Rich.) Engl. var. *stolzii* (Engl. and Brehmer) R. Fern. and A. Fern. and *Odina schimperi* Hochst. ex A. Rich. [61-65].

L. schimperi is a small to medium-sized tree, growing up to 15 m tall [64]. The trunk of the species is short, sometimes stunted characterized by low-branching with spreading crown, outer bark is smooth to rough, gray to black in color, and the inner bark is red in color with vertical orange streaks. The branchlets of the species are hairy and stout with flower-bearing terminal branches. The leaves of the species are alternate, imparipinnately compound, grouped at the end of branches; leaflets are opposite, elliptical, oblong-ovate to ovate in shape, basal leaflets somewhat broader and shorter, acute or obtuse at the apex, and the terminal leaflet being symmetrical and acute. The flowers are small to medium in size, greenish to yellow in color, crowded at the terminal branches, male flowers longer than female flowers. The fruit is an obliquely ovoid drupe, fleshy and red in color [64]. *L. schimperi* has been recorded from Cameron, Northern Nigeria, and Togo eastward to Kenya, Ethiopia, Uganda, Burundi, Rwanda, Tanzania, Central African Republic, South Sudan, Sudan, Eastern Democratic Republic of Congo,

to Southern Africa in Zambia, Mozambique, and Malawi [17,61-65]. The species has been recorded in open grassland, wooded grassland, woodland and often on rocky slopes, outcrops on volcanic limestone and basement complex or termite mounds at elevations from 800 m to 2200 m above sea level [17].

MEDICINAL USES OF *L. SCHIMPERI*

A bark and root decoction of *L. schimperi* is used as herbal medicine for abdominal pains in Kenya and Mozambique [66] while leaf decoction is used against blood diarrhea in Kenya and Tanzania [12,13,66] (Table 1). Root and bark decoction of *L. schimperi* is used against chest pains in Malawi, Kenya, and Tanzania [11-13,67-69] while root decoction is used against colds in Malawi and Tanzania [11-13]. The seed, leaf, root, and bark decoction of *L. schimperi* is used against cough in Rwanda and Tanzania [9,70] while root and stem bark decoction is used against diarrhea and dysentery in Burundi, Kenya, and Malawi [66-69,71]. The leaf and bark infusion of *L. schimperi* is used against skin infections and rashes in Ethiopia and Tanzania [16,72,73] while bark, root, and leaf infusion of the species is used against stomach problems in Kenya and Tanzania [67-70]. Bark decoction of *L. schimperi* is used as herbal medicine for tuberculosis in Namibia and Tanzania [16,72,74] while bark, leaf, and root decoction are used as ethnoveterinary medicine for blackleg, diarrhea, dysentery, intestinal parasites, and Texas fever in Ethiopia and Nigeria [18-21]. In Kenya, root decoction of *L. schimperi* is used against constipation and sore throat [66] while in Malawi, root or root bark decoction is used against syphilis [11,66]. In Ethiopia, the root decoction of *L. schimperi* is used against intestinal parasites [21] while in Mozambique, the bark, root, and leaf infusion is used for tussis [66]. In Tanzania, the bark, root, and leaf infusion of *L. schimperi* is used for anemia, mental disorders, snake bites, and tumor [70], the root decoction is used for toothache, yellow fever, and induce labor [12,13,75], the bark decoction is used for backache, chronic diarrhea, diabetes mellitus, epilepsy, general body weakness, herpes simplex, herpes zoster, and malaria [12,13,16,72,76,77]. In Kenya, the leaves of *L. schimperi* are mixed with roots or tubers of *Cissus Phyllanthus* Gilf as remedy for amoebic dysentery, diarrhea, and hiccups [78] while the bark of the species is mixed with the bark of *Ficus* spp. and *Dalbergiellanyasae* Baker f. as a remedy for dysentery in Malawi [11]. In Tanzania, the stem bark of *L. schimperi* is mixed with stem bark of *Gymnosporia senegalensis* (Lam.) Loes., *Ozoroa insignis* Del., and *Entada abyssinica* Steud. ex A. Rich. and leaves of *Rhynchosia recinosa* (A. Rich.) Bak. as a remedy for peptic ulcers [79].

PHYTOCHEMICAL CONSTITUENTS OF *L. SCHIMPERI*

Okoth [80] and Okoth and Koorbanally [81] identified alkenyl cyclohexenones, alkenyl cyclohexanols, and cardanols from the root and stem bark extracts of *L. schimperi* (Table 2). Okoth [80] and Okoth and Koorbanally [81] identified triterpenes and taraxerone and taraxerol

Table 1: Medicinal uses of *Lannea schimperi*

Medicinal use	Parts of the plant used	Country	References
Abdominal pains	Bark and roots	Kenya and Mozambique	[66]
Amoebic dysentery, diarrhea, and hiccups	Leaves are mixed with roots or tubers of *Cissus Phyllanthus* Gilf	Kenya	[78]
Anemia	Bark, leaves, and roots	Tanzania	[70]
Backache	Bark	Tanzania	[12,13]
Blood diarrhea	Leaves	Kenya and Tanzania	[12,13,66]
Chest pains	Bark and roots	Kenya, Malawi, and Tanzania	[11-13,67-69]
Chronic diarrhea	Bark	Tanzania	[16,72]
Colds	Roots	Malawi and Tanzania	[11-13]
Constipation	Roots	Kenya	[66]
Cough	Bark, leaves, roots, and seeds	Rwanda and Tanzania	[9,70]
Diabetes mellitus	Bark	Tanzania	[76]
Diarrhea	Bark	Burundi and Kenya	[67-69,71]
Dysentery	Bark combined with the bark of *Ficus* spp. and *Dalbergiellanyasae* Baker f.	Malawi	[11]
Dysentery	Root bark	Malawi	[66]
Epilepsy	Bark	Tanzania	[77]
General body weakness	Bark	Tanzania	[12,13]
Herpes simplex and zoster	Bark	Tanzania	[16,72]
Induce labor	Roots	Tanzania	[75]
Intestinal parasites	Roots	Ethiopia	[21]
Malaria	Bark	Tanzania	[77]
Mental disorders	Bark, leaves, and roots	Tanzania	[70]
Peptic ulcers	Stem bark mixed with stem bark of *Gymnosporia senegalensis* (Lam.) Loes., *Ozoroa insignis* Del., and *Entada abyssinica* Steud. ex A. Rich. and leaves of *Rhynchosia recinosa* (A. Rich.) Bark.	Tanzania	[79]
Skin infections and rashes	Bark and leaves	Ethiopia and Tanzania	[16,72,73]
Snakebites	Bark, leaves, and roots	Tanzania	[70]
Sore throat	Roots	Kenya	[66]
Stomach problems	Bark, leaves, and roots	Kenya and Tanzania	[67-70]
Syphilis	Root bark	Malawi	[11,66]
Tussis	Bark, leaves, and roots	Mozambique	[66]
Toothache	Roots	Tanzania	[12,13]
Tuberculosis	Bark	Namibia and Tanzania	[16,72,74]
Tumor	Bark, leaves, and roots	Tanzania	[70]
Yellow fever	Roots	Tanzania	[75]
Ethnoveterinary medicine			
Blackleg	Bark	Ethiopia	[20]
Diarrhea	Leaves	Ethiopia	[18]
Dysentery	Leaves	Ethiopia	[18]
Intestinal parasites	Roots	Ethiopia	[21]
Texas fever	Bark	Nigeria	[19]

and sitosterol from the root and stem bark extracts, respectively, of *L. schimperi* (Table 2). Other phytochemical compounds that have been identified from the stem bark and gum exudates of *L. schimperi* include alkaloids, anthocyanins, anthracene glycosides, carbohydrates, cardiac glycosides, carotenoids, condensed tannins, coumarins, flavonoids, phenolic glycosides, phenols, polyoses, polyuronoids, reducing sugars, saponins, steroids, tannins, triterpenoids, and volatile compounds [12,79,82,83] (Table 3). Some of these phytochemical compounds may be responsible for the pharmacological properties associated with the species.

Table 2: Cardanols, cyclohexenones, and triterpenes identified from root and stem bark of *Lannea schimperi* (after Okoth[80] and Okoth and Koorbanally [81])

Phytochemical composition	Formula
Alkenyl cyclohexenones	
5-[12'(E)-pentadecenyl]-4,5-dihydroxycyclohex-2-enone	$C_{21}H_{36}O_3$
5-[14'(E)-heptadecenyl]-4,5-dihydroxycyclohex-2-enone	$C_{23}H_{40}O_3$
5-[16'(E)-nonadecenyl]-4,5-dihydroxycyclohex-2-enone	$C_{25}H_{44}O_3$
5-[18'(E)-heneicosenyl]-4,5-dihydroxycyclohex-2-enone	$C_{27}H_{48}O_3$
Alkenyl cyclohexenones	
1-[12'(E)-pentadecenyl]-cyclohex-3-en-1,2,5-triol	$C_{21}H_{38}O_3$
1-[14'(E)-heptadecenyl]-cyclohex-3-en-1,2,5-triol	$C_{23}H_{42}O_3$
1-[16'(E)-nonadecenyl]-cyclohex-3-en-1,2,5-triol	$C_{25}H_{46}O_3$
1-[14'(E)-heptadecenyl]-4-cyclohex-4en-1,3-diol	$C_{23}H_{42}O_2$
1-[16'(E)-nonadecenyl]-4-cyclohex-4en-1,3-diol	$C_{25}H_{46}O_2$
1-[18'(E)-heneicosenyl]-4-cyclohex-4en-1,3-diol	$C_{27}H_{50}O_2$
Cardanols	
3-[12'(E)-pentadecenyl] phenol	$C_{21}H_{34}O$
3-[14'(E)-heptadecenyl] phenol	$C_{23}H_{38}O$
3-[16'(E)-nonadecenyl] phenol	$C_{25}H_{42}O$
3-[18'(E)-heneicosenyl] phenol	$C_{27}H_{46}O$
Phytosterol	
β-sitosterol	$C_{29}H_{50}O$
Pentacyclic triterpenoid	
Taraxerol	$C_{30}H_{50}O$
Triterpenoid	
Taraxerone	$C_{30}H_{48}O$

PHARMACOLOGICAL PROPERTIES OF *L. SCHIMPERI*

Pharmacological studies on *L. schimperi* bark, leaf, root, and stem extracts exhibited potent *in vitro* and *in vivo* pharmacological activities including anesthetic [79], antibacterial [79,86], antifungal [86,87], anticoccidial [88], anti-inflammatory [82], antinoceceptive [82], antioxidant [83], anti-trypanosomal [89], antiulcerogenic [79], cytotoxicity [77,79,81,90], and toxicity [8,79] activities.

Anesthetic activities

Haule *et al*. [79] evaluated anesthetic activities of the methanolic leaf extracts of *L. schimperi* using intracutaneous wheal test in guinea pigs for infiltration anesthesia and guinea pig corneal reflex method of surface anesthesia using lidocaine and normal saline as positive and negative controls, respectively. The extracts exhibited dose-dependent local anesthetic activities with faster onset and longer duration of action at 24 mg/ml than at 12 mg/ml of the extract. Additions of 5 µg of adrenaline into the 24 mg/ml preparation also prolonged the duration of local anesthetic activities of the extract. The extract at 24 mg/ml significantly inhibited corneal reflex[79].

Antibacterial activities

Haule *et al*. [79] evaluated antibacterial activities of *L. schimperi* extracts or combined with *Rhynchosia resinosa; O. insignis, G. senegalensis,* and *E. abyssinica* or combined with *R. recinosa;* and *G. senegalensis* or combined with *R. resinosa;* and *O. insignis* or combined with *R. resinosa;* and *E. abyssinica* or combined with *R. resinosa* and *G. senegalensis* against *Escherichia coli, Salmonella typhi, Vibrio cholera,* and *Klebsiella pneumoniae* using the microdilution method with gentamicin sulfate as the positive control. *L. schimperi* extracts alone exhibited activities with minimum inhibitory concentration (MIC) values of 1.6 mg/ml and 2.5 mg/ml against *S. typhi* and *K. pneumoniae*, respectively. *L. schimperi* combined with other plant species showed activities against all tested pathogens with MIC values ranging from 0.8 mg/ml to

Table 3: Phytochemical composition of *Lannea schimperi*

Nutritional composition	Values	Plant parts	References
Arabinose (%)	10.0	Gum	[84]
Ash (%)	0.04–4.2	Gum	[84]
Galactose (%)	69.5	Gum	[84]
Methoxyl (%)	0.9	Gum	[84]
Moisture (%)	7.2–8.9	Gum	[84]
Nitrogen (%)	0.27	Gum	[84]
Protein (%)	1.69	Gum	[84]
Rhamnose (%)	3.5	Gum	[84]
Uronic acid (%)	17.0	Gum	[84]
Uronicanhydride (decarboxyln) (%)	17.0	Gum	[84]
Total alkaloids (mg/ml)	−1.8−−4.1	Leaves, roots, and stem	[83]
Total flavonoids (mg quercetin equivalent/g dry weight)	26.3–43.9	Leaves, roots, and stem	[83]
Total phenolics (mg gallic acid/g dry weight)	165.5–292.8	Leaves, roots, and stem	[83]
Total tannin (mg tannic acid/g dry weight)	0.4–2.3	Leaves, roots, and stem	[83]
Amino acids (µmoles amino acid 1000 µmoles total)			
Lysine	13	Gum	[85]
Histidine	6	Gum	[85]
Arginine	15	Gum	[85]
Threonine	210	Gum	[85]
Serine	260	Gum	[85]
Glutamic acid	34	Gum	[85]
Proline	148	Gum	[85]
Glycine	28	Gum	[85]
Alanine	50	Gum	[85]
Valine	30	Gum	[85]
Isoleucine	17	Gum	[85]
Leucine	130	Gum	[85]
Tyrosine	37	Gum	[85]
Phenylalanine	14	Gum	[85]
Glucosamine	9	Gum	[85]

12.5 mg/ml [79]. Ekuadzi *et al*. [86] evaluated antibacterial activities of ethanol stem bark extracts of *L. schimperi* against *Enterococcus faecalis, Streptococcus pyogenes, Staphylococcus aureus, Bacillus subtilis, S. typhi, E. coli, Pseudomonas aeruginosa,* and *K. pneumonia* using the broth microdilution method. The extracts showed activities with MIC values ranging from 2.3 mg/mL to 8.4 mg/mL. Ekuadzi *et al*. [86] also evaluated the modulation effects when sub-inhibitory concentrations of plant extracts were combined with the standard antibiotic, ciprofloxacin using the checkerboard assay. The combinatorial cases yielded biologically significant modulation factors causing more than two-fold reduction of the MIC of the standard drug, ciprofloxacin [86].

Antifungal activities

Kisangau *et al*. [87] evaluated antifungal activities of dichloromethane and aqueous stem bark extracts of *L. schimperi* against *Candida albicans, Cryptococcus neoformans,* and *Aspergillus niger* using agar well and disk diffusion methods with fluconazole (2 µg/mL) as the positive control. Dichloromethane extracts showed activities against all tested fungi with a zone of inhibition ranging from 7.0 mm to 16.5 mm. The MIC and minimum fungicidal concentration values of dichloromethane crude extracts and semi-purified fractions ranged from 12.5 µg/mL to 50.0 µg/mL [87]. Ekuadzi *et al*. [86] evaluated antifungal activities of ethanol stem bark extracts of *L. schimperi* against *Candida albicans* using the broth microdilution method. The extract showed activities with MIC value of 3.0 mg/mL. Ekuadzi *et al*. [86] also evaluated the modulation effects when sub-inhibitory concentrations of plant extracts were combined with the standard drug, ketoconazole using the checkerboard assay. The combinatorial cases yielded biologically significant modulation factors causing more than two-fold reduction of the MIC of the standard drug, ketoconazole [86].

Anticoccidial activities

Mikail *et al*. [88] evaluated the anticoccidial activities of the methanolic leaf extracts of *L. schimperi* against oocysts of *Eimeria tenella* with amprolium (1 mg/ml) as a positive control. The extract was tested at concentrations of 25 mg/ml, 50 mg/ml, and 100 mg/ml against *E. tenella* isolated from infected chicks. The extracts showed activities against unsporulated and sporulated oocysts of *E. tenella* in a dose-dependent manner, the extract at concentration of 100 mg/ml inhibited oocyst sporulation (98 %) and inhibited the viability of sporulated oocysts (97%) similar to that recorded by the standard drug amprolium after 72 h of incubation [88].

Anti-inflammatory activities

Egbe *et al*. [82] evaluated the anti-inflammatory activities of the methanolic leaf extracts of *L. schimperi* at doses of 12 mg/kg and 24 mg/kg using the egg albumin-induced acute inflammation model in rat with aspirin at dose of 80 mg/kg used as a positive control while the drug vehicle was used as a negative control. The extracts showed activities at both doses, and there were no significant differences between the extract treated rats with those rats treated with the standard drug, aspirin [82]. The exhibited anti-inflammatory activities of the methanolic leaf extracts of *L. schimperi* could be beneficial in alleviating painful inflammatory conditions.

Antinociceptive activities

Egbe *et al*. [82] evaluated the antinociceptive activities of the methanolic leaf extracts of *L. schimperi* at doses of 12 mg/kg and 24 mg/kg using acetic acid-induced writhing model in mice with aspirin at dose of 80 mg/kg used as a positive control while the drug vehicle was used as a negative control. The extracts showed activities at both doses, decreasing the acetic -nduced writhing reflex in mice when compared with the negative control [82]. The exhibited antinociceptive activities of the methanolic leaf extracts of *L. schimperi* could be beneficial in alleviating painful inflammatory conditions.

Antioxidant activities

Sherfi *et al*. [83] evaluated antioxidant activities of methanolic leaf, root, and stem extracts of *L. schimperi* using 1,1-diphenyl-2-picrylhydrazyl free radical (DPPH) free radical scavenging assay with propyl gallate as a positive control. The extracts showed high effective free radical scavenging in the DPPH assay with a scavenging rate ranging from 86.0% to 92.0% and half maximal inhibitory concentration (IC_{50}) values ranging from 0.04 mg/ml to 1.2 mg/ml and these values were comparable to 91.0% and 0.03 mg/ml exhibited by propyl gallate, the standard drug [83].

Anti-trypanosomal activities

Mikail [8] evaluated the anti-trypanosomal activities of the methanolic extracts against *Trypanosoma brucei* brucei at concentrations of 3 mg/ml, 6 mg/ml, 12 mg/ml, and 24 mg/ml with 5% dextrose and 0.9% saline as controls. Complete mortality of the organism was observed at the concentrations of 24 mg/kg, 12 mg/kg, 6 mg/kg, and 3 mg/kg within 30 min, 60 min, 180 min, and 330 min, respectively, in a dose-dependent manner [8]. These findings suggest that the methanolic leaf extracts of *L. schimperi* possess some trypanocidal principles which may require further scientific elucidations.

Antiulcerogenic activities

Haule *et al*. [79] evaluated the ability of ethanol extract of *L. schimperi* mixed with *R. recinosa* and stem bark of *O. insignis, G. senegalensis,* and *E. abyssinica* to protect Sprague Dawley rats from gastric ulceration at doses of 100 mg/kg, 200 mg/kg, 400 mg/kg, and 800 mg/kg body weight. The cytoprotective effect was assessed by comparison with a negative control group given 1% tween 80 in normal saline and a positive control group given 40 mg/kg body weight pantoprazole. The combined ethanolic extracts of the five plant species caused dose-dependent protection against ethanol/hydrochloric acid-induced ulceration of rat gastric mucosa, reaching 81.7% mean protection as compared to 87.5% protection by 40 mg/kg body weight pantoprazole [79].

Cytotoxicity activities

Moshi *et al*. [77] evaluated the cytotoxicity activities of ethanol stem bark extract of *L. schimperi* using the brine shrimp lethality test with cyclophosphamide, a standard anticancer drug as a positive control. The extract exhibited weak activities with the median lethal concentration (LC_{50}) value of 110.8 µg/ml which was higher than LC_{50} value of 16.3 µg/ml exhibited by cyclophosphamide, a standard anticancer drug [77]. Kisangau *et al*. [90] evaluated the cytotoxicity activities of dichloromethane stem bark extracts against K562 Leukemia cell line using the CellTiter-Blue™ cell viability assay. In the CellTiter-Blue™ cell viability assay, the mean percentage of cell vitality growth for the extracts was 52.3% [90]. Haule *et al*. [79] evaluated the cytotoxicity activities of *L. schimperi* bark extracts using the brine shrimp lethality test with cyclophosphamide as the positive control. The extract exhibited weak activities with an LC_{50} value of 128.4 µg/ml which was higher than an LC_{50} value of 16.3 µg/ml exhibited by cyclophosphamide, a standard anticancer drug [79]. Okoth and Koorbanally [81] evaluated the cytotoxicity activities of compounds isolated from the stem and root bark of *L. schimperi* against the Chinese hamster ovary mammalian cell-line using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide (MTT) calorimetric assay with emetine as a positive control. The alkenyl cyclohexenone compounds, 5-[12'(E)-pentadecenyl]-4,5dihydroxycyclohex-2-enone, 5-[14'(E)-heptadecenyl]-4,5dihydroxycyclohex-2-enone, 5-[16'(E)-nonadecenyl]-4,5dihydroxycyclohex-2-enone, and 5-[18'(E)-heneicosenyl]-4,5dihydroxycyclohex-2-enone exhibited activities with IC_{50} value of 8.0 µg/mL while the standard drug, emetine exhibited IC_{50} value of 0.07 µg/mL [81].

Toxicity activities

Haule *et al.* [79] evaluated acute toxicity activities of *L. schimperi* ethanol bark extracts using both male and female Theiler's albino mice. A dose of 1000 mg/kg, 2000 mg/kg, 3000 mg/kg, 4000 mg/kg, and 5000 mg/kg body weight were administered to a group of six mice (three male and three female), and the mice observed for signs of immediate toxicity and/or death for 72 h. Extracts were solubilized in 1% tween 80 and administered at a single oral dose volume of 5 ml/kg body weight or two separate 5 ml/kg body weight doses given within an hourly interval, depending on solubility. A control group was run for each plant extract

which was administered a single 5 ml or two 5 ml/kg body weight of 1% tween 80 to match with the volume of plant extracted ministered. The extract caused increased defecation or diarrhea, but it did not kill any mice up to 2000 mg/kg body weight. Mortality to mice occurred at doses of 3000 mg/kg body weight and above [79]. Mikail [8] evaluated the toxicological activities of methanolic leaf extracts of *L. schimperi* in mice using the Lorke's assay. The mice were treated at doses of 10 mg/kg, 100 mg/kg, and 1000 mg/kg with extracts intraperitoneally and observed for 24 h for any signs of toxicity including death. Acute toxicity test indicated that the extracts produced 100% mortality at doses of 370 mg/kg, 600 mg/kg, and 1000 mg/kg. At these doses, the rats showed signs of toxicity including inactiveness, rough hair coat, dullness, depression, and death, and the median lethal dose of the extract was determined to be 288.5 mg/kg [8]. Therefore, the methanolic leaf extract of *L. schimperi* is considered to be moderately toxic.

CONCLUSION

The present review summarizes the botany, medicinal uses, phytochemistry, and pharmacological properties *L. schimperi*. In the past 40 years, *L. schimperi* has been the subject of phytochemical and pharmacological research, but there is not yet enough data correlating the ethnomedicinal uses of the species with its phytochemical and pharmacological properties. Detailed studies on the pharmacokinetics, *in vivo* and clinical research involving both extracts and compounds isolated from the species, are required. Therefore, future research should focus on the molecular modes or mechanisms of action, pharmacokinetics, and physiological pathways for specific extracts of the species including identification of the bioactive compounds of the species and their associated pharmacological activities.

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AUTHOR'S CONTRIBUTIONS

The author declares that this work was done by the author named in this article.

CONFLICTS OF INTEREST

The author declares that there are no conflicts of interest regarding the publication of this paper.

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