REVISTA DELOS DESARROLLO LOCAL SOSTENIBLE

The genus *Cochlospermum* Kunth: a comprehensive review of key species with a focus on botanical, pharmacological, and chemical atributes

O género *Cochlospermum* Kunth: uma revisão exaustiva das principais espécies com destaque para os atributos botânicos, farmacológicos e químicos

El género *Cochlospermum* Kunth: revisión exhaustiva de las especies clave con especial atención a los atributos botánicos, farmacológicos y químicos.

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ABSTRACT
The *Cochlospermum* genus plant species are commonly used in traditional medicine for its antimicrobial, antiparasitic, anti-inflammatory, and hypoglycemic properties. The objective of this review is to describe the mainly important medicinal plant species of the genus *Cochlospermum* Kunth in terms of its botanical aspects, popular use, biological activity (pharmacology), and chemical compounds, intending to identify potential areas for innovative studies. The study considered literature published between 2010 - 2024 on the ethnobotany, pharmacology, botanical aspects, biological activity, and chemical compounds. Excluded from this study were eBooks, book chapters, patents, review articles, course completion articles, theses, and abstracts published in the proceedings of the event. Chem Draw software was used to draw a total of sixty-one bioactive compounds. The results show that six species of the *Cochlospermum* genus are documented as vital sources of traditional medicine. Ten species of this genus have been identified to contain secondary metabolites, including Cocholospermin A and B, polysaccharides, polyphenols (such as gallic and ellagic acids), flavonoids, and tannins. These compounds, such as polyphenols, flavonoids, and tannins, contribute to the pharmacological activities of this genus. The compounds in the *Cochlospermum* genus have demonstrated various biological activities, such as anti-inflammatory, antioxidant, antimicrobial, and potential antidiabetic properties. The genus has demonstrated some of these activities both *in vitro* and *in vivo*, making it of great pharmacological importance. This work presents a comprehensive overview of the botanical aspects, ethnopharmacology, biological activities, and chemical properties of the *Cochlospermum* genus. Its abundant chemical molecules can serve as an alternative source for the treatment of various diseases. This work provides a new perspective for future studies.

Keywords: Bixaceae, traditional uses, secondary metabolites, medicinal plants, biological activity.

RESUMO

As espécies de plantas do gênero *Cochlospermum* são comumente utilizadas na medicina tradicional por suas propriedades antimicrobianas, antiparasitárias, antiinflamatórias e hipoglicêmicas. O objetivo desta revisão é descrever as principais espécies de plantas medicinais do gênero *Cochlospermum* Kunth quanto aos seus aspectos botânicos, uso popular, atividade biológica (farmacologia) e compostos químicos, pretendendo identificar áreas potenciais para estudos inovadores. O estudo considerou a literatura publicada entre 2010 e 2024 sobre etnobotânica, farmacologia, aspectos botânicos, atividade biológica e compostos químicos. Foram excluídos deste estudo e-books, capítulos de livros, patentes, artigos de revisão, artigos de conclusão de curso, teses e resumos publicados nos anais do evento. O software Chem Draw foi utilizado para desenhar um total de sessenta e um compostos bioativos. Os resultados mostram que seis espécies do gênero *Cochlospermum* estão documentadas como fontes vitais da medicina tradicional. Dez espécies deste gênero foram identificadas como contendo metabólitos secundários, incluindo Cocholospermina A e B, polissacarídeos, polifenóis (como ácidos gálico e elágico), flavonóides e taninos. Esses compostos, como polifenóis, flavonóides e taninos, contribuem para as atividades farmacológicas desse gênero. Os compostos do gênero *Cochlospermum* demonstraram diversas atividades biológicas, como propriedades antiinflamatórias, antioxidantes, antimicrobianas e potenciais antidiabéticas. O gênero tem demonstrado algumas dessas atividades tanto *in vitro* quanto *in vivo*, tornando-o de grande importância farmacológica. Este trabalho apresenta uma visão abrangente dos aspectos botânicos, etnofarmacologia, atividades biológicas e propriedades químicas do gênero *Cochlospermum*. Suas abundantes moléculas químicas podem servir como fonte alternativa para o tratamento de diversas doenças. Este trabalho fornece uma nova perspectiva para estudos futuros.

Palavras-chave: Bixaceae, usos tradicionais, metabólitos secundários, plantas medicinais, atividade biológica.

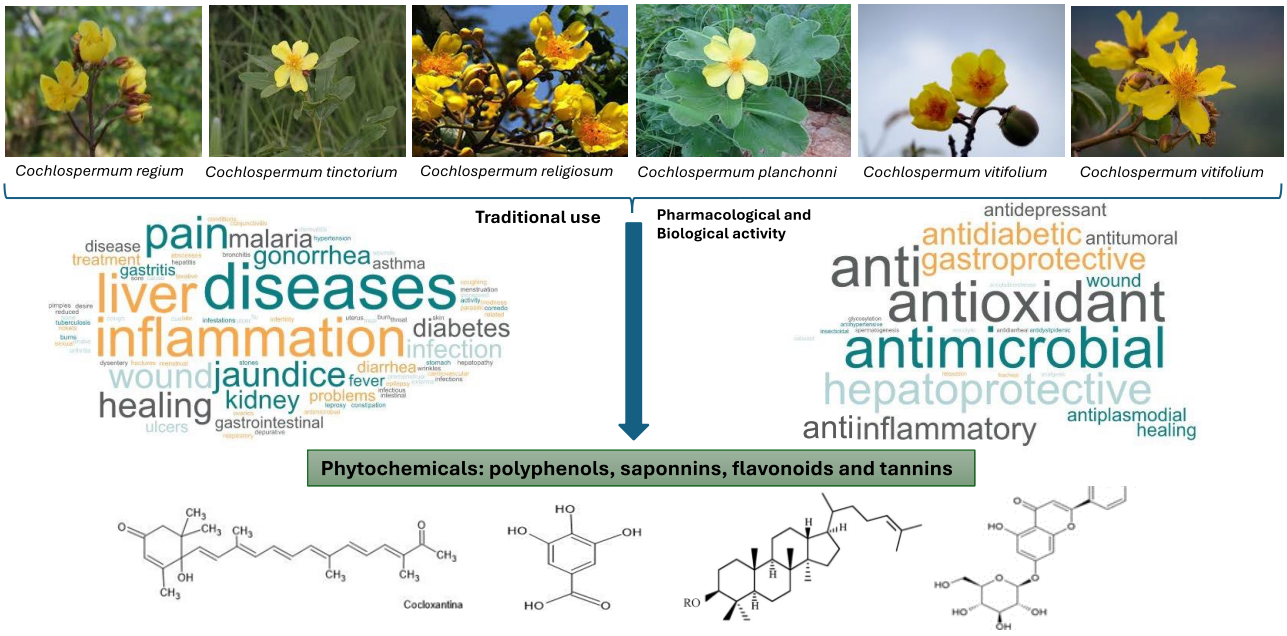
RESUMEN

Las especies de plantas del género *Cochlospermum* se utilizan comúnmente en la medicina tradicional por sus propiedades antimicrobianas, antiparasitarias, antiinflamatorias e hipoglucemiantes. El objetivo de esta revisión es describir las especies de plantas medicinales del género *Cochlospermum* Kunth de mayor importancia en términos de sus aspectos botánicos, uso popular, actividad biológica (farmacología) y compuestos químicos, con el fin de identificar áreas potenciales para estudios innovadores. El estudio consideró literatura publicada entre 2010 y 2024 sobre etnobotánica, farmacología, aspectos botánicos, actividad biológica y compuestos químicos. Se excluyeron de este estudio los libros electrónicos, capítulos de libros, patentes, artículos de revisión, artículos de finalización de cursos, tesis y resúmenes publicados en las actas del evento. Se utilizó el software Chem Draw para extraer un total de sesenta y un compuestos bioactivos. Los resultados muestran que seis especies del género Cochlospermum están documentadas como fuentes vitales de la medicina tradicional. Se ha identificado que diez especies de este género contienen metabolitos secundarios, incluidos cocolospermina A y B, polisacáridos, polifenoles (como los ácidos gálico y elágico), flavonoides y taninos. Estos compuestos, como los polifenoles, flavonoides y taninos, contribuyen a las actividades farmacológicas de este género. Los

compuestos del género *Cochlospermum* han demostrado diversas actividades biológicas, como propiedades antiinflamatorias, antioxidantes, antimicrobianas y potencialmente antidiabéticas. El género ha demostrado algunas de estas actividades tanto in vitro como in vivo, lo que lo hace de gran importancia farmacológica. Este trabajo presenta una visión integral de los aspectos botánicos, etnofarmacología, actividades biológicas y propiedades químicas del género *Cochlospermum*. Sus abundantes moléculas químicas pueden servir como fuente alternativa para el tratamiento de diversas enfermedades. Este trabajo proporciona una nueva perspectiva para futuros estudios.

Palabras clave: Bixaceae, usos tradicionales, metabolitos secundarios, plantas medicinales, actividad biológica.

Graphical abstract



1 INTRODUCTION

The genus *Cochlospermum* Kunth is classified under the family Bixaceae and consists of nineteen species of trees, shrubs, or sub-shrubs with underground rootstocks, as stated by World Flora Online (WFO, 2024). The plant has a broad geographical range and is indigenous to tropical areas such as "Mexico", "Central and South America", the "West Indies", "Africa", "India", "Southeast Asia", and "Northern Australia" (Johnson-Fulton and Watson, 2017).

Cochlospermum species have long been linked to the therapeutic management of inflammation, infection, asthma, jaundice, and ulcers, among other diverse illnesses (Arya and Buch, 2017; de Menezes Filho et al., 2020a). Multiple studies have demonstrated that the phytochemical makeup of many plant species in this genus includes bioactive chemicals, found in leaves, roots, bark, flowers, and other plant parts, which contribute to their widespread use (Abourashed and Fu, 2017; Abraham et al., 2017; Ahmad et al., 2021; Aklikokou et al., 2022; de Menezes Filho et al., 2020a; de Menezes Filho et al., 2021; Devi et al., 2010; Ferreres et al., 2013; 2020).

The species of primary interest include "*Cochlospermum regium* (Schrank) Pilg. (*C. regium*)", "*Cochlospermum tinctorium* Perrier ex A.Rich. (*C. tinctorium*)", "*Cochlospermum religiosum* (L.) Alston (*C. religiosum*)", "*Cochlospermum planchonii* Hook.f. ex Planch. (*C. planchonii*)", "*Cochlospermum vitifolium* (Willd.) Spreng. (*C. vitifolium*)", and "*Cochlospermum angolense* Welw. ex Oliv. (*C. angolense*)", which have been studied for their biological and pharmacological activities (Arya and Buch, 2017; Bai et al., 2011; Pandhure and Waghmare, 2012; Savithramma et al., 2011; Sharma and Mazumdar, 2013).

In Brazil, the Cerrado biome is home to native species such as *C. regium* and *C. vitifolium* (Solon et al., 2012). *C. regium*, commonly known as "semente de algodão", is a medicinal plant widely used in traditional medicine (de Menezes Filho et al., 2020b). *C. vitifolium*, also known as wild cotton or field cotton, is a small tree found in several states of Brazil (Almeida et al., 2005). In Africa, *C. angolense*, known as Ofefe, thrives in the central highlands of Angola (Abourashed and Fu, 2017). In India, *C. religiosum* is present (Johnson-Fulton and Watson, 2018). *C. tinctorium*, a plant native to the savannah region, is commonly found on farms in northern Nigeria (Hutchinson and Dalziel, 1937).

Several empirical, clinical, and pharmacological investigations have been carried out to examine the impacts of extracts derived from *Cochlospermum* species. Nevertheless, there is still

a dearth of systematic comparison data. This literature study provides a thorough analysis of the specific plant components utilized for the production of extracts or oils. It also identifies the phytochemical compounds present in these components and evaluates their pharmacological and toxicological effects. These actions encompass antibacterial, antifungal, hypoglycemic, and neuroprotective and cardioprotective properties. Furthermore, the evaluation will assess the potential effectiveness of these components in combating bacterial infections in individuals who are also afflicted with COVID-19. This information is vital for gaining a more profound comprehension of the practical uses of various therapeutic plants, health products, and cosmetics in our daily lives (de Menezes Filho et al., 2020a; Ebenezer Kolawole et al., 2023; Favi et al., 2022; Ponnamma et al., 2017; Rao and Pragada, 2012; Sanchez-Salgado et al., 2007; Solon et al., 2012).

Regarding toxicity, the literature has only investigated the toxicity of the species *C. regium* and *C. planchonii*. In their study, Leme et al. (2017) demonstrated that the ethanolic extract derived from the leaves of *C. regium* did not exhibit any cytotoxic or mutagenic effects when evaluated in vitro at the quantities used. Nevertheless, the hydroethanolic extract does not exhibit toxicity towards pregnant rats, while it may potentially disrupt embryonic development (Cunha-Laura et al., 2013). According to Ogbe et al. (2011), the hydroalcoholic extract of the rhizome of *C. planchonii* can cause liver toxicity if taken in large dosages and for a long time. The ingestion of the aqueous root extract, at doses ranging from 50-250 mg/kg body weight, for a period of 7 days, resulted in liver inflammation, kidney tubular cell necrosis, and complete loss of mucosal glands in the small intestine, indicating that it is not suitable for oral use as a remedy (Nafiu et al., 2012).

This study aims to examine and analyze the main species of the *Cochlospermum* genus in terms of their (ethno)botanical, phytochemical, and pharmacological/toxicological characteristics. Despite the limited number of studies conducted on this topic, the study will explore the potential pharmacological benefits of these species and investigate any differences or similarities between them. The objective is to provide a meaningful contribution to novel research endeavors and the preservation of species within the genus.

2 METHODS

This review article deals with the traditional medicinal uses, pharmacology, toxicology, and chemistry of *Cochlospermum* species. The literature considered covers the period from January 2010 to January 2024. It should be noted that "*Cochlospermum fraseri* Planch.", "*Cochlospermum gillivraei* Benth.", "*Cochlospermum intermedium* Mildbr.", "*Cochlospermum noldei* Poppend.", "*Cochlospermum tetraporum* Hallier f." and "*Cochlospermum wittei* Robyns" were excluded from this study due to the lack of relevant articles on their phytochemical and/or pharmacological/toxicological aspects. Only original articles were consulted in this review. The following keywords were used in the search: "*Cochlospermum regium* (Schrank) Pilg., *Cochlospermum tinctorium* Perrier ex A.Rich., *Cochlospermum religiosum* (L.) Alston, *Cochlospermum planchonii* Hook.f. ex Planch., *Cochlospermum vitifolium* (Willd.) Spreng., *Cochlospermum angolense* Welw. ex Oliv.*"*. "The plant name has been checked with "World Flora Online" (www.worldfloraonline.org) or MPNS (http://mpns.kew.org) mentioning the data of accessing that website". The review focused on their traditional or popular use, economic importance, ethnomedicine, (ethno)botany, ecology, distribution, occurrence, pharmacology, bioassays, toxicity, phytochemistry, metabolic classes and chemical compounds. Eighty articles were reviewed from various databases including "Scielo, SciFinder, Scopus, Taylor and Francis Online, Springer Link, National Center for Biotechnology Information (NCBI), ACS Publications, Chemspider, Google Scholar, PubMed, Scopus, GBIF database, and Science Direct". A methodical approach was used throughout the review process to guarantee that all pertinent articles were included and duplicates were removed. The content and quality of each article were carefully examined, and the findings were combined to provide a complete and critically analyzed summary of the state of the field's research at the time. Examining the ethnobotanical, phytochemical, and pharmacological research in further detail, this study concentrates on six significant medicinal plant species out of the nineteen that have been discovered in the *Cochlospermum* genus.

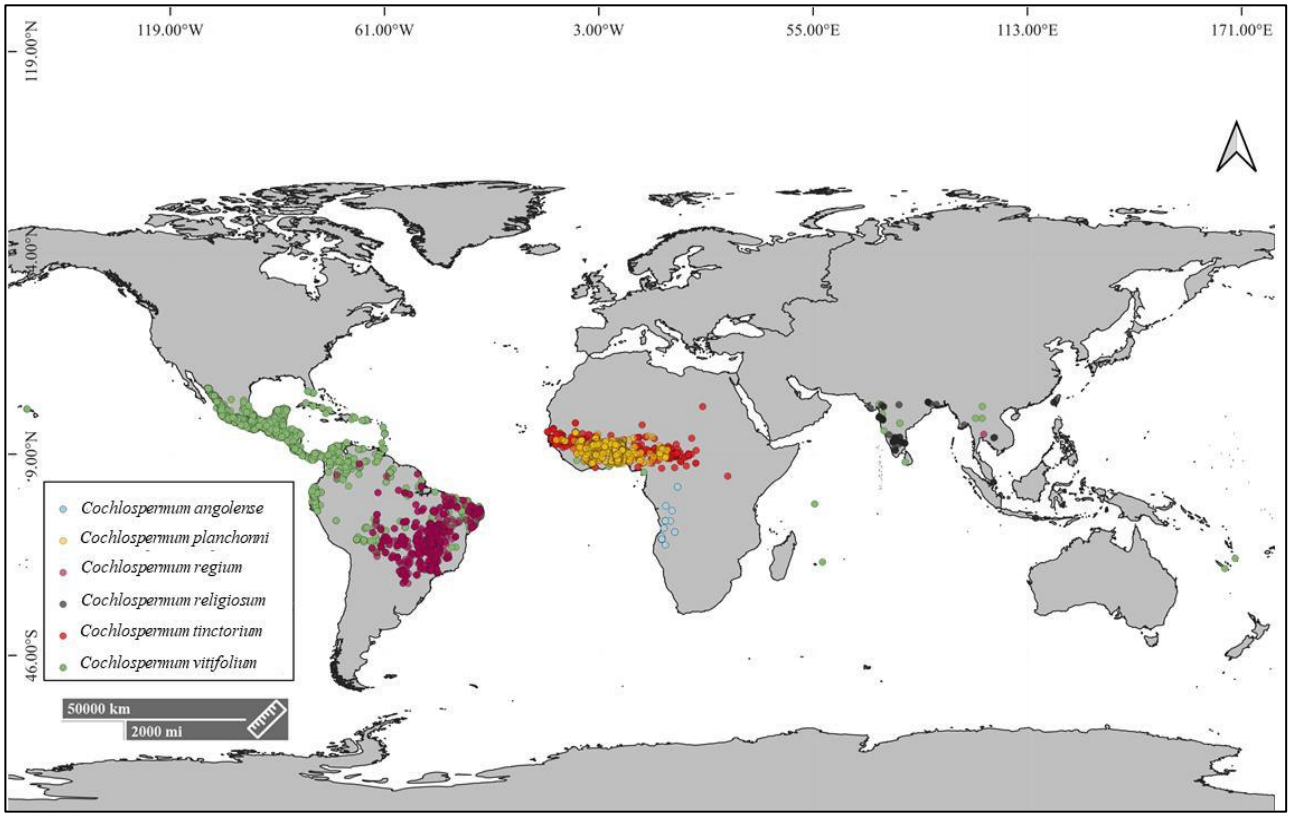
3 ETHNOBOTANICAL ASPECTS

3.1 BOTANICAL DESCRIPTION AND GEOGRAPHICAL DISTRIBUTION

The genus *Cochlospermum* contains nineteen species of tropical trees. *Cochlospermum* has a pantropical distribution, with species found in Mexico, Central and South America, the

West Indies, Africa, India, Southeast Asia, and northern Australia. (**Fig. 1**) (Johnson-Fulton and Watson, 2017; WFO, 2024).

Fig. 1. Distribution map of the mainly important medicinal species of the genus *Cochlospermum* Kunth (Quantum Geographic Information System 3.30).



Source: The Author

3.2 BOTANICAL ASPECTS

The Greek terms "kochlos" (snail or snail shell) and "sperm" (seed) are the origin of the name "*Cochlospermum*," referring to the cochlear or spiral seeds that are distinctive to the species (Quattrocchi, 2017). This genus of plants is woody, shrubby, or arboreal, with yellow flowers, hairy seeds, and capsular nuts (Joly, 2005).

The capsular fruit with alternating light and dark bands of endocarp and exocarp upon dehiscence, the palmately lobed leaves, the lovely yellow flowers with many stamens, and the mass of seeds with soft, white hairs are characteristics that help identify it (POWO, 2024).

3.2.1 C. regium (Schrank) Pilg.

The *C. regium* is endemic to the Cerrado vegetation of Brazil, Bolivia, and Paraguay. The mature plant is up to 2 meters tall and is shrubby. Growing mostly in the seasonally dry tropical habitat, it is a perennial or tuberous geophyte (Guarim Neto and Morais, 2003). According to Sales et al. (2002), the reproductive phase starts in April when the leaves fall, followed by the appearance of floral buds, flower opening, and fruiting. The plant has a fleshy, deep taproot that can reach a maximum length of 3 meters and a diameter of 20 centimeters. It has a knotty, reddish stem (Sólon et al., 2009). "*Maximilianea longirostrata* Barb. Rodr., *Maximilianea regia* Schrank, and *Maximilianea regia var. glaberrima* are some of the botanical synonyms for the *C. regium* species. *Wittelsbachia insignis* Mart. & Zucc., *Azeredia pernambucana* Arruda ex Allemão, Chodat & Hassl., *Cochlospermum insigne var. mattogrossensis*; *Cochlospermum insigne* A.St.-Hil., A. Juss. & Cambèss. Pilg., *Amoreuxia unipora* Tiegh., *Maximilianea regia var. mattogrossensis* (Pilg.) S.F. Blake, *Cochlospermum insigne var. pohlianum* Eichler, and *Cochlospermum trilobum* Standl (WFO, 2024).

3.2.2 C. tinctorium Perrier ex A. Rich.

The native This species is endemic to Uganda and West Tropical Africa. Growing mostly in the desert or arid shrubland biomes, it is a sometimes-tuberous sub-shrub (POWO, 2024). The plant has alternating, lanceolate to oblong lobes on its leaves. It normally yields few inflorescences with panicle or raceme flowers, which are often borne toward the base of the rootstock and occasionally at the top of green stems. The fruits of *C. tinctorium* are made up of three to five elongated valves with seed capsules within that are covered in cotton foam. The seeds are colored from brown to black and have a bean-like shape *Cochlospermum niloticum* Oliv., and *Maximilianea tinctoria* (Perrier ex A. Rich.) Kuntze (Royal Botanic Gardens, 2021; WFO, 2024).

3.2.3 C. religiosum (L.) Alston

The This species is endemic to India and Myanmar. *C. religiosum* is a tiny, densely branching tree that goes by several names, including *Bombax gossypium* L. and *Bombax religiosum* (L.) (WFO, 2024). Due to its large, glossy, golden-yellow blooms and silky-haired seeds, it is frequently known as yellow silk, cotton, buttercup, or torchwood (Sasikala et al., 2013). The use of its blooms in temple gifts is where the name "*religiosum*" originates. The tree

may be easily recognized by its beautiful golden-yellow bisexual blooms, severely wrinkled bark, and lobed leaves. The tree is well-known for generating orange gum, which is released from the bark (Ponnamma et al., 2017; Royal Botanic Gardens, 2021).

3.2.4 C. planchonii Hook. f. ex Planch.

C. planchonii is a shrub that usually grows to a height of two to three meters. It is native to Nigeria's savannas, mainly in the states of Kogi and Benue. It is also found in the Senegal area, which lies to the west of Cameroon. From eastern Senegal to Chad, it grows in savannahs and the mosaic of forests and savannahs at elevations between sea level to 1700 meters (Burkill, 1985; Johnson-Fulton and Watson, 2018). With underground woody stems (rootstock), palmately ribbed and lobed leaves that are dissected, and capsular fruits, it is a suffrutescent xeromorphic shrub. A 1.5–2.5 m height is reached by annual leafy shoots that arise from subterranean woody rootstocks during the wet season. Fruits appear one to two months after blossoming, which happens towards the end of the wet season (Jansen, 2005). One notable difference between *C. planchonii* and *C. tinctorium* is when they flower: the former blooms in the rainy season, while the latter blooms in the dry season. Bright yellow blooms are born basally in both species (Royal Botanic Gardens (2021).

3.2.5 C. vitifolium (Willd.) Spreng.

C. vitifolium is a shrub or small tree, or both, that can grow up to 5 m tall, commonly known as cotton tree or field cotton in Ceará and northeastern Brazil, as "pacotê". Its botanical synonyms are "*Wittelsbachia vitifolia* (Willd.) Mart. & Zucc., and *Bombax vitifolium* Willd., *Maximilianea codinae* (Eichler) Kuntze, *Maximilianea hibiscodes* (Kunth) Kuntze, *Maximilianea triphylla* S.F. Blake., *Maximilianea vitifolia* (Willd.) Krug & Urb., *Cochlospermum hibiscoides var. dasycarpum* Triana & Planch, *Cochlospermum hibiscoides var. gymnocarpum* Triana & Planch., *Cochlospermum codinae* Eichler, *Cochlospermum hibiscoides* Kunth, *Cochlospermum luetzeiburgii* Pilg., *Cochlospermum serratifolium* DC., *Cochlospermum triphyllum* (S.F.Blake) Pittier, and *Cochlospermum luetzelburgii* Pilg" (WFO, 2024).

Brazil has a large distribution of *C. vitifolium*, which is present across the nation. *Cochlospermum* species are widely distributed in lowland semi-deciduous seasonal forests, deciduous seasonal forests, thick ombrophile woods, and dense open shrub caatinga in Ceará,

both flooded and dry settings (Eggli, 2022). Furthermore, according to Martinez-Rodriguez et al. (2015), it grows naturally in semiarid regions of Zulia State, Venezuela, and yields a sizable amount of viscous, transparent gum that has not yet undergone extensive research. During the arid and leafless dry season, which lasts from December to March, it bears yellow flowers. As a result, the plant has no leaf, but it brightens the area with its final clusters of huge, beautiful blooms that are golden yellow in hue (Almeida et al., 2005).

3.2.6 C. angolense Welw. ex Oliv.

This species is endemic to Angola and the Democratic Republic of the Congo. It grows mostly in the humid tropical biome and is a shrub or tree. *Maximilianea angolensis* (Welw. ex Oliv.) Kuntze is the botanical synonym for *C. angolense* (WFO, 2024). The maximum height and diameter of this indigenous species are 6 m and 20 cm, respectively. The bark has longitudinal fractures and a grayish color. Its palmate leaves, which are 8 to 10 cm long and 15 to 18 cm wide, are divided into 5 to 7 segments. When ripe, the green fruits become brown and contain black seeds (Abourashed and Fu, 2017).

3.3 MEDICINAL USES

Table 1 lists the major medicinal species of the *Cochlospermum* genus, along with their uses in traditional medicine, common names, plant components used in preparation, and the relevant references.

Table 1. Ethnobotany and ethnomedicine of the mainly important medicinal species of the genus *Cochlospermum*.

[a]Number of articles	Species	Localization	Vernacular Name	Used plant parts	Preparation	Medicinal uses	Author/year
19	*Cochlospermum planchonii*	Burkina Faso; Nigeria; Benin; Togo	False cotton; Faux cotonnier; Soasga; N'Dribala	Rhizome, roots, leaves, root, bark	Decoction	Jaundice, liver-related diseases, treat infertility, premenstrual pain, gonorrhea, malaria, diarrhea, diabetes, gastritis; wound healing and burn	Bragagna et al. (2019); Abu (2012); Ezeja and Anaga (2013); Yerbanga et al. (2012); Kola et al. (2022); Abraham et al. (2017); Favi et al. (2022); Willcox (2011); Lamien-Meda et al. (2015); Aklikokou et al. (2022); Adelakun et al. (2018); Nafiu et al. (2011); Danjuma et al. (2022); Isah et al. (2013); Fankibe et al. (2020); Ogbe et al. (2011); Yakubu et al. (2020); Metowogo et al. (2020); Ashafa and Nafiu (2017)
07	*Cochlospermum tinctorium*	Nigeria; Chad	Cotton plant, Plante de coton; negro coffee	Roots, rhizome, flower, leaves	Decoction or infusion	Malaria, rickets, stomach pain, diarrhea, ulcer, parasitic infestations, liver diseases, fever, pain, inflammation, infection diseases, epilepsy, snake bite, burns, bronchitis, menstrual problems, gonorrhea, jaundice, gastrointestinal diseases, inflammation, leprosy, conjunctivitis, constipation, wound healing activity	Tijwun et al. (2022); Temdie et al. (2022); Musa (2012); Ahmed et al. (2011a); Inngjerdingen et al. (2014); Muhammad et al. (2020);Adam et al. (2015);
19	*Cochlospermum religiosum*	India	Silk-cotton tree, buttercup tree	Leaves, flowers, roots, fruits, gum, bark	Paste; decoction	Cough, asthma, jaundice, tuberculosis, inflammation, gonorrhea, fever, dysentery, treatment of bone fractures, liver disease, reduced wrinkles; due to increased sexual desire; wound healing, antimicrobial; laxative.	Ponnamma et al. (2017); Sasikala et al. (2013); Pandhure and Waghmare (2012); Savithramma et al. (2011); Sharma and Mazumdar (2013); Devi et al. (2010); Buch and Arya (2017); Bai et al. (2011); Sasikala et al. (2014);Benoît-Vical (1997); Sanchez-Salgado et al. (2007); Patrakar Ramling and Omprakash (2021); Swathi et al. (2019);Mahendra et al. (2017), Bhatt et al. (2022); Aziz et al. (2020); Ghodela et al. (2017);

							Maurya and Dongarwar (2012); Gari et al. (2022);
06	*Cochlospermum vitifolium*	Mexico; Brazil	Pacoté, algodão-bravo, algodão-do-campo, botão-de-ouro, ranúnculo; panicua, yellow rose, pongolote	Tree gum, dry bark	Decoction; infusion; maceration	Diabetes, hepatopathy, cardiovascular diseases, ulcers, jaundice, to cause menstruation, liver, kidney diseases, hepatitis, diabetes, hypertension; asthma, tiredness, healing, wound, sore throat, flu, infection, inflammation, kidney pain and coughing	Aguilar-Guadarrama and Rios (2018); Sanchez-Salgado et al. (2010); Sanchez-Recillas et al. (2014); Martinez-Rodriguez et al. (2015); (Sarmento-Filha et al., 2022); de Almeida Neto et al. (2015);
08	*Cochlospermum angolense*	Angola	Borututu tree	Roots, bark, leaves	Infusion	Malaria, liver disease	Leonardi et al. (2012); Pereira et al. (2013); Pereira et al. (2014); Pereira et al. (2015); Abourashed and Fu (2017); Chipaca-Domingos et al. (2023); Ferreres et al. (2013); Jain et al. (2020)
21	*Cochlospermum regium*	Brazil	Algodão-cravo, algodão-do-mato, algodoeiro-do- campo, butuá-do-corvo, pacote, periquiteira-do- campo	Roots, bark, leaves, xylopodium,sap	Decoction, infusion, Maceration, fresh	Inflammation of the uterus and ovaries, pain, inflammation, depurative gastritis, ulcers, infectious diseases, arthritis, intestinal infections, dermatitis, abscesses, respiratory treatment, gastrointestinal problems, kidney stones, liver infection, external wounds, comedo, pimples, skin conditions	Ribeiro et al. (2017); Cunha-Laura et al. (2013); Galvão et al. (2020); Leme et al. (2017); (Almeida-Apolonio et al., 2018); Carvalho et al. (2018); Santos et al. (2012); Nader et al. (2010); de Menezes Filho et al. (2020a); de Menezes Filho et al. (2020b); de Menezes Filho et al. (2021); Cruz et al. (2016); Solon et al. (2012); Inácio et al. (2016);Arunachalam et al. (2019); De David and Pasa (2015); Guimaraes et al. (2022); (Magalhães et al., 2021); Miranda Pedroso et al. (2019): Souza et al. (2016)

Source: The Author

[a] Total number of articles: 80

C. regium, commonly known in Brazil as “algodão-do-campo”, “algodão-bravo”, “butuá-de-corvo”, “piriquiteira”, “algodãozinho”, “algodãozinho-do-cerrado”, “algodão-do-mato”, “algodãozinho-do-campo”, “algodoeiro-do-campo”, “pacote”, “algodão-cravo”, “periquiteira-do-campo”, “rui-barbo-do-campo”, and “samaumá-do-iaguapó” (Poppendieck, 1981; WFO,

2024), serves various purposes. It may be used as animal feed, recognized for its decorative value owing to the beauty of its blossoms, and harvested for therapeutic purposes (Solon et al., 2012). In Campo Grande, Mato Grosso do Sul, it is commonly used in traditional medicine to treat inflammation. The plant's roots are especially used to treat uterine inflammation and liver infections by infusion, decoction, and fresh maceration (Guimaraes et al., 2022). According to Cruz et al. (2016), a tea made from its roots has been demonstrated to help fight intestinal infections. Bark compresses can also be used to treat dermatitis and abscesses.

C. tinctorium root has been used in traditional medicine to treat a variety of conditions, including "malaria, rickets, stomach pain, diarrhea, gastric ulcers, parasitic infestations, liver diseases, fever, pain, inflammation, infection, epilepsy, snakebite, burns, orchitis, labor, menstrual problems, infectious disease, diabetes, conjunctivitis, and leprosy" (Ahmad et al., 2021). The root decoction or infusion should be used as prescribed by a medical specialist. The rhizome can be used to treat rickets, stomach ache, helminthiasis, beriberi, fever, hepatitis, abdominal discomfort, and schistosomiasis. Meanwhile, *C. tinctorium* leaves are used to treat diarrhea, abscesses, and boils, while the blossoms are utilized to relieve constipation (Ndouyang et al., 2018).

C. religiosum gum powder has been used in India as an antibiotic, antifungal, pesticide, and to treat liver illness (Burkill, 1985; Savithramma et al., 2011). It has also been used for coughs, asthma, jaundice, tuberculosis, inflammation, gonorrhea, fever, dysentery, gastritis, ulcers, and as a sedative. The bark paste from the stem of *C. religiosum* is used as a plaster to repair bone fractures. Bark powder and water were utilized to cure jaundice (Dahare and Jain, 2010). According to Pandhure and Waghmare (2012), mixing root powder with water and applying it to the face will help minimize wrinkles. In Nallamalais, Andhra Pradesh, this herb is used to cure TB. Kekuda et al. (2019) discussed the usage of *C. religiosum* to treat gonorrhea and diarrhea. Singh et al. (2017) emphasized the plant's ability to stimulate sexual desire. The plant's leaves are used in ethno-veterinary medicine to treat reproductive abnormalities in cattle and buffaloes in Pakistan's Sargodha area (Dilshad et al. 2008). Ethno-veterinary medicine uses a decoction derived from the leaves and stem bark to treat infertility (Rao and Pragada, 2012). Plant infusions, decoctions, pastes, or powders are used to treat a variety of diseases, including gonorrhea, cough, and cold (Swathi et al., 2019). *C. religiosum* has a variety of common applications in India. The dried leaves and blossoms have been used as stimulants (Chopra et al.,

1956). Gum powder, when taken orally (approximately 20 g) and combined with ghee, acts as an aphrodisiac.

Danjuma et al. (2022) found that *C. planchonii* is utilized to treat jaundice and liver fever in northern Nigeria. *C. planchonii* root decompositions can also be used to treat infertility, premenstrual discomfort, gonorrhea, stomach pain, and diabetes. Burkill (1985) described the use of several plant components including the bark of the root to relieve stomach discomfort, particularly ulcers. Igoli et al. (2006) described the usage of *C. planchonii* to treat diabetes mellitus. The leaves are also used to treat malaria, diarrhea, and jaundice (Anthony et al., 2005). Furthermore, a decoction of *C. planchonii* roots has traditionally been used to treat fever and malaria in Burkina Faso and has been developed for phytomedicine (Benoit-Vical et al., 2003).

Favi et al. (2022) investigated the many uses and applications of *C. planchonii* in Benin, Africa. The leaves are used to cure fever and jaundice, while the roots treat abscesses, dermatoses, burns, constipation, malaria, and other ailments. The fruits are used to cure jaundice, while the seeds treat schistosomiasis.

According to Sanchez-Salgado et al. (2007), *C. vitifolium* is a medicinal plant that has long been used to treat diabetes, hepatopathy, and cardiovascular disease. This plant has been recognized for its therapeutic benefits in a number of nations. In Cuba, a decoction of the leaves is used to cure ulcers. The sap from the leaves is used to cure jaundice in Costa Rica, and to induce menstruation in Guatemala (Esposito-Avella et al., 2008). In various Mexican states, such as Morelos, Oaxaca, Puebla, and Veracruz, a decoction of this plant's wood and leaves is eaten as an alternative therapy for liver and kidney problems. In Morelos, an infusion made by boiling 10 g of bark in 1 L of water is used to treat hepatitis C, jaundice, liver illness, diabetes, metabolic syndrome, and hypertension (Banos et al., 2008; Monroy-Ortíz and España, 2007).

According to Sólon et al. (2009), *C. angolense* is suggested for jaundice, malaria, and schistosomiasis and is historically used to treat liver issues. Their phytochemical makeup is associated to these actions.

3.4 PHARMACOLOGICAL AND BIOLOGICAL ACTIVITIES

The pharmacological effects of the *Cochlospermum* species include analgesic; anti-inflammatory, anti-cholinesterase, antidepressant, antidiabetic, antidiarrheal, antidyslipidemic, antihypertensive, antimicrobial, antioxidant, antiplasmodial, antitumoral, gastroprotective,

hepatoprotective, spermatogenesis, and wound healing action. Many different substances, including as steroids, flavonoids, alkaloids, and polysaccharides, are present in plant extracts and are responsible for these effects. **Table 2** lists the species, bioactivity, dose/concentration, plant component utilized, study methods, and pertinent references.

Table 2. Pharmacological and biological activities, the plant parts utilized of the mainly important medicinal species of the *Cochlospermum* genus.

Species	Pharmacological and biological activity	Plant parts used	[a]Author/year
Cochlospermum planchonii	Spermatogenesis, antiplasmodial, gastroprotective, antioxidant; antitumoral; antidiabetic; antidyslipidemic; anti-inflammatory; wound healing; hepatoprotective; antimicrobial; antidiarrheal	Rhizomes, roots	(Bragagna et al., 2019); (Yerbanga et al., 2012); (Lamien-Meda et al., 2015); (Abu, 2012); (Ezeja and Anaga, 2013); (Adelakun et al., 2018); (Kola et al., 2022); (Aklikokou et al., 2022); (Nafiu et al., 2011); (Isah et al., 2013); (Fankibe et al., 2020); (Yakubu et al., 2020); (Ashafa and Nafiu, 2017)
Cochlospermum tinctorium	Antimicrobial; hepatoprotective; analgesic; anti-inflammatory; gastroprotective;	Leaves, roots, stem bark, leafy stem	(Tijwun et al., 2022); (Muhammad et al., 2020); (Temdie et al., 2022); (Adam et al., 2015); (Ahmed et al., 2011b); (Inngjerdingen et al., 2014)
Cochlospermum religiosum	Antimicrobial; Antioxidant; anti-cataract; antiplasmodial; insecticidal; antidepressant; anxiolytic; wound healing	Leaves, flowers, roots, bark; gum	(Sasikala et al., 2015); (Bai et al., 2011); (Ponnamma et al., 2017); (Devi et al., 2010); (Benoît-Vical, 1997); (Swathi et al., 2019); (Mahendra et al., 2017); (Bhatt et al., 2022); (Ojha et al., 2008); (Girotra and Singh, 2013);
Cochlospermum vitifolium	Antidiabetic; antihypertensive; hepatoprotective; tracheal relaxation; antioxidant; anti-inflammatory;	Tree gum, dry bark; flowers	(Sanchez-Salgado et al., 2007); (Sanchez-Salgado et al., 2010); (Sanchez-Recillas et al., 2014); (Sarmento-Filha et al., 2022);
Cochlospermum angolense	Antioxidant; antitumoral; antimicrobial; antidepressant, anticholinesterase	Roots, bark, leaves	(Jain et al., 2020); (Pereira et al., 2013); (Pereira et al., 2014); (Pereira et al., 2015); (Abourashed and Fu, 2017); (Ferreres et al., 2013);
Cochlospermum regium	Hepatoprotective; antimicrobial; antioxidant; gastroprotective; antidiabetic, anti-glycosylation	Roots, xylopodium, leaves, bark, flowers	(Cunha-Laura et al., 2013); (Galvão et al., 2020); (Leme et al., 2017); (Almeida-Apolonio et al., 2018); (Carvalho et al., 2018); (Santos et al., 2012); (Nader et al., 2010); (de Menezes Filho et al., 2020a); (de Menezes Filho et al., 2020b); (de Menezes Filho et al., 2021); (Inácio et al., 2016);

(Arunachalam et al., 2019); (Magalhães et al., 2021); (Miranda Pedroso et al., 2019);

Source: The Author

4 ANTIBACTERIAL

Magalhães et al. (2021) assessed the antioxidant, bactericidal, and cytotoxic properties of Artemia salina essential oil extracted from fresh leaves and *C. regium* xylopodium. Xylopodium and leaf extracts both demonstrated antioxidant activity, with IC_{50} values of 111.16 µL/mL and 47.65 µL/mL, respectively. Their activity, however, was not as high as that of BHT and ascorbic acid, whose IC_{50} values were 3.54 ± 0.64 µL/mL and 1.96 ± 0.91, respectively. By using the disk technique, it was shown that the extract was effective against a number of bacteria, including *S. aureus*, *E. coli*, *E. faecalis*, and *S. serovar Enteritidis/Thyphymurium*. With LC_{50} values of 90.17 and 625.08 µg/mL, respectively, the fresh leaf essential oil showed strong antibacterial capability against all strains and cytotoxic action against *A. salina*. The extract's strong antioxidant content is responsible for its great efficacy against these microbes.

The ethanolic extracts of *C. regium* leaves show a wide range of antibacterial activity, according to Galvão et al. (2020). The methicillin-resistant S. aureus strain isolates were tested by the authors to determine the antibacterial and antibiofilm properties of aqueous and ethanolic extracts. In comparison to the ethanolic extract, the aqueous extract showed larger levels of phenols and flavonoids as well as stronger antibacterial activity. The substances had a potent antibacterial impact within the concentration range of 62.5 - 250 µg/mL. Studies conducted *in vitro* on CHO-K1 cells demonstrated the cytotoxicity of the *C. regium* root extract, with an EC (50) of 1.5 mg/mL. Furthermore, an examination using fluorescence microscopy showed that apoptosis had been induced. Cells exposed to *C. regium* extract for four hours had a 13.6% rise in apoptotic cells after twenty-four hours (Ceschini and Campos, 2006). The aqueous and ethanolic leaf extracts were found to contain chemicals related to gallic and ellagic acids. These extracts are very efficient against gram-positive and gram-negative bacteria, including methicillin-resistant and methicillin-sensitive *S. aureus*, according to prior research (Carvalho et al., 2018). These results imply that *C. regium* leaf extracts may provide a viable substitute for the treatment and prevention of *S. aureus*-caused biofilm-associated infections.

The ethanolic extract derived from the leaves of *C. regium* demonstrated strong antibacterial activity, with a MIC of less than 500 µg/mL. The extract is characterized as having

high efficacy, especially at lower doses, according to studies conducted by Carneiro et al. (2008), Kosina et al. (2010), and Shikanga et al. (2010).

Leme et al. (2017) carried out an investigation to assess the antibacterial efficacy of the *C. regium* leaf ethanolic extract and its impact on the development of biofilms containing microorganisms linked to urinary tract infections. According to the study, the ethanolic extract of *C. regium* leaves decreased the production of biofilm in uropathogens including *E. coli* and *C. tropicalis* and showed antibacterial efficacy at doses of 1 mg/mL and 0.5 mg/mL. One can classify the activity at 0.5 mg/mL as moderate and the activity at 1 mg/mL as high. The usage of leaves is allowed by the research, which lessens the effect of eliminating xylopodium and roots. The inclusion of flavonoids (87.4 mg/quercetin equivalents), total phenolic compounds (167.2 mg/gallic acid equivalents), and condensed tannins (21.7 mg/catechin equivalents) may account for the extract's action, according to the data. Numerous research have examined the ethanolic extract of *C. regium* leaves, reporting on its powerful antioxidant components, associated photoprotective action, and range of antibacterial properties (Leme et al., 2017; Nader et al., 2010). 2010 saw the extraction of hexanic, chloroformic, and methanolic extracts from the bark, heartwood, and bark of *C. regium*. While Magalhães et al. (2021) utilized the essential oil of fresh leaves and xylopodium of *C. regium*, Solon et al. (2012) employed the hydroethanolic extract of the xylopodium.

Santos et al. (2012) used a variety of techniques (bioautography, disc, and microdilution) to examine the preliminary phytochemical profile and assess the antibacterial efficacy of several pharmacogenes of *C. regium*. The findings demonstrated that *C. regium* leaf extract had better antibacterial activity against *S. flexneri*, *E. coli*, and *S. aureus*. Using varying fractional dosages, the bactericidal activity of the bark and leaf ethyl acetate and chloroform fractions was assessed. With MIC < 500 µg/mL, the *C. regium* extract was shown to have a powerful antibacterial activity (Carneiro et al., 2008; Kosina et al., 2010; Shikanga et al., 2010). Good activity is assigned to this extract, especially at lower doses. A concentration of 1000 µg/disc is regarded as excessive, nevertheless. The in vitro development of *S. aureus* strains was suppressed by the hexanoic, chloroform, and methanolic extracts from the bark of *C. regium*, interbank, and heartwood of the plant root at doses of 125 µg/mL and 250 µg/mL, which are effective against bovine mastitis agent (Nader et al., 2010). Good activity was shown by the authors, particularly at the lowest MIC doses (less than 500 µg/mL).

A chemical analysis of the ethyl acetate fraction from the hydroethanolic xylopodium extract from *C. regium* was carried out by Solon et al. (2012). Dihydrokaempferol, dihydrokaempferol-3-O-b-glucopyranoside, dihydrokaempferol-3-O-b-(6'-galloyl) - glucopyranoside, excelsin, pinoresinol, and cochlospermines A and B were among the secondary metabolites found in the research. Antimicrobial activity has been associated with these metabolites. To support *C. regium* usage in infection and inflammation, the scientists investigated and pinpointed certain chemical compounds that are responsible for the plant's pharmacological effect. *S. aureus* and *P. aeruginosa* were the targets of the hydroethanolic extract's antibacterial activity (0.1 mg/mL) and its fractions. There was action of gallic acid against *S. aureus*.

The MIC values shown above indicate potent action. *C. regium* bark extracts (hexanoic, chloroform, and methanolic) inhibited the development of *S. aureus* strains *in vitro* at doses of 125 µg/mL and 250 µg/mL, respectively, which are lower than the MIC value of 500 µg/mL. *C. regium* bark extracts (hexanoic, chloroform, and methanolic) inhibited the development of *S. aureus* strains *in vitro* at doses of 125 µg/mL and 250 µg/mL, respectively, which are lower than the MIC value of 500 µg/mL. *C. regium* bark extracts (hexanoic, chloroform, and methanolic) inhibited the development of *S. aureus* strains *in vitro* at doses of 125 µg/mL and 250 µg/mL, respectively, which are lower than the MIC value of 500 µg/mL. A chemical analysis of the ethyl acetate fraction produced from the hydroethanolic extract of C. regium xylopodium indicated the presence of a number of secondary metabolites. These are dihydrokaempferol, dihydrokaempferol-3-O-b-glucopyranoside, dihydrokaempferol-3-O-b-(6'-galloyl)-glucopyranoside, cochlospermines A and B, excelsin, and pinoresinol. These metabolites have been connected with antibacterial action. According to studies, *C. regium* root extract contains the flavonoid kaempferol (F-52), which has been shown to have analgesic and antibacterial activity, as well as efficient antioxidant and cytotoxic properties (Lima et al., 1995; Oliveira et al., 1989; Solon et al., 2012; Toledo et al., 2000).

Carvalho et al. (2018) used the ethyl acetate fraction of *C. regium* roots, along with commercially available tannins and gallic acid, to obtain high antibacterial and antifungal effectiveness against eight bacteria and five yeasts at a dosage of 20 mg/mL. The antimicrobial activity was distinct against gram-positive bacteria *S. epidermidis*, *S. aureus*, and *S. agalactiae*, as well as non-fermenting gram-negative bacteria *P. aeruginosa* and *A. baumanni*. The EtOAc fraction demonstrated a broad spectrum of antibacterial activity. Gallic acid had higher antifungal action, but tannin was efficient against all bacteria tested. Catalase activity was inhibited, which

caused the antimicrobial action. In yeast, the EtOAc fraction, as well as gallic and tannic acid molecules, appear to bind to ergosterol in the fungal membrane. The concentration was effective because it was a purer fraction of *C. regium*, free of commercially accessible tannins and gallic acid, which can obscure its genuine impact.

Tijwun et al. (2022) studied the antibacterial activity of a methanolic extract from *C. tentorium* leaves, root, and stem bark. The extract demonstrated significant antibacterial action at doses ranging from 1.0 to 5mg/mL. Extracts of *C. tintorium* leaves, roots, and bark shown dose-dependent efficacy against *K. pneumonia*, *E. coli*, and *S. aureus*. The inhibition zones varied from 11.00 ± 0.45 mm to 20.00 ± 0.05 mm, compared to typical ciprofloxacin pills with inhibition zones of 25 mm, 22 mm, and 26 mm. A photochemical examination indicated the presence of alkaloids, glycosides, flavonoids, phenols, saponins, tannins, and steroids. However, no flavonoids were found in *C. tintorium* leaf or stem bark. Extract concentrations utilized included 0.5, 1.0, 1.5, 2.0, and 2.5 mg/mL. The methanolic extract of *C. tintorium* leaf, root, and stem bark was highly effective against bacteria. The concentrations were lower than those in the inhibitory zone, as shown by the (NCCLS, 2011). The methanolic extract of *C. tinctorium* leaf, root, and stem bark shown strong antibacterial activity.

Ponnamma et al. (2017) used an agar diffusion experiment to investigate the effects of chloroform, ethyl acetate, and methanol solvent extracts from *C. religiosum* leaf sections on five distinct human pathogenic bacteria, both Gram-positive and Gram-negative. The ethyl acetate extract had the highest inhibition zone (mm) and was most effective against *E. coli* (26 ± 0.27) and *P. aeruginosa* (23 ± 0.35), followed by *B. cereus* (18 ± 0.43), *B. subtilis* (17 ± 0.24), and *S. aureus* (14 ± 0.10). According to NCCLS (2011), the zone of inhibition was at an intermediate level. Sasikala et al. (2013) described the silver colloid nanoparticles' antibacterial mechanism against microorganisms. The nanoparticles bind to the cell surface and disrupt its energy processes, such as permeability and respiration. Silver nanoparticles have the ability to enter bacteria and interact with substances containing phosphorus and sulfur, such as DNA, causing damage. *C. religiosum* leaf extract can boost antibacterial activity while also increasing the plant's therapeutic value. Phenolic chemicals present in plants have a variety of activities, including protection against herbivores and diseases, and are responsible for the plant's biological activity.

The extract of *C. religiosum* flowers exhibited antibacterial action, as reported by Swathi et al. (2019). *S. aureus* (26 ± 0.00), *B. subtilis* (25.6 ± 0.05), *E. coli* (25.3 ± 0.05), *P. aeruginosa* (23.0 ± 0.00), *P. syringae* (20.3 ± 0.05), *K. pneumoniae* (18.0 ± 0.10), *X. campestris* (14.3 ± 0.05), and *S. typhi* (20.0 ± 0.00) were the halo of inhibition (mm), respectively. The *C. religiosum* floral extract's antioxidant activity was somewhat lower than BHA's (EC_{50} value of 1.42 µg/mL), but it was still higher than ascorbic acid's (EC_{50} value of 3.32 µg/mL). Ponnamma et al. (2017) reported significant levels of antioxidant activity using DPPH by *C. religiosum* extracts and demonstrated the presence of more secondary metabolites than other solvent extracts, including terpenoids, saponins, phenolics, alkaloids, and glycosides. This explains why *C. religiosum* has a high level of antioxidant and reducing power.

An antibacterial screening of the methanolic extract of *C. religiosum* leaves and flowers was reported in Bai et al. (2011)'s work. Inhibited were *S. aureus*, *S. typhi*, and *E. aerogenes*. At a dosage of 1.25 mg/disc, *C. religiosum* leaf and flower extracts demonstrated a broad spectrum of action against both gram-positive and gram-negative bacteria, ranging from mild to moderate. A panel of bacteria, including *S. aureus*, *S. typhi*, *E. aerogenes*, *X. oryzae*, *pv. oryzae*, and *X. axonopodis pv. malvacearum*, were all susceptible to the methanolic extracts' action. According to this, *C. religiosum* extract may be utilized to treat microbial infections due to its broad-spectrum action. Antioxidants such saponins, tannins, and polyphenols included in the extract are what are causing *C. religiosum* to be inhibited.

Using an aqueous extract of *C. religiosum* leaves, Mahendra et al. (2017) created hexagonal wurtzite shaped nanoparticles, which were verified by XRD examination. Significant suppression against Gram-positive (*B. subtilis* and *S. aureus*) and Gram-negative (*P. aeruginosa* and *E. coli*) bacteria was seen with both the plant extract and biofabricated ZnO-NPs. In the pathogen test verified by live and dead cell analysis, the minimum inhibitory concentration (MIC) of the biofabricated ZnO-NPS and the plant extract varied between 4.8 and 625 µg/mL. Additionally, ZnO-NP and plant extract showed antibacterial and antimitotic action, with mitotic indices of 75.42% and mitosis inhibitory activity (ID_{50}) of 0.40 µg/mL-1 and 61.41% (ID_{50} = 0.58 µg/mL-1), respectively. The findings verify that the plant extract has physiologically active characteristics, as do the ZnO-NPs that it mediated. This study would be more relevant at doses less than 500 µg/mL. It began with low quantities, such as 4.8 µg/mL. Concentrations with MIC

< 500 µg/mL are the most important ones that are taken into account (Carneiro et al., 2008; Kosina et al., 2010; Shikanga et al., 2010).

According to Djipa et al. (2000), a high tannin content is associated with antibacterial action. A study of the phytochemical components of *C. religiosum* revealed this high concentration of tannins (Savithramma et al., 2011).

In their 2015 study, Pereira et al. examined three distinct *C. angolense* preparations (syrup, tablets, and infusion). The phenolic content of each preparation was determined using HPLC-DAD-ESI/MS, and the preparations' *in vitro* antibacterial and anti-clinical isolates of bacteria resistant to drugs were assessed. The most prevalent chemical (epi) discovered in tablets was gallocatechin-O-gallate, whereas eucaglobulin/globulus was detected in syrup. Protocatechuic acid was only found in infusions. All tested bacteria were resistant to the infusion preparation's antibacterial action, with the exception of *P. aureginosa*. When tested against methicillin-resistant *S. aureus* and *E. coli*, the tablets demonstrated broad-spectrum action. With a lower minimum inhibitory concentration (MIC) value, the extract infusion exhibited the highest antimicrobial activity. It also inhibited the growth of *E. Coli* and *E. Coli* (ESBL producers of extended-spectrum beta-lactamases), *S. aureus*, and *P. aeruginosa*, with MIC values of 50, 6.2, 1.6, and 25 mg/mL, respectively.

When comparing the biological activity of pure substances to that of complex samples, like crude extracts of plant species, there are less interferences with the evaluation of the biological activity of the former. As a result, the reference values are lower for pure substances than for crude extracts, which are thought to represent good efficaciousness. Indeed, highlighting the interferences induced by unknown components present in the samples is made feasible by knowledge of the antimicrobial agent's physicochemical properties (solubility, ionic charge, and molecular mass) (Alves et al., 2008). An IC_{50} value of less than 30 µg/mL is the cytotoxicity standard for crude extracts set by the National Cancer Institute (NCI) (Suffness and Pezzuto, 1999). A MIC value of less than 1000 µg/mL is regarded by some writers as potent, whilst a MIC value of less than 500 µg/mL is regarded by others (Carneiro et al., 2008; Kosina et al., 2010; Shikanga et al., 2010). Good antibacterial activity is defined as values < 100 (µg/mL) in the MIC classification system used by Ayres et al. (2008) and Holetz et al. (2002). On the other hand, a phytopharmaceutical is easier to standardize for therapy and more effective at lower doses.

The methanol extract of *C. planchonii*, at a concentration of 10 mg mL^{-1}, inhibited the growth of *S. aureus*, *S. pyogenes*, *S. typhi*, and *P. mirabilis*, according to the measurement of the MIC. *P. aureginosa* and *Trychophyton* spp. at a 20 mg/mL concentration. The MBC of the plant extract demonstrated the eradication of *S. aureus*, *S. typhi*, *P. aureginosa*, and *Trychophyton* spp. at 40 mg/mL, while *S. pyogenes* and *P. mirabilis* were eliminated at 20 mg/mL (Isah et al., 2013). The hydroethanolic extracts of *C. planchonii* roots and leaves were demonstrated by Fankibe et al. (2020) to be efficacious against *E. Coli*, *P. aeruginosa*, *K. pneumonia*, *S. aureus*, and *C. albicans*.

After analyzing extracts from *C. tinctorium* roots, Muhammad et al. (2020) found that the methanol extract had a MIC of 0.25×10^3 µg/mL, the aqueous extract had a MIC of 1.0×10^3 µg/mL against *E. coli*, the methanol extract had a MIC of 0.5×10^3 µg/mL for *S. aureus*, and the methanol extract had a MIC of 0.5×10^3 µg/mL for methanol and 0.5×10^3 µg/mL. MBC values for methanol and aqueous extract were 1.0×10^3 µg/mL and 2.0×10^3 µg/mL, respectively. *S. aureus* isolate MBC values were 1.0×10^3 µg/mL and 2.0×10^3 µg/mL for the aqueous extract, while *E. coli* and *Klebsiella* isolates MBC values were 2.0×10^3 µg/mL.

4.1 ANTIFUNGAL

In terms of inhibiting fungal growth, the methanolic fractions of the leaf extract performed better than the aqueous fractions. A qualitative phytochemical analysis of these plants confirms the presence of various compounds, including terpenoids, steroids, anthocyanins, coumarins, fatty acids, tannins, leucoanthocyanins, and emodins, which are related to their activity. The methanolic fractions of *C. religiosum* leaf extract showed promising results in suppressing fungal growth. In experiments using the fungal species *C. globosum*, the methanolic and aqueous extracts of *C. religiosum* leaves demonstrated antifungal activity, blocking 100% growth at a concentration of 25% extract. Only the methanolic extract completely prevented the development of *A. alternata* and *F. oxysporum* (Arya and Buch, 2017; Savithramma et al., 2011).

The powerful antifungal activity of *C. religiosum* floral extract against phytopathogenic fungi was shown by Swathi et al. (2019). Fungal mycelial growth was significantly suppressed by the 1 mg/mL floral methanolic extract, with both fungi showing >40% growth suppression. Rhizopus sp. showed a somewhat higher degree of inhibition (49.57% inhibition) than *Curvularia* spp. (42.49% inhibition) among the fungi. With a reference MIC of less than 500

µg/mL, the activity was strong at a concentration of 1 mg/mL. When silver nanoparticles were created from the aqueous extract of *C. religiosum* bark and examined for antimicrobial activity, Sasikala et al. (2014) found that there was a zone of minimal inhibition against the *A. niger* species, suggesting a wide range of action against this species.

According to Santos et al. (2012), the inner bark fractions of *C. regium*, namely the chloroform fraction of the leaf extract, hydroethanolic extract (1000 µg/mL) and ethyl acetate (500 µg/mL), were assessed using the microdilution method and demonstrated growth inhibition for *C. krusei* and *C. parapsilosis*. With the MIC value less than 500 µg/mL as a reference, the activity was high at 1000 µg/mL but moderate at 500 µg/mL. essential oil extracted from *C. regium* flowers at quantities lower than those that impede mycelial development when *S. sclerotiorum* is separated. The highest effects of fungal growth inhibition were seen at 25, 50, and 100 µL/mL, with percentages of 79%, 43%, and 33%, respectively. For the essential oil of *C. regium* flowers, the concentration of 100 µL/mL was shown to be more efficient as a biological fungicidal agent (de Menezes Filho et al., 2020a). According to de Menezes Filho et al. (2020b), the essential oil of *C. regium* flowers in the strain *C. gloeosporioides* showed 100% inhibition at the highest concentrations of 100 µL/mL and 25 µL/mL, followed by 90% inhibition at a concentration of 12.5 µL/mL, and 10% and 44% inhibition at the lowest concentrations of 6.25 µL/mL and 3.13 µL/mL.

Almeida-Apolonio et al. (2018) investigated the antifungal and antibiofilm properties of an ethanolic extract of *C. regium* leaves against *C. Gattii* concentrations range from 62.5 to 250 µg/mL. According to a recent research, the groups of metabolites, phenolic compounds, flavonoids, triterpenes, saponins, alkaloids, and glycosides discovered in xylopodium, rhizome, flowers and leaves, bark and leaves of *C. Adewusi* and Afolayan (2010) cite *C. regium* as evidence for the extract's biological action.

Inácio et al. (2016) investigated how seasonality, phenological stage, geographic location, plant age, and plant growth substrate influence the antibacterial activity of *C. regium* roots against *C. albicans*. Although the plant demonstrated antimicrobial action in the tested conditions, roots harvested in the fall and winter were more efficient against *C. albicans*. The root cortex accumulates physiologically active metabolites throughout the season: it is inactive in the spring, but it becomes active in the summer and fall, culminating in the winter. *C. regium* leaves begin to senescence in early fall; by winter, practically all of the plants have aged owing

to the lack of leaves. Antimicrobial chemicals move to the root's cortex, protecting it. Antimicrobial activity is highest in other regions of the root in the fall and winter, indicating that secondary metabolites build in these areas during the drier seasons. This causes a buildup of active chemicals in the roots. *C. regium* antibacterial action was mostly attributed to its inner cortex and root core.

De Menezes Filho et al. (2020b) found that the essential oil of *C. regium* flowers inhibited the *C. gloeosporioides* strain at concentrations ranging from 100 µL/mL to 25 µL/mL, with 100% inhibition, followed by 12.5 µL/mL with 90%, and the lowest concentrations of 6.25 µL/mL and 3.13 µL/mL with inhibitory rates of 44 and 10%, respectively. The bark and leaves of the root and stem are used to treat the *C. capsici* fungus (Nduagu et al., 2008). At certain concentrations, essential oil from *C. regium* flowers inhibited the mycelial development of the isolate *S. sclerotiorum*. Menezes-Filho et al. (2020a) found that concentrations of 25, 50, and 100 µL/mL had the largest inhibitory effects (33%, 43%, and 79%, respectively). The chemical profile revealed the following predominant compounds: ocimene<(E)-β-> (15.87%), caryophyllene E (11.53%), γ-murolene (20.07%), bicyclogermacrene (16.11%), and rosifoliol (31.09%). The antioxidant activity was highly efficient in decreasing the DPPH radical at doses ranging from 50 to 0.031 mg/mL (95.25% to 40.09%). This explains why *C. regium* essential oil is active. The concentration in this investigation was high, with a MIC of less than 500.

In their evaluation of the ethanolic extracts of the rhizome, branches, and leaves as well as the hydroethanolic extract of *C. regium* flowers, Pereira de Menezes Filho and de Souza Castro (2020) and de Menezes Filho et al. (2020a) found the following classes of phytochemical compounds: cardiac glycosides; alkaloids; organic acids, with the exception of the ethanolic extract of the branches; reducing sugars and coumarins, which are only present in the ethanolic extract of the root; hemolytic saponins, phenols, tannins of the catechin class, flavonoids, and catechins. The excellent antioxidant activity found in the ethanolic extract and the hydroalcoholic fraction of *T. fagifolia* is explained by Ayres et al. (2008), who described the percentage of antioxidant activity (% AA) of samples of *T. fagifolia* and positive controls (rutin and BHT). The author claims that all of this information justifies the activity of (+)-catechin (1), the main substance isolated and responsible for this activity. According to Ayres et al.'s 2009 study, this extract's excellent activity may be justified by this group of antioxidants.

Studies analyzing extracts from the root, branches, and leaves show biological activity. There aren't many research on this plant's essential oils that provide significant information on their larvicidal, insecticidal, antifungal, antioxidant, and other actions. These studies can be employed as agricultural agents and in food processing as well as in chemical, pharmacological, and phytoremediation processes. The antibacterial and antioxidant action induced by isolateisorhamnetin-3-glucoside in *C. religiosum* extracts has been reported in several research, as this review illustrates. These studies demonstrate the plant's effectiveness against microorganisms, and two more demonstrate its healing properties. These findings validate the plant's traditional uses as an antioxidant, antifungal, and insecticidal (Arya and Buch, 2017; Bai et al., 2011; Devi et al., 2010; Mahendra et al., 2017).

4.2 ANTIOXIDANT

In a research by Kola et al. (2022), the hydroethanolic extract of *C. planchonii* roots showed strong antioxidant activity using DPPH, FRAP, and TAC analysis. The bioactive substances found in *C. planchonii* rhizome enhanced the rise in MDA brought on by cisplatin consumption and the decrease in the antioxidant parameters of SOD, CAT, GPx, and GSH (Adelakun et al., 2018). The hydroethanolic extract of *C. planchonii* root was discovered to contain a high concentration of flavonoids and polyphenols. Its strong antioxidant activity may be attributed to these chemicals, which may also have anticancer properties.

A notable antioxidant and anti-catalase-producing methanolic extract was obtained from the leaves of *C. religiosum*. After being separated, the active ingredient isorhamnetin-3-glucoside (IR3G) was discovered to have antioxidant qualities. In experiments involving radical scavenging, IR3G was also found to suppress Cu^{2+}-induced lipoprotein diene production and free superoxide. In an *in vitro* culture model, it also showed a protective effect against selenite-induced cataract. A flavonoid part that is O-glycosidically connected to the carbohydrate portion at position C7 makes up the molecule flavonoid-7-o-glycoside (Devi et al., 2010). This substance has antioxidant properties since it is phenolic. A bioactive flavonoid known as IR3G has been identified and extracted from *C. religiosum* leaves. Devi et al. (2010) claim that IR3G possesses antioxidant qualities that successfully shield ocular lens proteins, sustain Ca^{2+} ATPase function, avoid calcium buildup and oxidative stress, and stop lipid peroxidation.

The *C. religiosum* flower extract exhibited antioxidant activity, scavenging about 50% of radicals at concentrations of 3.12, 3.12, and 1.56 µg/mL of floral extract, BHA, respectively. Additionally, the extract exhibited ferric reduction activity. With an EC_{50} value of 1.50 µg/mL, the floral extract removed 2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) ($ABTS^{*+}$) radicals more effectively than ascorbic acid. But compared to BHA, which had an EC_{50} value of 1.42 µg/mL, its activity was somewhat lower (Swathi et al., 2019). According to Ponnamma et al. (2017), the DPPH reagent's color changed from purple to yellow, indicating that *C. religiosum* ethyl acetate and chloroform extracts significantly inhibited free radicals. The ethyl acetate extract exhibited the highest level of antioxidant activity.

According to a paper by Menezes Filho et al. (2020a), the hydroethanolic floral extract of *C. regium* has been shown to include a variety of classes of secondary metabolites and display antioxidant activity. This is demonstrated by the extract's strong DPPH free radical reduction efficiency and considerable quantity of total phenolic compounds. The results of the phytochemical and UV-Vis spectrum scanning investigations are in agreement with these conclusions. The sample showed notable photoprotective and hemotoxic effects. De Menezes Filho et al. (2020b) looked into the antioxidant properties of essential oils made from *C. regium* leaves and branches. The outcomes demonstrated notable decreases in β-carotene, linoleic acid, and the free radical DPPH. These results imply that the floral extract and essential oils of *C. regium* leaves, branches, and flowers may be useful in the creation of novel medications that target free radicals. High activity in the elimination of DPPH free radicals was noted by de Menezes Filho et al. (2021) in essential oils isolated from *C. regium* leaves and branches. The concentration range of 50-5.0 mg/mL yielded the best reduction values of 100% DPPH. With the greatest reported results being larger than 50%, the essential oils of *C. regium* demonstrated promise for oxidation activity in the β-carotene and linoleic acid system. This was noted at 10–50 µL of concentration. The investigation discovered that there were differences in the essential oil extraction yields and antioxidant capacities from the *C. regium* leaves and twigs. In the DPPH, β-carotene, and linoleic acid systems, both essential oils shown potential in lowering free radicals.

According to Magalhães et al. (2021), fresh *C. regium* xylopodium leaves' essential oil showed a noteworthy chemical profile and strong antioxidant activity in lowering the DPPH free radical. According to Miranda Pedroso et al. (2019), the extract's antioxidant activity was caused

by a high concentration of flavonoids and total phenolic compounds. The DPPH, ABTS, and MDA tests, as well as the suppression of β-carotene/linoleic acid oxidation, AGES production in *in vitro* BSA/glucose, and AChE enzyme, all revealed antioxidant activity in the extract.

According to Pereira et al. (2014), the dried bark of *C. angolense*, sometimes referred to as "borututu," has the greatest concentrations of flavonoids and total phenolics, along with the highest degree of antioxidant activity. The infusion's EC_{50} values ranged from 0.03 to 1.34 mg/mL, whereas the methanolic extract's values varied from 0.04 to 0.24 mg/mL. Using centrifugal chromatography, Abourashed and Fu (2017) identified antioxidant components including gallic acid and protocatechuic acid and discussed the antioxidant activity of "borututu." The primary phenolic compounds in the extracts were methyl ellagic acid, glycosides of ellagic acid, and ellagic acid itself. The phenolic chemicals included in the *C. angolense* extract are responsible for its action.

According to Leonardi et al.'s (2012) investigation on the chemical composition of essential oils, they used capillary gas chromatography (GC) and gas chromatography/mass spectrometry (GC-MS) to identify 67 and 130 chemicals, respectively, from the leaves and roots of *C. angolense*. Sesquiterpenoids (68.8% in the leaves and 53.2% in the roots) were present in both oils, but monoterpenoids (9.8% in the leaves and 26.2% in the roots) were present in lesser amounts. The principal constituents of the leaves were 6-epi-cubenol (6.2%), α-cadinol (7.4%), and germacrene D (9.4%). The most prevalent chemicals found in the root's essential oil were isoborneol (6.6%) and sesquiterpene β-caryophyllene (19.7%). According to Ludwiczuk et al. (2017), sesquiterpenoids have a variety of biological actions, such as cytotoxic and antibacterial properties. These substances are mostly present in essential oils, and because of their strong antioxidant content, they may be useful in the treatment of a number of illnesses (Leonardi et al., 2012; Pereira et al., 2013).

The genus *Cochlospermum* contains the following compounds: myricetin, quercetin, arjunoic acid, aromadendrin, kampferol, naringenin, and apigenin, either in free form or in combination to create glycosides. These substances include dihydrokaempferol 3-O-glucopyranoside, 5,7,4'-trihydroxy-flavan3-ol, naringenin 7 O-glucoside, and apigenin 7 O-glucoside. Research has shown that the diverse array of actions noted in this species might potentially be attributed to these substances (Diallo et al., 1991; Lima et al., 1995; Sanchez-

Salgado et al., 2007). The protective action mechanism in this species is linked to antioxidant and antibacterial properties, according to the literature (Taheri et al., 2020).

Phenolic chemicals have an inhibitory impact that is linked to changes in membrane permeability, interactions with enzymes, and metal ion and substrate depletion. It has been discovered that plant extracts from the genus *Cochlospermum* contain antioxidant properties. Triacylbenzenes and flavonoids are the genus's major isolated components (Almeida et al., 2005; Ouerghemmi et al., 2017).

4.3 HEPATOPROTECTIVE

Aqueous extract of the leafy stem of *C. tinctorium* (25 or 50 mg/kg) lowered blood total bilirubin level, increased glutathione, catalase, and SOD activity, and decreased the activity of gamma-glutamyl transferase (γ-GT) and alanine aspartate aminotransferase (ALT). The activation of natural antioxidant defense systems against liver damage generated by subacute injection of carbon tetrachloride (CCl_4) is linked to the hepatoprotective activity of leafy stem extract from aquatic plants (Temdie et al., 2022).

In rats with CCL_4-induced hepatitis, the renal function parameters were restored by the aqueous extract of *C. tinctorium* leaves. In comparison to the untreated groups, histopathological analysis showed that group two (positive control) had regeneration of certain damaged liver tissues. The leaf extracts had a fatal dosage (LD_{50}) of more than 5000 mg/kg body weight. This indicates that the *C. tinctorium* leaf aqueous extract appears to be almost non-toxic and may have a therapeutic effect against CCl4-induced hepatoxicity in rats (Adam et al., 2015).

The hepatoprotective benefits of *C. angolense* infusion (borututu) were documented by Pereira et al. (2013). There was no normal cell hepatotoxicity (IC_{50} > 400 g/mL) in the sample. The high concentration of phenolic chemicals and flavonoids in the infusion is responsible for these outcomes.

The hepatoprotective effect of *C. vitifolium* bark extracts, namely the hexanic extract (120 mg/kg) and the methanolic extract (100 mg/kg), was documented by Sanchez-Salgado et al. (2007). Furthermore, according to Nafiu et al. (2011), the aqueous extract of *C. planchonii* rhizome impacted serum albumin, bilirubin, creatinine, and urea levels as well as the activity of phosphatase in tissues. These modifications could have had an impact on the movement of ions across cell membranes and encouraged modifications to the way the animals' livers and kidneys

normally work. The study also discovered that the extract was safe to use acutely at levels of 50 mg/kg. An in vitro bilirubin degradation test was reported, demonstrating the potential to treat *C. planchonii* jaundice by revealing a dose-dependent and time-dependent degradation of bilirubin (100 mg/dl, 50 mg/dl, and 25 mg/dl) by *C. planchonii*. The plant referred to as "picão preto" is traditionally used to cure jaundice due to its high flavonoid content (Rodrigues and Carvalho, 2001). It has been discovered that *C. planchonii* has a variety of antioxidant agents in its aqueous root extracts, including Triacyl benzenes A, B, C, and D, as well as phenolics, steroids, anthraquinones, and minerals. The extracts' ability to prevent jaundice could be attributed to these secondary metabolites. Furthermore, hepatoprotective effect of the *C. planchonii* rhizome's aqueous extract has been demonstrated, confirming its traditional usage for liver illnesses (Nafiu et al., 2011).

According to Kviecinski et al. (2008), several constituents, especially flavonoids, can protect the liver from harm from harmful substances. Hepatoprotective action was demonstrated by the hexanic and methanolic extracts of *C. vitifolium* bark, confirming its traditional usage as a treatment for liver disorders. The medicinal plant *C. vitifolium* is used to treat respiratory, cardiovascular, and hepatopathic conditions (Haiat and Bucay, 2009; Sanchez-Salgado et al., 2007).

The metabolites found in *Cochlospermum* extracts, including alkaloids, glycosides, flavonoids, phenols, saponins, tannins, and sesquiterpenoids, are responsible for the hepatoprotective effects mentioned above (Leonardi et al., 2012; Pereira et al., 2013).

The *in vitro* bilirubin degradation assay was reported by Danjuma et al. (2022) and utilized a 13% methanolic extract of the bark of the stem of *C. planchonii*. The bilirubin degradation rate was found to be 27.45%, with a dose-dependent and time-dependent bilirubin degradation at 100 mg/dl, 50 mg/dl, and 25 mg/dl. These results imply that *C. planchonii* may be useful in the management of jaundice.

Aqueous extracts of *C. planchonii* roots were shown to contain a variety of chemicals, including minerals, steroids, anthraquinones, tannins, alkaloids, and phenolics (Nafiu et al., 2011). Furthermore, they discovered that *C. planchonii* bilirubin degradation activity was caused by triacylbenzenes A, B, C, and D.

The hydroalcoholic extract of *C. planchonii* rhizome, administered orally to rats for four weeks at dosages of 125, 250, and 500 mg/kg body weight, was found to have dose-dependent

effects on hematological and biochemical indicators of hepatotoxicity (Ogbe et al., 2011). In particular, as compared to the control group, the extract significantly raised the levels of liver enzymes in all treatment groups, including aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, triglycerides, and total bilirubin. Furthermore, all therapy groups saw a substantial decrease in high-density lipoprotein cholesterol. Hemoglobin concentration and packed cell volume (PCV) both significantly decreased at the maximum dose of the extract (500 mg/kg body weight). The study's observation of a dose-dependent elevation in liver enzymes raises the possibility that the hydroalcoholic extract of *C. planchonii* rhizome might be harmful to rats' livers. This discovery raises questions regarding the extract's safety for possible human application. Increased levels of the liver enzymes ALT and γ-GT signify damage to the liver cells and a decline in liver function.

4.4 ANALGESIC AND ANTI-INFLAMMATORY

Ahmed et al. (2011a) describe the analgesic and anti-inflammatory properties of aqueous methanol extracts of *C. tinctorium* against acid-induced writhing and hot plate test in mice, as well as root bark (20-80 mg/kg) and root (7.5-30 mg/kg). In contrast, the anti-inflammatory properties were examined using carrageenan-induced paw edema in rats. In a dose-dependent way, the extracts dramatically reduced the writhing that mice experienced when exposed to acetic acid. Aqueous methanol leaf extract, however, provided the best protection against writhing at a dosage of 80 mg/kg (96.65%), which was even higher than that of the common medication ketoprofen (82.30%). In the hot plate test, the extracts had no discernible effect on the mean delay of reaction. At a dosage of 20 mg/kg, however, aqueous methanol root bark extract markedly raised the mean latency of the pain response. At the end of the third hour, aqueous methanol leaf extract substantially and dose-dependently prevented carrageenan-induced hind paw edema, whereas plant extracts from the roots and bark offered non-dose-dependent protection against the edema caused by the carrageenan.

Sarmento-Filha et al. (2022) studied rats given ethanolic extract concentrations of 50, 100, and 150 mg/kg. In comparison to the carrageenan group, the study demonstrated that the extract prevented the production of edema in a time-dependent way. The extract's constituents may be responsible for the demonstrated anti-inflammatory action. This study highlights the wide variety of bioactive substances found in *C. vitifolium* flowers that may influence the oxidative

process at different phases, such as initiation (DPPH, reducing power, and total antioxidant capacity), propagation (copper ion chelation), and termination (scavenging superoxide radicals). Furthermore, the *C. vitifolium* flowers' ethyl acetate extract showed anti-inflammatory qualities, corroborating the species' long-standing usage in popular culture. Twenty-two compounds were found after the phenolic compounds were characterized using the UPLC-QTOF-MS/MS method. Strong anti-inflammatory and antioxidant properties are exhibited by these substances. Because they transfer electrons to free radicals and trap or suppress different reactive oxygen species, phenolic substances are essential for cell defense (Sun and Shahrajabian, 2023). This demonstrates that antioxidants are widely used to treat ulcers and respiratory illnesses (Esposito-avella et al., 2008).

The plant's dichloromethanolic extract was shown to relax the rat trachea, suggesting that it could have an antiasthmatic effect. The EC_{50} values of the dichloromethane and hexane extracts were 219.54 ± 7.61 µg/mL and 106.58 ± 2.42 µg/mL, respectively, according to Sanchez-Recillas et al. (2014). Flavonoids and triterpenic derivatives are the bioactive chemicals that cause this effect; the vasorelaxant's primary mechanism of action is through the NO/cGMP pathway. From the methanolic extract of *C. vitifolium* bark, the flavanone-like chemical (±)-naringenin (5,7,4-trihydroxyflavonone, NG) was obtained. Identification was verified by X-ray diffraction analysis. Early functional tests on the bioactive molecule NG revealed that it has vasorelaxant action (Sanchez-Salgado et al., 2010; Sanchez-Salgado et al., 2007). It has been demonstrated that flavonoids have calming effects on the rat trachea's smooth muscle (Flores-Flores et al., 2019).

Moreover, prior studies have demonstrated the presence of lignans, carotenoids, apocarotenoids, flavonoids, and sterols in *Cochlospermum* species (Aguilar-Guadarrama and Rios, 2018). Because these bioactive chemicals have a more relaxing impact on the tracheal rings of rats, they may be useful in the treatment of asthma.

4.5 CUTANEOUS WOUND HEALING

Extracted from *C. religiosum*, the whitish and semitransparent gum known as Katira gum is an insoluble, sweet, thermogenic anodyne. *C. religiosum* gum exudate has the potential to be developed into a novel natural medicine for use in traditional semi-solid, liquid, and solid drug delivery methods. Sharma and Mazumdar (2013) claim that the exudate is a great tool for the

creation of novel medications. According to Swathi et al. (2019), when mineral elements were present at a concentration of 1 mg/mL, the percentage of wound contraction in Wistar rats rose and wound healing was shown throughout the epithelialization stage. The ability of gels containing just katira gum and katira gum (from *C. religiosum*) combined with silver sulfadiazine to cure wounds was examined. Animals receiving treatment with both silver sulfadiazine and katira gum demonstrated a notable reduction in wound size and a shortened epithelialization period. Additionally, *C. religiosum* stem bark extracts showed antibacterial activity. The inhibition of microorganisms, especially gram-positive bacteria, determined the concentration seen in the extracts. It is well known that the gum taken from the plant may bioremediate harmful metals. Fonder et al. (2008) state that the optimal topical formulation for wound care should eliminate excess exudate, preserve moisture at the site, guard against bacteria, ease pain, encourage thermal insulation, and avoid triggering allergies. The amount of bacteria inhibited in the test determined the concentrations seen in the extracts. The extracts had minimal toxicity and had strong effectiveness against gram-positive bacteria.

In the control group in Girotra and Singh's (2013) study, the wound took about 26 days to epithelialize and shrank to a pitiful 41% in just 14 days. In group II (KG gel), the wound began to epithelialize on day 14 and shrank by around 76% over the next 18 days. Both the group treated with silver sulfadiazine and the group treated with Katira gum plus silver sulfadiazine showed significant reductions in wound area, of around 93 and 96%, respectively. Groups III and IV saw an epithelialization period of 16 days and 13 days, respectively. Compared to groups I and II, there was a notable rise in the proportion of burn wound contraction in the group treated with katira gum and sulfadiazine gel. The combined group's mean epithelialization time was 13 days less than that of the other groups, which is a substantial reduction. The shortened epithelialization period in the animal treatment group might be attributed to Katira Gum's strong water retention capacity.

According to research by Aklikokou et al. (2022), a hydroethanolic extract of *C. planchonii* leaves and roots can treat rodent burns. About half of the treated animals had considerably less vascular permeability than the control group after receiving 1000 mg/kg of the hydroethanolic extracts of the roots and leaves. Histology revealed that extracts from *C. planchonii* leaves at 2.5% and 5% concentrations enhanced wound healing by markedly raising contraction rates (78.63% ± 1.57 and 79.68% ± 1.48, respectively, on day 12). This is in line with

the 2019 findings of Swathi et al., even though our study employed a greater dose. Similar results were seen, with samples from animals treated with 2.5% and 5% *C. planchonii* on day 12 showing substantially greater levels of hydroxyproline and wound contraction rates. Histological methods were used to validate these results, which suggest that the hydroethanolic extract of *C. planchonii* root may have a place in the natural treatment of burn wounds (Metowogo et al., 2020).

4.6 GASTROPROTECTIVE AND HEALING

According to research by Ezeja and Anaga (2013), ethanol-induced stomach ulcers were significantly inhibited by the methanolic extract of *C. planchonii* root. In a dose-dependent way, the extract suppressed the ulcer and reduced its parameters. At 250, 500, and 1000 mg/kg of body weight, the extract exhibited the same mechanism of action as antagonists of the H2 receptor. Histamine H2 antagonists are often prescribed pharmaceuticals for disorders involving excessive production of chloride peptides, either by itself or in conjunction with other therapies like antacids. It has been demonstrated that the methanolic extract of *C. planchonii* root stimulates endogenous prostaglandin synthesis, inhibits capillary necrosis, increases gastric mucus and bicarbonate secretion, and may possess antioxidant qualities that shield rats' gastric mucosa from ethanol. At every dosage level examined, the methanolic extract of *C. planchonii* roots demonstrated a statistically significant protective effect against aspirin-induced stomach ulcers. The extract effectively prevented stress-induced stomach lesions compared to the negative group. The pylorus-bound stomach ulcer was not inhibited by the extract. Along with the volume of gastric juice and other ulcer parameters, it decreased the volume of total acid and free HCl. The extract contributed to ulcer inhibition by the same mechanism as H_2 receptor antagonists, just as the reference medication cimetidine. For therapy, oral dosages between 100 and 200 mg/kg are thought to be appropriate; however, doses between 500 and 1000 mg/kg are too high. Strong antioxidants found in the rhizome of *C. planchonii* have been reported by Adelakun et al. (2018) to potentially mediate this inhibition. They discovered that eating cisplatin raised MDA and enhanced antioxidant measures (SOD, CAT, GPx, and GSH) when the root's constituents were reduced.

Arunachalam et al. (2019) investigated the gastroprotective and antiulcer properties of a hydroethanolic extract of *C. regium* xylopodium utilizing *in vitro* and *in vivo* methods. The

findings point to decreased acid-secreting glandular activation, inflammatory cell infiltration, edema, and mucosal injury, while boosting gastric mucus production. *C. regium* xylopodium protected against HCl/EtOH-induced acute ulcers, inhibiting them by 47.52 and 62.69% at dosages of 100 and 400 mg/kg, respectively. In the chronic gastric ulcer model, *C. regium* xylopodium (25, 100, and 400 mg/kg, p.o.) decreased lesion area by 58.80%, 77.87%, and 71.10%, respectively. The recommended oral dosage is 100 mg/kg, and the higher dose of 400 mg/kg is inappropriate for this route. As previously stated, *C. regium* has a variety of chemical compounds, including tannins, alkaloids, and flavonoids, which may account for its antiulcer efficacy.

C. regium roots are used to produce a tea that treats intestinal infections, arthritis, and dermatitis. The bark can be used to produce compresses that help prevent abscesses. The hydroethanolic extract of xylopodium from *C. regium* possesses an antiulcer mode of action, which validates its widespread usage in gastrointestinal issues and inflammation, in addition to *C. regium* antiulcer activity (Cruz et al., 2016; Guimaraes et al., 2022; Nunes and Carvalho, 2003).

According to Inngjerdingen et al. (2014), there was a 43% decrease in bacterial adhesion when the aqueous extracts and separated polysaccharide fractions from the roots of *C. tinctorium* were used. These fractions contained a combination of inulin, pectic polysaccharides, phenols, and protein. The pectic-type fractions CtwA1 and CtwA2 that were separated from *C. tinctorium* inhibited the adherence of *H. pylori* by around 30%. These fractions are composed of side chains of arabinogalactans and/or arabinans with rhamnogalacturonan backbones. In contrast to other anti-adhesive polysaccharides that have been described, the fractions' low concentration of uronic acids raises the possibility that the neutral side chains are involved in the binding of bacterial adhesins. The anti-ulcer effects in this investigation may be partially explained by the anti-adhesive characteristics displayed by the separated polysaccharide fractions and crude water extracts.

4.7 ANTIPLASMODIAL

C. planchonii decoctions were shown to be more effective against malaria in people with uncomplicated P. falciparum infections than the usual treatment chloroquine. In vitro phytochemistry and pharmacology experiments found that the aqueous decoction of the root of

C. planchonii has an IC_{50} antiplasmodial activity of 75 µg/mL against chloroquine-sensitive and resistant strains of *P. falciparum* (Benoît-Vical, 1997; Benoit-Vical et al., 2003). Yerbanga et al. (2012) undertook a research to evaluate the antiplasmodial activity of an aqueous extract of *C. planchonii* and assess its prophylactic potential. In a trial of individuals with *P. falciparum* infection, the effectiveness of *C. planchonii* decoction against malaria was compared to the usual treatment chloroquine (Willcox, 2011). The chloroform extract of *C. planchonii* stem bark has also been shown to exhibit trypanocidal properties (Atawodi, 2005). In Burkina Faso, the roots and leaves of *C. planchonii* and *C. tinctorium* are widely used to cure malaria. Cocloxanthin carotenoids are thought to be responsible for some of the antimalarial action. Extracts from *Cochlospermum* spp. have shown antiplasmodial action in various investigations (Bragagna et al., 2019).

Yerbanga et al. (2012) used the *Plasmodium berghei*/*Anopheles stephensi* murine malaria system to verify the antiplasmodial activity of the *C. planchonii* aqueous extract and assess its potential for prophylaxis. When *C. planchonii* roots were extracted using ethanol as opposed to decoction, they showed higher antiplasmodium action. The studied extracts exhibited modest antiplasmodial activity, ranging from 16 to 63 µg/mL. Two primary apocarotenoids, dihydrococloxanthin and cocloxanthin, were extracted from the rhizomes of *C. planchonii* using spectroscopic techniques. These findings may support the genus's reported antiplasmodial efficacy. The present work presents the carotenoid profiles of *C. planchonii* and *C. tinctorium*, indicating notable natural diversity in carotenoid concentration and antiplasmodial action (Lamien-Meda et al., 2015).

4.8 REPRODUCTIVE ACTIVITY AND DEVELOPMENTAL

Abu (2012) assessed the impact of an aqueous ethanolic and ethanolic aqueous extract of *C. planchonii* roots on albino and Wistar rats' sperm characteristics. Sperm characteristics rose in tandem with a large increase in the weight of the reproductive organs.

The fertility-promoting properties of *C. planchonii* in cisplatin-induced reproductive dysfunction were the main focus of Lamien-Meda et al.'s (2015) study. After cisplatin was administered, luteinizing hormone and follicle stimulating hormone did not alter, but *C. planchonii* extract treatment resulted in a noticeable improvement. The testicular cytoarchitecture was rearranged, as evidenced by the testes' histologic profile. Significant reductions were seen

in the parameters of sperm, body, testes, weight of accessory sex organs, and seminiferous epithelium. Testosterone significantly changed, according to hormonal study. From the rhizome of *C. planchonii*, two main apocarotenoids were separated and named dihydrococloxanthin and cocloxanthin. The concentration of cocloxanthin and related carotenoids, which are typical of rhizomes but missing in leaves, exhibited significant diversity, according to comparative HPLC examinations of 39 samples from markets and collections in natural environments. The biological activity of the antioxidants found in the rhizome of *C. planchonii* is linked to sexual traits.

Regarding the additional activities, Adelakun et al. (2018) reported a research in which male rats were administered 500 mg/kg intraperitoneally and tested for reproductive hormones, testicular histology, testicular antioxidants, semen parameters, and fertility utilizing components of the rhizome of *C. planchonii*. Significant reductions were seen in serum epithelium, body, testes, weight of sexual organs, and sperm parameters. The hormonal assay revealed notable alterations in testosterone levels, but no changes in luteinizing hormone or follicle stimulating hormone were noted following cisplatin treatment. However, a notable amelioration was noted following *C. planchonii* administration. Given that the intraperitoneal dose could not go over 50 mg/kg, the dosage was excessive. Abu (2012) conducted a research to assess the impact of an aqueous ethanolic extract of *C. planchonii* root on albino spermatozoa features. The biological activity of the antioxidants found in the rhizome of *C. planchonii* is linked to sexual traits.

The impact of *C. regium* xylopodium hydroethanolic extract on pregnant rats during the organogenic phase was reported by Cunha-Laura et al. (2013). From day 6 to day 15 of gestation, pregnant rats were gavaged with a dosage of 11.5 mg/kg/day of the hydroethanolic extract of *C. regium* during the organogenic stage. There were no obvious symptoms of maternal poisoning. The fetal and placental weights of the treated and control animals were comparable. In spite of a marked decrease in the number of viable pregnancies and birth rate, the neonatal rats showed no deformities or anomalies. According to this study, pregnant women who use this plant carelessly run the risk of impeding the development of the embryo and fetus. This action is biologically influenced by *C. regium* xylopodium's antioxidant components. Other authors have cited its popular use for treating infertility and other sexual problems. (Adelakun et al., 2018; Lamien-Meda et al., 2015).

4.9 ANTIHYPERGLYCEMIC

The highest dose of the aqueous extract of *C. planchonii* leaves reduced blood glucose levels by 74.52% in comparison to the control and metformin-treated groups after 21 days of treatment. This effect was dose-dependent. The extract dramatically restored serum lipids. In the liver of streptozotocin (STZ)-induced diabetic mice, the aqueous extract of *C. planchonii* leaves markedly reduced the activity of G6PDH and raised the activity of AMY. Following 21 days of treatment, the *C. planchonii* leaf aqueous extract lowered blood glucose levels in a dosage-dependent manner; the highest dose decreased blood glucose levels by 74.52% in comparison to the groups receiving metformin and control. According to Anaga and Oparah (2009), the bioactive components of the methanolic extract of *C. planchonii* root show antidiabetic properties. The aqueous extract of *C. planchonii* leaves contains secondary metabolites that have been linked to a drop in blood glucose levels and have been evaluated for use in popular applications including the hypoglycemic effect (Abraham et al., 2017).

The antidiabetic effect of the *C. planchonii* root extract was assessed by comparing its saponin content to that of acarbose, and measuring the inhibition of α-glucosidase and AMY activities. This non-competitive inhibition of both enzymes was demonstrated by the lower Km and Vmax values in relation to the corresponding control. According to Ashafa and Nafiu (2017), these findings imply that although it exhibits greater inhibition of α-glucosidase and α-amylase, it is not a promising candidate for development of substitute oral hypoglycemic medications.

The components of *C. regium* roots were examined by Miranda Pedroso et al. (2019), who also assessed the effects of oral administration of 30 and 100 mg/kg on the control of glucose homeostasis, as well as the antioxidant and anticholinesterase activities of the plant. The extract's antihyperglycemic potential was demonstrated by the decrease in blood glucose levels in diabetic rats, normoglycemic rats fed a hyperglycemic diet, and normoglycemic rats exposed to glucose overload. As a result, the extract from *C. regium* shown encouraging properties that might be attributed to its high phenolic content, including antioxidant, antidiabetic, and gliadin. In free or mixed forms, myricetin, quercetin, arjunoic acid, aromadendrin, kaempferol, naringenin, and apigenin have been found; these constituents form the glycosides 5,7,4'-trihydroxy-flavan-3-ol, naringenin 7-O-glucoside, and dihydrokaempferol 3-O-glucopyranoside. The wide range of biological activity found in C. regium extracts can be attributed to these.(Lima and others, 1995).

The rhizome of *C. regium* has been the subject of several research, which have characterized its antioxidant, antiglycation, antidiabetic, and anticholinergic activities of its hydro-methanolic extract (Magalhães et al., 2021), while the literature does not mention its common usage against diabetes. Many different types of plants contain bioactive substances called saponins, which are the glycosides of triterpenoids and steroids (Rao and Gurfinkel, 2000). Some saponins generated from triterpenoids have the ability to lower blood sugar levels (Hill and Connolly, 2018).

The rhizome of *C. regium* has been the subject of several research, which have detailed its antioxidant, anti-inflammatory, antidiabetic, and anticholinergic properties of its hydro-methanolic extract; yet, the literature does not mention its common usage as a treatment for diabetes. Numerous plants contain bioactive substances called saponins, which are the glycosides of triterpenoids and steroids. Certain saponins produced from triterpenoids have hypoglycemic properties.

4.10 CENTRAL NERVOUS SYSTEM

Bhatt et al. (2022) detailed their assessment of the anxiolytic and depressive properties of *C. religiosum* leaf extract in their study. The locomotor activity of the extract was assessed at 400 mg/kg p.o. Fluoxetine was utilized as a positive control (20 mg/kg, intraperitoneal) in the test of two leaf extract dosages (50 and 100 mg/kg, p.o.). In addition to intraperitoneal administration of subeffective dosages of imipramine (10 mg/kg) and fluoxetine (10 mg/kg), the test extract was assessed at a dose of 25 mg/kg p.o. Compared to fluoxetine/imipramine (20 mg/kg) and *C. religiosum* leaves (50 mg/kg) alone, the coadministration of fluoxetine/imipramine with *C. religiosum* (25 mg/kg) demonstrated a significant synergistic effect. The intraperitoneal dosages are deemed sufficient. When utilizing an actophotometer, a dosage more than 50 mg/kg is deemed high for locomotor activity.

Bhatt et al. (2022) discovered that *C. religiosum* leaf extract (50 mg/kg b.w., p.o.) dramatically counteracted the effects of serpine in a rat model. Comparing the leaf extract to therapeutic dosages of imipramine and fluoxetine, the study discovered a strong synergistic impact on antidepressant and anxiolytic actions. Pentagalloyl glucose had a greater propensity for binding with 5HT1B (-10.79) and 5HT2A (-10.33) crystal structures than fluoxetine and imipramine, according to a molecular study of the chemical constituents of the leaves.

Cinnarizine binds to the β2 receptor at the timolol binding site with a score of -13.582, and it also binds to the serotonin binding sites of 5HT1B and 5HT2A in a similar manner. These results corroborate the plants' purported action.

Strong neuroprotective and antioxidant properties are exhibited by phenolic substances. Ferreres et al. (2013) conducted a research with the objective of characterizing the phenolic profile of this species and expanding understanding about its therapeutic qualities. These properties include possible resistance to depression, Alzheimer's disease, and oxidative stress. Eight chemicals were found in the investigation. Whereas the aqueous extract exhibited larger concentrations of ellagic acid and its derivatives, the hydromethanolic extract had higher quantities of methyl ellagic acid and its derivatives. The primary constituents present in the two extracts were ellagic acid and the methyl ellagic acid pentoside isomer, respectively. While ellagic acid and extracts both had a less effect on cholinesterase, they both demonstrated a better capacity to scavenge radicals than ascorbic acid. The substances had potent antidepressant effects. Strong neuroprotective and antioxidant properties are exhibited by phenolic substances. According to *C. angolense* chemical makeup, ellagic acid and its derivatives may have antidepressant properties.

4.11 ANTIHYPERTENSIVE

According to Sanchez-Salgado et al. (2010), the *C. vitifolium* bark's methanolic extract promotes NO generation, which is mediated via the creation of PGI2 and the activation of potassium channels under tissue dysfunctional conditions. This results in antihypertensive action. The methanolic extract of *C. vitifolium* bark and naringenin were studied for their antihypertensive effects in vivo and their functional vasorelaxant mechanism in vitro. According to this group's research, the extract may control hypertension by promoting the synthesis of NO, which is mediated via potassium channels and PGI2, especially in cases when endothelial dysfunction is severe. The study discovered that the *C. vitifolium* plant's dichloromethane and hexane extracts exhibited EC_{50} values of 106.58 ± 2.42 and 219.54 ± 7.61 µg/mL, respectively. The primary mechanism of action of bioactive compounds that cause vasorelaxation is the NO/cGMP system; these agents include flavonoids and triterpene derivatives (Sanchez-Salgado et al., 2010; Sanchez-Salgado et al., 2007).

The discovery that flavonoids have calming effects on the rat trachea's smooth muscle provides more proof of the plant's benefits (Flores-Flores et al., 2019). This is in line with the plant's traditional usage, as reported by Sanchez-Salgado et al. (2010), for treating respiratory and cardiovascular ailments. By generating PGI2, manufacturing nitric oxide, and activating potassium channels in situations of severe endothelial dysfunction, *C. vitifolium* plays a critical role in controlling hypertension (Martinez-Rodriguez et al., 2015). In their investigations utilizing *C. planchonii*, Yerbanga et al. (2012) verified this, demonstrating in vivo antihypertensive efficacy and a functioning vasorelaxant mechanism, in line with its application in the treatment of cardiovascular disorders.

4.12 INSECTICIDAL

The minerals and pesticide components that are present in *C. religiosum* floral extracts and exhibit insecticidal action were reported by Swathi et al. (2019). 100% death rates of *Aegypti anopheles* species larval instars I, II, and III were effectively caused by the floral methanol extracts. Furthermore, at a dose of 1 mg/mL, Wistar rats were used to observe the percentage of wound contraction and wound healing during epithelialization. These substances consist of a diverse range of secondary metabolites linked to the defense of different organisms. These substances, which may have insecticidal effect, are characterized in the literature as saponins, terpenoids, steroids, anthocyanins, coumarins, fatty acids, tannins, leucoanthocyanins, and emodins.

4.13 ANTI-DIARRHEAL

It was shown that the anti-diarrheal properties of *C. planchonii* leaves were due to the presence of flavonoids, coumarins, phenolics, and saponins, which may have worked alone or in combination. Additionally, it was shown that the extract upregulated the production of acetylcholine esterase while stimulating the antioxidant system, intestinal glucose, Na^{+}/K^{+-} ATPase, and alkaline phosphatase (Yakubu et al., 2020).

The principal medicinal species of the *Cochlospermum* genus are included in **Table 3**, together with their respective pharmacological and biological activity (dose ranges, experimental model details, and significant results).

Table 3. Biological and pharmacological properties of the major *Cochlospermum* species that are used as medicines.

Species	Pharmacology and biological activity	Dose/concentration	Plant part used	Methodology	References
Cochlospermum planchonii	Spermatogenesis in male albino rats	Hydroethanolic extract - 100, 200, and 400 mg/kg	Rhizome, seed, and bark	*In vivo*	Abu (2012)
	Antiplasmodial	Hydroethanolic extract - Limit of detection (LOD) 0.65 µg/mL	Roots and Leaves	*In vitro*	Bragagna et al. (2019)
	Gastric ulcers	Methanolic extract - 200, 500, and 1000 mg/kg	Roots and bark	*In vivo*	Ezeja and Anaga (2013)
	Antimalarial effect	Aqueous extract - 200mg/kg	Root	*In vitro*	Yerbanga et al. (2012)
	Investigation of antioxidant and anti- inflammatory activity, determination of the compounds.	Extract 50 µg and 100 µg	Root	*In vitro* and *in vivo*	Kola et al. (2022); Abraham et al. (2017)
	Malaria treatment	16 and 63 µg/mL	Rhizomes	*In vitro*	Lamien-Meda et al. (2015)
	Healing activity.	Healing activity of 1000 mg/kg	Roots and Leaves	*In vivo*	Aklikokou et al. (2022)
	Fertility Enhancing Activity Cisplatin- induced reproductive dysfunctions	500 mg/kg	Rhizome	*In vivo*	Adelakun et al. (2018)
	Toxic effects in albino rats on liver and kidney functional	50 mg/kg.	Rhizome	*In vivo*	Nafiu et al. (2011)
	Jaundice	100 mg/dL, 50 mg/dL and 25mg/dL	Stem bark	*In vitro*	Danjuma et al. (2022)
	Antioxidant	EC_{50} 170 g/mL	Stem Bark, Infusion, pills, and syrup	*In vitro*	Pereira et al. (2013); Pereira et al. (2014); (Pereira et al., 2015); Abourashed and Fu (2017)

	Antimicrobial and antifungal	10, 20 and 40 mg/mL	Leaves and roots	*In vitro*	Isah et al. (2013); Fankibe et al. (2020)
	Anti-diarrheal	125, 250 and 500 mg/kg	Leaves	*In vivo*	(Yakubu et al., 2020)
	Burn wound healing	2.5% and 5%	Roots	*In vivo*	(Metowogo et al., 2020)
	Antidiabetic		Roots	*In vitro*	(Ashafa and Nafiu, 2017)
Cochlospermum angolense	Anti-inflammatory, antioxidant an anti-Alzheimer's disease and antidepression		Root	*In vitro*	Ferreres et al. (2013)
Cochlospermum regium	Effect on pregnant rats	Hydroethanolic extract -1.5 mg/kg	Xylopodium	*In vivo*	Cunha-Laura et al. (2013)
	Antimicrobial	Ethanolic extract 6.25 -250 µg/mL, aqueous extract 125- 500 µg/mL	Leaves	*In vitro*	Galvão et al. (2020)
	Antimicrobial	Ethanolic extract mg/mL $^{-1.}$ And 0.5 mg/mL^{-1}	Leaves	*In vitro*	Leme et al. (2017)
	Antifungal	Hydroethanolic extract 62.5 to 250 µg/mL	Leaves	*In vitro*	Almeida-Apolonio et al. (2018)
	Antifungal	Hydroethanolic extract - 1000 µg/mL and Ethyl acetate 500 - 1000 µg/mL	Leaves between the bark and root	*In vitro*	Santos et al. (2012)
	Antimicrobial	Hexane	Bark	*In vitro*	Nader et al. (2010)
	Photoprotective Activity bands at 289, 376, 396, and 423 nm.	Essential oil	Flowers	*In vitro*	de Menezes Filho et al. (2020a)
	Antioxidant and antifungal	Essential oil/ 50 to 0.031 mg/mL between 95.25% and 40.09% (Antioxidant activity)/antifungal activity 100 and 50 µg/mL *S.*	Flowers	*In vitro*	de Menezes Filho et al. (2020b)

		Sclerotinia, *C. Gloeosporioides*, and *A. Flavus*.			
	Infections, arthritis, dermatitis, and abscesses.	Aqueous extract – 50 µg/mL; 37.5 µg/mL; 25 µg/mL; 12.5 µg/mL and µg/mL^{-1}	Roots	*In vitro*	Cruz et al. (2016)
	Antimicrobial	Hydroethanolic extract, ethyl acetate fraction obtained 0.1 mg/mL)	Xylopodium	*In vitro*	(Solon et al., 2012)
	Antifungal	Diameter of the inhibition zone 16.67, 15.33 and 23.50 mm	Root	*In vitro*	Inácio et al. (2016)
	Ulcers	100-400 mg/kg	Xylopodium	*In vivo*	Arunachalam et al. (2019)
	Antioxidant activity.	10 to 50 mg/mL reduction in DPPH radicals, and 50 µL with 92 % and 100 % oxidation.	Leaves and twigs	*In vitro*	de Menezes Filho et al. (2021)
Cochlospermum religiosum	Antifungal	Methanolic and hydroethanolic extract - inhibition percentage: 5, 10 and 25%.	Leaves	*In vitro*	Arya and Buch (2017)
	Antimicrobial activity	Methanolic extract - 1.25 mg/disc	Roots and bark	*In vitro*	Bai et al. (2011)
	Antioxidant activity	Methanolic extract /0.1 mm selenite (G-II) and selenite + 25 µg/mL R3G (G-III)	Leaves	*In vivo*	Devi et al. (2010)
	Gonorrhea, asthma and ethnoveterinary use	The paste was prepared from the stem bark.	Leaves	*In vitro*	Pandhure and Waghmare (2012)
	Antibacterial and antioxidant	Extracts with three solvents via chloroform, ethyl acetate, and methanol	Leaves	*In vitro*	Ponnamma et al. (2017)
	Bactericidal	Nanoparticles	Leaves and roots	*In vitro*	Sasikala et al. (2013)

	Hepatoprotection	Fractions (methanol, ethyl acetate, n-butanol, and water). - 1, 10, 25 and 100 mg/mL	Leaves	*In vitro*	Savithramma et al. (2011)
	Antimicrobial and antifungal	Nanoparticles	Bark	*In vitro*	Sasikala et al. (2014)
	Wound healing	3.75%	Katira Gum	*In vivo*	Girotra and Singh (2013)
Cochlospermum vitifolium	Diabetes, liver disease, and cardiovascular disease, vasorelaxant, antihypertensive, against hepatitis B virus, antidiabetic, anti- inflammatory, and immunomodulatory	Methanolic extract, chloroform, and ethyl acetate >2000 mg/kg	Leaves and essential oil from bark and flowers;	*In vitro*	Aguilar-Guadarrama and Rios (2018)
	Properties, tracheal relaxant.				
	Toxicity	Flower infusion	Flower	*In vivo*	Martinez-Rodrigues *et al*., 2015
	Diabetes, liver disease, and cardiovascular disease	Hexane extract 120 mg/kg: Methanol extract 100 mg/kg	Bark	*In vivo*	Sanchez-Salgado et al. (2010)
	Antiasthmatic	Dichloromethane and hexane extract EC50 (106.58 ± 2.42) % and EC_{50}: (219.54 ± 7.61) µg/mL	Whole plant	*In vivo*	Sanchez-Recillas et al. (2014)
Cochlospermum tinctorium	Cytotoxicity	62.5; 125; 250; 500 and 1000 µg/mL of 80% acetone extract	Rhizomes	*In vivo*	Musa (2012)
	Analgesic and Anti-inflammatory	leaf (20-80 mg/kg), root (7.5-30 mg/kg), and root bark (20-80 mg/kg)	Leaves, roots and root bark	*In vivo*	Ahmed et al. (2011a)
			Roots	*In vitro*	Inngjerdingen et al. (2014)
	Gastroprotective				

Antibacterial	0.25, 0.5, 1.0 and 2.0 $\times 10^3$ µg/mL	Roots	*In vitro*	Muhammad et al. (2020)
Hepatoprotective fraction at doses of 50, 100 and 150 mg / kg.	10, 100 and 1000mg/kg	Leaves	*In vivo*	Adam et al. (2015)

Source: The author

5 PHYTOCHEMICAL STUDIES

The literature has reported on a number of secondary metabolites for the genus *Cochlospermum* (**Table 4, Fig. 2**). These compounds have been linked to allelopathies, defense against microbes, defense against herbivores, and protection against UV radiation (Galvão et al., 2023). In this genus, the most often isolated chemical components are flavonoids and triacylbenzenes. The latter include the following: Almeida et al., 2005; Diallo et al., 1991; Lima et al., 1995; Sanchez-Salgado et al., 2007; myricetin, quercetin, arjunoic acid, aromadendrin, kampferol, naringenin 7-O-glucoside (**27**), apigenin 7-O-glucoside (26), 5,7,4'-trihydroxy-flavan3-ol (**28**) and dihydrokaempferol 3-O-glucopyranoside (**23**) have been reported. According to Solon et al. (2012), the genus's extract included derivatives of gallic acid, triacyl benzenes, and flavonoids.

Three primary chemicals were found in the essential oil of *C. regium* flowers: bicyclogermacrene (**15**) at 39.82%, γ-murolene (**9**) at 16.69%, and caryophyllene (**8**) at 9.76%. According to Portis et al. (2016), oxygenated sesquiterpenes made for 15.67% of the total, whereas these hydrocarbon sesquiterpene compounds accounted for 81.13%. The ethanolic extracts of the rhizome, twig, and leaves, as well as the hydroethanolic extract of the *C. regium* flowers, were assessed by de Menezes Filho et al. (2020a) and de Menezes Filho et al. (2021) for the presence of several phytochemical components. Heart glycosides, alkaloids, organic acids (not the branch ethanolic extract), reducing sugars, and coumarins (found exclusively in the root ethanolic extract) are among the substances discovered. Apart from the branch ethanolic extract, other substances detected were flavonoids, phenols, hemolytic saponins, and tannins of the catechin class. Only depsidones, anthraquinones, and derivatives of benzoquinone (**3**) are present in the ethanolic extract of the leaves. The ethanolic leaf extract is free of triterpenoids and steroids. Heart and cyanogenic glycosides, organic acids, hemolytic saponins, phenols, tannins, flavonoids, catechins, and flavanols are all present in the flower extract. The existence of several chemicals was examined in the hydroethanolic floral extract of *C. regium*. The extract included alkaloids, phenolics, flavonoids, and carotenoids, as evidenced by absorption peaks at 289, 376, 396, and 423 nm. Strong hemolytic activity in the extract further suggested the existence of hemolytic saponins.

The chemical composition of the essential oils in the rhizome (xylopodium) of *C. regium* was assessed by Sturmer's research (Sturmer, 1989) using GC-MS. The following chemicals

were detected: aromadendrin 2.1% (14), α-selinene 1.2% (13) and δ-cadinene 0.8% (**12**). β-selinene 34.1% (**16**), elemene 5.4% (**18**), trans-caryophyllene 4.8% (**17**), α-pinene 3.4% (**19**), α-humulene 2.8% (**20**). Following phytochemical analysis of *C. regium* xylopodium, seven phenol derivatives were identified: pinoresinol (**21**), excelsin (**57**), ellagic acid (**11**), gallic acid (**10**), dihydrokaempferol (**22**), dihydrokaempferol-3-O-β-glucopyranoside (**23**), dihydrokaempferol-3-O-b-(6"-galoyl)-glucopyranoside (**23**), dihydrokaempferol-3-O-b-(6"-galoyl)-glucopyranoside (**23**), and dihydrokaempferol-3-O-β-glucopyranoside (**23**). Two triacylbenzenes, cochlospermine A and B (**47**), were also discovered. Additionally, the fatty acid 1-hydroxytetradecanone-3 (**29**) and the presence of flavonoids were found by Portis et al. (2016) from the *C. regium* root. Kakaferol, a flavonoid, was identified by phytochemical study of the *C. regium* root extract (**6**).

The hydroethanolic extract of xylopodium was found to include kaempferol (**6**), gallic acid (**10**), rutin (**2**), myricetin (**4**), and morin (**5**), according to Arunachalam et al. (2019). By using GC-MS analysis, Magalhães et al. (2021) found that the essential oil of fresh leaves had 20 compounds in total, accounting for 90.18% of the oil, and 17 compounds in the oil from xylopodium, which made up 99.95% of the oil. In the leaf essential oil, the primary constituents were longiborneol (**46**), copaen-4-α-ol <β (48), viridiflorol (**44**), and β-bisabolene (**43**). Thujopsene (**45**), aromadendrene (**14**), and β-selinene (**16**) were all present in the xylopodium essential oil. Furthermore, the xylopodium rhizome, flowers and leaves, bark, and leaves of *C. regium* were discovered to contain a variety of metabolite groups, including flavonoids, phenolic compounds, triterpenes, saponins, alkaloids, and glycosides (Adewusi and Afolayan, 2010; Magalhães et al., 2021; Solon et al., 2012).

Nergard et al. (2005) reported that the aqueous extract of *C. tinctorium* included ferulic acid, galotanins, polyphenols, and polysaccharides. According to Tijjani et al. (2009), the methanol rhizome extract of *C. tinctorium* contains flavonoids, glycosides, and tannins. Musa (2012) reports that the n-butanol fraction of *C. tinctorium* includes cardiac glycosides, saponins, and carbohydrates, whereas the 80% acetone fraction contains anthraquinones, flavonoids, and carbohydrates. The plant's aqueous extracts of the methanol extracts (leaf, root, and root bark) include alkaloids, steroids, flavonoids, tannins, and saponins. The aqueous extract of *C. tinctorium* was shown to include alkaloids, tannins, cardiac glycosides, saponins, flavonoids, triterpenes, cyanogenic glycosides, and volatile oils by Etuk et al. (2009). Secondary metabolites found in the root of *C. tinctorium* include tannins (total, hydrolysable, and condensate), phytates,

oxalates, carotenoids, cyanides, alkaloids, flavonoids, and phenols, as reported by Ndouyang et al. (2018). According to a photochemical investigation by Tijwun et al. (2022), alkaloids, glycosides, flavonoids, phenols, saponins, tannins, and steroids were present. On the other hand, *C. tintorium* leaf and stem bark lacked flavonoids. The flavonoid content of the *C. tintorium* stem's bark was found to be the greatest at 6.54 mg/dL, whilst the leaf had the lowest concentration at 3.66 mg/dL. Phenol levels were highest (4.37 mg/dl) in the bark of the stem and lowest (1.48 mg/dl) in the roots of *C. tintorium*.

Devi et al. (2010) found that when *C. religiosum* was extracted in methanol rather than other solvents, the content of secondary metabolites such as terpenoids, saponins, phenolics, alkaloids, and glycosides was greater in the methanolic extract. Furthermore, it was discovered that the Katira gum that was isolated from *C. religiosum* included traces of ketohexose (35), as well as an equimolecular ratio of ramnose (**40**), d-galactose (**55**), and d-galacturonic acid (**41**). The results of the methylation study showed that methylated uronic acid (**42**) and ramnose (40) were present. Furthermore, comparable residues of neutral sugars were found in the gum exudate of *C. religiosum*, as well as d-galacturonic acid (**41**) in the inner chain of this polysaccharide (Sharma and Mazumdar, 2013). Arya and Buch (2017) discovered that *C. religiosum* has a number of different chemical components, such as flavonoids, phytosterols, tannins, and saponins. *C. religiosum* leaf extract was shown to contain leucoanthocyanidin (Savithramma et al., 2011). Numerous secondary metabolites, including alkaloids, steroids, flavonoids, terpenoids, glycosides, carbohydrates, tannins, saponins, and phenols, were discovered to be present in the extract. According to a phytochemical screening, *C. religiosum* contains a variety of phytoconstituents in its leaves and stem, including isorhamnetin-3-glycosides (**1**) (methylated quercetin), alkaloids, glycosides, flavonoids, phenolics, saponins, steroids, coumarins, and leucoanthocyanidin (Savithramma et al., 2011).

In terms of secondary metabolites, aqueous extracts of *C. planchonii* roots were found to include triacylbenzenes A, B, C, and D as well as alkaloids, saponins, tannins, phenolics, steroids, and anthraquinones. Kola et al. (2022) discovered in a more recent investigation that the hydroethanolic extract of *C. planchonii* roots had a noticeably high polyphenol and flavonoid content.

Uronic acid has been shown to be present in *C. vitifolium* found in karaya and kondagogu (**34**). In addition, there have been discovered the triterpene arjunolic acid (24), tannins,

carotenoids, β-bisabolene (**43)**, 1-hydroxy-3-octadecanone (**29**), and cocloxanthin (**59**). Parra et al. (2016) used GC/MS to analyze the essential oil content of the leaves, bark, roots, and root wood of *C. vitifolium*. Together, these four main components account up 87.9% of the leaf essential oil: β-caryophyllene (46.5%) (**8**), α-humulene (26.0%) (**20**), β-pinene (58) (10.6%), and α-pinene (**19**) (4.8%). β-bisabolene (29.3%) (**43**) 1-hydroxy-3-hexadecanone (19.5%) (**29**), and β-caryophyllene (**8**) (8.2%), which account for 57.0% of the total, are present in the root bark essential oil. The main constituents of root wood essential oil composition are γ-murolene (**9**) (28.4%), 1-hydroxy-3-hexadecanone (16.2%), β-caryophyllene (11.6%) (**8**), β-bisabolene (11.5%) (**43**), and 2-dodecanone (**7**) (6.3%). These constituents comprise 74.0% of the essential oil. The ethanolic extracts of the root, bark, and wood include gallic acid, excelsin (**57**), epinoresinol (**32**) flavonoids naringenin (**25**), aromadendrin (**14**), and sterol β-sitosterol (**33**), among other compounds. Additionally, the root contains 1-dodecanoyl-3,5-di(tetradecanoyl)benzene (**60**) (Sanchez-Salgado et al., 2010).

Table 4. Chemical substances, molecular formulas, traditional medicine components, and activity are all found in the most significant medicinal species of the *Cochlospermum* genus.

Name of the compound	**Molecular formula**	**Species**	**Part of the plant**	**Bioactivity**	**References**
Isorhamnetin-3-glucoside **(1)**	$C_{22}H_{22}O_{12}$	*C. religiosum*	Leaves	Protection against heart attacks and strokes, tumors, inflammation, and antioxidants; protection of organs; prevention of obesity; control of cell signaling pathways; and production of associated cytokines and kinases.	Devi et al. (2010)
Rutin **(2)**	$C_{27}H_{30}O_{16}$	*C. regium*	Xylopodium	Anti-inflammatory, antidiabetic, hepatoprotective, and cardiovascular protection.	Arunachalam et al. (2019)
Benzoquinone **(3)**	$C_6H_4O_2$	*C. regium*	Leaves	Antioxidant, anti-inflammatory, and antitumor	Castro (2020); de Menezes Filho et al. (2021)
Myrecitin **(4)**	$C_{15}H_{10}O_8$	*C. regium*	Xylopodium	Effects that include those that are antioxidant, antiviral, anticancer, anti-inflammatory, antiamyloidogenic, and antidiabetic.	Arunachalam et al. (2019)
Morin **(5)**	$C_{15}H_{10}O_7$	*C. regium*	Xylopodium	anti-inflammatory, scavenging of free radicals, and antioxidant	Arunachalam et al. (2019)
Kaempferol **(6)**	$C_{15}H_{10}O_6$	*C. regium*	Xylopodium, Root	Antioxidant, antimicrobial, anticancer, neuroprotective, and hepatoprotective	Arunachalam et al. (2019); Cruz et al. (2016)
2-dodecanone **(7)**	$C_{12}H_{24}O$	*C. vitifolium*	Wood	Not confirmed.	Aguilar-Guadarrama and Rios (2018)
β-caryophyllene **(8)**	$C_5H_{24}O$	*C. vitifolium* *C. regium*	Leaf, root and wood,	Antitumor, antioxidant, and antimicrobial	Aguilar-Guadarrama and Rios (2018)

			flowers, leaves, barks		
γ-muurolene **(9)**	$C_{15}H_{24}$	*C. vitifolium*, *C. regium*	Root, flowers, leaves, barks	Not confirmed.	(de Menezes Filho et al., 2020a); de Menezes Filho et al. (2020b);(Solon et al., 2012); Aguilar-Guadarrama and Rios (2018); (Sólon et al., 2009)
Gallic acid **(10)**	$C_7H_6O_5$	*C. regium*	Xylopodium	Radical scavenging and antitumor	Arunachalam et al. (2019)
Ellagic acid **(11)**	$C_{14}H_6O_8$	*C. regium*	Xylopodium	Antioxidant, antihepatotoxic, antisteatotic, anticholestatic, antifibrogenic, antihepatocarcinogenic, antiviral.	Arunachalam et al. (2019)
γ-cadinene **(12)**	$C_{15}H_{24}$	*C. regium*	Xylopodium	Not confirmed.	Arunachalam et al. (2019)
α-selinene **(13)**	$C_{15}H_{24}$	*C. regium*	Xylopodium	Not confirmed.	Arunachalam et al. (2019)
Aromadendrin **(14)**	$C_{15}H_{12}O_6$	*C. regium*	Xylopodium and flowers	Accelerating amyloid aggregation and fibrillation while lowering neuroblastoma/insulinoma toxicity of Aβ42 and hiapp37.	Arunachalam et al. (2019); (Solon et al., 2012)
Bicyclogermacrene **(15)**	$C_{15}H_{24}$	*C. regium*	Xylopodium	Anti-inflammatory, anti-tumor, antiplasmodial, and antimicrobial	Arunachalam et al. (2019)
β-selinene **(16)**	$C_{15}H_{24}$	*C. regium*	Xylopodium	Anti-inflammatory, antipyretic, and analgesic	Arunachalam et al. (2019)
Trans-caryophyllene **(17)**	$C_{15}H_{24}$	*C. regium*	Xylopodium	Antispasmodic	Arunachalam et al. (2019)
Beta-elemene **(18)**	$C_{15}H_{24}$	*C. regium*	Xylopodium	Antitumor	Arunachalam et al. (2019)

Alpha-pinene **(19)**	$C_{10}H_{16}$	*C. regium*	Xylopodium	Antibiotic resistance modulation, anticoagulant, anticancer, antibacterial, antimalarial, antioxidant, anti-inflammatory, anti-leishmanial, and analgesic	Arunachalam et al. (2019)
Alpha-hulumene **(20)**	$C_{15}H_{24}$	*C. regium*	Xylopodium	Antioxidant, anti-inflammatory, antitumor, and antimicrobial	Arunachalam et al. (2019)
Pinoresinol **(21)**	$C_{20}H_{22}O_3$	*C. regium*	Xylopodium	Antimicrobial	Arunachalam et al. (2019)
Dihydrokaempferol **(22)**	$C_{15}H_{12}O_6$	*C. regium*	Xylopodium	This substance has properties that can inhibit tumor growth, lower blood sugar levels, reduce inflammation, and protect the nervous system.	Arunachalam et al. (2019)
Dihydrokaempferol 3-β-D-glucopyranoside **(23)**	$C_{21}H_{20}O_{11}$	*C. regium*	Xylopodium	Neuroprotective	Arunachalam et al. (2019)
Arjunoic acid **(24)**	$C_{30}H_{48}O_5$	*C. regium*	Roots	Activities include antioxidant, antibacterial, anticholinesterase, anticancer, anti-asthmatic, and insect growth inhibition.	Miranda Pedroso et al. (2019)
Naringenin **(25)**	$C_{15}H_{12}O_5$	*C.vitifolium*	Leaves, root bark, and root wood.	The mentioned properties include antioxidant, anticancer, antiviral, antibacterial, anti-inflammatory, antiadipogenic, and cardioprotective effects.	Aguilar-Guadarrama and Rios (2018)
Apigenin 7-O-glucoside **(26)**	$C_{21}H_{20}O_{10}$	*C.vitifolium*	Leaves, root bark, and root wood.	Antimicrobial	Aguilar-Guadarrama and Rios (2018)

Naringenin O-glucose **(27)**	$C_{21}H_{22}O_{10}$	*C.vitifolium*	Leaves, root bark, and root wood.	The mentioned properties include antidiabetic, anticancer, antimicrobial, anti-obesity, gastroprotective, immunomodulatory, cardioprotective, nephroprotective, and neuroprotective effects.	Aguilar-Guadarrama and Rios (2018)
5,7,4'-trihydroxy-flavan3-ol **(28)**	$C_{15}H_{14}O_4$	*C.vitifolium*	Leaves, root bark, and root wood.	Antimicrobial	Aguilar-Guadarrama and Rios (2018)
1-hydroxy-3-hexadecanona **(29)**	$C_{16}H_{32}O_2$	*C.vitifolium*	Leaves, root bark, and root wood.	Not confirmed.	Aguilar-Guadarrama and Rios (2018)
methylated uronic acid **(30)**	$C_4H_6O_5$	*C. religiosum*	Katira Gum	Not confirmed.	Sharma and Mazumdar (2013)
Keto-hexose **(31)**	$C_7H_{12}O_7$	*C. religiosum*	Katira Gum	Not confirmed.	Sharma and Mazumdar (2013)
Epinoresinol (PINORESIDOL) **(32)**	$C_{20}H_{22}O_6$	*C.vitifolium*	Leaves, root bark, and root wood.	The effects include augmenting the pace at which tumour development is inhibited, boosting the functioning of the immune system, preventing the activation of androgen receptors, and decreasing the proliferation of prostate cancer cells.	Aguilar-Guadarrama and Rios (2018)
steroid β-sitosterol, estigmasterol **(33)**	$C_{29}H_{50}O$	*C.vitifolium*	Leaves, root bark, and root wood.	Anti-inflammatory, estrogenic, and immunostimulant	(Sanchez-Recillas et al., 2014)
Diidroquercetina **(34)**	$C_{15}H_{12}O_7$	*C.vitifolium*	Leaves, root bark, and root wood.	Antitumor, cardioprotective, and anti-inflammatory.	Aguilar-Guadarrama and Rios (2018)

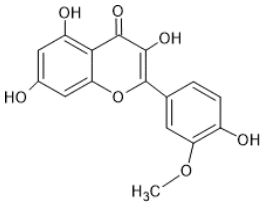
β-carotene **(35)**	$C_{40}H_{56}$	*C. vitifolium*	Leaves, root bark, and root wood.	Antioxidant	Aguilar-Guadarrama and Rios (2018)
γ-carotene **(36)**	$C_{40}H_{56}$	*C.vitifolium*	Leaves, root bark, and root wood.	Antitumor, cardioprotective, and anti-inflammatory	Aguilar-Guadarrama and Rios (2018)
Capsanthin **(37)**	$C_{40}H_{56}O_3$	*C.vitifolium*	Leaves, root bark, and root wood.	Anti-tumor, antioxidant, and weight loss-promoting activities, as well as protective effects against liver disease and other health benefits.	Aguilar-Guadarrama and Rios (2018)
Zeaxanthin **(38)**	$C_{40}H_{56}O_2$	*C.vitifolium*	Leaves, root bark, and root wood.	Anti-inflammatory and antioxidant	Aguilar-Guadarrama and Rios (2018)
Trihidroxiflavonon (Trihidroxiflavonid) **(39)**	$C_{15}H_{12}O_5$	*C.vitifolium*	Leaves, root bark, and root wood.	Anti-inflammatory and antioxidant	Aguilar-Guadarrama and Rios (2018)
Rhamnose **(40)**	$C_6H_{12}O_5$	*C. religiosum*	Katira Gum	Not confirmed.	Sharma and Mazumdar (2013)
d-galacturonic acid **(41)**	$C_6H_{12}O_7$	*C. religiosum*	Katira Gum	Not confirmed.	Sharma and Mazumdar (2013)
Uranic acid **(42)**	$C_5H_4N_4O_3$	*C. religiosum*	Katira Gum	Antitumor, cardioprotective, and anti-inflammatory	Sharma and Mazumdar (2013)
β-bisabolene **(43)**	$C_{15}H_{24}$	*C. vitifolium*	leaves, root bark, and root wood.	Antitumor and antibacterial	Aguilar-Guadarrama and Rios (2018)

Viridiflorol **(44)**	$C_{15}H_{24}O$	*C. regium*	Leaves and Xylopodium	Antitumor	Magalhães et al. (2021)
Thujopsene **(45)**	$C_{15}H_{24}$	*C. regium*	Leaves and Xylopodium	Not confirmed.	Magalhães et al. (2021)
Longiborneol **(46)**	$C_{15}H_{26}O$	*C. regium*	Leaves and Xylopodium	Not confirmed.	Magalhães et al. (2021)
Cochlospermine **(47)**	$C_{11}H_{23}$	*C. regium*	Xylopodium	Not confirmed	Arunachalam et al. (2019); Solon et al. (2012)
Beta-Coapen-4-alpha-ol **(48)**	$C_{15}H_{24}O$	*C. regium*	Leaves and Xylopodium	Inhibitor of cholesterol biosynthesis	Magalhães et al. (2021)
Aromadendrene **(49)**	$C_{15}H_{24}$	*C. regium*	rhizome, twig and leaves, and flowers	Antifungal, antibacterial, antiviral, anti-inflammatory, and enzyme inhibition	de Menezes Filho et al. (2020a); de Menezes Filho et al. (2020b)
7-40 dimethyltaxifolin **(50)**	$C_{15}H_{12}O_7$	*C. angolense*	Leaves and Roots	Antithrombotic, and anticonvulsant	Leonardi et al. (2012)
Germacrene D **(51)**	$C_{15}H_{24}$	*C. angolense*	Leaves and Roots	Antimicrobial	Leonardi et al. (2012)
Cadinol **(52)**	$C_{15}H_{26}O$	*C. angolense*	Leaves and Roots	Smooth muscle relaxation, inhibition of intestinal hypersecretion, antiparasitic effects, and immune system modulation	Leonardi et al. (2012)
10-epi-cuben-ol **(53)**	$C_{15}H_{26}O$	*C. angolense*	Leaves and Roots	Antinociceptive	Leonardi et al. (2012)

Isoborneol **(54)**	$C_{10}H_{18}O$	*C. angolense*	Leaves and Roots	Cardioprotective	Leonardi et al. (2012)
Galactose **(55)**	$C_6H_{12}O_6$	*C. angolense*	Leaves and Roots	Immunoregulatory, anti-inflammatory, antitumor	Leonardi et al. (2012)
(epi)gallocatechin-O-gallate **(56)**	$C_{22}H_{18}O_{11}$	*C. angolense*	Leaves and Roots	Antitumor, cardioprotective, antiviral,	Leonardi et al. (2012)
Excelsin **(57)**	$C_{25}H_{36}O_9$	*C. angolense*	Leaves and Roots	Not Confirmed	Leonardi et al. (2012)
β-pinene **(58)**	$C_{10}H_{16}$	*C. vitifolium*	Bark and rhizome	Plant growth inhibition and induction of oxidative stress	Sanchez-Salgado et al. (2010)
Crocoxanthin **(59)**	$C_{40}H_{54}O$	*C. vitifolium*	Bark and rhizome	Not confirmed.	Sanchez-Salgado et al. (2010)
1-Dodecanoyl-3,5-di (tetradecanoyl) benzene **(60)**	$C_{46}H_{80}O_3$	*C. vitifolium*	Bark and rhizome	Anti-inflammatory	Sanchez-Salgado et al. (2010)
Acid protocatechuic **(61)**	$C_7H_6O_4$	*C. angolense*	Bark	Antioxidant, anti-inflammatory, and antitumor	(Chipaca-Domingos et al., 2023)

Source: The author

Fig. 2. Chemical structural formulae of the bioactive chemicals discovered in plants belonging to the *Cochlospermum* genus.



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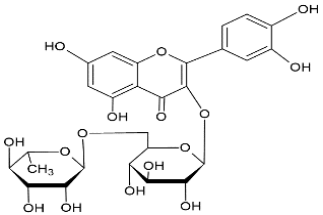

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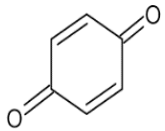

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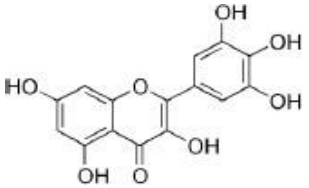

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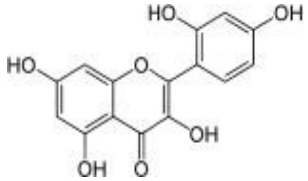

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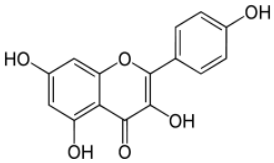

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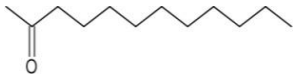

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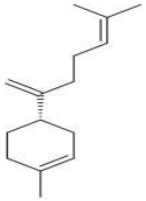

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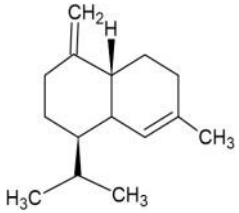

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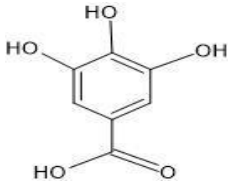

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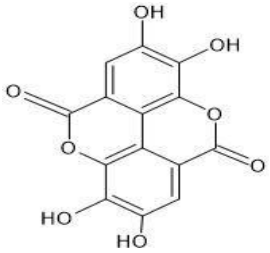

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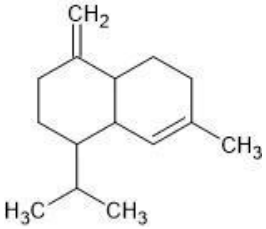

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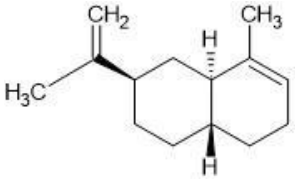

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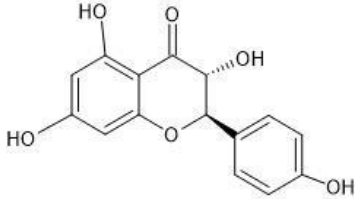

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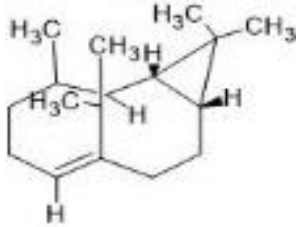

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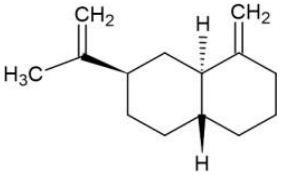

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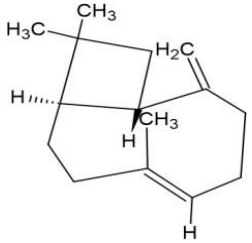

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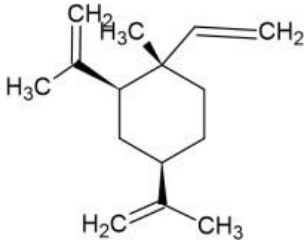

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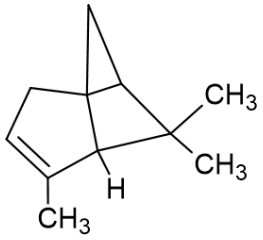

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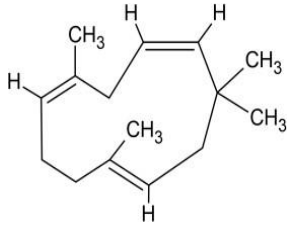

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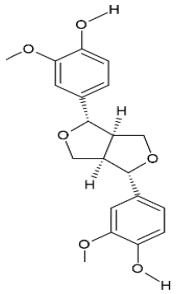

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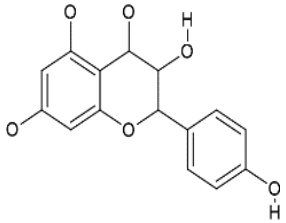

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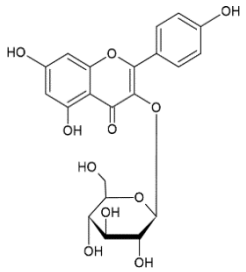

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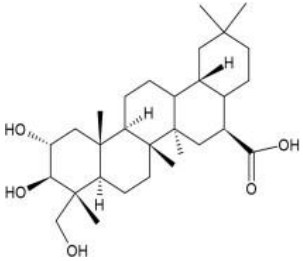

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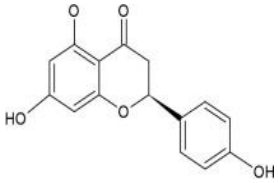

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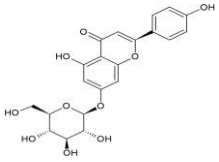

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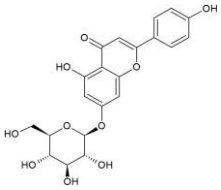

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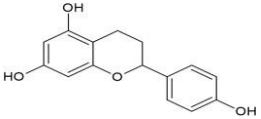

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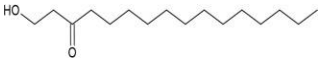

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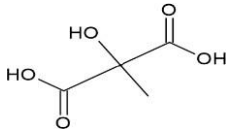

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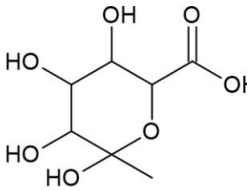

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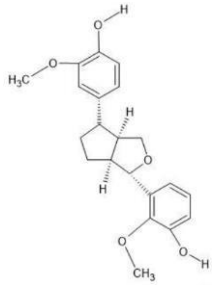

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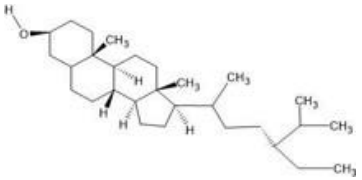

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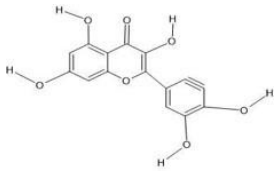

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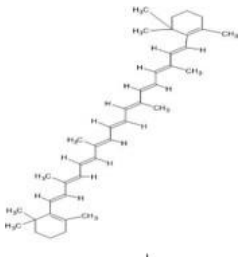

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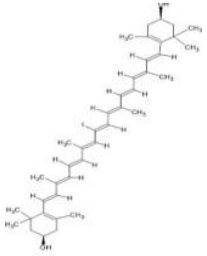

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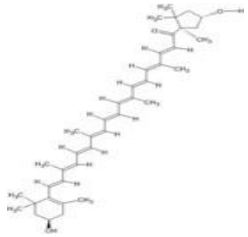

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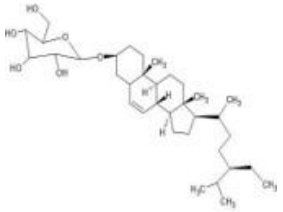

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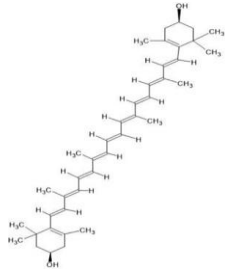

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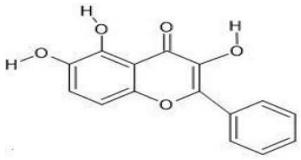

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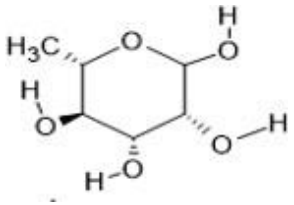

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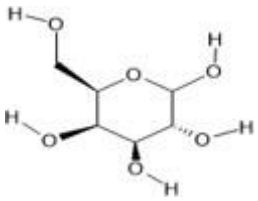

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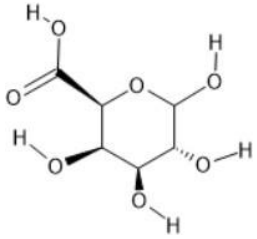

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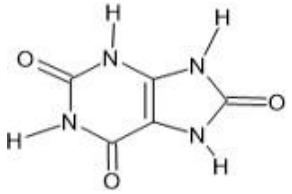

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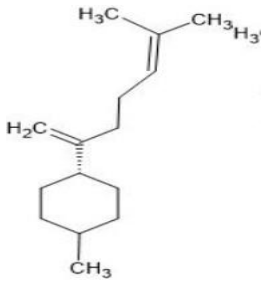

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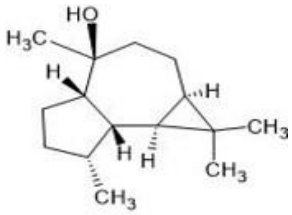

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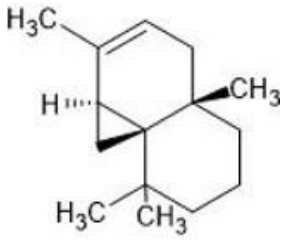

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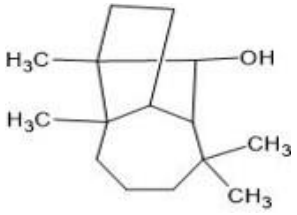

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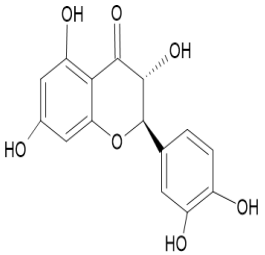

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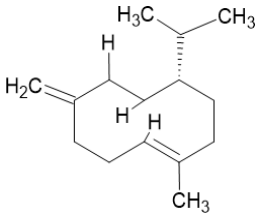

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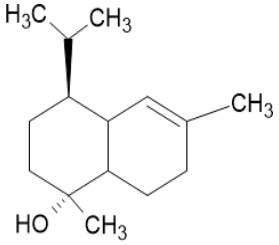

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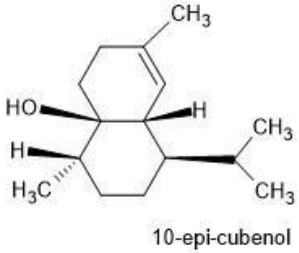

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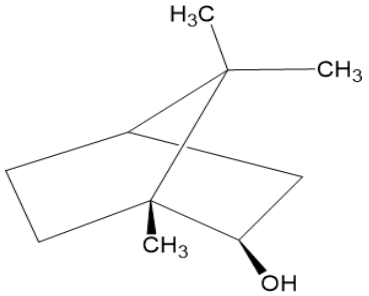

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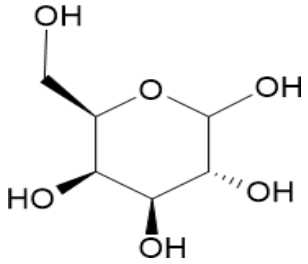

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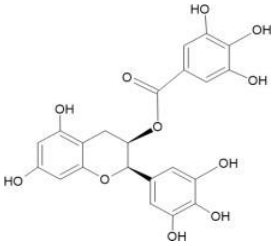

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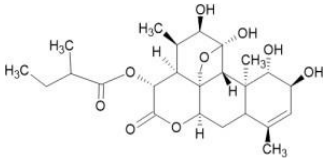

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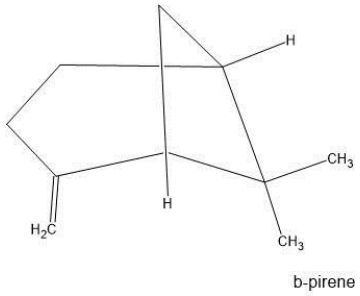

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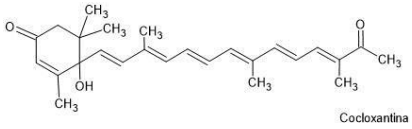

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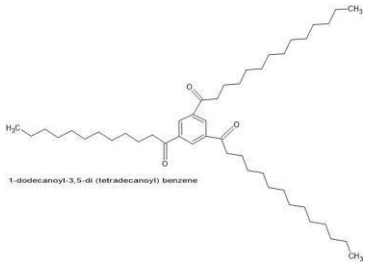

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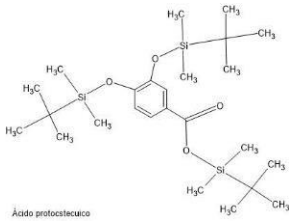

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Source: The author

The blossoms of the plant contain several chemicals, including flavonoids such as apigenin (26), naringenin (25), and dihydroquercetin (34), as well as carotenoids including β-carotene (35), γ-carotene, lycopene (36), capsanthin (37), and zeaxanthin (38). These investigations indicate that *Cochlospermum* species possess a high abundance of sterols, flavonoids, carotenoids, apocarotenoids, and lignans. Out of the 20 chemicals obtained from the bark of *C. vitifolium*, 13 have previously demonstrated beneficial effects on the liver both in laboratory experiments and in living organisms (Aguilar-Guadarrama and Rios, 2018). (±)-Naringenin (5,7,4-trihydroxyflavonone, NG), a chemical similar to flavanone, was obtained from the methanolic extract of *C. vitifolium* bark. NG is a biologically active molecule that has been examined in first functional investigations and has the ability to relax blood vessels (Sanchez-Salgado et al., 2007). *C. vitifolium* was discovered to contain sterols 3 and 4, aromatic compounds 6, 7, and 9, apocatrotenoid 10, flavonoids 11 and 13-17, and lignan 20 in the dichloromethane extract of its dried bark. These substances have demonstrated advantageous benefits in mitigating diverse liver ailments. The metabolites identified in this work, as well as the previously documented chemical composition of *C. vitifolium*, align with the metabolite profile seen in other *Cochlospermum* species. The flavonoids, sterols, carotenoids, apocarotenoids, and lignans that were separated in this investigation demonstrate chemotaxonomic characteristics (Aguilar-Guadarrama and Rios, 2018).

Abourashed and Fu (2017) established that borututu (*C. angolense*) is an African tree renowned for its bark, which has gained popularity as a plant-based nutritional supplement owing to its potent antioxidant properties. The major antioxidant components, gallic acid (**10**) and protocatechuic acid (**61**), were found by investigations employing centrifugal chromatography. The chloroform fraction produced two apocarotenoids, cocloxanthine and dihydrococloxanthin, as well as one flavonoid, namely 7,40-dimethyltaxifolin (**50**). Chipaca-Domingos et al. (2023) did research on pressurized liquid extraction (PLE) with the purpose of obtaining extracts from borututu root. The samples included ellagic acid (**11**) and glycosides of ellagic acid and methyl ellagic acid as the primary phenolic components. The use of PLE is a highly effective method for extracting borututu roots, resulting in extracts that have both high quantities of phenolic components and strong antioxidant activity.

Leonardi et al. (2012) characterized the chemical makeup of essential oils extracted from the leaves and roots of *C. angolense* using capillary gas chromatography (GC) and gas chromatography/mass spectrometry (GC-MS). A total of 67 compounds were discovered from the leaves, while 130 compounds were found from the roots. The oils in both the leaves and roots were

predominantly composed of sesquiterpenoids, accounting for 68.8% and 53.2% respectively. Monoterpenoids were also present, but in lesser proportions, making for 9.8% in leaves and 26.2% in roots. The predominant constituents of the leaves were germacrene D (9.4%), α-cadinol (7.4%), and 10-epi-cubenol (6.2%), but the primary chemicals in the essential oil of the root were sesquiterpenes β-caryophyllene (19.7%) and isoborneol (6.6%). The borututu infusion exhibited the greatest quantities of total phenolics and flavonoids, as well as the highest antioxidant activity in all tests. The bioactive properties of the infusions, specifically their antioxidant and antitumor effects, were found to be directly linked to the levels of phenolics and flavonoids present (Pereira et al., 2013). Pereira et al. (2015) determined the chemical constituents present in *C. angolense*. Protocatechuic acid (**61**) was the most prevalent chemical only detected in infusions. In tablets and eucaglobulin pills and syrup, (epi)gallocatechin-O-gallate (**56**) was the primary molecule discovered.

6 CONCLUSIONS

The traditional objective of research has been to discover and create powerful, efficient, and secure bioactive substances derived from plant chemicals for utilization in conventional methods of medication administration. It is strongly suggested to conduct safety studies on the use of plant extracts, including subacute, subchronic, chronic, carcinogenic, mutagenic, and teratogenic toxicity studies, in order to enhance trust in their usage and ensure their safety for therapeutic development. The genus *Cochlospermum* is linked to several pharmacological and biological activities.

This research specifically examines the ethnobotanical, ethnopharmacological, and chemical characteristics of the most significant medicinal species within the *Cochlospermum* genus. The knowledge provided may enhance our comprehension of this genus, which holds considerable pharmaceutical significance owing to its diverse biological functions. The preservation of this genus is crucial because to its many activities that have potential as future phytopharmaceuticals for treating diverse diseases. The copious compounds it contains can function as an alternate resource, offering a fresh outlook for future investigations on plants belonging to this species.

Abbreviations

ABTS	2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid),
CAT	Catalase
BSA	bovine serum albumin
BHA	butylated hydroxyanisole
AMY	α-Amylase
AGES	Advanced glycation end products
AChE	Acetylcholinesterase
DPPH	2,2-diphenyl-1-picrylhydrazyl
FRAP	Ferric reducing antioxidant power assay
G6PDH	Glucose-6-phosphate
GSH	Glutathione
GPx	Glutathione peroxidase
HCl	Hydrochloric acid
MDA	Malondialdehyde
MIC	Minimum inhibitory concentration
MPO	Myeloperoxidase
NO	Nitric oxide
PBMC	Peripheral blood mononuclear cell

Source: The Author

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