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REVIEW ARTICLE

Phytochemical profiling of Mango ginger (*Curcuma amada*): A comprehensive review of bioactive compounds and health implications

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Abstract

Mango ginger (*Curcuma amada*) is a rhizomatous plant of the Zingiberaceae family and has gained considerable attention because of its unique flavor and potential health benefits. The plant was widespread throughout the tropical regions of South and Southeast Asia in both wild and cultivated environments for its cure for respiratory, skin and digestive diseases. Traditionally, mango ginger has been utilized in various ethnic medicinal practices and documented in classical medical texts such as Ayurveda, Unani and Siddha for its therapeutic properties, including the treatment of respiratory disorders, digestive issues and skin ailments. Phytochemical analyses have shown various bioactive compounds, including curcuminoids, terpenoids and flavonoids, which possess various biological activities such as antioxidant, anti-inflammatory, antimicrobial and anticancer activity. This review presents an in-depth review of the prevalence, distribution, traditional uses and phytochemical characteristics of mango ginger while emphasizing its pharmacological potential. It also highlights the requirement for future research to uncover the molecular mechanisms involved in producing therapeutic effects to improve delivery methods and to explore possible synergies with other bioactive compounds. Its findings provide evidence supportive of the development into a functional food, dietary supplement and medicinal agent. This review synthesizes existing research on the phytochemical profiling of mango ginger, focusing on its bioactive compounds and applications in various industries.

Keywords

bioactive compounds; health implications; phytochemical profiling; mango ginger; therapeutic applications

Introduction

Curcuma amada Roxb. is a significant member of the genus *Curcuma*, belongs to the family Zingiberaceae, and has a chromosome number of 2n=42. It is often referred to as mango ginger as a result of the similarities in appearance between its aromatic rhizome and ginger (*Zingiber officinale*) and because it has an aroma similar to raw, unripe mango (1). Mango ginger rhizomes differ from ginger rhizomes in terms of their morphological and biochemical makeup, which consists of starch granules (2). The term "amada," which describes the immature mango essence of the rhizome, is derived from Bengali and means "mango ginger" (1, 3). The diverse vernacular names of *Curcuma amada* reflect its

widespread recognition and cultural significance across various regions (Table 1). The crop originated in the Indo-Malayan region but has since expanded considerably throughout the tropics, from Asia to Africa and Australia (4-7). *Curcuma amada* is found throughout India in both wild and cultivated forms (7). The crop is geographically restricted to Southeast Asia, primarily India, Thailand, Myanmar and Bangladesh. (3, 8). It is grown on a modest scale in the Northeastern states of India, West Bengal, Gujarat, Uttar Pradesh, Kerala, Tamil Nadu and Karnataka -11). The planting material has a low multiplication rate and the absence of seeds in this species presents a significant challenge to traditional breeding methods (12). The traditional use of mango ginger in medicine has been well documented across the Indian subcontinent and dates back to ancient times, reflecting its enduring role in ethnic healing practices. The plant has been coolant, aromatic and astringent in those traditional systems and has very commonly been used in the treatment of digestive disorders (13).

Table 1. Vernacular names of *Curcuma amada*

Language	Name	
English	Mango Ginger	(7, 22, 70)
Sanskrit	Karpuraharidra	
Hindi	Ama-haldi	
Bengali	Amada	
Gujarati	Amba Haldar	
Tamil	Mangai inji	
Kannad	Mavinakayi shunti	
Malayalam	Mannayinchi	
Assamese	Ama ada	(70)
Manipuri	Yai hanuman	

In Ayurveda and Unani medicine, *C. amada* is valued for its aphrodisiac, expectorant, appetite-boosting, diuretic and emollient effects. It is also used to alleviate fever and to treat various conditions, including asthma, skin issues, itching, biliousness, bronchitis, hiccups and inflammation caused by accidents. The essential oil contains cuminyl alcohol, a-pinene, myristic acid, a-and b-curcumene, turmerone and camphor (9). The rhizome's distinctive mango scent is a result of the contributions of car-3-ene and cis-ocimene (14, 8, 9). Rhizomes yield 1% essential oil containing linalool 11.2%, ocimene 47.2%, linalyl acetate 9.1%, linalool 11.2%, safrole 9.3% and d-a -pinene 18% (9). A report on the new anticancer activity of 2,4,6 -trihydroxy-3,5-diprenyldihydrochalcone (M1), a bioactive compound from *C. amada* was published. This *in vitro* research looked into M1's antileukemia capabilities and how it affected mitochondrial metabolism (15).

Traditionally, they have been utilized in treating conditions for spleen issues, enlarged liver, coughs, boils, diabetes, stomach ulcers, rheumatism, chest pain, skin diseases, blood purifiers and hepatic disorders (16, 17). They are regarded as nutritionally valuable food products, as the plants are abundant in starch, carbohydrates, proteins, fats, vitamins and minerals (18). The paste of the rhizome, in general, has been applied for treating wounds, cuts and pruritus, thereby showing its anti-inflammatory and wound-healing properties (19, 20).

As a carminative and stomachic, the rhizome is valued for its action against distension, improving digestion and maintaining the general health of the digestive system. Furthermore, a preparation made by boiling the rhizome, frequently mixed with table salt, has been noted for its efficacy in alleviating symptoms associated with colds and coughs. Moreover, its medicinal use for hemorrhoids is recorded in traditional medicine alongside ground long peppers (*Piper longum*) (21).

Amba, an indigenous germplasm selection from the High Altitude Research Station of Orissa University of Agriculture and Technology in Pottangi, Orissa, is the only improved variety documented in India, while in Kerala, local cultivars with significant diversity are used, primarily grown in homesteads rather than commercially (22). Mango ginger has gained popularity not only because of its remarkable culinary qualities but also because of its possible health advantages. Uncovering the medicinal potential of this less widely recognized member of the ginger family requires an understanding of its phytochemical composition. This review delves into the various roles that the bioactive chemicals included in mango ginger have in human health. It is believed that spices are a repository of active phytochemicals.

Morphological description of the plant

Curcuma amada, commonly known as mango ginger, thrives in tropical and subtropical regions. The plant prefers well-drained, fertile soils, often found in forest edges, riverbanks and lowland plains. It grows well in humid climates with an annual rainfall of 1500-2000 mm, typically flourishing in areas with temperatures between 20°C to 30°C. The plant is cultivated primarily in India, especially in states like West Bengal, Odisha, and Andhra Pradesh, for its medicinal and culinary uses (23, 24). The unique physical characteristics that distinguish *C. amada* from other species are detailed in its morphological description (Table 2 and Fig. 1).

Ethnobotanical uses

Mango ginger, which is mostly grown in Indo-Malaysia, is highly esteemed for its unique mango aroma in culinary applications like pickles (25). The rhizome is an essential component of sauces, pickles, curries, preserves and desserts (10, 26-28). Its exotic flavour and medicinal qualities make it useful for making innovative foods, beverages and medications. It's also a common ingredient in cosmetics (1, 7). The ethnobotanical uses of *C. amada* are presented, highlighting its medicinal properties and traditional applications (Table 3).

Ethnomedicinal uses

C. amada has been successfully employed in folk or traditional medicine for many centuries in the Indian subcontinent and is integrated into the diet of many Asian people (1, 7, 14) (Table 4). Mango ginger is widely recognized as a traditional and ayurvedic herbal remedy for the digestive system due to its carminative and stomachic qualities (11, 29) which assist in warding off serious stomach issues, including ulcers, hyperacidity and gastritis. The anti-inflammatory, stomachic rhizome serves as a remedy for dyspepsia (1), malaria and headaches (7). Individuals throughout every corner of the world use it to ease rheumatism (1), stomach discomfort and toothaches (7). Rhizome paste is applied externally or wrapped around aching joints to treat

Table 2. A structural illustration of morphological and anatomical characteristics of *Curcuma amada*

	Characteristic Features	Reference
Habit	The rhizomatous herb that grows erect up to a height of 80 cm - 1 m tall.	(5, 32, 35, 37)
Root	The rhizomes of this species are between 2 and 5 centimetres wide and 5 to 10 centimetres lengthy with a fleshy, buff-coloured. They are separated into internodes and nodes. On the rhizomes, sympodial branching takes place. Scaly leaves are organized in a circle at the rhizome nodes, resembling growth rings with surface scars.	(1, 8, 35)
Leaves	Tufts of leaves that are long, radical, sheathed, lanceolate, oblong, and petiolate. There are five to six leaves per plant, with a pale green underside and a dark green top.	(5, 35)
Flower	It is sterile, unisexual, and produces no viable seeds. pink, 2-4 cm long, blooms all year round, and has lateral or central inflorescence with terminal comma bracts that are light violet in colour.	(1, 35)
Fruit	Thin septate, pilose, oblong, wrinkled pod.	(35)

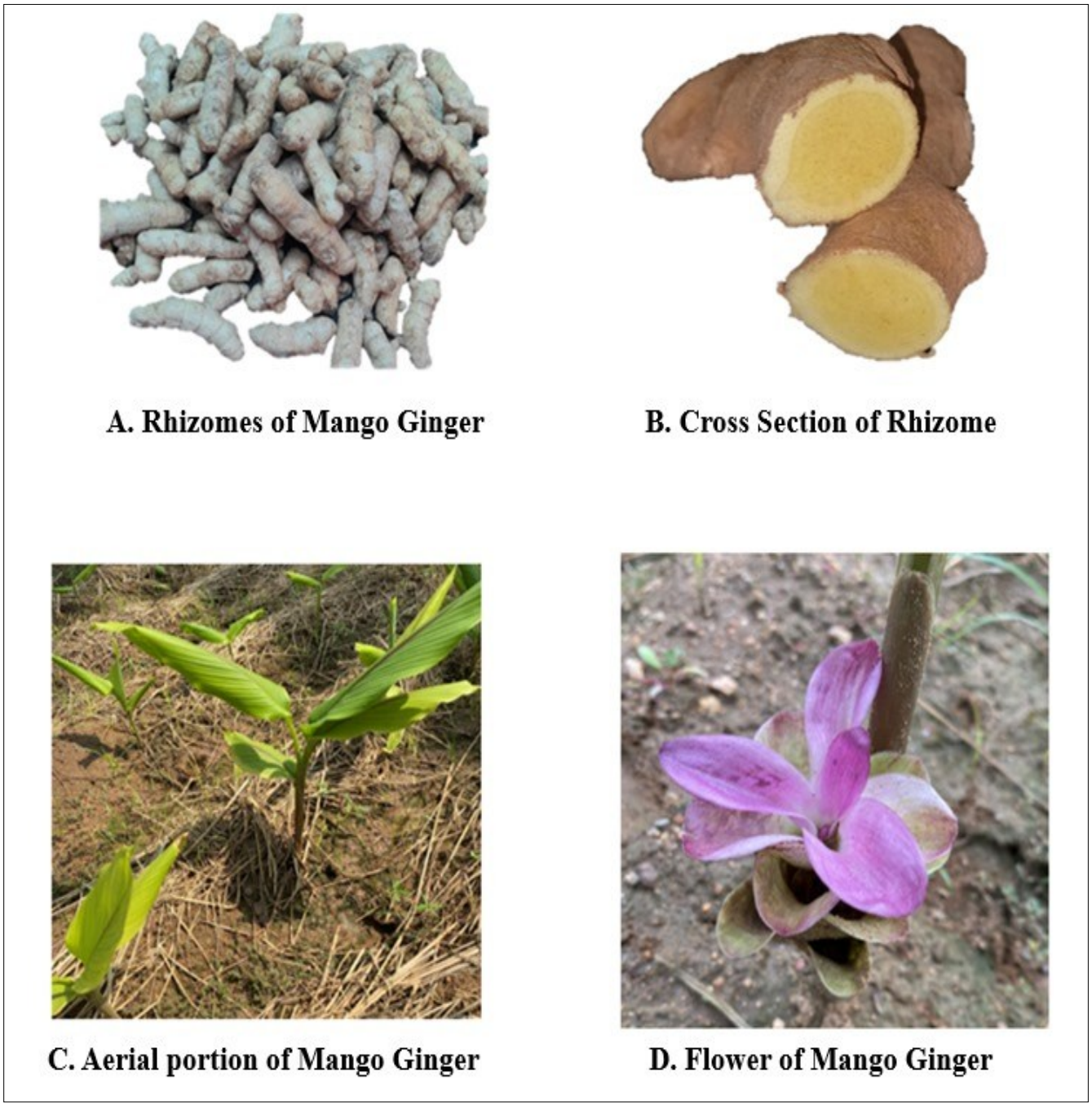


Fig.1. a. Rhizomes of mango ginger; b. Cross section of mango ginger; c. The aerial portion of mango ginger; d. Flower.

Table 3. The ethnobotanical uses of mango ginger

Plant Part Used	Mode of Application	Ethnobotanical Use	References
Food			
Rhizome	Relief from gas and bloating Aiding digestion and promoting stomach health	Carminative agent and Stomachic properties	(21)
Rhizome	Culinary use in sauce, salads, pickles, preserves, curries and candies for flavouring and seasoning	Culinary applications	(71)
Rhizome	Oral consumption	Lowers high blood cholesterol, treating obesity, detoxification, digestion, prevents constipation	(51)
Rhizome	Dyes and spices	Used as natural food colourants and helps to improve the taste of the food in various ways	(34, 35)
Beverage			
Rhizome	Combined with other medicines, Herbal remedy	Decoction of rhizome with salt for the treatment of colds and coughs	(72)
Cosmetics			
Rhizome	External application for relief from sprains	Topical use	(73)
Rhizome	Ground and applied on skin	Treatment for skin diseases	(53)
Leaf	Oil extract applied on skin	Relief from contusions and sprains	(34)

Table 4. The ethnomedicinal uses of mango ginger

Plant Part Used	Mode of Application	Ethnomedicinal Use	References
Rhizome	Paste (external use)	Healing of wounds, cuts, and itching	(13)
Rhizome	Paste (external use)	Treatment of sprains and skin diseases	(73)
Rhizome	Oral consumption	Carminative, stomachic	(20)
Whole Plant	Paste with crushed long peppers (*Piper longum*)	Treatment of piles	(72)
Rhizome	Decoction (3 mL) with common salt (2 g)	Treatment for colds and coughs	(72)
Rhizome	Oral consumption	Stomachic (bitter, aromatic, cooling, astringent, and carminative qualities)	(33, 74)
Rhizome	Combined with other medicines	Improving blood quality	(75)
Rhizome	Oral consumption and topical application	Carminative, stomachic, and topical treatment for contusions and sprains	(21, 33, 74, 76)

rheumatism; a water-based suspension of the dry powdered form is taken orally to treat respiratory and gastrointestinal disorders. The plant is mostly grown in India for its potential as a condiment. In addition to being delicious and well-liked as a condiment, pharmacologically, Mango ginger rhizomes are also thought to have a number of health advantages (30, 31). It effectively treats hypercholesterolemia (high cholesterol in the blood), gastrointestinal disorders and rashes on the skin (21, 27, 30), asthma, hiccough and bronchitis (30, 32). Mango ginger rhizome has been utilized as a stomachic (1, 10, 27, 33) because it possesses bitter, fragrant, cooling, astringent (1, 7, 34) and carminative properties (1, 10, 33).

Ayurvedic system of medicine

According to the oldest medical system in India, Ayurveda, mango ginger rhizome was held in high esteem for its therapeutic use as a purgative, stimulant, alexteric, antipyretic and aphrodisiac (2, 5, 14, 27, 31, 32). Historical evidence of plants being used for medicinal purposes was extensively recorded in ancient Ayurvedic texts, tracing back to the prehistoric Vedic period. This is evident in a Sanskrit verse describing the medicinal qualities of mango ginger: "Mango ginger, with its raw mango flavor, brings a cooling effect to the body, albeit aggravating Vata. It effectively calms imbalanced Pitta, providing relief from various skin conditions and itching" (34). The rhizome is traditionally employed to treat conditions such as biliousness, itching, skin diseases, asthma and inflammation from injuries. Its therapeutic applications are well-documented in Ayurvedic literature, highlighting its significance in promoting digestive health and overall well-being (35).

The anti-inflammatory and stomachic properties of the mango ginger rhizome are used to treat dyspepsia (1), headaches and stomach discomfort (7). The rhizome paste is applied externally or wrapped around aching joints to relieve rheumatism (1) and its powdered form is used to treat respiratory and gastrointestinal disorders (31).

Unani system of medicine

The plant is especially known in the Unani medical system, where it is used as an antipyretic, diuretic and expectorant (31). The Unani medical system claims that it is effective against scabies, lumbago, stomatitis, ulcers on the male genitalia and inflammation of the mouth, ears and gleet (2, 5, 30). In Unani medicine, mango ginger is utilized as a remedy for rheumatism (1), malaria and toothaches (7). The water-based suspension of the dry powdered rhizome is taken orally for respiratory and digestive issues, while its external application provides relief from joint pain and inflammation (31)

Nutritional profile

Rhizomes of *C. amada* and a few other Zingiberaceae species were used to isolate starches. Compared to the other species under investigation, the *C. amada* rhizome exhibited a higher moisture content (12.1%) and starch content (57.8%) (21). It was discovered that the mango ginger rhizome is a significant source of starch and fiber. It possesses unique structural and biological attributes (5). *C. amada* has a lot of nutrients (36) (Table 5). The primary components of the essential oil extracted from the rhizome of *C. amada* are terpene hydrocarbons, particularly alpha-pinene, car-3-ene and cis-ocimene. The smell of mango is attributed to the former two compounds (1).

Table 5. A breakdown analysis of the nutritional profile in *Curcuma amada*

Sl no.	Reference	(71, 77)			(22)			(18)	(35)
	Compounds	Fresh Weight	Dry Weight		Fresh weight	Dry Weight			
1.	Fibre	1.4%	-	-	-	-	1.3%	+	+
2.	Crude fibre	-	10.6%	-	1.49g	10.63 g	-	-	-
3.	Ash	0.8%	5.7%	1.3%	-	5.746%	-	-	-
4.	Total ash	-	-		0.803%	-	-	-	-
5.	Moisture	86%	-	9.8%	86g	-	9.8%	-	-
6.	Starch	6.9%	45.6%	45%	6.9g	45.64 g	45%	+	+
7.	Amylose	-	43%	43%	-	-	43%	-	-
8.	Total sugars	0.8%	5.8%	-	0.82g	5.86g	-	+	+
9.	Reducing sugars	+	+	-	+	+	-	-	-
10.	Essential oil	0.1%	0.9%	-	0.1 ml/100g	0.93/100 g	-	+	+
11.	Total ether extractives	-	-	-	-	6.55	-	-	-
12.	Alcohol solubles	-	-	-	-	16.69g	-	-	-
13.	Proteins	-	-	-	-	-	-	+	+
14.	Amino acids	-	-	-	-	-	-	+	+
15.	Minerals (Fe, Zn, Cu, Mo, Ca, Cr, Mn, Mg, P, N, K, Na, S)	-	-	-	-	-	-	+	+
16.	Vitamins-A, B1, B2,B3,B6, C, E.	-	-	-	-	-	-	+	+

(+) Indicates 'Presence

Chemical constituents

Over a hundred phytochemicals were successfully identified from *C. amada* fresh and dried extracts (5, 21) (Table 6). The nutritional and therapeutic relevance of *C. amada* has led to a growing interest in investigating its phytochemical makeup. The essential oil of *C. amada,* which is produced by steam or hydro-distillation of the fresh or dry rhizome, has been found to contain over 150 chemicals (37).

Bioactive Compounds

It has been widely recognized that bioactive chemicals play a variety of roles in fruits, vegetables, tubers and rhizomes, serving as precursors to give distinctive flavour, colour, defence intermediates and health-promoting elements (2). The literature lacks any publications on the purification and characterization of bioactive compounds from mango ginger, despite the rhizome's numerous therapeutic benefits and great food value due to its unique flavour (34).

Plants and herbs have medicinal qualities because of the existence of bioactive elements such flavonoids, alkaloids, saponins, glycosides, tannins, steroids and phenolic compounds, among others (38). The bioactive component was isolated and purified using the chloroform extract, which exhibited strong antibacterial activity. It was decided to pursue further purification and characterization of the antibacterial component due to the chloroform extract's excellent antibacterial activity with low minimum inhibitory concentration (MIC) for various types of gram-positive bacteria (5). Mango ginger aqueous extracts and dichloromethane may contain lesser bioactive chemicals, yet they nevertheless possess the capacity to scavenge radicals (32). According to reports, leaves are an excellent source of bioactive substances that help in the prevention of certain diseases (39). Rather than harvesting the mango ginger rhizomes conventionally between 200 and 240 days after planting, a more effective method to determine the optimal physiological maturity would be to measure an increase in antioxidant activity associated with the accumulation of bioactive compounds like phenolics and difurocumenonol at 180 days (2). Plant extracts serve as a rich source of bioactive compounds, showcasing a diverse array of structures that contribute to their therapeutic potential (Table 7 and 8).

Pharmacological properties

Many medicinal qualities, including antiobesity (35), antibacterial, anti-inflammatory, analgesic, anticancer (35), antihyperglyceridemic (11), antioxidant activity (6, 10, 14, 32, 39), antidiabetic (40), anti-tuberculosis (41), are possessed by *C. amada*. The inclusion of various bioactive substances, such as phenol, terpenoids, demethoxy, bis-demethoxy and curcumin, may explain the mentioned medicinal activity (5, 6, 11, 21). Aphrodisiac (34), antipyretic (38), antibacterial (40), antifungal (38), anti-inflammatory (42), anti-mycobacterial (43), anti-hypercholesterolemic (21), antioxidant (11) qualities are just a few of the therapeutic benefits of mango ginger extract that have been documented in the literature (30).

Antibacterial

Zingiberaceae family spice extracts and a few synthesized compounds were tested for their antibacterial efficacy against a few clinically significant bacterial strains (44). The first report of antibacterial activity of mango ginger extracts was provided by Akter (14), where difurocumeninol, amadannulen and amadaldehyde, isolated from the rhizome of *Curcuma amada*, demonstrated antibacterial, cytotoxic and antioxidant properties.

A new and naturally occurring antibacterial compound called dirofurocumenonol was isolated from mango ginger. The chloroform extract exhibited measurable antibacterial activity against both Gram-positive and Gram-negative bacteria. For *Micrococcus luteus*, the inhibition zones were 15 mm (Fr.1), 13 mm (Fr.2), 17 mm (Fr.3) and 12 mm (Fr.4). *Staphylococcus aureus* showed an inhibition zone of 15 mm (Fr.3). For *Enterococcus fecalis*, inhibition zones ranged from 12 mm (Fr.1, Fr.2) to 14 mm

Table 6. The chemical constituents that have been extracted from *Curcuma amada*

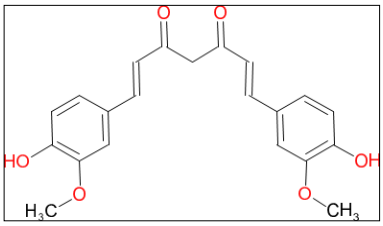
S.No	Nature of the compounds	Name of the compound	Method detection	Reference
1	Benzodioxoles	safrole	GC MS	(10)
2	Carbonyl compounds	2-nonanone	GC MS	(78)
3	Carbonyl compounds	propanone	GC MS	(79)
4	Monoterpenoid	perillene	GC MS	(43)
5	Monoterpenoids	(E)-β-ocimene	GC MS	(80)
6	Monoterpenoids	(Z)-β-ocimene	GC MS	(80)
7	Monoterpenoids	borneol	GC MS	(78)
8	Monoterpenoids	camphene	GC MS	(78)
9	Monoterpenoids	camphor	GC MS	(78)
10	Monoterpenoids	cis- and trans hydroocimene	GC MS	(40)
11	Monoterpenoids	cuminyl alcohol	GC MS	(11)
12	Monoterpenoids	curzerenone	GC MS	(78)
13	Monoterpenoids	dihyro-ocimene	GC MS	(11)
14	Monoterpenoids	Cis-ocimene	GC MS	(21)
15	Monoterpenoids	isoborneol	GC MS	(78)
16	Monoterpenoids	limonene	GC MS	(80)
17	Monoterpenoids	linalool	GC MS	(78)
18	Monoterpenoids	linalyl acetate	GC MS	(40)
19	Monoterpenoids	myrcene	GC MS	(80)
20	Monoterpenoids	ocimene	GC MS	(40)
21	Monoterpenoids	terpinen-4-ol	GC MS	(78)
22	Monoterpenoids	α-pinene	GC MS	(78)
23	Monoterpenoids	α-terpinene	GC MS	(43)
24	Monoterpenoids	β-pinene	GC MS	(80)
25	Monoterpenoids	sabinene	GC MS	(43)
26	naturally produced cyclic ether and monoterpenoid	1,8-cineole	GC MS	(80)
27	Sesquiterpenoids	ar-curcumene	GC MS	(78)
28	Sesquiterpenoids	caryophyllene oxide	GC MS	(78)
29	Sesquiterpenoids	germacrene D	GC MS	(43)
30	Sesquiterpenoids	germacrone	GC MS	(78)
31	Sesquiterpenoids	spathulenol	GC MS	(78)
32	Sesquiterpenoids	zerumbone	GC MS	(78)
33	Sesquiterpenoids	zingiberene	GC MS	(78)
34	Sesquiterpenoids	α -curcumene	GC MS	(11)
35	Sesquiterpenoids	α-bergamotene	GC MS	(78)
36	Sesquiterpenoids	α-copaene	GC MS	(21)
37	Sesquiterpenoids	α-humulene	GC MS	(79)
38	Sesquiterpenoids	α-longipinene	GC MS	(21)
39	Sesquiterpenoids	α-selinene	GC MS	(78)
40	Sesquiterpenoids	β -selinen	GC MS	(78)
41	Sesquiterpenoids	β-bisabololt	GC MS	(78)
42	Sesquiterpenoids	β-caryophyllene	GC MS	(78)
43	Sesquiterpenoids	β-curcumene	GC MS	(78)
44	Sesquiterpenoids	β-elemene	GC MS	(40)
45	Sesquiterpenoids	β-selinene	GC MS	(78)
46	Sesquiterpenoids	γ-elemene	GC MS	(21)
47	Sesquiterpenoids	γ-guaiene	GC MS	(21)
48	Sesquiterpenoids	δ-elemene	GC MS	(40)
49	Sesquiterpenoids	ledol	GC MS	(43)
50	Sesquiterpenoids	β-gurjunene	GC MS	(40)

Table 7. Extraction Techniques and Bioactive Compounds Identified in *Curcuma amada*

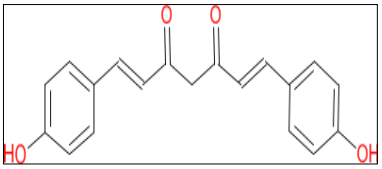
S.No.	Plant part utilized	Initial extraction medium	Nature of the compounds	Name of the compound	Method of detection	Use/Remarks	Reference
1.	Rhizomes	Steam distillation, Distillation-extraction and low-temperature -high-vacuum distillation technique	Monoterpenoids	Cis-ocimene Car-3-ene	GC-MS analysis	Cis-ocimene contributes to the aroma of green mangoes, whereas α-pinene and car-3-ene is for floral and leafy mango aromas.	(9, 81)
2.	Freeze-dried rhizome powder	Hexane	Monoterpenoids	Myrcene, Ocimene, Cis and Tran-di-hydrocimene	Hexane Extraction	It contributes on the aroma of both raw mango and turmeric.	(27, 81)
3	Rhizome	Dichloromethane, ethyl acetate, methanol and double distilled water	Monoterpenoids Phenol ethers	β-myrcene, α-asarone	Spectrophotometric assay	It predominantly has myrcene (88.6%) and β-pinene (4.9%). Dietary phenolic acids (e.g., caffeic, ferulic) exhibit antiulcer, antibacterial and antioxidant properties.	(27, 32)
The free phenolic compounds							
4	Rhizome	Gallic acid	Hydroxycinnamic acids and derivatives Benzoic acids and derivatives Hydroxycinnamic acids and derivatives	Caffeic (26%, 195 mg/g) Gentisic(24%, 180 mg/g) Gallic acid (10%, 75 mg/g)	HPLC analysis	Serve as an effective indicator for determining the physiological age and quality of rhizomes	(25)
The bound phenolic compounds							
5	Rhizome	Methanol AR, ethyl acetate AR and dicloromethane	Hydroxycinnamic acids and derivatives Cinnamic acids and derivatives Hydroxycinnamic acids and derivatives	Ferulic acid (47%, 391.5 mg/g) Cinnamic acid (29%, 237 mg/g) p-coumaric acid (11%, 95 mg/g)	UV-Visible spectrophotometer analysis	It has many medicinal properties like anti-ageing, antibacterial, antioxidant, anti-inflammatory, antiallergic, antifungal, platelet aggregation inhibiton activity and analgesic activity.	(32)
Curcuminoids							
6	Rhizome	EPA 524.2 fortification solution	Linear diarylheptanoids / Curcuminoids	Curcumin Demethoxycurcumi Bisdemethoxycurcumin	HS-SPME and GC-TOF-MS	Widely used in food industries and alternative medicines to treat a variety of internal diseases such as cough, bronchitis, indigestion, colic, loss of appetite, hiccups and constipation.	(37)
7	Rhizome powder	n-hexane, chloroform, ethyl acetate, acetone and methanol	Terpenoid	Difurocumenonol	UV,IR,LC-MS, 2D-HMQUCT-NMR Spectral data	It is demonstrated as high antibacterial activity against gram-negative and gram-positive bacteria	(2, 82)
			FattyAcyls/ terpenoid	Amadaldehyde	UV,IR,LC-MS, 2D-HMQUCT-NMR Spectral data	It has anti-cancerous and antibacterial properties method in them	(45)
			Terpenoid	Amadannulen	UV,IR,LC-MS, 2D-HMQUCT-NMR Spectral data	It has anti-bacterial, anti-oxidant and anti-microbial activity.	(83)

(HS-SPME - Headspace solid-phase microextraction, GC-TOF-MS -Gas chromatography-time-of-flight-mass spectrometry, UV-Ultra-Violet Rays, IR - Infra-Red Rays, LC-MS -Liquid chromatography-mass spectrometry, 2D-HMQUCT- NMR -2D Heteronuclear multiple quantum coherence transfer spectroscopy-Nuclear magnetic resonance Spectra data)

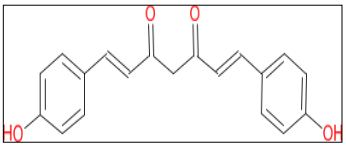
Table 8. Bioactive compounds present in *Curcuma amada*



Curcumin



Bis-demethoxycurcumin



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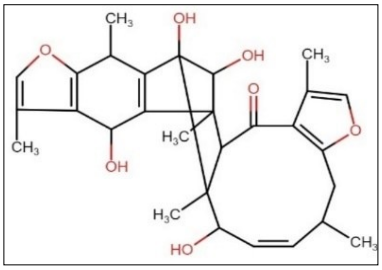

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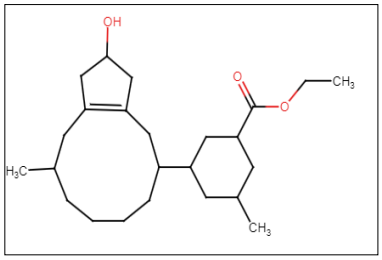
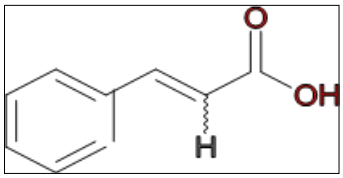
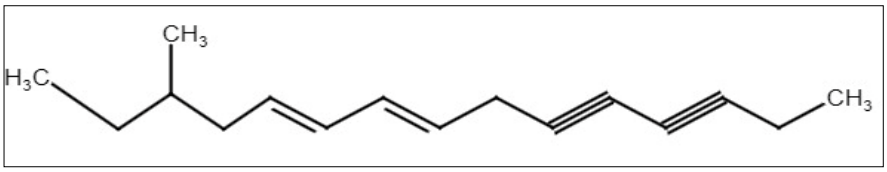


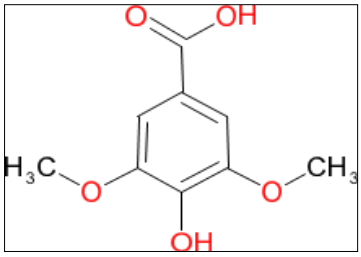
Amadannulen



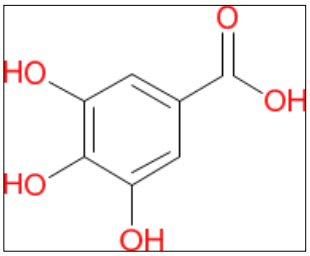
Cinnamic acid



Amadaldehyde



Syringic Acid



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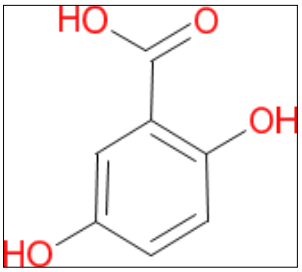
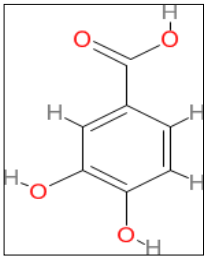
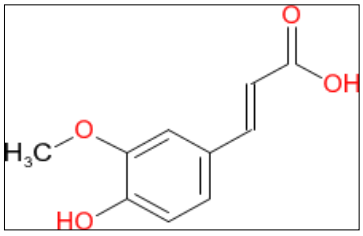


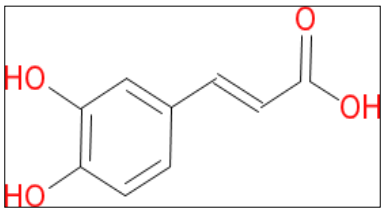
Gentisic acid



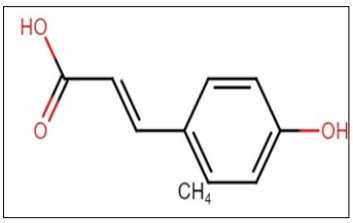
Protechuic acid



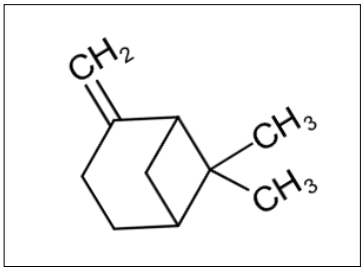
Feulic acid



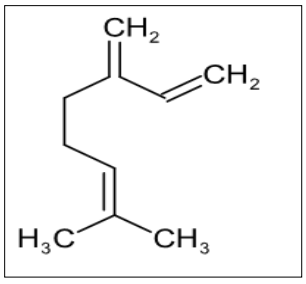
Caffeic acid



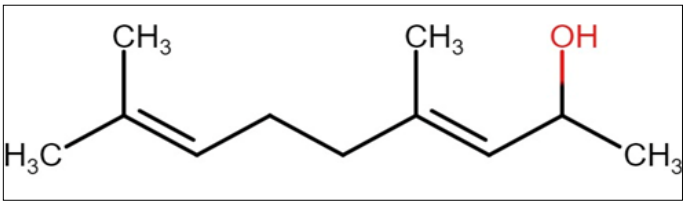
coumaric acid



Pinene



Beta-Myrcene



4,8-dimethyl-3,7-Nonadien-2ol

(Fr.3). *Bacillus cereus* displayed inhibition zones between 12 mm (Fr.1) and 16 mm (Fr.3), while *Bacillus subtilis* exhibited inhibition zones from 13 mm (Fr.1) to 16 mm (Fr.3). *Listeria monocytogenes* showed inhibition zones of 14 mm (Fr.2) and 15 mm (Fr.3). No inhibition was observed for *Pseudomonas aeruginosa*, *Escherichia coli*, *Salmonella typhi*, *Klebsiella pneumoniae*, *Proteus mirabilis*, *Enterobacter aerogenes* and *Yersinia enterocolitica* across all fractions (45). The bacterial inhibition results from mango ginger extract and Ciprofloxacin at 200 µg/mL, showing varying levels of antibacterial activity. Across the bacteria tested, C. amada extract exhibited moderate inhibition zones, with *Staphylococcus aureus* ML 267 showing the largest zone of 17 mm in both dichloromethane and chloroform. Ciprofloxacin, used as the standard, consistently displayed higher inhibition zones, ranging from 16 mm to 20 mm, indicating stronger antibacterial activity. The results suggest that while *C. amada* extracts show potential antibacterial properties, Ciprofloxacin remains more potent against all bacteria tested (46).

The antibacterial properties of mango ginger were proven against agar ditch and disc diffusion methods against *Escherichia coli* (13.5 and 0 mm), *Bacillus subtilis* (10.75 and 9.5 mm) and *Staphylococcus aureus* (11 and 9.5 mm) of mean zone diameter in heated and unheated extract, respectively (44). A variety of pathogenic microorganisms *viz., Pseudomonas mangiferae-indicae*, *Vibrio cholerae*, *Salmonella paratyphi*, *Xanthomonas campestris*, *Bacillus subtilis*, *B. pumilus*, *B. mycoides* and *Bacillus anthracis* inhibited by the tubers and essential oils of *C. amada*. Mango ginger tubers demonstrated the highest specific activity of enterokinase inhibitor, with 47.1×10^{-3} units/mg protein (21). Mango ginger exhibited no antibacterial action against subtilisin and solely inhibited trypsin; its antichymotryptic activity was nonexistent (21).

Antifungal

Curcumin and demethoxycurcumin, the two primary curcuminoids, were absent from *C. amada*, yet it still exhibited potent inhibitory action against *Fusarium solani* sensu lato (FSSL). *Fusarium* is hazardous to both humans and animals due to its production of mycotoxins (14).

The methanol (MeOH) extract from the fresh rhizome of *C. amada* inhibited the hyphal growth of *F. solani* sensu lato (FSSL) in a dose-dependent manner. Zederone and furanodienone, two antifungal sesquiterpenes, were identified in *C. amada* (14). The extracts of *C. amada* with acetone and ethanol have shown the greatest degree of activity *A. niger, O. sativum* and *C. albicans* were the three fungal pathogen strains against which the antifungal efficacy of various *C. amada* rhizome extracts was tested (47). In the natural world, mango ginger has antifungal properties. The antifungal activity of extracted mango ginger oil was evaluated against various *Candida* species. Notably, the oil showed the largest zone of inhibition against *Candida auris*, suggesting its potential for managing fungal infections. Given its strong antifungal properties, mango ginger oil could be an effective treatment for fungal skin infections (48). Pharmacological investigations have identified bioactive compounds, including ar-turmerone, difurocumenonol and amadannulen, as key contributors to anti-fungal properties (18).

The fungal inhibition zones of *C. amada* extracts at 1,500 µg/mL against four fungal species. For *Candida albicans*, the inhibition zones ranged from 11 mm (petroleum ether) to 15 mm (griseofulvin). *Aspergillus niger* showed inhibition between 12.5 mm (petroleum ether) and 14.5 mm (griseofulvin). *Penicillium notatum* exhibited inhibition zones from 10.5 mm (chloroform) to 13.5 mm (petroleum ether), while *Penicillium funiculosum* had inhibition ranging from 10 mm (chloroform) to 13 mm (petroleum ether and griseofulvin). Griseofulvin consistently demonstrated the highest antifungal activity across all fungi tested (46).

Antioxidant

Organic extracts and essential oil from *Curcuma amada* rhizomes have demonstrated strong antioxidant and radical scavenging activities, highlighting the plant's potential as a natural defense against oxidative damage (10). Reactive oxygen species (ROS) also play a crucial role in cell-mediated cytotoxicity (CMC) of the immune system. Several studies indicate that curcumin may act as both an antioxidant and a pro-oxidant mediator (49). The presence of antioxidants has been directly associated with anticancer properties (39). Difurocumenonol, in particular, exhibits abundant antioxidant activity, which provides stability against auto-oxidation (2). Previous research by Mahadevi and Kavita (32) emphasized that the presence of phenolics, curcuminoids, essential oils, terpenoids and flavonoids is essential for plants to exert antioxidant effects. The high antioxidant activity, cytotoxicity and platelet aggregation inhibitory effects of mango ginger extracts have been attributed to their phenolic content and other bioactive compounds. However, dichloromethane and aqueous extracts of mango ginger have shown very low antioxidant potential (32).

In-vitro study on antioxidant properties of mango ginger

The antioxidant activity of mango ginger (MG) extract was evaluated using several *in vitro* methods such as the DPPH-1,1-diphenyl-2-picrylhydrazyl, Nitric Oxide, DMPD- N,N-Dimethyl-p-phenylenediamine Assay, ABTS- 2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) Assay, ORAC- Oxygen Radical Absorbance Capacity Assay and TBARS - Thiobarbituric Acid Reactive Substances assays and the results found that methanol and ethyl acetate extracts showed good antioxidant activity. Additionally, the antioxidant properties were assessed through a few *in vivo* models involving rats and mice (32).

In-vivo study on antioxidant properties of mango ginger

The antioxidant activity potential of ethanolic extracts from *Alpinia galanga, Curcuma amada* and *Curcuma caesia.* The findings indicate that all three extracts exhibit antioxidant properties, as demonstrated through various *in vitro* antioxidant assays. Among the extracts, *C. amada* emerged as the most effective antioxidant. Additionally, in an *in vivo* study, *C. amada* was able to protect against cyclophosphamide-induced DNA damage in the bone marrow cells of Swiss albino mice, likely due to the presence of phytochemicals identified by HPLC and GC-MS in the mango ginger extract (50).

Effects on lipids, triglycerides and cholesterol

The hypolipidemic effects of Mango Ginger (*C. amada* Roxb.) in rats revealed significant reductions in liver and serum triglycerides, particularly in the VLDL+LDL fractions. Rats fed 10%

whole Mango Ginger or 0.3% curcumin-free extract for four weeks showed notable decreases in triglycerides in both normal and Triton WR-1339 induced hyperlipidemic conditions. The Mango Ginger and its curcumin-free extract effectively attenuated increases in liver and serum lipids, while the curcumin portion alone did not exhibit these effects. Mechanistically, Mango Ginger reduced hepatic triglyceride synthesis and enhanced lipid clearance from the blood, as evidenced by increased lipoprotein lipase activity in post-heparin plasma. These findings suggest that components other than curcumin are responsible for hypolipidemic action, highlighting its potential as a natural agent for modulating lipid metabolism through pathways affecting hepatic triglyceride synthesis and blood clearance (27).

Additionally, it reduced the blood cholesterol levels in hypercholesterolemic rabbits, particularly through ether extracts, which also contributed to a reduction in aorta weight (51). Additionally, it demonstrated significant anti-allergic and anti-inflammatory effects, with dose-dependent efficacy observed in carrageenan-induced edema and granuloma models (52) (53). The rhizomes' high starch content further indicates their potential for pharmaceutical applications (54).

Skin allergy

It has been claimed that *C. amada* is utilized in a number of herbal remedies, such as those for allergies. Chemicals having hydroxyl, ester, carbonyl and olefin functionalities were present in the *C. amada* extract (53). The rhizome is valued for its anti-inflammatory, antimicrobial and antioxidant properties, making it effective in treating skin conditions like eczema, acne and dermatitis. It helps reduce inflammation, prevent infections and promote skin healing, offering relief from itching, redness and irritation (10).

Anti-inflammatory

Mango ginger (*C. amada*), a rhizomatous crop closely related to turmeric, has been widely studied for its potent anti-inflammatory properties. Research indicates that its bioactive compounds, primarily curcuminoids, possess significant anti-inflammatory effects. A study by Tabtipwon *et al.* (55) highlights the inhibitory action of mango ginger extract on pro-inflammatory cytokines, particularly TNF-α and IL-6, thus reducing inflammation in animal models. The presence of essential oils, such as α-pinene and camphene, further contributes to its anti-inflammatory capacity by modulating immune responses and inhibiting the production of nitric oxide, a key inflammatory mediator (56).

In vitro and *in vivo* studies demonstrate the effectiveness of mango ginger in reducing inflammation induced by various stimuli, such as carrageenan and formalin, suggesting its role in mitigating both acute and chronic inflammation (57). Furthermore, its antioxidant activity complements its anti-inflammatory potential, as oxidative stress is a known contributor to inflammatory processes. The rhizome's extracts have been shown to significantly downregulate cyclooxygenase-2 (COX-2) expression, a crucial enzyme in the inflammatory pathway (42).

Anti-nociceptive

In a study by Jabsuwan *et al.* (58), the ethanolic extract of mango ginger rhizomes exhibited a dose-dependent reduction in pain perception in animal models. This was demonstrated using acetic acid-induced writhing and hot plate tests, both of which are standard models for evaluating antinociceptive effects. The extract's activity was comparable to that of standard analgesics, suggesting its potential as a natural pain-relief agent.

Additionally, Policegoudra *et al.* (34) reported that mango ginger's essential oils exhibited anti-inflammatory and antinociceptive effects, likely due to the presence of compounds like myrcene, a monoterpene known for its analgesic properties. Their research highlighted that mango ginger might work by modulating the central and peripheral pain pathways involving opioid receptor systems.

Anticancer

A study by Donipati *et al*. (59) highlighted that mango ginger extract significantly induced apoptosis in human breast cancer cells (MCF-7) by modulating various molecular pathways such as the activation of caspases and upregulation of pro-apoptotic proteins like Bax. The extract also demonstrated inhibitory effects on NF-κB, a transcription factor involved in cancer progression and metastasis. Similarly, Ramachandran *et al.* (60) reported that curcuminoids from *C. amada* exhibited cytotoxic effects against colon and prostate cancer cell lines by arresting the cell cycle and promoting apoptosis.

Moreover, the essential oils from mango ginger, particularly ar-turmerone and germacrone, suppress the growth of lung cancer cells by inducing mitochondrial dysfunction, as demonstrated in a study by Jayasankar *et al.* (15). These findings suggest that mango ginger holds potential as a natural anticancer agent, although further clinical studies are needed to validate its efficacy.

Antidiabetic

Research indicates that mango ginger possesses bioactive compounds such as curcuminoids, terpenoids, and flavonoids, which exhibit potential for managing diabetes. These compounds enhance insulin sensitivity, inhibit α-glucosidase and α-amylase enzymes (key enzymes involved in carbohydrate metabolism), and reduce postprandial hyperglycemia. For instance, curcuminoids present in mango ginger exhibit antioxidant and anti-inflammatory activities, which help reduce oxidative stress and improve pancreatic β-cell function (61).

A study by Syiem *et al.* (62) demonstrated that mango ginger extract significantly lowered blood glucose levels in streptozotocin-induced diabetic rats, improving insulin secretion and reducing glycosylated hemoglobin levels. Furthermore, these extracts were found to modulate lipid profiles, reducing cholesterol and triglycerides, which are often elevated in diabetic conditions (62).

Hepatoprotective

Bhawna and Kumar (63) mentioned that hepatoprotective refers to the ability of a substance to prevent damage to the liver or to help restore liver function after injury. Hepatoprotective agents are often studied for their potential to safeguard the liver from toxins, drugs, alcohol and other harmful substances. These agents may work by scavenging free radicals, enhancing antioxidant defenses, reducing inflammation, or promoting the repair of damaged liver cells.

Mango ginger has been known for its medicinal properties, including hepatoprotective effects. Various research studies have highlighted its bioactive compounds, such as curcumin, terpenoids, flavonoids and phenolic compounds, which contribute to its antioxidative and anti-inflammatory properties. These compounds play a crucial role in reducing oxidative stress and lipid peroxidation in liver cells, helping in liver detoxification and regeneration. Studies have shown that mango ginger extracts can ameliorate liver damage induced by toxins like paracetamol and carbon tetrachloride, providing evidence of its hepatoprotective efficacy (64, 65).

In addition to its hepatoprotective activity, mango ginger possesses antimicrobial, anticancer, anti-inflammatory and anti-diabetic properties, which further enhance its therapeutic potential (66). The rhizome is traditionally used in Ayurvedic medicine for digestive health and liver disorders, underscoring its ethnomedicinal relevance.

Neuroprotective

Neuroprotective refers to the ability of certain substances, or interventions to protect nerve cells (neurons) from damage, degeneration, or dysfunction. Neuroprotective agents can help preserve the structure and function of neurons, thereby offering potential therapeutic benefits in neurodegenerative diseases such as Alzheimer's, Parkinson's and stroke. These agents work by various mechanisms, including reducing oxidative stress, preventing inflammation, inhibiting excitotoxicity and promoting neuronal survival and regeneration (67).

The rhizome has gained attention for its therapeutic properties, including neuroprotection. Mango ginger contains bioactive compounds such as curcumin, curcuminoids, flavonoids and terpenoids, which contribute to its antioxidant, anti-inflammatory and antimicrobial effects (68). Studies have highlighted its potential neuroprotective properties, primarily attributed to its antioxidant activity. The high phenolic and flavonoid content in mango ginger aids in scavenging free radicals, thereby reducing oxidative stress-a key factor in neurodegeneration (69). Additionally, its anti-inflammatory properties help inhibit pro-inflammatory cytokines, reducing neuronal inflammation that can lead to neurodegenerative conditions. Research indicates that the bioactive compounds in mango ginger may modulate signaling pathways involved in cell survival and apoptosis, promoting neuronal health (68).

Conclusion

Mango ginger (*C. amada*) is a significant member of the Zingiberaceae family renowned for its culinary and ethnomedicinal applications across South and Southeast Asia. Traditionally used in systems like Ayurveda and Unani, it possesses diverse therapeutic properties, including carminative, anti-inflammatory and antioxidant effects. Its rich phytochemical profile, featuring curcuminoids, terpenoids and flavonoids, enhances its potential as a functional food and dietary supplement, addressing health concerns such as hypercholesterolemia, gastritis and respiratory disorders. Historically, mango ginger has been applied to treat rheumatism, skin infections and various digestive issues, demonstrating its versatility as both food and medicine. The use of rhizome paste for external application and oral consumption underscores its cultural significance and health benefits. Despite the existing knowledge, gaps remain in understanding its bioavailability and interactions with other bioactive compounds, necessitating further research. As scientific inquiry into mango ginger's therapeutic potential progresses, it is crucial to promote awareness of its health benefits. This exploration can pave the way for integrating mango ginger into contemporary health regimens, ensuring the preservation of its ethnobotanical heritage while unlocking new avenues for enhancing human health and wellness worldwide.

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Authors' contributions

PDB Conceptualization of the review and overall supervision. PDB contributed significantly to writing the original draft and editing the manuscript. RV Conducted the literature search, organized the data and wrote sections of the original draft. RV and MM contributed to data visualization and formatting of the manuscript. RR played a key role in writing parts of the original draft and in the review and editing process. MP Contributed to the formal analysis and validation of the collected data and participated in writing the manuscript and ensuring the integrity of the review process.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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