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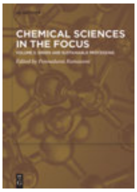

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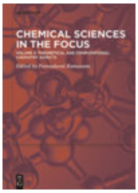

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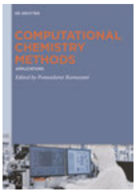

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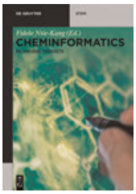

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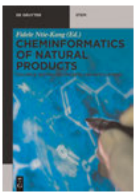

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Chemical Sciences in the Focus

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Preface of the Book of Proceedings of the Virtual Conference on Chemistry and its Applications (VCCA-2020)

A virtual conference on chemistry and its applications (VCCA-2020) was organized online from 1st to 31st August 2020. The theme of the virtual conference was “Research and Innovations in Chemical Sciences: Paving the Way Forward”.

There were 190 presentations for the virtual conference with 300 participants from 50 countries. A secured platform was used for virtual interactions of the participants. After the virtual conference, there was a call for full papers to be considered for publication in the conference proceedings. Manuscripts were received and they were processed and reviewed as per the policy of De Gruyter.

This book, volume 1, is a collection of the ten accepted manuscripts having pharmaceutical applications.

Ojo and Derek reviewed the traditional uses, biological activities and phytochemicals of *Lecaniodiscus cupanioides*. Mshelia et al studied the phytochemical and antioxidant activity of *Cadaba farinosa* stem bark extracts. Binang and Takuwa applied reverse phase high performance liquid chromatography for the determination of selected antihypertensive active flavonoids (rutin, myricetin, quercetin and kaempferol) in medicinal plants used to manage hypertension by herbalists in Botswana. Fotsing et al reviewed the synthesis of biologically active heterocyclic compounds by the Michael addition and the double Michael addition of various amines and diamines on allenic nitriles, acetylenic nitriles, hydroxyacetylenic nitriles, acetylenic acids and acetylenic aldehydes. Djellouli et al applied differential scanning calorimetry, Fourier transformed infrared spectroscopy, scanning electron microscopy and X-ray powder diffractometry techniques to evaluate the interaction between diclofenac sodium with excipients commonly used in solid dosage forms: microcrystalline cellulose as diluent and stearic acid acid. Lukhele et al provided an overview of the traditional uses *Rapanea melanophloeos* bark, fruit and leaf extracts and compared the phytochemicals and antibacterial activities of various crude extracts validate their uses. Omobolanle et al evaluated the extracts and isolated compounds from *Alternanthera brasiliensis* plant for their activity against Methicillin-resistant *Staphylococcus aureus*. Kafeelah et al evaluated the raw, treated and effluent water quality from selected water treatment plants from Lagos Water Corporation. Attah et al extracted the peptide -rich aqueous portion of *Tragia benthamii* and subjected this to pre -purification via solid phase extraction to yield an optimized crude peptide mixture whose biophysical properties, nature and individual masses were determined by a combination of reversed phase liquid chromatography, chemical derivatization and Matrix assisted laser desorption time of flight mass spectrometry. Maria et al reported on combinatorial library

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designing and virtual screening of cryptolepine derivatives against Topoisomerase IIA by molecular docking.

I hope that these chapters of this volume 1 will add to literature and they will be useful references for researchers.

To conclude, VCCA-2020 was a successful event and I would like to thank all those who have contributed. I would also like to thank the Organising and International Advisory committee members, the participants and the reviewers.

Prof. Ponnadurai Ramasami

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Olusesan Ojo and Derek T. Ndinteh*

1 Traditional uses, biological activities, and phytochemicals of *Lecaniodiscus cupanioides*: a review

Abstract: Medicinal plants are indispensable source of therapeutic agents, and have proved to be “warehouse” of lead drug candidates. *Lecaniodiscus cupanioides* Planch. ex Benth is a medicinal tree plant that is extensively distributed in both Asia and Africa. The species has many ethnomedicinal uses in the treatment of fever, cough, typhoid, wound, skin infection, measles, jaundice, diabetes, sexual dysfunction, cancer, bone fracture, and as galactogogues. In the recent decades, the extracts and phytochemicals of *L. cupanioides* have been investigated to possess antibacterial, anticancer, aphrodisiac, antifungal, cytotoxic, antidiabetic, antiprotozoal, antioxidant, antidiarrhoeal, analgesic and ameliorative properties. However, triterpenoids which have been linked to its anticancer and antifungal actions, are the only isolated active constituents identified from the species despite the results of the phytochemical screenings and reported biological activities. Moreover, the mechanisms of action of the extracts and active components are yet to be fully elucidated. This paper provides a general review on the ethnomedicinal, phytochemicals, and biological activities of *L. cupanioides*, and lays a solid foundation for future investigations on the plant.

Keywords: biological activity; ethnomedicine; *Lecaniodiscus cupanioides*; medicinal plants; phytochemicals.

1.1 Introduction

There have been arousing interests nowadays in the utilization of medicinal plants. This is partly due to continuous and alarming rise in the prices of synthetic drugs as well as partly due to associated side effects, such as human toxicity of these synthetic drugs [1]. Medicinal plants and/or plant-derived medicines are currently used globally to treat various forms of ailments. Plant-based medicines have shown their potential over synthetic drugs by mostly having fewer or no side effects, and lower or no toxicity. Moreover, they serve as templates or models structurally and pharmacologically for synthetic drugs, and sometimes they are used directly as therapeutics [2, 3]. The World Health Organization (WHO) opined that up to 80% of the people living in developing

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countries currently utilize medicinal plants as remedies for one disease or the other [4]. Plants have been used for treating diverse diseases from the time immemorial by the traditional herbal healers or rural dwellers. For several decades, plants have been employed in medicine, nutrition and cosmetics, with little or no harmful effects [5]. It has been reported that medicinal plants possess several bioactive phytochemicals with pharmacological properties, including antibacterial, anticancer, antioxidant, antifungal, antiviral, analgesic, and anti-inflammatory [6–10]. These bioactive phytochemicals include alkaloids, terpenoids, coumarins, steroids, tannins, saponins, flavonoids, phenolic acids, lignin, and quinines to mention a few [11].

Our nature environment provides us with variety of chemical compounds that are diverse in structure, and naturally-derived compounds are well-known for unique pharmacological properties. Natural products possess structurally diverse chemical compounds that are "optimized" by the evolutionary changes as drug-like molecules [12]. It is well reported in the literature that natural products provide a matchless resource for the discovery of novel drug candidates. A synthetic review of natural products (NPs) from 1981 to 2014 showed that approximately 40% of the therapeutics licenced by the U.S. Food and Drug Administration (FDA) were mainly NPs, derivatives of NPs, or synthetic mimetic products related to NPs [13]. Literature is replete with examples of phytochemicals or drugs derived from natural products or medicinal plants. This includes morphine (from the opium poppy *Papaver somniferum*), anticarcinogenic agent Taxol (from *Taxus brevifolia*), and the artemisinin, an antimalarial drug, from a Chinese plant, *Artemisia annua* [14–16].

Medicinal plants, undoubtedly, have become a focal point for meeting or improving the health needs of man [17]. Nature is endowed with amazing medicinal plants to handle every human disease as well as health challenges, and to serve as alternative bio-resources to synthetic drugs. Unfortunately, many of these medicinal plants have been underutilized to enhance quality of human health because of lack of adequate information on their pharmacological potential. One of such medicinal plants is *Lecaniodiscus cupanioides* Planch. ex Benth. This plant is chosen because of its numerous medicinal values, and lacks of review literature on its medicinal potential. Therefore, the present study is designed to review previously published and original data on the traditional uses, biological properties, and phytochemistry of *L. cupanioides* as a potential source of new bioactive molecules.

1.2 Botanical description of *L. cupanioides*

The plant *L. cupanioides* belongs to the family Sapindaceae (Table 1.1). It is an elegant, tropical tree widely common in Asia and Africa. It is known by several local names. For instance, it is named "Akika" among the Yoruba tribe, "Ukpo" among the Igbos, and "Kafi-nama-zaki" among the Hausa in Nigeria; in Sierra Leone as Bulati (Limba), Babwi (Loko), and in Ivory Coast as Bue (Akye) and Klima (Baule). The plant is about 6–12 m

Table 1.1: Taxonomical classification of *Lecaniodiscus cupanioides*.

Taxonomy	
Kingdom	Plantae
Phylum	Tricheophyta
Class	Magnoliopsida
Order	Sapindales
Family	Sapindaceae
Genus	Lecaniodiscus
Species	*Lecaniodiscus cupanioides*

high or more, with a low-branching, spreading crown. It is planted as shade tree in some towns. The tree is evergreen, semi-deciduous, and often found in seasonally flooded forest, on rocky riverside, and sometimes on the forest outliers in Savanna regions. It extends from Senegal to West Cameroons and across Africa to Sudan, Uganda, and Southern Angola. The tree has alternate compound leaves. The leaflets have a petiolule which is swollen at the bottom (Figure 1.1). The flowers have unusual disc which surrounds the stamens. Hence, the name "*Lecaniodiscus*", meaning saucer-shaped disc [18, 19].

1.3 Ethnomedicinal uses of *L. cupanioides*

L. cupanioides has been used in the traditional clinical practices of many cultures worldwide, including those of the African and Asian to treat a number of diseases and

Figure 1.1: *L. cupanioides* plant, showing fruiting branches (Photograph by: International Institute of Tropical Agriculture (IITA), Oyo State, Nigeria).

sickness. The leaves, stems, roots, and barks of *L. cupanioides* have been documented in the existing literature for use in the treatment of infections among the traditional healers. The plant has enormous potential for medicinal uses, especially in the treatment of infertility and sex-related challenges and malaria [20]. The leaves and the roots are used to treat malaria, a deadly infectious disease, by the rural dwellers in Benin [21]. The ethnomedicinal uses of *L. cupanioides* in traditional medicine have been detailed in Table 1.2. Various parts of the plant are used for the treatment of oral hygiene, wounds, burns, wound, fever, and abdominal swelling [20].

1.4 Biological activities of *L. cupanioides*

Different pharmacological activities have been reported for *L. cupanioides* by various researchers. The extracts and chemical constituents isolated from *L. cupanioides* have been shown to exhibit varying biological activities which include, but not limited to, antibacterial, analgesic, ameliorative, antioxidant, antiprotozoal, antifungal, anti-CNS depressant, and anticancer activities (Figure 1.2).

1.4.1 Antibacterial activity

It has been documented in the literature that *L. cupanioides* exhibited antibacterial activity against a number of human pathogens [33, 34]. Sofidiya et al. [33] screened

Table 1.2: Ethnomedicinal uses of *L. cupanioides*.

Category of use	Part(s) used	Reference
Malaria fever	Leaves, roots	[21]
Sexual dysfunction	Roots	[20–22]
Typhoid	Leaves, roots, stem	[23, 24]
Jaundice	Leaves, stem, roots	[23, 24]
Cough	Stem, bark	[23, 24]
Skin infection	Bark	[25]
Cancer, tumour	Bark, roots	[26]
Pain	–	[27]
Scalp infection	Roots, bark	[28]
Diabetes	Stem-bark	[29]
Wound and sore	Leaves, stem, bark	[30]
Abdominal swelling	Leaves, bark, stem	[30]
Measles	Leaves, bark, stem	[30]
Boils and burns	Leaves	[30]
Galactogogues	Roots	[31]
Bone fracture	Leaves	[32]

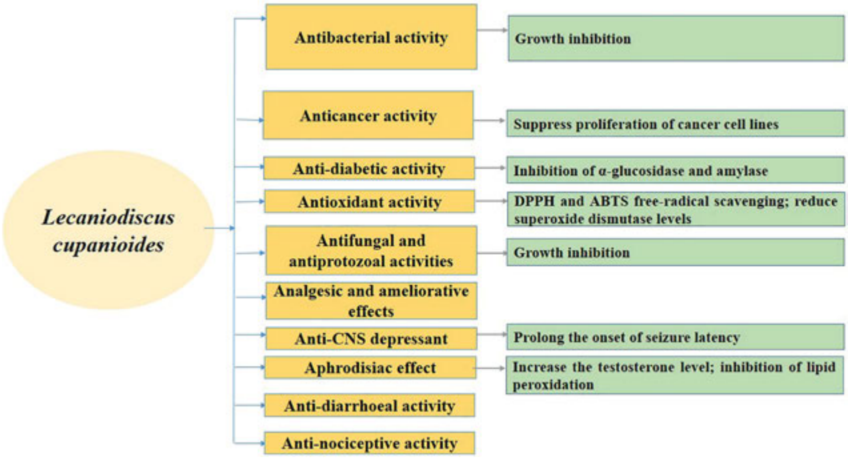

Figure 1.2: Schematic representation of the biological activities of *L. cupanioides* extracts and active constituents, showing some of their mechanisms of actions.

methanolic leaves extract of *L. cupanioides* against 10 bacteria. The authors revealed that six of the tested organisms were inhibited. They found that *Bacillus cereus*, *Streptococcus pyrogens*, *Micrococcus kristinae*, and *Staphylococcus aureus* were more inhibited by the extract, with minimum inhibitory concentration (MIC) value <1.0 mg/mL. Similarly, *Pseudomonas aeruginosa* and *Salmonella pooni* were inhibited at MIC value of 2.0 mg/mL. However, *Staphylococcus epidermidus*, *Escherichia coli*, *Serratia marcescens*, and *Klebsiella pneumoniae* were not inhibited at the highest concentration of the extract. Ethanolic and hexane root extracts of *L. cupanioides* were tested against six pathogens, including *E. coli*, *S. aureus*, *Streptococcus pneumonia*, *Shigella flexmeri*, *Pseudomonas aeroginosa*, and *Salmonella typhi*. It was revealed that ethanol extract of *L. cupanioides* showed the highest zone of inhibition of 30 mm at 125 µg/mL against *S. aureus*, which is comparatively as active as the ceftriaxone sodium used as the standard. Similarly, *L. cupanioides* was singly active against *S. aureus*, with a zone of inhibition of 8 mm at 7.8125 µg/mL for the hexane extract [35]. Thus, it can be inferred that the phytochemicals that are responsible for the antibacterial efficacy were more present or soluble in ethanolic extract than hexane extract of *L. cupanioides*, because it had the same inhibitory potency as the standard (ceftriaxone sodium) against *S. aureus*. Kazeem and his co-author [36] reported the antimicrobial activities of *L. cupanioides* leaf extract against some typed cultures and locally isolated pathogens. The authors assessed the antimicrobial efficacy by using agar-well diffusion as well as by determining the minimum bacteriostatic and bactericidal concentrations. The findings revealed that the extract exhibited zones of inhibition, ranging from 20 ± 0.00 to 23 ± 0.58 mm at 20 mg/mL. The MICs were between 1.25 and 2.50 mg/mL, and the minimum bactericidal concentrations (MBCs) ranged from 2.50 to 5.00 mg/mL.

The ethanol and the aqueous extracts of *L. cupanioides* leaves were comparatively assessed for their antibacterial activities. The clinical isolates of *S. aureus*, *E. coli*, *P. aeruginosa*, *Klebsiella pneumoniae*, and *Bacillus subtilis* along with a standard strain of *S. aureus* were used for the study. The MICs of the extracts were reportedly varied from 2.5 to 6.25 mg/mL. Comparatively, the ethanol extract showed more potency than the aqueous extract against all the pathogens, with the exception of the clinical isolates of *S. aureus* [37]. Research carried out by Okore et al. [38] on the aqueous pods extract against standard strains of *E. coli*, *S. aureus*, *P. aeruginosa*, and the untyped strains of *K. pneumoniae*, *B. subtilis*, and *Salmonella paratyphi* using agar-cup diffusion method showed no inhibitory action against all the tested bacteria strains. Differences in these test results when compared with the previous findings may be due to various parameters, such as plant parts, places and time of plant collection, soil composition, solvents, season, climate and difference in bioassay method used [39]. However, further studies need to be conducted using the same parameters with the previous findings to either validate or invalidate the above assertions.

Pharmacologically, *L. cupanioides* may be a promising source of new antibacterial drugs based on the reported MIC values, though some authors are of the opinion that only extracts having the MIC value of <0.1 mg/mL could have promising antimicrobial activity. Gibbons [40] opined that a plant extract or its isolated pure constituent is of little or no relevance clinically when its MIC value is greater than 1.0 mg/mL. However, there is tendency it may have some inert substances having good antibacterial activities at higher concentrations. Thus, the minimum inhibitory zone displayed by *L. cupanioides* extracts against different bacteria strains indicates that the plant has clinical value in the search for new drugs, especially as it inhibited bacteria strains that are already resistant to the orthodox drugs [41, 42]. Table 1.3 summarizes the antibacterial activities of different extracts of *L. cupanioides* against different strains of bacteria.

1.4.2 Analgesic and ameliorative effects

Adeyemi et al. [43] reported analgesic activities of *L. cupanioides* aqueous root extract. In the study, the authors revealed that the extract (400 mg/kg) had comparable effects ($P < 0.05$) to the reference drug, morphine or aspirin. In another separate study carried out on the *L. cupanioides* using loperamide-induced Wistar rats, it was reported that the aqueous root extract (250 mg/kg) significantly normalized ($P < 0.05$) the body weight gain (8.15 g) as well as the gastrointestinal ratio (87.75) of the rats compared to the control [44].

1.4.3 Antioxidant activity

Ogbunugafor et al. [45] investigated ethanol leaves extract of *L. cupanioides* on the serum antioxidant system and lipid profile of Albino rats. The findings revealed that

Table 1.3: Summary of in vitro antibacterial activities of *L. cupanioides* different extracts.

Extract	Antibacterial testing model	Bacteria tested[a]	Results	MIC	Reference
Methanol	Agar diffusion	Bc	Sensitive	<1.0 mg/mL	[34]
		Se	Resistant	No activity	[34]
		Sa	Sensitive	<1.0 mg/mL	[34]
		Mk	Sensitive	<1.0 mg/mL	[34]
		Sp	Sensitive	<1.0 mg/mL	[34]
		Ec	Resistant	No activity	[34]
		Sp*	Sensitive	2.0 mg/mL	[34]
		Sm	Resistant	No activity	[34]
		Pa	Sensitive	2.0 mg/mL	[34]
Ethanol	Microdilution	Ec	Resistant	No activity	[35]
		Sa	Sensitive	16 µg/mL	[35]
		Sp**	Resistant	No activity	[35]
		Sf	Resistant	No activity	[35]
		Pa	Resistant	No activity	[35]
		St	Resistant	No activity	[35]
Hexane	Microdilution	Ec	Resistant	No activity	[35]
		Sa	Sensitive	Not stated	[35]
		Sp**	Resistant	No activity	[35]
		Sf	Resistant	No activity	[35]
		Pa	Resistant	No activity	[35]
		St	Resistant	No activity	[35]
Methanol-water	Agar diffusion	Ah	Sensitive	2.50 mg/mL	[36]
		Ac	Sensitive	1.25 mg/mL	[36]
		Bp	Sensitive	1.25 mg/mL	[36]
		Ec	Sensitive	2.50 mg/mL	[36]
		Ef	Sensitive	1.25 mg/mL	[36]
		Ef *	Sensitive	2.50 mg/mL	[36]
		Kp	Sensitive	2.50 mg/mL	[36]
		Ls	Sensitive	1.25 mg/mL	[36]
		Ss	Sensitive	1.25 mg/mL	[36]
		Sf	Sensitive	2.50 mg/mL	[36]
		St*	Sensitive	2.50 mg/mL	[36]
		St	Sensitive	1.25 mg/mL	[36]
		Sa	Sensitive	1.25 mg/mL	[36]
		Ps	Sensitive	1.25 mg/mL	[36]
		Pv	Sensitive	1.25 mg/mL	[36]
		Pa	Sensitive	1.25 mg/mL	[36]
Water	Agar diffusion	Sa	Sensitive	2.50 mg/mL	[37]
		Bs	Sensitive	2.50 mg/mL	[37]
		Ec	Sensitive	2.50 mg/mL	[37]
		Pa	Sensitive	6.25 mg/mL	[37]
		Kp	Sensitive	5.00 mg/mL	[37]
Ethanol	Agar diffusion	Sa	Sensitive	2.50 mg/mL	[37]
		Bs	Sensitive	2.50 mg/mL	[37]
		Ec	Sensitive	2.50 mg/mL	[37]

Table 1.3: (continued)

Extract	Antibacterial testing model	Bacteria tested[a]	Results	MIC	Reference
		Pa	Sensitive	5.00 mg/mL	[37]
		Kp	Sensitive	2.50 mg/mL	[37]
Water	Agar diffusion	Ec	Resistant	No activity	[38]
		Sa	Resistant	No activity	[38]
		Pa	Resistant	No activity	[38]
		Kp	Resistant	No activity	[38]
		Bs	Resistant	No activity	[38]
		Sp***	Resistant	No activity	[38]

[a]Bc—*Bacillus cereus*; Se—*Staphylococcus epidermidus*; Sa—*Staphylococcus aureus*; Mk—*Micrococcus kristinae*; Sp—*Streptococcus pyrogens*; Ec—*Escherichia coli*; Sp*—*Salmonella pooni*; Sm—*Serratia marcescens*; Pa—*Pseudomonas aeruginosa*; Kp—*Klebsiella pneumoniae*; Sp**—*Streptococcus pneumonae*; Sf—*Shigella flexineri*; St—*Salmonella typhi*; Ah—*Aeromonas hydrophilla*; Ac—*Acinotobacter calcaoceuticus anitratus*; Bp—*Bacillus pumilis*; Ef—*Enterobacter faecalis*; Ef*—*Enterococcus faecalis*; Ls—*Listeria* sp.; Ss—*Shigella soonei*; St*—*Salmonella typhimurium*; Ps—*Plesiomonas shigeloides*; Pv—*Proteus vulgaris*; Bs—*Bacillus subtilis*; Sp***—*Salmonella paratyphi*.

the extract significantly exhibited lower ($P < 0.05$) catalase and superoxide dismutase activities in the treated rats when compared with the control and vitamin E-treated rats. The malondialdehyde which was employed as the index for lipid peroxidation was significantly higher ($P < 0.05$) in animals treated with *L. cupanioides* extract (4.20 ± 0.35 mmol/L) compared to the control rats (2.87 ± 0.23 mmol/L). Lipid profile estimation showed that the levels of triacylglycerides were significantly reduced ($P < 0.05$) in all the rats treated. Sofidiya and his co-authors [33] reported that methanol extract of *L. cupanioides* leaves possesses radical scavenging activity against 2, 2-diphenyl-1-picrylhydrazyl (DPPH) and 2, 2′-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS). It was revealed that 0.1 mg/mL of the crude methanol extract displayed DPPH and ABTS radicals scavenging activity up to 99.4 and 98.5%, respectively. Quantitatively, the flavonoid and the proanthocyanidin contents of the leaves extract were 4.142 ± 0.06 and 2.548 ± 0.32 mg/g, respectively. Owing to the relatively high proportion of flavonoids in *L. cupanioides*, the species could be a rich and natural source of antioxidants against oxidative stress diseases, including Alzheimer and Parkinson. The toxic effects of ethanol leaves extract of the species on antioxidant enzymes in Albino rats have been reported. The authors revealed that at the extract concentrations of 800 and 1600 mg/kg there was significant ($P < 0.05$) increased in the sizes of liver, brain and kidney compared to the control [46].

1.4.4 Anti-protozoal activity

Studies have shown that *L. cupanioides* extracts possess anti-protozoal activities. In a study, aqueous root extract of the plant was reported to exhibit antimalarial activity against a chloroquine-sensitive strain of *Plasmodium berghei* (NK 65) in Albino mice model [47]. Meanwhile, the methanol leaves extract of *L. cupanioides* was screened against chloroquine-sensitive strains, including *Plasmodium falciparum*, *Trypanosoma brucei brucei* and *Leishmania donovani*. The extract exhibited no significant anti-plasmodial activity against *P. falciparum*, with inhibitory activity lesser than 47%. However, it displayed more than 90% inhibition against *T. brucei brucei* [33]. The excellent inhibitory activity of *L. cupanioides* against *T. brucei brucei* is an indicative that it would be a novel source of drugs against *T. brucei brucei*, a parasitic protozoon, of the genus *Trypanosoma*. In man, it causes trypanosomiasis (also called sleeping sickness) [48]. It is a neglected, and potentially fatal disease in Africa, especially if left untreated immediately.

1.4.5 Anti-CNS depressant activity

According to the existing literature, the aqueous root extract has been investigated for central nervous system (CNS) anti-depressant activity in Swiss mice. The extract reportedly showed anti-CNS depressant activity which is comparable to the effects produced by the standard, chlorpromazine (4 mg/kg). Similarly, the extract significantly prolonged the onset of seizure latency at concentrations of 400 mg/kg p.o. and 100 mg/kg i.p. for both the strychnine-induced seizure and the picrotoxin-induced seizure [30].

1.4.6 Antifungal activity

L. cupanioides aqueous pod extract was screened against the clinical isolate of *Candida albicans*. The extract exhibited selective inhibitory activity against *C. albicans*, without showing any inhibition on other fungi or bacteria strains [37]. Adesegun et al. [49] reported that triterpenoid saponins isolated from ethanolic stem extract exhibited antifungal activity against three fungi, including *C. albicans*, *Candida neoformans* and *Aspergillus fumigates*. Straadt et al. [50] identified fungal plasma membrane H+-ATPase inhibitors from the ethyl acetate stem-bark extract of the species. In a study carried out by Ugorji et al. [51], clotrimazole creams formulated with saponin obtained from the seeds of *Lecaniodiscus cupanioides* were found to possess anti-candidal activity. The anti-candidal activity of the creams was evaluated against the clinical isolates of *C. albicans*. It was reported that the saponin exhibited dual functions when used in combination with clotrimazole—as an emulsifier in creams as well as a potent anti-candidal drug.

1.4.7 Anticancer activity

Phytochemicals from *L. cupanioides* have been reported to exhibit anti-tumour and anti-cancer activity. Two triterpenoid saponins from the plant have been linked with the ability to inhibit cancerous cells growth. First, the constituent 3-O-[α-L-arabinofuranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranosyl-]-hederagenin was reportedly active against human cancer cell lines, including colon carcinoma (H-116), lung carcinoma (A-549) and lung carcinoma (HT-29), with IC_{50} of 5.0, 2.5 and 2.5 µg/mL, respectively. Second, the compound 3-O-[α-L-arabinopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranosyl-]-hederagenin showed anticancer activity, with IC_{50} of 5.0, 5.0 and 2.5 µg/mL respectively [52]. Ogbole and his colleagues [53] reported that methanol leaves extract of *L. cupanioides* exhibited cytotoxic activity (CC_{50} = 17.23 ± 1.98 µg/mL) against Rhabdomyosarcoma (RD) cell line. This finding is significant in the search of new anti-cancer drugs from medicinal plants as the cytotoxic activity of the methanol leaves extract falls within the range of CC_{50} < 30 µg/mL which is the criterion of cytotoxicity for crude extracts in a preliminary anticancer assay as stipulated by the American National Cancer Institute (NCI) [54].

1.4.8 Toxicity activity

Toxicity of the *L. cupanioides* aqueous root extract was investigated in Albino rats model by Joshua et al. [55]. The root extract produced any serious toxicity or mortality at 200 mg/kg dose within two weeks of treatment. In another study, the aqueous root extract was administered orally to fasted mice at doses up to 20 g/kg, or at doses up to 800 mg/kg intraperitoneally. The study revealed that the extract produced no signs of toxicity up to 14 days after oral administration. However, acute (24 h) i.p toxicity was noticed at a dose of 455.2 mg/kg [30]. The cytotoxic effect of the leaf extract against the larvae of *Artemia salina* has also been reported. The lethality doses at LD_{50} and LC_{90} were 4.255 and 36.766 µg/mL, respectively [36].

1.4.9 Anti-diabetic activity

Ayokun-nun et al. [56] investigated inhibitory activity of ethyl acetate fraction of the leaves on *α*-amylase and *α*-glucosidase enzymes, which have been implicated for the role they play in blood glucose levels. The fraction displayed significant and mild inhibitory effects on *α*-amylase and glucosidase (IC_{50} = 0.73 and 0.58 mg/mL respectively). The study showed that ethyl acetate leaf fraction of *L. cupanioides* displayed anti-diabetic potential. In another separate study, aqueous leaves extract of *L. cupanioides* was investigated for anti-diabetic activity *in vitro*. It was revealed that aqueous leaves extract of *L. cupanioides* inhibited *α*-amylase (12.5–75.0%) and *α*-glucosidase (33.3–75.0%) from 0.001 to 0.004 mg/mL in a concentration dependent manner [57]. Considering these results, *L. cupanioides* is arguably an important species for fighting diabetes because of the roles it plays in inhibiting *α*-amylase and *α*-glucosidase enzymes.