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A Review of Curry Leaves (*Murraya koenigii*): A Multifunctional Medicinal Plant with Diverse Potentials

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Abstract:
"Food is medicine and medicine is food" aptly captures the essence of how vegetables and plants were historically used for both nourishment and healing. In ancient times, the boundary between diet and therapy was fluid, as many edible plants served medicinal purposes in traditional systems of health. One such remarkable plant is Murraya koenigii, commonly known as curry leaves. Referred to as the "Magical Plant of Indian Spice," it has played a significant role not only in enhancing the flavour of Indian cuisine but also in traditional medicine, especially in rural areas and among tribal communities. For centuries, Murraya koenigii has been widely utilized to treat various health conditions. It has proven to be beneficial in alleviating morning sickness, stomach aches, kidney pain, and dysentery. The use of this plant in indigenous healing practices underscores its therapeutic potential and the deep-rooted knowledge of natural remedies passed down through generations. The medicinal properties of curry leaves are largely attributed to the presence of carbazole alkaloids, a class of bioactive compounds known for their pharmacological effects. Several important alkaloids have been isolated from Murraya koenigii , including Koenigin, bicyclomahanimbicine, cyclomahanimbine, murrayastine, coumarine, koenidine, and pypayafolinecarbazole. These compounds are known to exhibit a wide range of therapeutic activities, such as anti-inflammatory, antioxidant, antimicrobial, antidiabetic, and anticancer properties. Their presence in curry leaves supports the plant's traditional use in medicine and highlights its potential for the development of modern therapeutic agents. Thus, Murraya koenigii stands as a testament to the idea that natural food sources can possess potent medicinal properties, reaffirming the wisdom of ancient practices where diet was closely linked to healing.

Keywords: *Murraya koenigii, Pharmacological activity, Carbazolealkoloids, Caumarine*

INTRODUCTION:

Curry leaf, or *Murraya koenigii* Spreng, is a member of the Rutaceae family and is sometimes called Surabhinimba in Sanskrit (1). In India, it is known by a variety of colloquial names in different parts of the country, such as Karivempu in Tamil, Barsunga in Bengali, and Kurrypatta in Hindi (2). Only two of the fourteen species known to exist in the genus *Murraya* are native to India: *Murraya paniculata* (Linn) and *Murraya koenigii* Spreng. There are over 150 genera and 1,600 species in the *Rutaceae* family worldwide. P-gurjunene, P-caryophyllene, P-element, and O-phellandrene belong to the complex mixture of volatile molecules responsible for the distinctive aroma of *M. koenigii* leaves, which are used extensively in Indian cooking(3). Moreover, components including β-pinene, β-caryophyllene, β-phellandrene, and α-pinene, which can work independently or in collectively, support the plant's function in food preservation(4).Three morphotypes of the species are known to exist, each with a unique flavour profile and growth pattern. The dark green leaves of the normal type are visually appealing and grow quickly (5).

The dwarf variety grows as a bushy shrub with outward-spreading branches, is somewhat taller than the ordinary version, and has lighter green leaves. The short, thick, dark brown leaves of the brown type are renowned for their exceptional fragrant intensity. The leaves of *M. koenigii* have long been used to promote the production of digestive secretions and cure digestive disorders such as indigestion, nausea, and vomiting. Several carbazole alkaloids, including murrayanine, girinimbine, mahanimbine, and murrayafoline-A, as well as a triterpene molecule, have been identified by phytochemical studies. Five further carbazole alkaloids with strong radical scavenging properties have been identified through ongoing research: euchrestine B, bismurrayafoline E, mahanine, mahanimbicine, and mahanimbine. Koenigii is known to have a wide range of pharmacological qualities, including as antidiabetic, antioxidant, anti-inflammatory, and antidysenteric effects. From the leaves, a protein with a molecular weight of about 35 kDa and antioxidant capacity was extracted (6). Two physiologically active chemicals with significant bioactivity have been identified from acetone extracts of the leaves. Furthermore, compared to mature leaves, fresh leaves exhibit increased concentrations of non-enzymatic antioxidants such ascorbic acid, reducing sugars, phenolic compounds, and proteins, as well as enzymatic antioxidants like peroxidase and polyphenol oxidase (7). The use of *Murraya koenigii* (curry) leaves as a seasoning agent is prevalent in Indian cuisine. Recent studies aimed to characterize the phenolic and flavonol content of curry leaf extracts using different solvents such as ethanol, methanol, and acetone (8). The flavanol profile and antioxidant properties were analyzed through liquid chromatography coupled with atmospheric pressure chemical ionization mass spectrometry (LC-MS–MS) in negative ion mode. Major flavonols identified included kaempferol-O-glucoside, kaempferol-aglucoside, myricetin-3-galactoside, quercetin-O-pantheonize, quercetin-3-diglucoside, quercetin-3-O-rutinoside, quercetin-3-glucoside, quercetin-3-acetylhexoside, and quercetin-O-xylo-pentoside(9). These phenolic compounds were found to inhibit cupric-ion-induced oxidation of low-density lipoprotein (LDL), as demonstrated by lag-time and TBARS assays. Among the solvents, 80% ethanol showed the highest extraction efficiency, whereas acetone extracts exhibited the strongest antioxidant activity, indicated by longer lag-time formation (10). Although the in vitro biological activity of curry leaf flavonols is well documented, further research is needed to understand their potential health benefits and to discover new flavonols that are yet to be identified. Additionally, a dimeric carbazole alkaloid—8,10′-[3,3′,11,11′-tetrahydro-9,9′-dihydroxy-3,3′,5,8′-tetramethyl-3,3′-bis(4-methyl-3-pentenyl)]—along with other carbazole alkaloids such as O-methylmurrayamine A, O-methylmahanine, isomahanine, bismahanine, and bispyrayafoline, was isolated from the dichloromethane (CH_2Cl_2) extract of curry leaves (11). The antioxidant properties of these compounds were evaluated using the oil stability index and radical scavenging activity (RSA) against the DPPH radical. It is believed that an aryl hydroxyl group on the carbazole ring contributes to the stabilization of the reaction rate and enhances thermal oxidation resistance against the DPPH radical(12).

2.Taxonomic Classification

2.1 Table-1 Taxonomic Classification of *Murraya koenigii*

Kingdom	Plantae
Subkingdom	Tracheobionta
Division	Magnoliophyta
Superdivision	Spermatophyta
Class	Magnoliopsida
Subclass	Rosidae
Family	Rutaceae
Genus	Murraya J. Koenig ex L.
Species	Murraya koenigii (L.) Spreng

3.Nutritional composition of curry leave

Mature curry leaves contain high moisture content (63.2%), while coriander leaves have an even higher moisture level (87.9%). In terms of protein, curry leaves contain 1.15% nitrogen, and coriander leaves contain 3.3%. Both types of leaves are also rich in dietary fiber, minerals, and essential vitamins (13). Curry leaves are particularly abundant in calcium, carotene, nicotinic acid, and vitamin A, whereas

coriander leaves are rich in phosphorus, calcium, iron, vitamin B2, niacin, and vitamin C. Beyond these basic nutrients, both curry and coriander leaves contain functional bioactive compounds that contribute significantly to human health and healing when consumed (14) In curry leaves, notable bioactive components include oxalic acid, resins, carbazole alkaloids, and volatile oils, which are particularly rich in compounds such as bicyclomahanimbicine and mahanimbicine. Similarly, coriander leaves also contain volatile oils that contribute to their characteristic flavour. These oils include alcohols such as terpinen-4-ol (in trace amounts up to 3%) and linalool (60–80%); ketones (7–9%); hydrocarbons such as ρ-cymene (trace to 3.5%) and γ-terpinene (1–8%); as well as esters(14).

Table: 2 Nutritional values of curry leaves

S.no	Nutrients	Value of fresh leaves(100gm)	Value of dehydrated curry leaves (100gm)	References
1.	Fat	1gm	5.4 gm	(15)
2.	Proteins	6gm	12 gm	(16)
3.	Calcium	830 mg	2040 mg	(17)
4.	Iron	0.93 mg	12 mg	(18)

4.PHYTOCHEMISTRY:

Mature leaves have the following contents: 63.2% moisture, 1.15 percent total nitrogen, 6.15 percent fat, 18.92 percent total sugars, 14.6% starch, 6.8% crude fibre, 13.06 percent ash, 1.35 percent acid insoluble ash, 1.82% alcohol-soluble extractive, 27.33% cold water (20°C) extractive, and up to 33.45% hot water-soluble extractive (19) The constituents that have sparked the most interest are carotenoids, essential oils, and a variety of carbazole alkaloids. Murraya's components can be summed up in the following key category of bioactive elements(20).

Carotenoids.

The leaves have a fresh weight of 9744 ng of lutein, 212 ng of α-tocopherol, and 183 ng of carotene. Palaniswamy and associates (2003) According to Bhaskarachary et al. (1995), there are 51.4 mg of total carotene and 7.1 mg of β-carotene per 100 g (21) . HPLC measurements of the total carotenoids in leaves range from 14570 to μg/100 g, according to E. Siong Tee. Of the total carotenoids, there were 5252 lutein and 9328 μg/g of β-carotene(22).

Carbazole alkaloids:

Leaves:

Tachibana et al. isolated a dimeric carbazole alkaloid, 8,10'-{3,3',11,11'-tetrahydro-9,9'-dihydroxy-3,3',5,8'-tetramethyl-3,3'-bis(4-methyl-3-pentenyl)}bispyrano[3,2-a]carbazole, from the methylene chloride extract of *Murraya koenigii* leaves. Along with this, they also identified six known alkaloids: koenimbine, O-methyl murrayamine, O-methyl mahanine, isomahanine, bismahanine, and bispyrayafoline (Tachibana et al., 2001; 2003). From the dried leaves, glycozoline (Adesina et al., 1988), 1-formyl-3-methoxy-6-methylcarbazole, and 6,7-dimethoxy-1-hydroxy-3-methylcarbazole (Chowdhury et al., 2012) were isolated (23). Using acetone extract of the leaves, koenigine, koenine, koenidine, and (-)-mahanine were identified (Narasimhan et al., 1975). From the hexane extract, mahanimbine, isomahanimbine, koenimbidine, and murrayacine were isolated (Joshi et al., 1970) (24). Isomahanimbicine was specifically isolated from petroleum ether extract of *M. koenigii* leaves collected in February. Additionally, Euchrestine B, mahanine, mahanimbicine, mahanimbine, and bismurrayafoline (Nutan et al., 1999), bicyclomahanimbicine (Kureel et al., 1970), cyclomahanimbine, bicyclomahanimbine, mahanimbidine (Kureel et al., 1969), and mukonicine (Mukherjee et al., 1983) were identified (25) . Furthermore, 8,8"-bis koenigine, a novel binary carbazole alkaloid, was isolated along with its monomer koenigine (Wang et al., 2002), and a minor alkaloid mahanine (Atta-Ur-Rahman et al., 1988). The leaves also contained murrayanine (0.32%), scopolin glycoside (0.25%), free glucose (3.5%), and ash (10.4%) (25). The aerial parts were also found to contain murrayanine and 8,8"-bis koenigine. Petroleum ether extract of the leaves yielded mahanimbine (3,5-dimethyl-3-(4-methylpent-3-enyl)-11H-pyrano[5,6-a] carbazole) (Kumar et al., 2010). The methanolic extract of *M. koenigii* was analyzed using qualitative thin-layer chromatography (TLC) and

high-performance liquid chromatography (HPLC) with different solvent systems (Gupta, 2007) (26). Structural elucidation of the isolated compounds was carried out using IR, ^{1}H NMR, ^{13}C NMR, and MS. Based on spectrometric data, six bioactive carbazole alkaloids—mahanimbine, girinimbine, isomahanimbine, murrayazoline, murrayazolidine, and mahanine—were confirmed (Gupta and Singh, 2007)(26).

Stem:

From alcohol extract of stem bark Saha et al. (1998) has isolated koenigine- quinone A and koenigine quinone B, structures were established as 7- methoxy3 methyl carbazole- 1,4- quinone and 6, 7-dimethoxy3-methyl carbazole-1, 4- quinone respectively (Saha et al.,1998) 9- carbethoxy-3-methyl carbazole and 9- formyl –3- methyl carbazole were identified form M. koenigii by (Chakraborty et al .,1997) me- 2-methoxy carbazole –3- carboxylate and 1- hydroxy –3- methyl carbazole were isolated form stem bark (Bhattacharya et al., 1994) (26). In stem bark, mukonal, a likely biogenetic precursor of the pyrano carbazole alkaloid, was found (Bhattacharya, 1984). Murrayazolinol (a minor carbazole alkaloid) (Bhattacharya, 1989), mahanimbinol (Rama Rao et al., 1980), murrayazolidine (Chakraborty et al., 1974; Chakraborty et al., 1970), murrayacinine (Chakraborty et al., 1974), mukonidine (Chakraborty, 1978), murrayazolinine (Chakraborty et al., 1973), murrayanine, girinimibine, and mahanimbine (Das, 1965), girinimbinol and mahanimbilol (Reisch et al., 1994), and other potential biogenetic precursors of girinimbine and mahanimbine, have also been identified and isolated from stem bark(27).

Roots:

Root extract was used to isolate Murrayanol, Murrayagetin, and Marmesin-1"-Orutinoside (Srivastava et al., 1993). Root and stem bark were used to isolate bis–2-hydroxy-3-methyl carbazole, bismahanine, bi koeniquinone-A, and bismurrayaquinone A, as well as three monomeric and five binary carbazole alkaloids called mukoenine-A, -B, and C and murrastifoline-F (Chihiro et al., 1993) (28). Mukoline and mukolidine were extracted from the benzene extract of roots (Srivastava et al., 1993), while koenoline (1-methoxy-3-hydroxy methyl carbazole) was extracted from the root bark (Bandyopadhyaya et al., 2001). Girinimbine has been found in the roots(29).

Seeds:

In Marassana, Sri Lanka, seeds of M. koenigii were used to isolate mahanine, girinimbine, koenimbine, isomahanine, and mahanimbine (Johannes, 1994). The petroleum ether extract of seeds was used to isolate 2-methoxy-3-methyl carbazole (Bhattacharya et al., 1984) (30). Using 2D-NMR spectra to confirm their structure, Mandal et al. (2010) identified three bioactive carbazole alkaloids: kurryam (I), koenimbine (II), and koenine (III)(31).

Fruits:

Fruit ether extract was used to separate mahanimbine and koenimbine (Narsimha et al., 1968). In addition to five previously identified carbazole alkaloids—mahanimbine, murrayazolidine, girinimbine, koenimbine, and mahanine—Reisch et al. (1992) extracted isoahanine and murrayanol from fruits(32).

Coumarin:

The seeds were used to isolate 2', 3' epoxy indicolactone (a furocoumarin lactone), anisoalctone, and indolactone. This is the first furocoumarin in the genus Murraya to have a monoterpenoid lactone chain (Adeleke, 1997) (33). Minor furocoumarins in M. koenigii seeds have also been identified as xanthotoxin, isobyaknagelicol, byakangelicol, and isogosferol (Adeleke, 2000). According to Johannes (1994), seeds from Marassana village in Sri Lanka were found to contain isoheraclenin, isoimperatonin, oxypeucedanin, isopimpinellin, and bergaptan, indicating the possibility of a new chemical race (25). Osthol, umbelliferone, and a novel coumarin galactoside marmesin-1'-O-β-Dgalactopyranoside were separated from ethanol stem bark extract (Ravindra, 1992). 3-(1, 1-) dimethyl allyl xanthyletin was extracted from M. koenigii stem bark petroleum ether extract (Bhattacharya et al., 19984)(34).

5. GROWING SEASON:

The curry leaf plant produces flowers and vibrant green leaves during the spring, summer, and rainy seasons. During its dormant period in the winter months, the leaves fall off. The plant prefers full sunlight and well-drained soil that remains relatively dry(34). It also requires fertilization during the summer months. The fruiting season typically lasts from late June to the end of August, with July being the peak

month for fruit production. In India, leaf harvesting begins about 15 months after planting, with subsequent collections occurring every 2 to 3 months (35). In colder regions, such as Southern California, South Texas, and South Florida, outdoor cultivation of the curry leaf plant requires protection from freezing temperatures. As the seeds are delicate, they should be handled with care(36).

6. PLANT DESCRIPTION AND HABITAT:

Murraya koenigii , commonly known as curry leaf, is extensively distributed and cultivated throughout India (37). It occurs naturally across a wide geographic range, from the Himalayan regions—such as Uttarakhand, Sikkim, and Garhwal—to Bengal, Assam, the Western Ghats, and the Travancore-Cochin region. Propagation is typically achieved through seeds, which exhibit good germination rates under partial shade (38). Beyond India, *M. koenigii* is also found across various parts of Asia, particularly in moist forested areas at elevations ranging from 500 to 1600 meters. Notable regions include Guangdong, southern Hainan, and southern Yunnan (Xishuangbanna) in China, as well as Bhutan, Laos, Nepal, Pakistan, Sri Lanka, Thailand, and Vietnam. Botanically, the curry leaf plant is a strongly aromatic, unarmed, semi-deciduous shrub or small tree, growing up to 7 meters in height with a stem diameter ranging from 14 to 42 cm (39). The main stem is dark green to brownish in color, and the bark peels longitudinally to reveal the white wood beneath. The stem and branches are woody, slender yet robust, and covered in dark grey bark Leaves are imparipinnate, glabrous, and intensely aromatic, typically comprising 9 to 25 or more leaflets. These leaflets are alternate, short-stalked, gland-dotted, and highly fragrant. The flowers are small, white, fragrant, and ebracteate, featuring a deeply five-cleft, pubescent calyx (40). The five free petals are whitish, glabrous, and bear dotted glands Fruits are borne in compact clusters and are small, ovoid to subglobose, glandular, and possess a thin pericarp enclosing one or two seeds of spinach-green color. The curry leaf plant was introduced to regions such as Malaysia, South Africa, and Réunion Island through South Indian migration. However, outside areas influenced by Indian cultural practices, the plant remains relatively uncommon(34).

7. MICROSCOPY AND MACROSCOPY STUDIES:

The macroscopical examination of the leaves of *Murraya koenigii* L. Spreng reveals that they are obliquely ovate or somewhat rhomboid in shape, with an apex that may be acuminate, obtuse, or acute. The petiole measures approximately 20 to 30 cm in length (41). The leaves exhibit reticulate venation, a dentate margin, and an asymmetrical base. Microscopic analysis shows that stomata are present only on the abaxial (lower) surface, while the adaxial (upper) surface is devoid of stomata. The type of stomata observed is anomocytic. A transverse section of the leaf displays a single layer of epidermis made up of rectangular cells, forming the outermost covering on both the upper and lower surfaces. Additionally, the upper epidermis is coated with a cuticular layer. In the midrib region, the epidermis is underlain by one to four layers of collenchymatous hypodermis, followed by two to five layers of chlorenchyma cells, which are rich in chlorophyll content (41). The ground tissue is composed of oval to polygonal parenchyma cells and is interspersed with a vascular bundle. In this area, calcium oxalate crystals are present in both sandy and prismatic forms(42).

8. EXTRACTION METHODS FOR CURRY LEAVES

1.1 Extraction by Soxhlet

In Soxhlet apparatus 10 g of curry leaf powder was extracted by mixing 250 ml of distilled water, hexane, chloroform, EtOH, and an EtOH and water combination (1:1). After the solvents were removed, the extracts were kept at 4 °C until they were needed for antioxidant tests (23). The dry weight of the entire extract per litre of assay solution was used to calculate the extracts' effectiveness. Phenolic concentration and yield in various extracts Hexane at room temperature produced the lowest yield (4.8±0.07%), while Soxhlet extraction using a combination of EtOH and water gave the highest yield (22.8±0.80%)(43).

Preparation of M. Koenigii Leaves Extract:

The technique used to produce the M. koenigii extract was taken from Sablania et al. with a few minor modifications. In short, 5 g of powdered M. koenigii leaves were combined with 100 mL of methanol and left for 56 hours in a dark or shady place (44). This helps to maintain a steady temperature and prevents

the extracted components from deteriorating. M. koenigii leaves were centrifuged for 10 minutes at 10,000 rpm and 24 °C to create the aqueous extract. To get rid of any fine solid particles, the filtrates were filtered through filter paper after being completely dried. Acetone and ethanol were used to repeat the steps(45). The phytochemical characteristics of the extracts were studied. The largest percentage yield of crude extract (21.42%) is obtained when M. koenigii is extracted using methanol, which enables a thorough identification of the phytochemical components in this herbal plant(46).

1.2 Ultrasound-assisted extraction

Curry leaves (1 g) and methanol (20 mL) in various concentrations (ranging from 40% to 80%) were combined. An ultrasonic bath was used to hold the solutions (47). The temperature was changed from 40 to 80°C, and the ultrasonic power was changed from 80 to 150 W. Two hours were used for extracting under these different parameters (48). Twenty trials using various variables for extraction were finished in total. The maximum amount of catechin (0.536 mg/g DW) was obtained at an extraction temperature of 60°C and a methanol concentration of 86.3%(49).

1.3 Microwave assisted extraction:

A microwave-assisted method was used to efficiently create carbon dots (CL-C dots) from residue curry leaf extract. To completely characterise the resulting CL-C dots, a variety of analytical techniques have been used(50). According to high-resolution transmission electron microscopy (HR-TEM), the average particle size was 3.55 nm. With a maximum emission at 425 nm, the CL-C dots displayed green fluorescence when stimulated at 340 nm. It was found that the quantum yield (QY) of the green emissive CL-C dots was 27.13% (50). According to an analysis using Raman spectroscopy, an intensity ratio (I_D/I_G) of 1.1 indicated the existence of structural flaws typical of carbon-based nanomaterials. A white light-emitting diode (WLED) device was additionally developed with the acquired CL-C dots, and it showed CIE chromaticity coordinates of (0.307, 0.354) and a correlated colour temperature (CCT) of 6617 K (51). In anti-counterfeiting applications, CL-C dots were also utilised as fluorescent ink, offering a cost-effective and user-friendly alternative to commercial fluorescent inks. The study shows the potential of CL-C dots in energy applications, materials science, forensics, optoelectronics, and anti-counterfeiting(52).

1.4 Maceration:

The plant material was completely submerged in 2000 millilitres of 96% ethanol after 500 grams of curry leaf powder had been contributed to a maceration vessel. Over a period of three days, the mixture was kept out of direct sunlight in a sealed container and stirred occasionally (53). For seventy-two hours, the liquid ethanol extract was collected by filtration three times a day, in the morning, afternoon, and evening. After that, the leftover plant material was re-macerated with 1500 millilitres of 96% ethanol, with comparable stirring and a three-day break(54). This re-maceration's filtrate was mixed with the initial ethanol extract. Following that, after dissolving the residue from the second maceration in 1200 millilitres of fresh 96% ethanol, it was mixed and let to stand for an additional three days (55). To create a thick ethanol extract, the final filtrate was mixed and concentrated using a rotary vacuum evaporator. 52.613 grams of thick extract in total, or a 9.50% yield, were extracted (53). Based on the immersion method,

this percentage yield does not identify the precise chemical ingredients but rather shows the amount of secondary metabolites that the solvent was able to extract(56).

Figure 1 Extraction of curry leaves by different methods

9. Pharmacological studies

1.5 Antibacterial activity

Murraya koenigii leaves' essential oil showed antibacterial activity against Pasteurella multocida, B. subtilis, S. aureus, C. pyogenes, and P. vulgaris. Even at a dilution of 1: 50033, the pure oil remained effective against the first three organism (57). Three bioactive carbazole alkaloids, mahanimbine, murrayanol, and mahanine, are obtained from the acetone extract of fresh Murraya koenigii leaves during fractionation. These alkaloids have demonstrated antibacterial, mosquitocidal, and topoisomerase I and II inhibitory properties(58).

1.6 Antifungal activity

The antifungal activity of Murraya koenigii 's essential oil from leaves was demonstrated against Candida albicans, Candida tropicalis, A. niger, A. fumigates, and Microsporum gypseum, even at a 1:500 dilution(59). Fungitoxicity against Rhizoctonia solani35 and Colletotrichum falcatum has been shown by the ethanolic extract of the leaves. Murraya koenigii 's ethanolic extract of the roots and the entire plant, except the roots, did not, however, exhibit any antifungal action against Microsporum canis, Trichophyton mentagrophytes, or Cryptococcus neoformans(60).

1.7 Antiprotozoal activity:

The essential oil extracted from the leaves of Murraya koenigii was shown to have antifungal action against Microsporum gypseum, Candida albicans, Candida tropicalis, A. niger, and A. fumigates, even at a 1:500 dilution (61). The ethanolic extract of the leaves has demonstrated fungitoxicity against Rhizoctonia solani35 and Colletotrichum falcatum (62). Trichophyton mentagrophytes, Cryptococcus neoformans, and Microsporum canis weren't harmed by the ethanolic extract of Murraya koenigii 's roots or the complete plant, with the exception of the roots(63).

1.8 Hypoglycaemic effects

Rats given aqueous and methanolic extracts of Murrayakoenigii leaves showed a decrease in plasma glucose levels after being given alloxan. The ethanolic extract of the stem of Murraya koenigii exhibits a noteworthy decrease in body weight17, triglycerides, total cholesterol, and blood glucose levels (64). Mahanimbine, a carbazole alkaloid derived from Murraya koenigii leaves, exhibits both hypolipidemic and antihyperglycemic activity. An intraperitoneal administration of 50 mg/kg and 100 mg/kg once weekly for 30 days has demonstrated hypolipidemic and antihyperglycemic effects on adult male Wistar rats induced by streptozotocin that do not have diabetic shock in diabetic rats (65). The levels of triglycerides, low density lipoprotein, very low-density lipoprotein, and total cholesterol were shown to have significantly decreased after the 30-day course of treatment, while the levels of high-density lipoprotein increased. In addition, mahanimbine has poor alpha glucosidase inhibitory effects and strong alpha amylase inhibitory effects when compared to the synthetic medication acarbose(66).

1.9 Hepatoprotective activity:

Adult Sprague Dawley rats administered carbon tetrachloride showed a decrease in the elevation of hepatic marker enzymes (aspartate transaminase, alanine transaminase, serum bilirubin, and alkaline phosphate) when treated with methanolic extract of Murraya koenigii leaves at doses of 200 mg/kg, 300 mg/kg, and 500 mg/kg (67). The maximum dosage of 500 mg/kg was equivalent to the conventional medication, silymarin, which has been used in clinical trials to treat liver disease (68). The hepatoprotective effect of Murraya koenigii at aqueous extract was assessed in adult Wistar rats that had been given ethanol at doses of 1g/kg and 2g/kg. The extract showed positive hepatoprotective effect against ethanol-induced hepatitis at 1g/kg. The aqueous extract prevents the oxidation of lipids(69).

2.0 ANTIPROTOZOAL ACTIVITY:

Curry leaf ethanol extracts showed strong antiprotozoal activity against Entamoeba histolytica, antihypertensive effects in dogs and cats, and antispasmodic effects on the ileum of guinea pigs(70).

2.1 Anticancer Activity:

Curry extract had antitumor effects in vitro. In mice with tumours, we observed a significant drop in the quantity of cancer cells and the size of the tumour (Muthumani et al., 2009). The methanol extract of curry leaves collected in several parts of India also demonstrated strong anticancer activity against breast cancer cell lines in another study (39). Curry leaf methanol extract was used in an MTT experiment that demonstrated strong anticancer effects in a prior work(71).

2.2 Mosquitocidal activity:

Aedes aegypti larvae have been destroyed by petroleum ether extract and Murraya koenigii leaf acetone extracts at concentrations that vary from 250 ppm to 900 ppm(72).

2.3 Anthelmintic effects

Murraya koenigii leaves have anthelmintic activities; both the ethanolic and aqueous extracts of the leaves exhibit anthelmintic properties against Pheretima posthuma, and both extracts were equivalent to the conventional medication piperazine(73). It has been suggested that the polyphenolic component called tannins, which is present in Murraya koenigii leaves, has antihelminth properties. Furthermore, by binding to the free protein in the host's gastrointestinal tract or to the glycoprotein on the parasite's cuticle, tannins can have lethal effects on the parasite or destroy energy production by uncoupling oxidative phosphorylation, just like synthetic phenolic antihelmints like oxyclozanide, niclosamide, and bithionol (74). Murraya koenigii 's methanolic extract has dose-dependent anthelminthic actions against the Indian earthworm (Pheretima posthuma). Indian earth worms become disable by the methanolic extract after 18 minutes, and it has a deadly effect after 45 minutes(75).

2.4 Nephroprotective effects:

In streptozotocin-induced diabetic male rats, oral administration of Murraya koenigii leaf aqueous extract daily for 30 days resulted in a significant decrease in serum urea and creatinine levels and promoted kidney tissue regeneration(76).

2.5 Antimicrobial activity:

The Murraya koenigii root extracts in hexane, methanol, and chloroform were evaluated against Salmonella typhi, Bacillus subtilis, Staphylococcus aureus, Escherichia coli, and the fungus strains Aspergillus niger, Candida albicans, and Trichophyton rubrum (77). All the investigated organisms were successfully treated by the hexane, methanol, and chloroform extracts of Murraya koenigii root; however, the methanol extract exhibited the most antibacterial activity, with the greatest inhibitory effect on Trichophyton rubrum and Staphylococcus aureus (78). All three of the aforesaid extracts were efficient against Staphylococcus aureus, and the root's aqueous extract was also ineffective against the tested microbe(79).

2.6 Antitrichomonal Activity:

Inalis, showing that they may be utilised as trichomoniasis natural treatments. THE DE In addition to their culinary use, curry leaves have sparked research due to potential medical advantages, including as antitrichomonal activity (80). Infections caused by the common sexually transmitted parasite Trichomonas vaginalis can be effectively treated with curry leaves due to their potent antitrichomonal properties, according to studies (81). Bioactive substances in these leaves, including as alkaloids,

flavonoids, and phenolic compounds, have potent antibacterial qualities that protect against trichomonads and other disorders (82). Research has indicated that extracts from curry leaves can suppress the growth and survival of Trichomonas vagveloping. The true therapeutic potential of curry leaves in the treatment of trichomonal infections requires the development of standardised formulations and further investigation into the exact mechanisms of action (64). Carbazole Trichomonas gallinae is inhibited by alkaloids and their derivatives found in curry leaves. Girinimbilol and girinimbine were the most potent substances; their respective IC50 values were 1.20 and 1.08 mg/mL. Acetylation increased the activity of girinimbilol and mahanimbilol to 1.08 and 0.60 mg/mL, respectively (83).

2.7 Anthelmintic Activity:

Research has shown that curry leaf extracts have strong anthelmintic properties, which can help eliminate parasitic worms from the digestive system. These effects are mainly due to the presence of bioactive compounds like tannins, flavonoids, and alkaloids (14). Moreover, the rich antioxidant content in curry leaves may reduce the oxidative stress caused by parasitic infections, potentially boosting their anthelmintic effectiveness. Studies indicate that curry leaves may be effective against different types of intestinal worms, making them a potential natural remedy for helminthic infections (84) . Exploring the mechanisms behind this property may lead to the development of curry leaf-based anthelmintic medications that offer safer and more eco-friendly treatment options (85). Experiments using aqueous and ethanolic extracts of curry leaves against *Pheretima posthuma* revealed significant anthelmintic activity at a dose of 100 mg/mL. Of the tested extracts, the alcoholic extract showed markedly greater anthelmintic activity compared to the petroleum ether extract(86).

2.8 Anti-ulcer Activity:

Research has shown that curry leaf components possess anti-ulcerogenic properties, which may support the prevention and treatment of stomach ulcers. Many of the bioactive compounds found in curry leaves—such as alkaloids, flavonoids, and tannins—exhibit strong gastroprotective effects. Studies have indicated that curry leaf extracts help strengthen the gastric mucosal barrier, promote mucin secretion, and reduce stomach acid production, all of which contribute to ulcer prevention (87). In addition, the antioxidant and anti-inflammatory properties of curry leaves play a role in protecting against ulcer formation. Whether consumed as part of the diet or used in herbal remedies, curry leaves may offer a safe and natural approach to managing gastric ulcers and supporting stomach health (88). The anti-ulcer activity was demonstrated using aqueous extracts at doses of 200 and 400 mg/kg. Significant inhibition of gastric lesions was observed in ulcers induced by pylorus ligation and non-steroidal anti-inflammatory drugs (89). In the pylorus ligation model, the extract decreased the volume of gastric juice, ulcerative lesions, and both free and total acidity, while increasing the pH level. These results confirm that the extract possesses strong anti-ulcer potential(90).

2.9 Skin Protection Formula and Anti-ageing:

Curry leaves' significant variety of properties provides a stimulating subject for skincare and anti-aging formula research. Strong free-radical scavenging qualities of curry leaves, which are rich in antioxidants such flavonoids, phenolic compounds, and vitamin C, can help protect the skin from oxidative stress-induced skin damage (91). By providing defence against UV rays, pollutants, and other environmental aggressors, this protection reduces the likelihood of developing early ageing symptoms including wrinkles, fine lines, and age spots (92). Curry leaves also contain essential nutrients like beta-carotene and amino acids, which promote collagen formation and skin suppleness, providing the impression of skin that is healthier and more supple. Additionally, curry leaves have anti-inflammatory properties that help reduce acne and other skin conditions that affect sensitive skin(93).

3.0 Oral Health/ Effect on Dental Caries:

Curry leaves, widely used in various cuisines, are also well known for their positive effects on oral health. They are rich in antioxidants and antimicrobial compounds that help fight oral pathogens, thereby reducing the risk of dental caries and gum disease (64). The presence of essential oils and alkaloids in curry leaves inhibits the growth of bacteria like *Streptococcus mutans*, a major cause of tooth decay. Furthermore, their anti-inflammatory properties help soothe gum inflammation and prevent periodontal issues (94) . Regular use of curry leaves—either by chewing them directly or including them in the diet—can greatly improve oral hygiene, eliminate bad breath, and support overall dental health. Their wide-

ranging oral health benefits make curry leaves a valuable natural remedy. Curry leaf branches are traditionally used as *datun* for cleaning teeth and are believed to strengthen both gums and teeth. In addition to their medicinal uses, the plant's compound leaves add ornamental value, making it suitable for use as a hedge or decorative shrub(8). A food and cake composition containing active ingredients such as isomahanine, mahanine, murrayanol, and other compounds derived from Murraya species has been found to exhibit antimicrobial activity against bacteria responsible for dental caries and periodontal diseases. This formulation is safe for human consumption and can be taken daily, even by infants, to help prevent oral health issues(95).

4.0 CONCLUSION:

Curry leaf, scientifically known as *Murraya koenigii* , is a remarkable medicinal plant that has been valued and utilized for generations by our ancestors due to its wide range of therapeutic benefits. In rural and tribal regions, it was traditionally used to treat various ailments while also enhancing the flavor and aroma of food. However, with increasing urbanization and globalization, curry plants have become far less common in-home gardens. Consequently, many modern diets have shifted away from natural ingredients like curry leaves, relying instead on artificial flavoring agents. Given the growing concerns over the adverse effects of synthetic chemicals and the increasing prevalence of drug-resistant diseases, it is essential to re-emphasize the significance of *Murraya koenigii* . This plant contains numerous bioactive compounds known for their therapeutic properties, including antibacterial, anti-inflammatory, antidiabetic, and antioxidant effects. Therefore, extensive research should be undertaken to isolate and characterize these compounds more thoroughly. Additionally, synergistic studies combining *Murraya koenigii* with conventional medicines or other herbal extracts should be explored to enhance therapeutic outcomes and combat drug resistance. Promoting its sustainable use and scientific validation can significantly contribute to both the revival of traditional medicine and advancements in modern healthcare**.**

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