Trop J Nat Prod Res, January 2024; 8(1):5715-5726 ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

Review Article

Exploring the Phytochemical Composition and Pharmacological Activities of *Cerbera manghas* and *C. odollam*: A Comprehensive Review

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ARTICLE INFO

Article history:
Received 22 October 2023
Revised 10 January 2024
Accepted 11 January 2024
Published online 01 February 2024

ABSTRACT

Cerbera manghas and *C. odollam*, often perceived as similar species, exhibit distinct physical characteristics and phylogenetic classifications. Despite their reputation as poisonous plants, both species have diverse benefits and are potential sources of pharmacological compounds. This report comprehensively summarizes the compounds identified within the *genus Cerbera*, coupled with reported bioactivities. Over 100 compounds, including phenolics, flavonoids, terpenoids, and steroids, have been isolated from *C. manghas* and *C. odollam*. Cardiac glycosides (steroids) are the predominant compounds in these species and demonstrate robust cytotoxic activity. Furthermore, both plants show promise as antioxidants and antimicrobial agents, and exhibit insecticidal, termiticidal, and larvicidal properties. This review consolidates the current understanding of the phytochemical and pharmacological attributes of *C. manghas* and *C. odollam*.

Keywords: *Cerbera*, *Cerbera manghas*, *Cerbera odollam*, Pharmacological activities, Phytochemicals

Introduction

Cerbera genus is a mangrove plant that belongs to the Apocynaceae family and is widespread in tropical Asia, Australia, and various islands in the Indian and western Pacific Oceans.[1] The two most common species of *Cerbera* are *C. odollam* and *C. manghas*. In Indonesia these two species are known as "bintaro", while in other countries they are known as pong-pong tree, blind rhino, mango laut, wood octopus, and babuto.[2]

C. manghas is a tree that can reach 20 m in height with a diameter of 70 cm. The branches of the tree are thick and succulent, while the stem contains prominent lenticels and softwood. The leaves are dark green and spirally arranged. The fruit is oval and has a single seed. When ripe, it changes colour to bright red.[3] *C. odollam* is a tree measuring up to 12 m and has dark green leaves with leaf stalks measuring 2–5 cm long. The fruit is round, like an apple or a small mango, with poisonous seeds. When the fruit is ripe, it will change from green to reddish purple to brownish black and fall from the tree.[4] Distinguishing features include the flowers of *C. odollam* with tiny yellow eyes and the oval fruits. In contrast, flowers of *C. manghas* have a prominent pink eye, and fruits are more elongated, resembling mango.[5] In several reports, it is stated that the *C. manghas* species is the same as *C. odollam*. Based on the phylogenetic tree, *C. odollam* and *C. manghas* are different plants.[6] Based on literature search, the two species are also reported to contain different compounds or secondary metabolites.[5]

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Citation: Ilmiawati A, Mujahidah U, Arinana, Batubara I, Nurcholis W. Exploring the Phytochemical Composition and Pharmacological Activities of *Cerbera manghas* and *C. odollam*: A Comprehensive Review. Trop J Nat Prod Res. 2024; 8(1):5715-5726. http://www.doi.org/10.26538/tjnpr/v8i1.1

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria

Almost all parts of the bintaro plant contain a toxin called "Cerberin" which is a toxin that can block human calcium ion channels, thereby disrupting the heartbeat and can cause death, therefore this plant is known as 'suicide tree.' Ingestion of the kernel can cause nausea, vomiting, hyperkalemia, thrombocytopenia, and ECG abnormalities. Exposure to high doses of *Cerbera odollam* carries the highest risk of mortality.[7] Apart from that, there are also reports of cases of death due to ingestion *C. odollam* seeds in the US, with symptoms of vomiting and bradycardia.[8] There are also reports of women committing suicide several hours after ingestion pong-pong seeds obtained via the internet.[9] However, this plant is also reported to have various activities, including antioxidant,[10-11] anticancer,[12] anti-inflammatory,[13] and antimicrobial.[14] These activities are due to the secondary metabolites contained therein, such as saponins, terpenoids, and alkaloids, phenolic acids, flavonoids, cardiac glycosides, steroids, iridoids, lignans, and other compounds.[3] Various reports also show its potential as a bioinsecticidal and pesticide in the agricultural field and termiticidal activity in various species.[12]

This review article summarizes various compounds reported from *C. manghas* and *C. odollam*, along with their multiple bioactivities, including cytotoxic, antioxidant, antimicrobial, insecticidal, termiticidal, and larvicidal activities. Although several studies also discuss reviews of the *Cerbera* genus, in this article, the review is more comprehensive regarding compounds that have been reported in both species (*C. odollam* and *C. manghas*) as well as their activities, starting from the first report up to the latest data. This review is essential to provide more information regarding the potential of *Cerbera* plants in various bioactivities, both from extracts and isolated compounds, so that this plant is not only known as a poisonous plant but also a valuable plant.

Methodology

This review was based on a literature review. The literature used was reliable literature published from 1976 until 2023. The literature used were scientific articles, research journals, and books on both national and international levels. The literature review was carried out by searching for articles using the keywords "bintaro," "*Cerbera*,"

"*Cerbera manghas*," "*Cerbera odollam*," "compound of *Cerbera*," "bioactivity of *Cerbera*," and so on Google Scholar, ScienceDirect, Springer, MDPI, PubMed and Researchgate.

Results and Discussion

Compounds in Cerbera manghas and Cerbera odollam

More than 100 compounds, including phenolics, terpenoids, and steroids, have been isolated from *C. manghas* and *C. odollam*. The most common group of compounds among these two groups is the cardiac glycoside group, a steroid derivative. The complete data are presented in Table 1. Data were sorted by library year, from oldest to latest. The compounds previously reported in the literature have not been rewritten. The first report was published in 1976, reporting the isolation of flavonoid and steroid compounds, namely Nicotiflorin, Rutin, and (+)-Bornesitol.[15] The subsequent discovery was reported in 1977, reporting the isolation of several compounds belonging to the cardiac glycoside group, including Cerberin, Nerifoliin, and Thevetin B. The compound most often found in *Cerbera* plants (*C. manghas* and *C. odollam*) is Cerberin, a group of cardiac glycosides. This compound is found in several parts of plants, namely leaves,[17] fruit,[18] and seeds.[16, 19-21].

Most of the compounds were isolated from parts of plant leaves, whereas parts of plants rarely studied are fruits. Only one publication was found regarding compounds from *C. manghas* fruit parts, namely phenolic acid and terpenoid groups,[18] including benzoic acid, vanillic acid, Vanillin, and Isophthalaldehydic acid.

Bioactivities

Cytotoxic Activity

The bintaro plant is known to be toxic and poisonous. Some studies on the cytotoxic activity of bintaro plants are presented in Table 2. Cytotoxic activity in the genus *Cerbera* was partly reported as the ED_{50} value (μg/mL) and partly as the IC_{50} value (μg/mL). Some of the literature initially said concentrations in micromolar units, but in this study, it was converted to μg/mL to be compared with other studies.

Almost all of the literature reports the activity of the isolated compounds from the genus *Cerbera*, except for one report regarding the cytotoxic activity of *Cerbera* extract.[40] The cytotoxic activity of *Cerbera* compounds and extract was tested against oral human epidermoid carcinoma (KB), breast cancer cells (BC, MCF7 & T47D), human small cell lung cancer (NCI-H187), ovarian cancer cell lines (SKOV3 & CaOV3), kidney of an African green monkey (Vero), human liver hepatocellular carcinoma cell line (HepG2), promyelocytic leukemia cell line (HL-60), cervical carcinoma cells (HeLa), human colon cancer cells (Col2), and human endometrial cancer (Ishikawa).

Most of the compounds tested for cytotoxic activity were cardiac glycosides, and most showed strong cytotoxic activity, including 17*α*- and 17*β*-Neriifolin, Cerberin, 7,8-Dehydrocerberin, Tanghinin, Neriifolin, and Tanghinigenin. Cerberin's cytotoxic activity against KB, BC, and NCI-H187 cells was reported twice by different literature and gave results that were not much different, showing strong activity against all three cancer cells.[19,21] The mechanism of cell death by17*β*H-Neriifolin was further evaluated using Hoescht 33342 assay, and it was found that the compound killed the cancer cells via apoptosis. 17*β*H-Neriifolin and ouabain both bound at *α*-subunit in Na^+, K^+-ATPase and their binding energy were -8.16 ± 0.74 kcal/mol and -8.18 ± 0.48 kcal/mol respectively.[41]

Besides of that, other literature states that the compound 2'-Epi-2'-O-Acetylthevetin B (GHSC-74) (cardiac glycoside group) isolated from *C. manghas* seed, can reduce the viability of HepG2 cells, which is influenced by time and dose.[46] Other research states that *β*-D-Glucosyl-(1→4)-*α*-L-thevetosides of 17*β*-digitoxigenin (GHSC-73) (cardiac glycoside group) isolated from the seed of *C. manghas* can reduce the viability of HepG2 cells which is influenced by time and dose without decreasing the viability of Chang human liver cells and Swiss albino 3T3 fibroblasts, induced efficiently stimulated apoptosis in HepG2 cells as evidenced by DNA fragmentation, annexin V/PI binding assay and DAPI staining.[47]

Table 1: Compounds isolated from *C. odollam* and *C.manghas*

Compound	Group	Plant part	Species	Reference
Nicotiflorin	Flavonoid	Leaves	*C. manghas*	15
Rutin				
(+)-Bornesitol	Steroid			
Cerberin				
Neriifolin				
Thevetin B		Seed		
2'-O-Acetyl thevetin B				
Deacetyltanghinin	Steroid (Cardiac glycosides)		*C. manghas*	16
Gentiobiosyl deacetyltanghinin				
17*β*H-tanghinigenin *β*-L-thevetoside		Root bark & stem		
17*β*H-tanghinigenin *β*-D-glucosyl-(1"→4')-*β*-L-thevetoside				
Digitoxigenin *β*-L-thevetoside		Leaves		
17*β*H-digitoxigenin *β*-L-thevetoside				
Cerbinal				
Cerberic acid	Iridoid	Bark	*C. manghas*	22
Cerberinic acid				
Manghaslin	Flavonoid	Leaves	*C. manghas*	23
Clitorin				
3-O)-(2-RhamnosyIrutinosyl-7-O-*β*-glucosylquercetin	Flavonoid	Leaves	*C. manghas*	24
17*α*-Neriifolin	Steroid (Cardiac glycosides)	Leaves	*C. manghas; C. odollam*	25
17*α*-Deacetyltanghinin				

Compound	Group	Plant part	Species	Reference
Cerleaside A 8*β*-Hydroxydigitoxigenin-*α*-L-thevetoside (= Cerdollaside) 17*α*-Cerdollaside Digitoxigenin *α*-L-acofrioside (= solanoside) 17*α*-Solanoside Tanghinigenina *α*-L-Acofrioside 17*α*-Digitoxigenin *β*-D-allopyranosyl-*α*-L-thevetoside 17*α*-Tanghinigenin *β*-D-glucos-3-ulosyl-(1→4)-*α*-L-thevetoside Oleagenin *β*-D-glucosyl-(1→4)-*α*-L-thevetoside (= Cerleaside B)			*C. odollam*	
Digitoxigenin *β*-D-Gentiotriosyl-(1→4)-*α*-L-thevetoside 17*α*-Digitoxigenin *β*-D-glucosyl-(1→4)-*α*-L-thevetoside 17*β*-Digitoxigenin *β*-D-glucosyl-(1→4)-*α*-L-thevetoside 17*α*-Tanghinigenin 17*β*-Tanghinigenin Digitoxigenin Gentiotriosyl-(1→4)-*α*-L-thevetoside Tanghinigenin	Steroid (Cardiac glycosides)	Leaves	*C. manghas* *C. manghas;* *C. odollam*	26
17*α*-Digitoxigenin *β*-D-Apiosyl-(1→6)-*β*-D-glucosyl-(1→4)-*α*-L-thevetoside 17*α*-Digitoxigenin *β*-D-cellobiosyl-*α*-L-thevetoside 17*α*-Digitoxigenin β-D-Gentiobiocyl-(1→4)-*α*-L-thevetoside	Steroid (Cardiac glycosides	Stem	*C. manghas*	27
(-)-Olivil (+)-Cycloolivil 5-5"-Bis-olivil (= Cerberalignan A) 5'-5"-Bis-olivil (= Cerberalignan B) 5'-5'"-Bis-olivil (= Cerberalignan C)	Lignan	Stem	*C. manghas;* *C. odollam*	28
Olivil 4-O-*β*-D-glucoside Olivil 4'-O-*β*-D-glucoside		Leaves	*C. manghas*	
Cerberalignan D-I	Lignan	Stem	*C. manghas;* *C. odollam*	29
Cerberalignan J-N	Lignan	Stem	*C. manghas*	30
Cerberidol Epoxycerberidol Cyclocerberidol Cerberidol-3-O-*β*-D-allopiranosyde Cerberidol-3,10-bis-O-*β*-D-allopiranosyde Epoxycerberidol-3-O-*β*-D-allopiranosyde Cyclocerberidol-3-O-*β*-D-allopiranosyde	Terpenoid	Leaves	*C. manghas;* *C. odollam*	31
10-O-Benzoyltheveside 10-Dehydrogeniposide Loganin Theviridoside	Iridoid	Leaves	*C. manghas*	32

Compound	Group	Plant part	Species	Reference
Theveside 10-Carboxyloganin Cyclocerberidol-3-O-*β*-D-glucoside Epoxycerberidol-3-O-β-D-glucoside 3-(Hydroxyisopropyl)pentane-1,4-diol-1-O-*β*-D-glucoside 3-(Hydroxyisopropyl)pentane-1-ol-1-O-*β*-D-glucoside (3ξ,4ξ)-3-Isopropyl-3,4-epoxypentane-1,5-diol-1-O-*β*-D-glucoside (Z)-3-Isopropyl-3-pentene-1,5-diol-1-O-*β*-D-glucoside (–)-14-Hydroxy-3*β*-(3-O-methyl-6-deoxy-*α*-L-rhamnosyl)-11*α*,12*α*-epoxy-(5*β*,14*β*,17*β*H)-card-20(22)-enolide	Iridoid Terpenoid	Leaves	*C. manghas*	33
(–)-14-Hydroxy-3*β*-(3-O-methyl-6-deoxy-*α*-L-glucopyranosyl)-11*α*,12*α*-epoxy-(5*β*,14*β*,17*β*H)-card-20(22)-enolide	Steroid (Cardiac glycoside)	Roots	*C. manghas*	34
(–)-17*β*-Neriifolin (-)-Cycloolivil 17*β*-Neriifolin	Lignan			
3*β*-O-(2'-O-Acetyl-L- thevetosyl)-15(14→8)-abeo-5*β*-(8R)-14-oxo-card-20(22)-enolide (= 2'-*O*-Acetyl cerleaside A)	Steroid (Cardiac glycoside)	seed	*C. odollam*	19
3β-*O*-(2'-*O*-acetyl-*α*-L-thevetosyl)-14*β*-hydroxy-7-en-5*β*-card-20(22)-enolide (= 7,8-Dehydrocerberin)	steroid (Cardiac glycoside)	seed	*C. manghas*	21
1,3-Bis(*m*-carboxylphenyl)-propan-2-one 2-(*m*-carboxylphenyl)-3-(*m*-carboxylbenzyl) succinic acid	Phenolic acid	Bark	*C. manghas*	35
Cerberic acid A & B	Iridoid	Bark	*C. manghas*	36
p-Hydroxybenzaldehyde Benzamide n-Hexadecane acid monoglyceride Loliolide *β*-Sitosterol Daucosterol Triticusterol	Phenol Amide Fatty acid Iridoid Steroid Steroid	Leaves	*C. manghas*	17
Dihydroxy-4-methoxy benzoic acid 2-Hydroxy-4-methoxy-6-methyl benzoic acid	Phenol	Stem bark	*C. odollam*	37
Uvaol (23Z)-9,19-cycloart-25-ene-3β,24-diol Euphorbol Ursolic acid 2*α*-Hydroxyursolic acid 3-*O*-Acetyl ursolic acid *α*-Amyrin	Terpenoid	Leaves	*C. manghas*	38
Benzoic acid Vanillic acid Vanillin	Phenolic acid	Fruit	*C. manghas*	18

Compound	Group	Plant part	Species	Reference
p-Hydroxybenzaldehyde				
Isophthalaldehydic acid				
β-hydroxygpropiovanillone				
Ficusol				
Evofolin B				
3,4'-Dihydroxypropiophenone				
p-Hydroxybenzoic acid				
Protocatechuic acid				
Cerbinal	Terpenoid			
β-Amyrin				
Lupeol	Steroid	Leaves	*C. odollam*	39
β-Sitostenone				
Triticusterol				

Table 2. Cytotoxic activity of extracts/compounds on *C. odollam* and *C. manghas*

Compound	Group	Cytotoxic to-	Concentration	Value	Species	Reference
3*β*-O-(2'-O-acetyl-L- thevetosyl)-15(14→8)-abeo-5β-(8R)-14-oxo-card-20(22)-enolide (= 2'-O-Acetyl cerleaside A)	Steroid (Cardiac glycoside)	KB	ED_{50} (μg/mL)	7.56	*C. odollam*	19
		BC		4.62		
		NCI-H187		7.42		
Cerleaside A		KB		Inactive		
		BC		9.12		
		NCI-H187		inactive		
17*α*-Neriifolin		KB		0.078		
		BC		0.049		
		NCI-H187		0.032		
17*β*-Neriifolin		KB		0.017		
		BC		0.048		
		NCI-H187		0.076		
Cerberin		KB		1.92		
		BC		1.63		
		NCI-H187		1.24		
7,8-Dehydrocerberin		KB		1.29	*C. manghas*	21
		BC		0.77		
		NCI-H187		2.3		
Tanghinin		KB		1.75		
		BC		0.0006		
		NCI-H187		16.7		
17*β*H-Neriifolin		KB		0.05		
		BC		1.48		
		NCI-H187		0.1		
		MCF7	IC_{50} (μg/mL)	0.009	*C. odollam*	42
		T47D		0.011		
		SKOV3		0.015		
		CaOV3		0.017		

Compound	Group	Cytotoxic to-	Concentration	Value	Species	Reference
		Vero		0.013		
Neriifolin		HepG2		0.15		43
Tanghinigenin		HL-60		0.84		44
		HepG2		44.7		
Cerberic acid A	Iridoid	MCF-7		52.3		36
		HeLa		48.7		
(–)-14-Hydroxy-3*β*-(3-O-methyl-6-deoxy-*α*-L-rhamnosyl)-11*α*,12*α*-epoxy-(5*β*,14*β*,17*β*H)-card-20(22)-enolide	Steroid (Cardenolide)	Col2		0.015	*C. manghas*	34
		Ishikawa		0.0042		
(–)-14-Hydroxy-3*β*-(3-O-methyl-6-deoxy-*α*-L-glucopyranosyl)-11*α*,12*α*-epoxy-(5*β*,14*β*,17*β*H)-card-20(22)-enolide		Col2		0.02		
		Ishikawa		0.008		
(–)-17*β*-Neriifolin	Steroid (Cardiac glycoside)	Col2		0.01		
		Ishikawa		0.09		
	Methanol extract of leaves	MCF-7		8.49	*C. odollam*	40
		T47D		10.99		
	Methanol extract of fruit	MCF-7		100		
		T47D		> 100		

Note: Activity category in ED_{50} values (µg/ml); Strong if <5, moderate if 5-20, weak if 20-50, and inactive if >50.[19] Activity category in IC_{50} values (µg/ml); strong if <10, moderate if 10-50, weak if 50-100, and inactive if >100.[45]

Antioxidant activity

Several studies have reported the antioxidant activity of the bintaro plant. However, the literature is limited to the activity of the plant extract or fraction (both *C. odollam* and *C. manghas*) with several different extracting solvents, and no reports have been found regarding the antioxidant activity of compounds in the bintaro plant. A summary of the antioxidant activities of *the C. odollam* and *C. manghas* extracts and their fractions is presented in Table 3. Overall antioxidant activity was stated to be very strong if IC_{50} value is < 50 µg/mL, strong if IC_{50} value is 51-100 µg/mL, moderate if IC_{50} value is 101-150 µg/mL, and weak if IC_{50} value is > 150 µg/mL.[48] From these results it can be seen that extracts that provide powerful antioxidant activity are methanol extract of the bark *C. odollam*, and fractions that provide extreme antioxidant activity are carbon tetrachloride and chloroform fraction of the methanolic extract of leaves and bark *C. odollam*.[37,39]

Antimicrobial activity

The bintaro plants (*C. odollam* and *C. manghas*) have been reported to have antimicrobial (both antibacterial and antifungal) potential. However, the literature regarding the antifungal activity of *Cerbera* plants is less than that regarding its antibacterial activity. Several reports on the antimicrobial activities of bintaro plants are presented in Table 4.

Overall, polar solvent extracts were better antibacterial agents than nonpolar solvents. This can be seen from the antibacterial activity of butanol extract of *C. manghas* leaves against *K. pneumonia* which is better than n-hexane extract.[50] Likewise, ethyl acetate extract of *C. manghas* leaves has better antibacterial activity against *E. coli* than dichloromethane extract.[51] However, water extracts do not seem to provide good antibacterial activity, such as water extracts of *C. manghas* seed and meat.[52]

Other literature also reports that phylloplane yeast isolated from C. manghas leaves can inhibit growth and sporulation of *Aspergillus* sp. and *Penicillium* sp.[53]

Insecticidal, Termiticidal and Larvicidal Activities

Several studies have reported the *Cerbera* plant's insecticidal, termiticidal, and larvicidal activities. The data are presented in Table 5. Most of the literature reports the activity of *Cerbera* leaves. Based on the data in Table 5, the seed is the part of the *Cerbera* plant that has the potential to be an insecticidal is the seed.[56] Literature related to termiticidal activity on *Cerbera* plants is still rare. Based on research by Hashim et al.[57], a part of the *Cerbera* plant that provides the highest termiticidal activity after 14 days is the flower, with a termite mortality (TM) of 100%.

The larvicidal activity reported by Komalamisra et al.[58] and Tarmadi et al.[59] yielded different results, even though they used the same samples and plant parts. This is because the origin of the plants used is different, where the *C. odollam* samples tested by Komalamisra *et al*.[58] came from Thailand, while those tested by Tarmadi *et al*.[59] came from Indonesia. Differences in the growing locations of plants can produce different secondary metabolites, thus providing other activities.

Reports of insecticidal, termiticidal, and larvicidal activities of *C. manghas* extract were lower than those of *C. odollam*. *C. manghas* leaf extract does not have a significant lethal effect on *R. linearis* insects; it also provides mortality of only 33%.[60,65]

Apart from the data in the table, there was also termiticidal activity against *Coptotermes* sp. observed every two days during the ten days of observation. The report showed that the methanol extract of *C. odollam* leaves caused 100% termite mortality on the last observation. Whereas bark extracted with n-hexane and acetone caused 100% termite mortality on the eighth day of the treatment.[66] Termiticidal activity of the compound was carried out by Tarmadi et al.[67] where the oleic acid isolated from *C. manghas* showed low termicidal activity as it delivered

low mortality in *Coptotermes gestroi* Wasmann and *Cryptotermes cynocephalus* Light.
Other literature also reports that leaves, rinds, and stem bark extracts of *C. odollam* showed low larvicidal activity against *Culex quinquefasciatus*. In contrast, seed kernel extract and its fractionation using n-hexane and ethyl acetate solvents showed high activity.[68]

Conclusion

In conclusion, *Cerbera manghas* and *Cerbera odollam* have emerged as promising sources of pharmacologically relevant compounds, often recognized for their toxicity. The presence of diverse secondary metabolites, including phenolics, flavonoids, terpenoids, and steroids, highlights their potential medicinal significance. Notably, cardiac glycosides, identified as the dominant steroid compounds, exhibit robust cytotoxic activity, emphasizing the pharmacological potential of these plants. This investigation revealed variations in antioxidant and antimicrobial activities, with methanol extracts displaying high antioxidant potential and polar extracts demonstrating superior antimicrobial efficacy. Despite their documented insecticidal, termiticidal, and larvicidal activities, a comprehensive comparative analysis across species, plant parts, and extraction solvents remains limited because relevant reports are scarce. This study highlights the need for further research to explore a wider range of bioactivities inherent in *Cerbera* plants that are yet to be extensively investigated. Continued exploration of their pharmacological properties is key to unlocking the full spectrum of potential applications of these intriguing botanical species.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

Acknowledgments

The authors gratefully acknowledged the Directorate General of Higher Education, Research, and Technology, Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, for Penelitian Tesis Magister (PTM) No. 102/E5/PG.02.00/PL/2023.

Table 3; Antioxidant activity of *C. odollam* and *C. manghas* extracts/fractions with DPPH method

Species	Extract/fraction	IC_{50}	Reference
C. manghas	Ethanol extract of leaves	292 µg/mL	49
	Methanol extract of the bark	46.0 µg/mL	
	n-hexane soluble fraction of the methanol extract of the bark	135.0 µg/mL	
	Carbon tetrachloride soluble fraction of the methanol extract of the bark	26.0 µg/mL	37
	Chloroform soluble fraction of the methanol extract of the bark	21.0 µg/mL	
	Aqueous fraction of the methanol extract of the bark	62.5 µg/mL	
C. odollam	Methanol extract of leaves	75.02 µg/mL	
	Carbon tetrachloride fraction of the methanolic extract of leaves	72.01 µg/mL	39
	Chloroform fraction of the methanolic extract of leaves	40.00 µg/mL	
	Petroleum ether fraction of the methanolic extract of leaves	280.01 µg/mL	
	Aqueous fraction of the methanolic extract of leaves	265.17 µg/mL	
	Standard equivalent in methanolic extract. (IC %) at 5 µg/mL	80.029%	14
	Standard equivalent in aqueous extract. (IC %) at 5 µg/mL	88.381%	

Table 4: Antimicrobial activity of extracts/compounds on *C. odollam* and *C. manghas*

Species	extract/fraction	Mass/ Concentration extract/ fraction	Bacteria	Diameter of the inhibition zone (mm)	Reference
Antibacterial					
C. manghas	n-hexane extract of the leaves	250 mg/mL	*Klebsiella pneumonia*	17.5	50
		500 mg/mL		18	
		1000 mg/mL		19	
	Butanol extract of the leaves	250 mg/mL		21	
		500 mg/mL		23.5	
		1000 mg/mL		25	
	n-hexane extract of the seed	0.05 g/mL	*Staphylococcus aureus*	8.43	52
			Bacillus cereus	4.88	

Species	extract/fraction	Mass/ Concentration extract/ fraction	Bacteria	Diameter of the inhibition zone (mm)	Reference
	Ethyl acetate extract of the seed		*Escherichia coli.*	3.56	
			Staphylococcus aureus	5.15	
			Bacillus cereus	2.26	
	Aquades extract of the seed		*Escherichia coli.*	0.11	
			Staphylococcus aureus	0.39	
			Bacillus cereus	0	
			Escherichia coli.		
	Ethyl acetate extract of the meat		*Staphylococcus aureus*	10.95	
			Bacillus cereus	4.24	
			Escherichia coli.	8.35	
	n-hexane extract of the meat		*Staphylococcus aureus*	5.28	
			Bacillus cereus	1.31	
			Escherichia coli.	2.59	
	Aquades extract of the meat		*Staphylococcus aureus*	0.16	
			Bacillus cereus;	0	
			Escherichia coli.		
	Ethyl acetate extract of the leaves	10 mg/mL		10	51
		20 mg/mL	*Staphylococcus aureus*	11.33	
		30 mg/mL		13.67	
		10 mg/mL		8.5	
		20 mg/mL	*Escherichia coli*	9.17	
		30 mg/mL		10.33	
	Dichloromethane extract of the leaves	10 mg/mL		9.83	
		20 mg/mL	*Staphylococcus aureus*	13.33	
		30 mg/mL		15.83	
		10 mg/mL		7.17	
		20 mg/mL	*Escherichia coli*	8.33	
		30 mg/mL		10.17	
C. odollam	Methanol extract of the seed	500 µg/hole	*Streptococcus saprophyticus*	16	54
			Streptococcus pyogenes	11	
			Salmonella typhi	15	
			Shigella boydii;		
			Shigella sonnie; Staphylococcus epidermis	0	
			Shigella flexneri;		
			Shigella dysenteriae;	6	
			Staphylococcus aureus		
	Methanol extract of the leaves	400 µg/disc	*Bacillus megaterium;*	8	39
			Shigella flexneri		

Species	extract/fraction	Mass/ Concentration extract/ fraction	Bacteria	Diameter of the inhibition zone (mm)	Reference
	Pet ether fraction of methanol extract of the leaves		*Bacillus cereus; Shigella sonni*	7-8	
	Carbon tetrachloride fraction of methanol extract of the leaves		*Bacillus subtilis, Bacillus megaterium, Bacillus cereus, Staphylococus aureus & Sarcina lutea*	7-9	
	Chloroform fraction of methanol extract of the leaves	400 µg/disc	*Bacillus subtilis, Bacillus polymyxa, kleb species*	7-8	
	Aqueous fraction of methanol extract of the leaves		*Bacillus subtilis*	7	
C. odollam	Methanol extract of the leaves	100 µL/well	*Bacillus subtilis; Staphylococcus aureus; Escherichia coli*	2	14
			Salmonella typhi	3	
			Corynebacterium diphtheria; Klebsiella pneumonia	0	
Antifungal					
	Ethanol extract of the leaves	100 mg	*Aspergillus niger*	13.4	55
			Fusarium oxysporum	0	
			Penicilium citrum	15.73	
			Aspergillus niger	10.72	
C. odollam	Ethanol extract of the fruit		*Fusarium oxysporum*	9.39	
			Penicilium citrum	8.67	
	Methanol extract of the leaves	100 µL/well	*Saccharomyces cerevisiae*	26	14
			Candida albicans	25	
	Aqueous extract of the leaves		*Saccharomyces cerevisiae*	16	
			Candida albicans	9	

Table 5: Insecticidal, termiticidal, and larvicidal activity of extracts on *C. odollam* and *C. manghas*

Species	Part of plant	Species of larvae	Value	References
Insecticidal				
C. manghas	Seed	*Riptortus linearis*	Mortality = 33.33%	60
	Leaf	*Spodoptera litura*	Mortality = 16.66%	61
	Fruit		Mortality = 100%	
	Leaves	*Spodoptera litura (instar 2)*	LC_{50} = 0.6 % LC_{95} = 11.88%	62
		Spodoptera litura (instar 2+3)	LC_{50} = 0.28 % LC_{95} = 2.89%	
	Granule extract of leaves	*Spodoptera litura Fab*	LC_{50} = 1.41%	63

Species	Part of plant	Species of larvae	Value	References
	Seed		LC_{50} = 0.189 %	
			LC_{95} = 1.36%	
C. odollam	Flesh of fruit	*Eurema sp*	LC_{50} = 0.315 %	56
			LC_{95} = 3.783%	
	Leaves		LC_{50} = 0.297 %	
			LC_{95} = 6.453%	
Termiticidal				
	Leaves		TM = 75.76%	
	Fruit		TM = 60.61%	
	Wood		TM = 36.36%	
C. odollam	Bark	*Coptotermes gestroi*	TM =63.64%	57
	Flower		TM = 100%	
	Seed		TM =48.48%	
Larvicidal				
C. manghas	Leaves		LC_{50} = 5.097%	64
			LC_{90} = 25.300%	
	unripe fruits		LC_{50} = 102.23 mg/L	
			LC_{90} = 312.42 mg/L	58
	Leaves		LC_{50} = 96.16 mg/L	
			LC_{90} = 229.9 mg/L	
	Rind	*Aedes aegypti*	LC_{50} > 1.0 g/L	
C. odollam			LC_{90} > 1.0 g/L	
	Bark		LC_{50} > 1.0 g/L	
			LC_{90} > 1.0 g/L	59
	Leaves		LC_{50} > 1.0 g/L	
			LC_{90} > 1.0 g/L	
	seed kernel		LC_{50} = 0.76 g/L	
			LC_{90} > 1.0 g/L	

Note: TM = Termite Mortality; LC = Lethal Concentration

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