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A review on Anti-microbial potential of Murrya koeingii

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***Abstract**: Medicinal plants have been used for healing purposes for thousands of years. In many rural and tribal areas, they are still a primary source of healthcare because they are easily available, affordable, and trusted. The study of how people use plants for medicine is called ethnobotany. It combines knowledge from different fields such as botany, medicine, culture, history, and ecology. In recent years, there has been growing global interest in herbal medicines and traditional healing systems, leading to more scientific research on medicinal plants. One such plant is Murraya koenigii, commonly known as curry leaf. It is not only used as a spice in Indian cooking but also valued for its many health benefits. In traditional Indian medicine, different parts of this plant—especially the leaves—are used to treat various illnesses. The leaves are used as a health tonic and help in improving digestion. They are also believed to reduce symptoms like vomiting, dysentery, and stomach disorders. Additionally, they are used to treat conditions such as piles, body heat, inflammation, and skin itching. The plant also has anti-worm, pain-relieving, and thirst-quenching properties. Because of the wide range of traditional uses, scientists have taken an interest in studying the plant more deeply. Research has shown that Murraya koenigii may have several important medicinal effects. These include benefits for heart health, lowering blood sugar levels, reducing cholesterol, fighting infections, protecting against ulcers, reducing oxidative stress, and even showing potential in cancer treatment. It also has properties that support the immune system and help control diarrhea. This review focuses on the ethnobotanical uses, plant characteristics (pharmacognosy), chemical makeup (phytochemistry), and healing properties (pharmacology) of Murraya koenigii. The plant is widely used by different tribal communities across India, and ongoing research supports many of its traditional uses. As a result, Murraya koenigii is gaining recognition as an important plant in both traditional and modern medicine.*

***Keywords**: Curry leaf, ethnobotany, pharmacognosy, pharmacology, phytochemistry.*

INTRODUCTION

Infectious diseases are spreading through worldwide and also causes death. It is said that about 50,000 people are killed everyday. The causes of these infections are the pathogenic strains such as varities of bacterial etiologic agents such as Klebsilla sp. , salmonella sp. Etc.[54] The mainstay of treatment for microbial (bacterial and fungal) infections is antibacterial medicines. Multi-drug-resistant microorganisms are posing a threat to the therapeutic effectiveness of many current medicines and have made treating infectious diseases even more challenging.[55]

Plant derived natural Anti-microbials in essential oils have Phenolics (flavonoids and non-flavonoids), terpenes, aliphatic-alcohols, Aldehydes, Ketones, organic acids, saponins, thio-sulfinates, and glucosinolates are the primary substances found in essential oils that give plants, especially herbs and spices, their antibacterial qualities[56,57,58,59,60,61].The growth of bacteria, yeast, and molds can be postponed or inhibited by edible, medicinal, and herbal plants, their associated essential oils, byproducts like hydrosols, and secondary metabolites. [57,61,62] India is rich in medicinal plants, and Murraya koenigii (Curry Leaf) is one of them. This plant has many beneficial compounds that make it valuable for health. Despite its potential, scientists haven't explored it much. Thus, is proven for its medicinal properties. [1,2] Murraya koenigii also referred as curry leaf or kari patta in Indian language Correspond, which encompasses more than 150 genera and over 1600 species. It also grows very well. The Murraya koenigii ingredient has been biologically exploited for the extraction of a number of chemical constituents. The most common chemical constituents in its sharp and smoking properties includes: P-gurjunene, P-caryophyllene, P-elemene and O-phellandrene. This plant guarnty substaintal breakdown of whole class of bioactive furoquinoline coumarin alkaloids, acridone and carbazole alkaloids family. M. koenigii has been widely consumed in the Indian cuisine since centuries and has variety of applications in the distinct

areas of medicine. Immature leaves are consumed to effectively treat dysentery, diarrhea and to prevent nausea. Roots and leaves are also used in the form of tinstures to treat internal fever, parasitic infestation, pain, treatment of hemorrhoids, swelling, dryness of skin, and in conditions like leucoderma and blood related diseases. The M. koenigii plant also encompasses various other bioactive molecules which exhibit drug like properties. Several of such natural active phytochemicals associated with the surgical nutritional factors have been demonstrated and delineated. They reported that this plant has approximately similar activities of antioxidant, cytotoxic, antimicrobial, anti-bacterial, antiulcer, and positive inotropic and cholesterol lowering activity.

Kingdom	Plantae
Subkingdom	Tracheobionta
Super divison	Sperma-tophyta
Divi-sion	Magno-liophyta
Classs	Magno-liospida
Sub-class	Rosidaae
Orderr	Sapin-dales
Famiily	Ruatceae.
Genuss	MurrayaJ. Koeniig eX L
Species	Murraya-koenigii L-Spreng.

Table 1: Taxonomy of. Murraya-koenigiii

Macroscopical Description of the Plant

This plant is a shrub or small tree that typically grows between 2.5 to 6 meters in height and spreads about 15 to 40 centimeters in width. It has a short, sturdy trunk covered with smooth bark that is either grey or brown in color. One of the most noticeable features of the plant is its strong, pleasant aroma. The leaves are especially fragrant. Each leaf is about 30 centimeters long and is made up of 9 to 25 smaller leaflets. These leaflets are arranged alternately on the stem and show a network-like pattern of veins, which is called reticulate venation. The leaflets are green, narrow, and slightly pointed at the tips. The plant produces small, white flowers that are funnel-shaped and have a nice fragrance. Each flower typically has five petals and grows in small clusters. These flowers later turn into fruits. The fruits are small, round or oval-shaped, and grow in tight bunches. They have a thin outer covering and contain one or two seeds inside. When the seeds are mature, they are spinach green in color. The fruits are usually not eaten raw but may have traditional or medicinal uses. Because of its aromatic leaves and fruit characteristics, this plant is often used as a spice or herb in cooking. It may belong to the Rutaceae or Myrtaceae plant family, both of which include plants known for their strong scents and flavorful parts. Overall, this plant is easy to identify due to its fragrant leaves, small white flowers, and clustered green fruits. It is widely used in herbal remedies and as a flavoring in food, especially in traditional cuisines.[6,7,8]

Microscopical Description of Murraya koenigii

When the leaves and roots of Murraya koenigii, commonly known as the curry leaf plant, are examined under a microscope, they show some special features that help in identifying the plant. The leaves have tiny hair-like structures called trichomes. These are single-celled and curved, and unlike some other plant hairs, they do not have hollow centers. In the stalk of the leaf (petiole), there is soft tissue known as parenchymatous pith, which helps store nutrients and water. The middle part of the leaf (midrib) contains strong fibers, giving it support and strength. The surface of the leaf also has tiny openings called stomata,

which are used for breathing. These are surrounded by crystals of calcium oxalate, giving them a special appearance under the microscope. The root of the plant also has a unique internal structure. It shows a tetrarch to pentarch stele, which means it has four to five groups of vascular tissues (xylem and phloem). The outer layer of the root, called the phelloderm, does not contain fibers. Instead, there are several circular layers of parenchyma cells, which serve as storage tissue. When the plant is dried and made into powder, it appears green in color and does not have a strong smell or taste. Under the microscope, the powder shows clear features such as curved trichomes, two layers of palisade cells (tightly packed, column-like cells), secretory canals, strong fibers, and calcium oxalate crystals. The powder also shows fluorescence when treated with certain chemicals. For example, it glows brownish-black with methanolic sodium hydroxide and yellowish-white when placed in nitrocellulose. It also shows a chocolate-colored glow under specific conditions. These microscopic features help confirm the identity of Murraya koenigii and differentiate it from other similar-looking plants.[11,12]

Various names:

English: Curry Leaves,Kannada: Karibevu,Hindi: Karipatta, Meetha Neem, Tamil: Kariveppilai, Malayalam: Kariveppu, Marathi: Kadhilimb, Sanskrit: Girinimba, Telugu: Karepeku, Tulu: Bevusoppu, Gujarati: Mitho Limado, Portuguese: Folhas de Caril, Russian: *Листья карри* (Listya karri), Spanish: Hojas de Curry, Italian: FogliediCurry, French: Feuilles de Curry.[67]

Traditional Uses of Murraya koenigii

The curry leaf plant, also known as Murraya koenigii, has been widely used in traditional cooking and medicine. Its fresh leaves, dried leaf powder, and essential oils are all highly valued. In cooking, the leaves are commonly added to curries, soups, meat and fish dishes, egg preparations, and even ready-to-eat meals to enhance flavor. The unique aroma and taste of curry leaves make them an important ingredient in many South Asian recipes. Apart from culinary uses, the essential oil extracted from curry leaves is used in the cosmetic and aromatherapy industries. It is also an ingredient in some soaps and perfumes due to its pleasant smell. In traditional medicine, curry leaves are considered very beneficial. They are used as a natural remedy to promote hair health. People boil the leaves in coconut oil until a thick, dark residue forms. This mixture is applied to the scalp as a hair tonic to maintain natural hair color and boost hair growth. Different parts of the curry leaf plant are used to treat a wide range of health issues. Traditionally, the plant has been used to relieve nausea (anti-emetic), purify blood, reduce depression, and act against fungal infections. It also helps in treating body aches, inflammation, diarrhea, kidney pain, and vomiting. Tribal communities use the bark and roots of the plant to treat bites from poisonous animals. In folk remedies, chewing raw curry leaves is believed to help control diarrhea and reduce morning sickness when taken with lime juice. The plant is also used externally. A paste made from the leaves is applied to the skin to soothe boils, while the juice extracted from the roots is used to relieve pain in the kidneys.

Ayurvedic Perspective on Antimicrobial Plants

Since ancient times, people across the world have used plants as natural medicines to fight infections. In Ayurveda, India's traditional system of medicine, many plants are known for their strong ability to fight bacteria and other harmful microbes. These natural remedies have been trusted for generations and are still used today for treating various illnesses. Herbal medicines work because of special natural compounds in them, called phytochemicals. Some of the most important ones include alkaloids, flavonoids, terpenes, and polyphenols. These substances attack bacteria and other microbes in different ways, stopping their growth or killing them altogether. What makes these plant-based medicines powerful is their broad-spectrum activity—they can act against many different types of germs. In many cases, combining several medicinal plants together makes the treatment even more effective. This is called a synergistic effect, where the combined power of different plants becomes stronger than using just one. This not only improves treatment but can also help prevent bacteria from becoming resistant to these medicines—something that is a big problem with regular antibiotics today. However, there are some factors that can affect how well herbal medicine works. These include the type of plant, the part of the plant used (such as leaves, roots, or bark), the place where the plant is grown, and how the medicine is prepared and taken. Because of these differences, not all herbal treatments work the same way every time. To make herbal medicine more reliable, it is important to focus on quality control, scientific testing, and standardization. These steps help make sure the medicine is safe, effective, and consistent. Also, studying these plants

through modern science can help us understand exactly how they work and possibly lead to the discovery of new, plant-based drugs. Looking ahead, the future of herbal medicine in fighting infections seems promising. With rising problems like antibiotic resistance, where bacteria stop responding to regular medicines, herbal treatments could provide safe and natural alternatives. They can also help in making personalized medicine, where treatments are tailored to a person's individual health needs. For herbal medicine to grow and be successful in today's world, it needs support from both local traditions and global cooperation. Governments, scientists, and communities must work together to promote sustainable use of medicinal plants. This means growing and using these plants responsibly, without harming nature. In conclusion, herbal medicine, especially from the Ayurvedic tradition, holds great value in the treatment of microbial infections. It not only honors ancient knowledge but also provides new hope in modern healthcare. With the right support, these natural remedies can continue to play a key role in keeping people healthy and fighting infections in the future.[63]

GENERAL METHODS OF ANTI-MICROBIAL ACTIVITY:

SNO.	MODEL	ACTIVITY
1.	IN VIVO MODELS	Vasodilating activity[36]
		Anti-diabetic activity[37]
		Hypocholesterolemic activity[38]
		Anti-ulcer activity[39]
		Anti-diarrheal activity[40]
		Phagocytic activity[41]
		Analgesic and Antinociceptive activity[42]
		Antilipid-peroxidative activity[43]
		Radioprotective and chemoprotective activity[44]
		Antiamnesic activity[38]
		Antihelmintic activity[45]
		Memory enhancing [38]
		Wound healing[46]
2.	IN VITRO MODELS	Anti microbial activity[47]
		Antioxidative activity[47,48]
		Skin pigmenting [49]
		Cytotoxic activity[50,51]
		Antitumor assay[52,53]

In vivo Pharmacological studies on Murraya koenigii:

Antimicrobial Activity

Murraya koenigii, also known as the curry leaf plant, has been found to contain several natural compounds with strong antimicrobial properties. Some of the main active compounds identified in the plant include mahanimbine, murrayanol, mahanine, and gurjunene. These substances help the plant fight against harmful microorganisms such as bacteria and fungi. Researchers have studied the stem bark of Murraya koenigii and discovered several useful compounds, including benzoisofuranone derivatives, three types of steroids, and six carbazole alkaloids. These compounds have shown effective antimicrobial activity at concentrations ranging from 3.13 to 100 micrograms per milliliter. In a comparative study involving methanolic extracts from 21 different plant species, Murraya koenigii showed the strongest antibacterial activity. It was particularly effective against Staphylococcus epidermidis, a type of bacteria that can cause skin infections and other health problems. The leaves of the curry leaf plant were also tested using acetone extracts, which led to the discovery of three major carbazole alkaloids: mahanimbine,

murrayanol, and mahanine. These compounds were not only effective in killing bacteria, but they also showed other beneficial properties. For example, mahanimbine displayed antioxidant activity at a concentration of 33.1 micrograms per milliliter. Murrayanol was found to be active in anti-inflammatory tests, with specific effects on human enzymes hPGHS-1 and hPGHS-2. The IC50 values, which indicate the strength of inhibition, were 109 and 218 micrograms per milliliter, respectively. All three carbazole alkaloids were also noted for their ability to kill mosquitoes and inhibit topoisomerase I and II—enzymes involved in DNA replication. These properties suggest that Murraya koenigii could be a valuable natural source for developing new antimicrobial and insect-repellent products.[94,95,96]

Antibacterial Activity of Murraya koenigii

The essential oils extracted from the leaves of Murraya koenigii have been found to fight against several harmful bacteria. These include Corynebacterium pyogenes, Streptococcus aureus, Bacillus subtilis, Pasteurella multocida, and Proteus vulgaris. Even when the oil was diluted to a very small amount—one part oil to 500 parts liquid—it still worked effectively to stop the growth of these bacteria. Scientists have also studied the compounds found in curry leaves. When fresh leaves are treated with acetone and separated into parts, they yield important bioactive substances called murrayanol, mahanine, and mahanimbine. These compounds are known to have antibacterial properties and may help fight infections. In another study done by Harbi and colleagues in 2016, an alcohol-based (ethanol) extract from curry leaves was tested against different types of bacteria. These bacteria included Staphylococcus, E. coli, Streptococcus, Proteus, Klebsiella pneumoniae, and Pseudomonas aeruginosa. The results showed that the curry leaf extract was able to stop the growth of all these bacteria except Klebsiella pneumoniae and Pseudomonas aeruginosa. The areas where bacterial growth was prevented were similar to those created by common antibiotics such as Amikacin and Gentamycin. This research shows that Murraya koenigii has strong antibacterial effects and may be useful in developing natural treatments against infections caused by various bacteria. The plant's essential oils and extracts could serve as alternatives or supplements to conventional antibiotics, especially in times when bacteria are becoming resistant to regular medicines.[70,71,72]

Antifungal Activity of Murraya koenigii

Extracts from the leaves of Murraya koenigii have shown the ability to fight against several types of harmful fungi. These fungi include Candida tropicalis, Candida albicans, Aspergillus fumigatus, Aspergillus niger, and Microsporum gypseum. These fungi can cause infections in humans as well as plants, making the antifungal properties of curry leaves very useful. Alcohol-based (alcoholic) extracts of curry leaves have been tested and found to be toxic to fungi such as Rhizoctonia solani and Colletotrichum falcatum. These fungi are known to cause diseases in plants, especially crops, and the ability of curry leaf extracts to stop their growth suggests potential use in protecting plants naturally. In addition to alcoholic extracts, extracts made using methanol and ethanol (types of alcohol) have been studied for their effect on fungal growth. These extracts were found to be effective in preventing the growth of fungal threads called mycelia in Rhizoctonia solani and Fusarium oxysporum. These fungi are common plant pathogens that can damage many important crops. The efficiency of the extracts varied depending on the type of fungus and the solvent used to prepare the extract. Overall, the antifungal activity of Murraya koenigii makes it a valuable plant for both medicinal and agricultural purposes. It can be used to control fungal infections in humans and also help protect crops from harmful fungal diseases. This natural antifungal property offers an alternative to synthetic chemicals, which can sometimes cause side effects or environmental harm. The findings suggest that curry leaf extracts have the potential to be developed into natural fungicides and medicines, helping reduce reliance on chemical treatments and supporting sustainable health and farming practices.[73,74]

Anti-Cancer Activity of Murraya koenigii

Certain natural compounds found in Murraya koenigii, especially in its bark and leaves, have shown promising effects against cancer cells. One important group of these compounds is called carbazole alkaloids, which include substances like girinimbine and mahanine. Research by Bhattacharya and colleagues in 2010 found that girinimbine causes cancer cells to die through a process called programmed cell death or apoptosis. This means the cancer cells are guided to destroy themselves without harming nearby healthy cells. Mahanine was shown to trigger a specific pathway involving death receptors on

cancer cells, which also leads to apoptosis. This anti-cancer effect was seen in certain types of blood cancer cells known as MOLT-3 cells, although it was not effective against all cancer cells, such as K562 cells.
Other compounds like pyrayafoline and murrafoline, along with carbazole alkaloids including mahanine, were found to be active against HL-60 leukemia cells. This supports the idea that mahanine is a major bioactive molecule in Murraya koenigii with anti-cancer properties.
Additional studies by researchers like Amna and others have shown that extracts from curry leaves can kill HeLa cancer cells, which are a type of human cervical cancer cells. Similar experiments using animal models showed that leaf extracts could help fight cancers of the intestine and colon. Overall, these findings suggest that Murraya koenigii contains natural compounds that may help in developing new anti-cancer treatments. While more research is needed, the plant's ability to target and kill cancer cells makes it a promising candidate for future cancer therapies.[75,76,77,78,79]
Immunomodulatory Effects of Murraya koenigii
The methanol extract made from the leaves of Murraya koenigii has shown the ability to boost the immune system. One way it does this is by increasing the phagocytic index. This means it helps the body's immune cells remove harmful particles, like carbon, from the bloodstream faster. This is important because phagocytosis is the process where immune cells "eat" and clear out bacteria, dead cells, and other foreign substances. In addition to helping phagocytic cells, the extract also increased the production of antibodies against ovalbumin, which is a protein often used in immune system studies. Antibodies are proteins made by the immune system to fight off infections. The extract also protected against myelosuppression, a condition where the bone marrow produces fewer blood cells, caused by a drug called cyclophosphamide. This shows that Murraya koenigii can support the body's immune defenses during stressful conditions. The research found that while the plant extract helped improve humoral immunity (which involves antibodies) and phagocytic function (the cleaning action of immune cells), it did not significantly boost cellular immunity, which is the immune response involving certain white blood cells like T-cells. In another study, methanol extract of Murraya koenigii was tested in animals whose immune systems were weakened by the drug azathioprine. The extract helped improve several important immune responses, including the delayed-type hypersensitivity (DTH) response, which is a measure of cellular immunity. It also increased the phagocytic index, white blood cell (WBC) count, and the percentage of neutrophils, which are a type of immune cell that fights infection. Overall, these findings suggest that Murraya koenigii leaf extract can act as a powerful natural agent to boost the immune system, especially by supporting antibody production and helping immune cells remove harmful substances from the body.[80,81]

Antioxidant Activity of Murraya koenigii:

Green leafy vegetables are well-known for their rich antioxidant content, which helps protect the body from harmful molecules called free radicals. Among several leafy vegetables tested, Murraya koenigii leaves showed the highest antioxidant power. This means the curry leaf plant is very effective in stopping damage caused by oxidative stress. Studies have shown that water-based (aqueous) extracts made from curry leaves can protect the heart tissues of rats from damage caused by cadmium, a toxic heavy metal. This shows that Murraya koenigii can help protect important organs from harmful effects. In another important study, Murraya koenigii was found to reduce stomach damage caused by a common painkiller called Piroxicam. This drug can sometimes cause gastric ulcers or stomach sores in people with arthritis. Researchers induced gastric ulcers in rats and then treated them with curry leaf extracts, which helped heal the stomach damage. This suggests that the plant may protect against some side effects of medicines. The benzene extract (a specific type of chemical extract) from Murraya koenigii also showed both antioxidant and antimutagenic activities in animal studies. Antimutagenic means it can help prevent changes in DNA that might lead to cancer or other diseases. These protective effects highlight the plant's potential in supporting overall health. In summary, Murraya koenigii is rich in antioxidants, which protect the body from damage caused by harmful substances. It helps protect the heart, reduce stomach ulcers caused by some medicines, and may prevent DNA damage. These benefits make curry leaves a valuable natural source for improving health and preventing diseases related to oxidative stress.[82,83,84,85]

Antipyretic Activity of Murraya koenigii;Murraya koenigii, commonly known as the curry leaf plant, has shown promising antipyretic (fever-reducing) properties in scientific studies. Researchers have tested the plant's leaf extracts, especially those made with alcohol (ethanol), in animal models to understand how well it works in reducing fever. In one study, fever was induced in rats using yeast—a common method to create a controlled fever (called pyrexia) for research. The rats were then given an ethanolic (alcohol-based) extract of Murraya koenigii leaves. The extract helped reduce the body temperature of the rats significantly. This result suggests that curry leaf extract may help in managing fever naturally. Another group of scientists, including Rageeb and his team, carried out a similar experiment using albino rats. These rats were given the alcoholic extract of curry leaves after fever was induced using yeast. The outcome was positive, showing a noticeable drop in body temperature. In fact, the results were very similar to those seen with paracetamol, a widely used commercial medicine for fever. Additionally, the alcoholic extract was tested in another model where high fever was induced using PGE1 (Prostaglandin E1), a substance known to raise body temperature. The curry leaf extract again showed a strong fever-reducing effect. These findings show that Murraya koenigii has natural compounds that can help control fever. Its antipyretic effects are similar to standard fever medicines, making it a potential natural remedy for managing fever. However, more research is needed to confirm its safety and effectiveness in humans.[86,87,88]

Anti-Ulcer Activity of Murraya koenigii

Murraya koenigii, commonly known as the curry leaf plant, has been studied for its ability to protect the stomach from ulcers. Ulcers are painful sores that can form in the stomach lining, often caused by stress, infections, or certain medications like non-steroidal anti-inflammatory drugs (NSAIDs). In one study, researchers used a hot water (aqueous) extract made from the leaves of Murraya koenigii. This extract was given to test animals in doses of 250 mg/kg and 400 mg/kg to check its effect on ulcer formation. Two models were used to create ulcers: one involved the use of NSAIDs, and the other involved pylorus ligation, a process that ties off a part of the stomach to cause ulcers by increasing acid buildup. The curry leaf extract was found to reduce the formation of ulcers in both models. It helped lower the total volume of stomach acid, decreased the number and size of ulcer wounds, and reduced both free and total acidity in the stomach. Interestingly, it also raised the pH level of gastric juice, meaning the stomach became less acidic, which is helpful in preventing ulcers. These results show that Murraya koenigii has strong anti-ulcer properties. Its ability to reduce acid and protect the stomach lining suggests it could be useful as a natural treatment for ulcers, especially those caused by stress or medications. In summary, the hot water extract of curry leaves can help protect the stomach from damage, reduce acid levels, and promote healing, making it a valuable plant for digestive health.[89,90]

Anti-Diarrheal Activity of Murraya koenigii

Murraya koenigii, also known as the curry leaf plant, has been traditionally used in Ayurvedic medicine to treat diarrhoea. This natural remedy has been used for generations, but modern scientific studies have also confirmed its effectiveness in treating digestive issues like diarrhoea. In experimental research, the leaves and seeds of Murraya koenigii showed strong anti-diarrheal effects. In one study, rats were given castor oil to induce diarrhoea, which is a common method used to test anti-diarrheal activity in animals. When these rats were treated with curry leaf extract, the number of loose stools was reduced significantly. This showed that the plant helps in controlling and reducing diarrhoea. Further tests used a part of the plant called the n-hexane extract made from the seeds. This extract was separated into different parts and was found to contain bioactive compounds such as koenimbine, carbazole, and kurryam. These compounds were responsible for reducing diarrhoea and slowing down the movement of food through the intestines. Another test called the charcoal meal test was used to study how the extract affects digestion. In this test, rats are given charcoal along with food, and the distance the charcoal travels in the intestines is measured. The curry leaf extract helped slow this movement, showing that it can reduce bowel activity and improve the symptoms of diarrhoea. In summary, both traditional use and scientific studies show that Murraya koenigii is an effective natural treatment for diarrhoea. Its seed extracts and active compounds help manage bowel movements and reduce symptoms, making it a useful herbal remedy for digestive health.[91,92,93]

Morphological description:

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Figure 1: (a)Murraya koenigii plant (b) Leaves (c) Fruits

Morphological Description of Murraya koenigii:

Murraya koenigii, commonly known as the curry leaf plant, is a small shrub or tree that usually grows to a height of about 2 to 2.5 meters. The plant has a slender stem that is dark green to brown in color. Its leaves are long, green, and show a net-like pattern of veins, which is known as reticulate venation. These leaves are the most well-known part of the plant, as they are widely used in cooking for their distinct aroma and flavor. The plant also produces small white flowers that are funnel-shaped and give off a pleasant, sweet fragrance. These flowers later develop into fruits that are small, round, and dark-colored when ripe. The fruits measure around 1.4 to 1.6 centimeters in length. Murraya koenigii is commonly found across India and is grown in many regions, including Sikkim, Assam, and the Western Ghats. It prefers warm and moist environments and can be found growing naturally in forested areas, particularly at altitudes between 500 and 1600 meters. Outside of India, the curry leaf plant grows in countries like Sri Lanka, Nepal, Bhutan, Laos, Thailand, Vietnam, and parts of China such as southern Hainan, Guangdong, and southern Yunnan. With the migration of South Indian communities, the plant was introduced to other parts of the world, including Malaysia, South Africa, and Réunion Island. In these countries, it continues to be cultivated for culinary and medicinal use. Overall, Murraya koenigii is a hardy and useful plant, valued both for its flavor and its role in traditional medicine across Asia and beyond..[68,69]

The Murraya koenigii shrub has a brown and dark green stem and is only 1-2 m tall. The leaves appear to have reticulate venation and are long. White, funnel-shaped shrubs with blooms and round, fragrant fruits that are 1.4–1.6 cm long and fragrant were found. It grows in several places of India and is found there in nation comprising the Western Ghats, Sikkim, Assam, and so on. Moist woodlands are home to Murraya koenigii trees. 500–1600 Meters above sea level, particularly in S. Hainan, Guangdong, South Yunnan, Nepal, Bhutan, Laos, and Sri Lanka, Vietnam and Thailand. When the immigrants from South India arrived,

When the curry leaves get to South-Africa, Malaysia, and Reunion-island. [4,5]

PHYTOCHEMICAL CONSTITUENTS :

SNO.	PART OF THE PLANT	PHYTOCHEMICAL PRESENT	CHEMICAL COMOSITION

1.	LEAVES	VOLATILE OILS[13-20]	Linalol (0.56%), trans-Sabinene hydrate (0.53%), trans-2-Cyclohexen-1-ol (0.48%), cis- 2-Cyclohexen-1-ol (0.54%), para-Cymen-8-ol (10.31%), β-Terpinol (2.52%), trans-Piperitol (0.40%), Chrysanthenyl acetate (0.39%), Lavandulyl acetate (1.67%), Bornyl acetate (1.68%), α-Copaene (0.82%), β- Elemene (0.35%), -Jasmone (0.11%), β-Caryophyllene (19.50%), Aromadendrene (0.72%), α- Humulene (15.24%), Butanedioic acid (2.18%), β-Selinene (3.81%), Naphthalene (1.90%), α-Selinene (6.10%), δ-Cadinene (2.03%), Nerolidol (2.64%), trans-Nerolidol (1.32%), Cycloheptane (0.13%), Spathulenol (1.98%), Caryophyllene oxide (2.14%), Viridiflorol (1.51%), 2-Naphthalenemethanol (0.66%), Trivertal (0.35%), Juniper camphor (1.57%), Cubenol (0.57%), β-Cadina-1(6), 4-diene (0.50%), Selina-6-en-4-ol (4.78%), Phytol (10.07%) [21]
		CAROTENOIDS[22]	9744 ng of lutein, 212 ng α-tocopherol 183 ng of carotene /g
		CARBAZOLE ALKALOIDS[23,24]	koenimbine, O-methyl murrayamine, O- methyl mahanine, isomahanine, bismahanine bispyrayafoline, koenigine, koenine, koenidine, mahanimbine, isomahanimbine,

			koenimbidine and murrayacine, isomahanimbicine, Euchrestine B, bismurrayafoline E, mahanimbicine, bicyclomahanimbicine, cyclomahanimbine, bicyclomahanimbine, mahanimbidine, mukonicine, 8, 8”-bis koenigine
2.	STEM	(Alcoholic extract) QUIONONE[25]	koenigine quinone A and koenigine quinone B
		ALKALOID[26-35]	pyrano carbazole alkaloid Murrayazolinol Mahanimbinol, Murrayazolidine, Murrayacinine, Mukonidine Murrayazolinine Murrayanine, Girinimbine Mahanimbine, Girinimbinol Mahanimbilol
	ROOTS[24]	Murrayanol, Murrayagetin, Marmesin-1”-O-rutinoside (benzene extract) Mukoline, Mukolinidine Girinimbin koenoline	
	FRUITS[23,24]	Mahanimbine and Koenimbine Isomahanine, Murrayanol, Murrayazolidine, Girinimbine and Mahanine	

	SEEDS[23,24]	CARBAZOLE ALKALOIDS	Iskurryam, Koenimbine and Koenine
		Mahanimbine, Girinimbine, Koenimbine, Mahanine and Isomahanine.	
		LACTONE	Indicolactone, Anisoalctone and 2,3 Epoxyindicolactone

The whole part of Murraya koenigii consists of various phytoconstituents. The entire Murraya koenigii plant contains many natural chemical compounds called phytochemicals. These include important substances like alkaloids, flavonoids, terpenes, and polyphenols. These compounds contribute to the plant's medicinal properties and make it useful for health and cooking purposes. These constituents are listed below.

CURRENT STATUS OF ANTI-MICROBIAL POTENTIAL OF PLANTS:

The antimicrobial potential of plants has gained significant attention due to growing concerns about antibiotic resistance and the side effects of synthetic drugs. Medicinal plants are known to produce a wide range of bioactive compounds, such as alkaloids, flavonoids, tannins, and essential oils, which can act against various bacteria, fungi, and viruses. These natural antimicrobials are considered safer and more affordable compared to synthetic options. They are also more accessible, especially in rural and low-resource areas, making them a practical alternative for primary healthcare.[64]

Despite their promising properties, the use of plant-based antimicrobials should be approached with caution. Many studies highlight the potential of these compounds in laboratory settings, but there is still a lack of strong clinical evidence to support their safety and effectiveness in humans. Well-designed clinical trials, especially double-blind and controlled studies, are limited. Without such studies, it is difficult to confirm the therapeutic benefits and possible side effects of plant-based treatments. Therefore, while medicinal plants hold potential as antimicrobial agents, more scientific research and clinical validation are needed to ensure their safe and effective use in modern medicine.[65,66]

FUTURE PROSPECTIVE: The research strategies mentioned offer great potential for advancing the study of Murraya koenigii (M. koenigii) genomics. By using advanced tools and sequencing methods, we can build large and detailed databases, including gene contigs and transcriptome assemblies. These databases will serve as valuable resources for understanding the genetic makeup of M. koenigii. One of the key benefits of this work is the ability to predict coding DNA sequences (CDS), which are the parts of the genome that are translated into proteins. After identifying these sequences, researchers can perform functional annotation by comparing them with known sequences in non-redundant databases. This process helps in understanding what each gene might do and how it contributes to the plant's growth, development, and other functions. Gene Ontology (GO) analysis will also be carried out to categorize these genes based on their roles in biological processes, cellular locations, and molecular functions. This helps in identifying genes that are important for specific traits or responses in the plant. In addition, genes will be classified using COG (Clusters of Orthologous Groups) or KOG (Eukaryotic Orthologous Groups) systems. This classification will help identify both paralogous genes (similar genes within the

same species) and orthologous genes (similar genes between different species). These insights will be useful in evolutionary studies and in identifying gene functions more accurately. Pathway analysis using the KEGG (Kyoto Encyclopedia of Genes and Genomes) database will allow researchers to map genes to specific biological pathways. This will give a clearer picture of how genes interact and function together in various metabolic and signaling processes. Furthermore, important genetic elements such as transcription factors—which regulate gene activity—and simple sequence repeats (SSRs), which are useful markers in breeding and genetic diversity studies, will also be identified. Overall, this comprehensive approach will significantly enhance our understanding of M. koenigii at the molecular level and open up possibilities for further genetic research, crop improvement, and medicinal applications

CONCLUSION

Murraya koenigii, also known as curry leaf, is a medicinal plant that has been used for centuries in traditional medicine. Our ancestors recognized its health benefits long ago, and today, modern science is continuing to explore its potential. This plant is known for its strong pharmacological properties, meaning it has the ability to help treat or manage various health conditions. Many scientific studies, especially preclinical ones, have shown that M. koenigii may help in reducing the symptoms of a wide range of diseases. Different parts of the plant, such as leaves, roots, and bark, can be used to make crude extracts that have many medical uses. However, while these natural extracts are helpful, they still need to be studied in greater detail before being developed into modern medicines. To create safe and effective drugs from M. koenigii, scientists need to fully understand how its compounds work in the body. This includes researching its bioactive compounds, how they affect different diseases, how much is safe to use, and how to properly standardize the dosages. Before any medicine can be approved for public use, it must go through detailed clinical trials to ensure it is both effective and safe. Therefore, it is important to carry out more scientific research on M. koenigii and its bioactive compounds. These compounds may lead to the development of new, natural-based medicines in the future. In addition to its health benefits, M. koenigii also has economic value. If its medicinal potential is properly explored, it could benefit not only patients but also farmers and industries involved in growing and processing medicinal plants. In summary, Murraya koenigii is a valuable plant with many health and economic benefits. More focused research and development efforts are needed to explore its full potential. This will help in turning traditional knowledge into modern medical solutions, making use of this natural resource in a way that benefits both healthcare and the economy.

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