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Phytochemical and pharmacological study of *Cinnamomum tamala*: A review

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Abstract
Cinnamomum tamala is a medicinal plant used in traditional system of medicine for its diverse therapeutic properties. This review explores the phytochemical composition and pharmacological activities of *Cinnamomum tamala*, focusing on its bioactive compounds, including saponins, tannins, terpenoids, phenolics, flavonoids, and alkaloids. These compounds have been shown to exhibit a wide range of pharmacological effects, such as antimicrobial, antioxidant, anti-inflammatory, analgesic, antidiabetic, anticancer, neuroprotective, hepatoprotective, and cardioprotective activities. Studies also highlight its potential in treating various health conditions, including infections, oxidative stress, inflammation, and metabolic disorders. Furthermore, the review discusses the traditional uses of the plant in Ayurvedic and folk medicine, as well as its safety profile based on available toxicity studies. This review emphasizes the need for continued research to explore the full potential of *Cinnamomum tamala* as a source of novel therapeutic agents.

Keywords: Medicinal plant, Ayurvedic medicine, phytochemical studies and pharmacological studies

Introduction
Cinnamomum tamala Indian bay leaf, is a genus of evergreen tree of aromatic type that occurs in the Indian subcontinent and predominantly in tropical as well as temperate tracts of Bangladesh, Nepal, and India. The nearest relationship of this genus is with the other renowned species belonging to the same genus, i.e., *Cinnamomum verum* or true cinnamon, and *Cinnamomum cassia or cassia*. It is a member of Lauraceae family. *Cinnamomum tamala* unlike these relatives, is valued for its aromatic leaves instead of the bark. In cooking and medicine, the plant has been a vital part of Indian life. Due to their distinct taste and aroma and numerous medicinal applications, the leaves, or "Tej Patta" in Hindi, have found extensive use across numerous traditional methods, from herbal medicine to cooking [1].
Cinnamomum tamala is a tall medium-sized tree that generally grows 15 to 20 meters tall with dense bushy crown and smooth leathery leaves. The leaves are lance-shaped and elongated, having a top surface of deep green colour and slightly hairy underside. They possess aromatic nature due to the essential oils, particularly eugenol, that are responsible for imparting the plant with typical spicy, warm odour. The plant prefers subtropical and temperate temperatures in the Himalayan foothills and parts of the Western and Eastern Ghats. It thrives well in well-drained fertile soil and is commonly found between 1,000 and 2,500 meters in elevation [2]. *Cinnamomum tamala* can tolerate different climates because it is an evergreen and therefore has leaves on the plant throughout the year. It has berry-like fruit which matures into black drupes containing planting seeds, while its tiny, yellow-green flowers are very inconspicuous [3]. Indian cuisine is deeply rooted in the use of *Cinnamomum tamala* in Indian cooking. The leaves are highly prized for their pungent aroma and are used almost entirely dry. They are a key ingredient in the preparation of most Indian recipes, particularly rice recipes such as pulao and biryani. In these preparations, the leaves are put into the pot so that they release their essential oils, which provide a distinctive, delicate flavour to the food that is a balance of sweetness and heat. Because of their rough texture, the leaves are frequently used whole and removed before serving [4]. Indian bay leaves are a significant ingredient in spice mixtures like garam masala, which are fundamental to Indian

subcontinental cuisine. Other than in the flavouring of food, *Cinnamomum tamala* is employed in tempering, a method of adding a foundation flavour to stews, curries, and other foods through frying whole spices in hot oil to release their aromatic oils [5].

Beyond the kitchen, *Cinnamomum tamala* finds application in traditional medicine, particularly in Ayurveda, where its numerous medicinal applications are greatly appreciated. Various medical conditions, including digestive, inflammatory, and respiratory diseases, are treated with leaves and essential oil of the tree. *Cinnamomum tamala* was considered to be warm in nature that causes hunger as well as facilitates the ease of digestion within Ayurvedic medicine [6].

Cinnamomum tamala is also used as anti-inflammatory and used in most typically in the cure of a disease like arthritis and sore muscle. Because of its notable reported antibacterial and antioxidant activity, the plant's essential oil can cure infection as well as boost immunity. *Cinnamomum tamala* antibacterial activity are especially helpful in treatment of respiratory conditions like cough, bronchitis and colds. Additionally, it is frequently combined with herbal oils and drugs that are said to be used to treat congestion symptoms. Also, research has indicated that certain plant parts may be useful in controlling blood sugar level, which may help in diabetic patients in treatment of diabeties [7]. To extract the essential oils, *Cinnamomum tamala* is also very important. The leaves are steam-distilled to produce an oil with a high concentration of phenolic compounds, including cinnamon aldehyde and eugenol, which give the oil its distinct ascent and therapeutic properties. *Cinnamomum tamala* used in fragrance therapy to relieve stress, anxiety, and mental conditions because of its calming and mood-enhancing properties. The oil is used in the fragrance and perfumery industries. Also, due ot its antibacterial and anti-inflammatory properties, which helps in skin disorders like acne and irritated skin, *Cinnamomum tamala* oil is used in cosmetics [8].

Although *Cinnamomum tamala* is widely used and has a high economic value, there are a few sustainability concerns. Due to habitat loss in some areas and overuse of wild plants, there have been problems meeting the species long-term needs. Against this drwaback, efforts are being made to promote the cultivation of *Cinnamomum tamala* in controlled environments in an attempt to guarantee its sustainable use without depleting natural resources. Research is being done on cultivation systems that allow for sustainable harvesting and species conservation in order to balance environmental preservation with demand [9].

Cinnamomum tamala is important outside of India. Because of its similar culinary and medicinal uses, its fragrant leaves and essential oil are currently in style in other parts of Asia, the Middle East, and even some parts of Africa. As the influence spread to other civilisations, the spice was bartered and utilised by others for centuries in their regional cuisine and traditional medicines. The continued global demand for *Cinnamomum tamala* particularly in essential oils and herbal products, is indicative of the plant's continued use in various industries.

Multi-functional tree, it is currently in great demand on the global market, and continued cultivation is required to supply consumers everywhere [10]. The tree's natural habitat is under threat from habitat loss and deforestation, which may have an effect on its natural populations. There has been a demand for alternative ecologically friendly cultivation techniques that aim to reduce the environmental impact of the tree that is taken from the wild. Due to the increasing demand of *Cinnamomum tamala* essential oil and its therapeutic uses, pressure on both wild and planted resources has increased. Therefore, sustainable agriculture and conservation measures are crucial in an attempt to provide the benefits of this magnificent plant for the upcoming years [11].

Plant Profile

- **Scientific Name:** *Cinnamomum tamala*
- **Common Name:** Indian Bay Leaf, Tamala, Tejpatta (in Hindi), Dalchini.
- **Kingdom:** Plantae
- **Subkingdom:** Tracheobionta (vascular plant)
- **Division:** Magnoliophyta (flower plant)
- **Class:** Magnoliopsida (Dicot)
- **Subclass:** Magnoliidae (group of flower plant)
- **Order:** Laurales
- **Genus:** *C. Schaef*
- **Family:** Lauraceae
- **Species:** *C. tamala*
- **Synonyms:** *C. zeylanicum*, *C. glaucescens*.

Source: Botanical Garden, MJP Rohilkhand University, Bareilly

Fig 1: Image of *Cinnamomum tamala* tree

Fig 2: Image of *Cinnamomum tamala* fresh leaves

Source: Botanical Garden, MJP Rohilkhand University, Bareilly

Fig3: Image of *Cinnamomum tamala* Dry leaves

Phytochemical Study

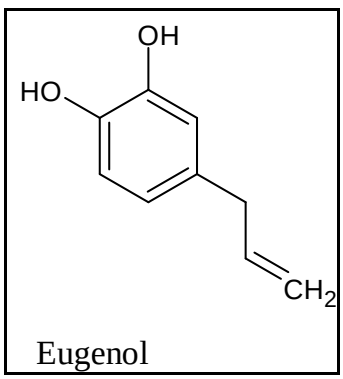
The phytochemical study of *Cinnamomum tamala* gives a wide range of bioactive compounds with culinary, medicinal, and aromatic applications in the leaves, essential oils, and other plant parts. This plant, native to the Indian subcontinent, has long been valued for its therapeutic properties in traditional medical systems such as Ayurveda and Unani system. Uninterrupted research continues to explore and identify the many bioactive compounds it contains [12]. Research has shown that plant essential oils have broad antimicrobial activity, antiviral, antifungal, and antibacterial properties, which make them effective against a variety of diseases. In addition, *Cinnamomum tamala* has been considered one of the most probable sources of natural antioxidants with a high potential for preventing oxidative damage and maintaining general health. *Cinnamomum tamala* incredibly diverse phytochemical composition suggests that it will be used in the development of natural medications and treatments of a variety of illnesses, such as microbial infections, oxidative stress, analgesic, viral infection and inflammation. Further research is required to better understand the therapeutic value of such chemicals to humans [13].

The naturally occurring phytochemical elements in plants affect their bioactivity, flavour, aroma, and colour. The plant's bioactivity, sensory qualities, occurrence of medicinal properties, and remedial qualities are all determined by its essential oils, phenolic compounds, flavonoids, terpenoids, alkaloids, and organic acids. According to reports, *Cinnamomum tamala* contains phytochemicals with a variety of pharmacological properties, such as antibacterial, antioxidant, analgesic, cardioprotective, diuretic, anti-inflammatory, anti-diabetic, and anti-cancer properties. The important phytochemicals found in *Cinnamomum tamala* will be discussed in this section [14].

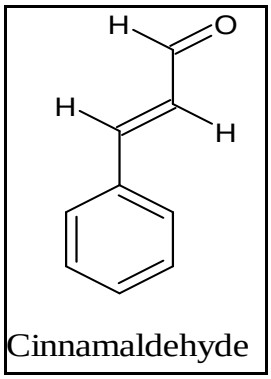
- Eugenol is the main component as an essential oil, eugenol possesses strong analgesic, antiseptic, and anti-inflammatory properties. It is frequently utilised as an antimicrobial agent and in dental care products. The *Cinnamomum tamala* ability to lower oxidative stress in the body is also a result of its antioxidant activity, which is the main factor influencing senescence and disease prevention [15].
- Cinnamaldehyde is also in charge of giving *Cinnamomum tamala* its distinct scent. Cinnamaldehyde has demonstrated potent antifungal, antibacterial, and anti-inflammatory properties in addition to its odour. As well it has shown promise in controlling blood sugar levels, making it a potential medication for the treatment of diabetes patients [16].
- Linalool *Cinnamomum tamala* contains the bioactive and multipurpose phytochemical compound linalool, it has a variety of therapeutic uses. It is an important element in both conventional and traditional medicine because of its neuroprotective, anti-inflammatory, anxiolytic, analgesic, antioxidant, and antimicrobial properties. In addition to improving gastrointestinal, skin, and sleep health, linalool also has also use to repel insects [17].
- Caryophyllene is a phytochemical compound with a wide range of medicinal uses. It is a valuable phytochemical compound in both traditional and modern medicine because of its anti-inflammatory, analgesic, antioxidant, antimicrobial, anticancer, neuroprotective, and cardioprotective properties. Its applications in a variety of health and well-being contexts are further supported by its therapeutic uses in treating anxiety, improving skin health, and acting as an insect repellent [18].
- Quercetin *Cinnamomum tamala* contains bioactive flavonoids called quercetin, which play a major role in the plant's therapeutic and pharmaceutical value. They are useful compound for maintaining overall health and preventing disease because of their anti-inflammatory, anti-cancer, antimicrobial, neuroprotective, and cardioprotective properties. The compounds also help treat skin conditions like, allergies, itching, rashes and diabetes [19].
- Kaempferol is an extremely potent substance with a variety of medicinal applications. Kaempferol is a flavonoid that has anti-inflammatory, anti-cancer, antimicrobial, neuroprotective, cardioprotective, and antidiabetic properties. Its value as a compound for enhancing general health cannot be magnified. Its value as a medication for these conditions is increased by its ability to prevent stress, inflammation, and cell damage [20].
- alpha-pinene *Cinnamomum tamala* contains alpha-pinene, a valuable bioactive compound with a wide range of application. The compound is remarkable therapeutic agent that has the potential to treat hundreds of diseases due to its anti-inflammatory, antioxidant, antimicrobial, bronchodilator, and cognitive-enhancing properties. In addition to its pharmacotherapeutic action, the compound has anticancer, neuroprotective, and analgesic properties. When used in both traditional medicine and contemporary regimens, its anti-anxiety, anti-ulcer, dermatology, and insect-replicant properties give it more value.
- Beta-caryophyllene oxide is one of the main phytochemical components of *Cinnamomum tamala* that gives the plant its variety of therapeutic uses is beta-caryophyllene oxide. It is an important bioactive molecule because of its anti-inflammatory, antimicrobial, antioxidant, analgesic, and

neuroprotective properties. Its benefits for wound healing, cardiovascular protection, stress management, and respiratory health [21].

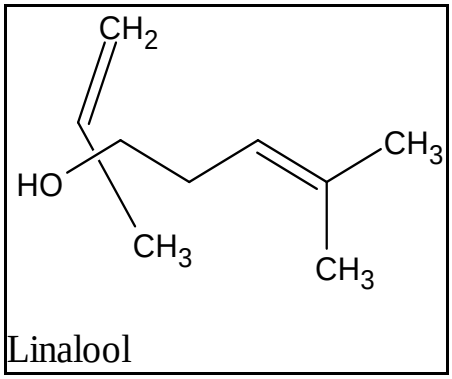
- Citric acids in *Cinnamomum tamala*, citric acids are important phytochemical molecules that are in charge of the plant general health. Their presence in the plant enhances its detoxifying, antimicrobial, anti-inflammatory, antioxidant, and digestive health benefits. *Cinnamomum tamala* is an important herb used in the preservation of general well-being because the acids also support energy production, liver health, and skin health [22].
- Malic acid is a multipurpose phytochemical compound with a possible health advantage, including antibacterial, detoxifying, anti-inflammatory, and antioxidant properties. As a result, it is a substance that is very helpful in maintaining general health. Malic acid supports a healthy digestive system, helps produce energy, maintains healthy skin, and may even help treat stress and fatigue [23].
- Camphor is well known for its ability to keep insects away. Moreover, they are widely used in the manufacturing of products that repel insects, especially mosquitoes and other insects. *Cinnamomum tamala* camphor has a variety of biological properties that make it useful in medications and medical treatments, especially in respiratory, analgesic, antimicrobial, and anti-inflammatory.
- Gallic acid has a variety of pharmacological properties, such as antibacterial, anti-inflammatory, antimicrobial properties, cancer prevention. and cardiovascular protective activity, gallic acid, a bioactive component of *Cinnamomum tamala*, is necessary for preserving good health. The medicinal benefits of *Cinnamomum tamala* in traditional medicine and its application in a variety of therapeutic procedures are due to the presence of gallic acid in the plant's roots and leaves.
- Cinnamonic acid is the main factor contributing to *Cinnamomum tamala's* therapeutic value is its bioactive component, cinnamonic acid. It is a costly and highly effective substance that can be used in both traditional and modern medicine due to its broad range of pharmacological activities, which include anti-inflammatory, anti-cancer, antimicrobial, antioxidant, and neuroprotective effects [24].
- Chlorogenic acid is the bioactive component of *Cinnamomum tamala*. Chlorogenic acid, greatly enhances the plant potential. It is a significant compound for both traditional and contemporary medical applications due to its numerous pharmacological activities, which include antioxidant, anti-inflammatory, antimicrobial, anticancer, antidiabetic, and neuroprotective properties.
- Ferulic acid a phytochemical found in *Cinnamomum tamala*, is the preferred medication that gives the plant its therapeutic properties by providing a variety of beneficial biological activities. It is an intriguing substance that can be used in both conventional and contemporary medical treatment because of its antimicrobial, cardioprotective, neuroprotective, anti-inflammatory, anticancer, and antioxidant properties [25].
- Piperine *Cinnamomum tamala* contains a wealth of pharmacological activity from piperine, which is primarily found in black pepper. It is an important molecule to be used in medical and health applications because of its diverse range of biological effects, which include weight modulation, antioxidant, anti-inflammatory, antimicrobial, anticancer, neuroprotective, and bioavailability enhancement.
- Apigenin a bioactive phytochemical compound found in *Cinnamomum tamala* that has important implications for its pharmacological activity. The plant drug-like properties are due to apigenin, which has many desirable properties, including antioxidant, anti-inflammatory, anticancer, neuroprotective, antimicrobial, and anxiolytic activity. The fact that *Cinnamomum tamala* contains apigenin supports the use of the plant in traditional medicine to treat a variety of illnesses, including dermatitis, cancer, inflammation, and anxiety.
- Limonene *Cinnamomum tamala* contains limonene, a potent phytochemical compound that gives the plant medicinal and pharmacological properties. Globally the plant's health value is increased by its anti-inflammatory, anti-microbial, anticancer, neuroprotective, anti-anxiety, and cardioprotective properties [26].



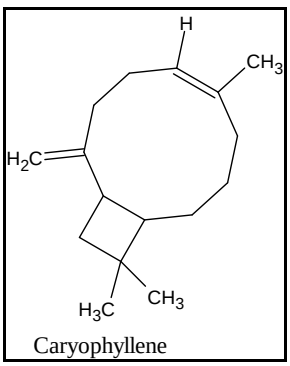
Eugenol

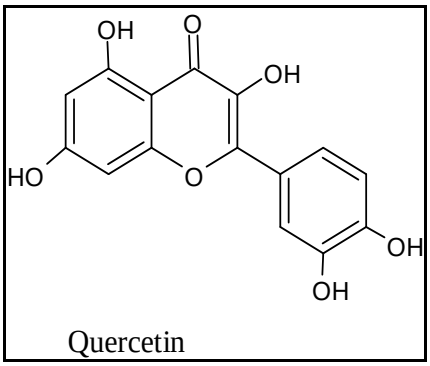


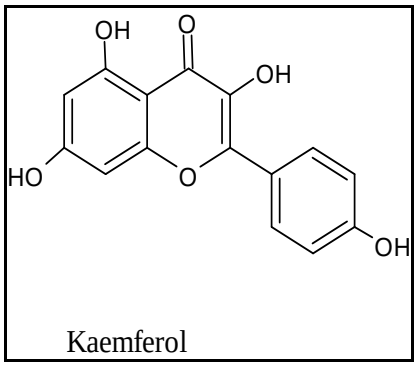
Cinnamaldehyde

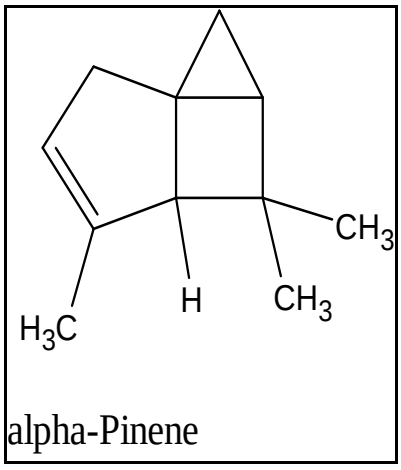


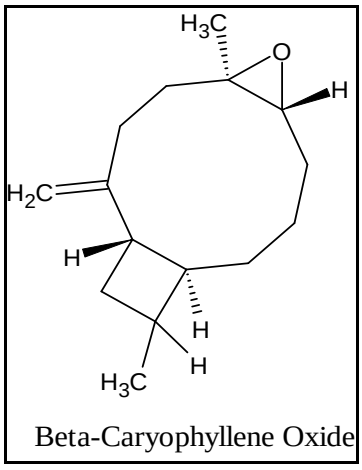
Linalool

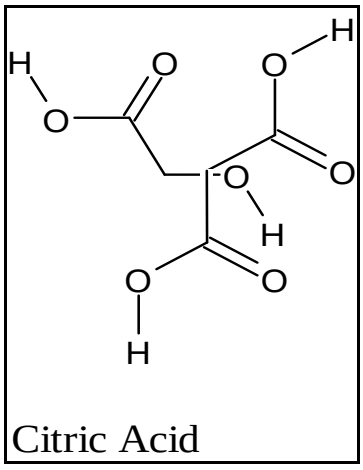

Caryophyllene

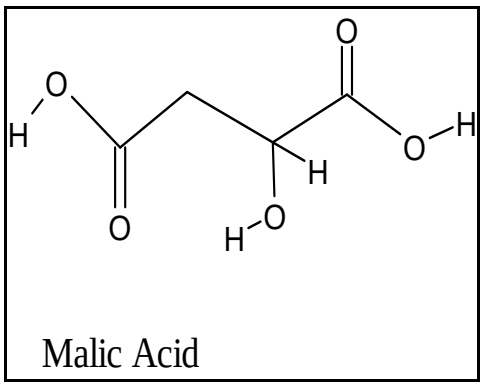

Quercetin

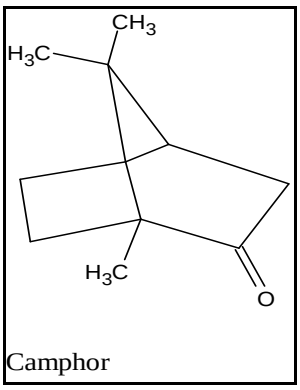

Kaemferol

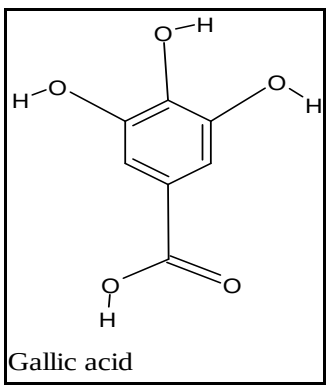

alpha-Pinene

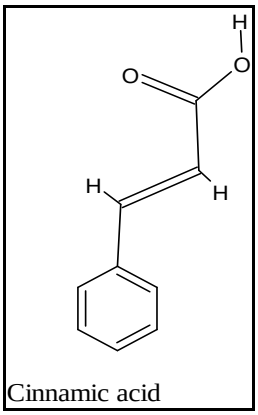

Beta-Caryophyllene Oxide

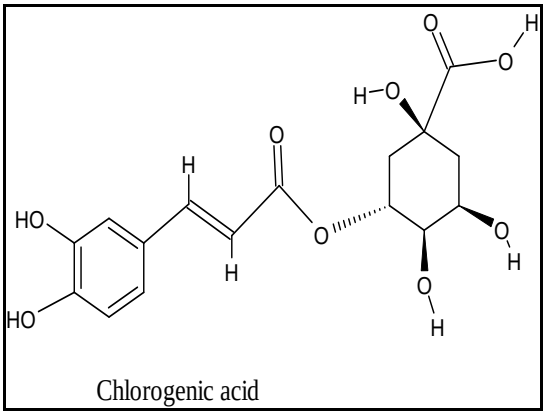

Citric Acid

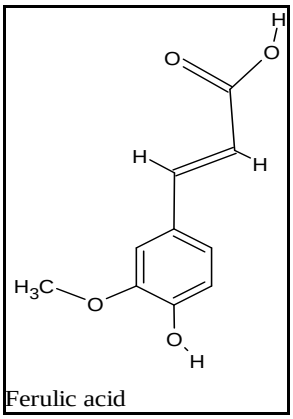

Malic Acid


Camphor


Gallic acid


Cinnamic acid


Chlorogenic acid


Ferulic acid

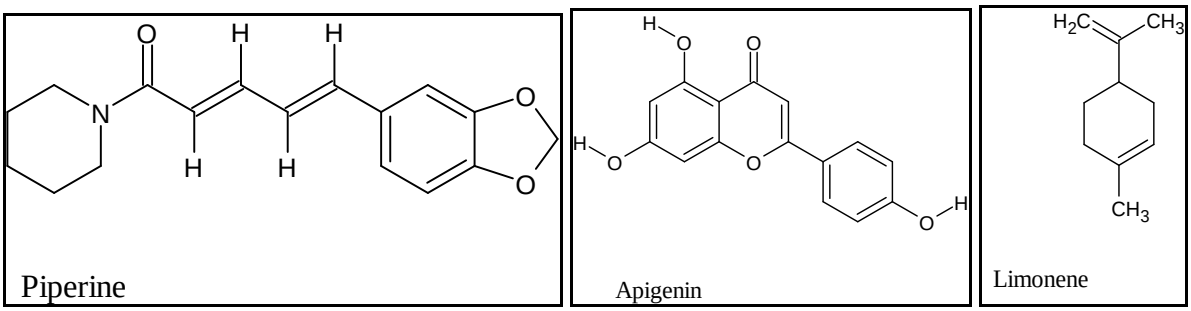


Fig 4: Structures of various phytochemicals compounds

Pharmacological Study

Over the past few years, pharmacological research on *Cinnamomum tamala* has gained more attention as scientists start to confirm the plant's therapeutic potential based on its chemical makeup. Preclinical studies have found a variety of pharmacological properties, including analgesic, antimicrobial, antibacterial, anti-inflammatory, antioxidant, anti-diabetic, cardioprotective, diuretic, hepatoprotective, antidiarrheal and anticancer activities. In light of these discoveries, *Cinnamomum tamala* shows promise for a number of therapeutic uses [27].

Pharmacological research on *Cinnamomum tamala* aims to explain the mechanism of action for the plant's therapeutic benefits. The plant's many bioactive components, particularly its essential oils and phenolics, are likely responsible for its anti-inflammatory, anti-infection, control blood sugar level, oxidative stress protective, and possibly anticancer properties, which include inhibiting the growth of cancer cells. With this knowledge of its pharmacological properties, *Cinnamomum tamala* traditional use can now be expanded as it can be more effectively incorporated into current medical treatments. Antioxidant activity is among *Cinnamomum tamala* most well-known pharmacological properties. It will fight off free radicals and protect cells from oxidative damage, which is a major cause of chronic diseases like diabetes, heart disease, and neurological disorders. Since inflammation is a common cause of conditions like arthritis, inflammatory bowel disease, and cardiovascular disorders, the plant's anti-inflammatory properties are also crucial for managing inflammation. *Cinnamomum tamala* has been demonstrated to have potent antibacterial activity against a variety of bacterial, viral, and fungal pathogens, making it a potential natural remedy for infection [28].

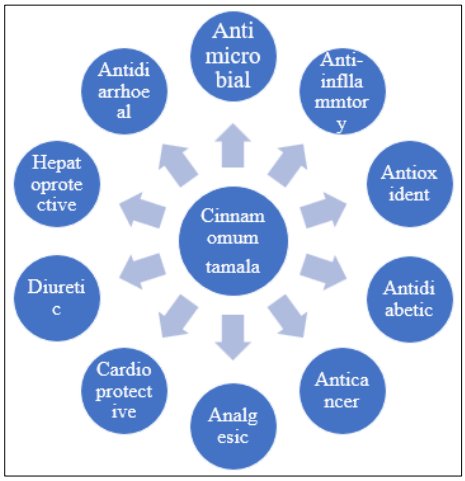


Fig 5: Various pharmacological activities

- Antimicrobial Activity Indian Bay leaf or *Cinnamomum tamala* is one of the most studied plants for its antimicrobial activity, which has proven to be effective against numerous microbial infections. The plant is rich in bioactive phytoconstituents such as essential oils (eugenol), flavonoids, and phenolics, which are responsible for the antimicrobial activity of the plant. Research has proven that *Cinnamomum tamala* extracts possess strong antibacterial activity against Gram-positive and Gram-negative bacteria such as the common pathogens Pseudomonas aeruginosa, Escherichia coli, and Staphylococcus aureus [29]. The disruption of microbial cell membranes is thought to be responsible for the plant's essential oils, particularly eugenol. Besides this, *Cinnamomum tamala* also exhibited antifungal activity against various fungi with maximum efficacy shown against fungus like Candida albicans, which are most infectious to human beings. *Cinnamomum tamala* is also antibacterial and antiviral; it has been shown to suppress some viruses from multiplying [30]. *Cinnamomum tamala* antibacterial activity is a result of its capacity to interfere with synthesis of vital cellular components of the microorganisms, inhibit microbial enzymes, and suppress the formation of cell walls. *Cinnamomum tamala* broad-spectrum antibacterial activity makes it a potential natural medication for infections, particularly in light of the growing antibiotic resistance. However, more study is required to determine its efficacy and safety for clinical use. If all else is equal, the plant's antibacterial properties make it a strong contender for the manufacturing of natural antimicrobial medications [31].
- Anti-inflammatory Activity Numerous studies have documented the anti-inflammatory properties of *Cinnamomum tamala* shows the plant's efficacy in treatment of illnesses linked to inflammation. The plant's abundance of bioactive substances, such as flavonoids, phenolic acids, and essential oils, is primarily what gives it its anti-inflammatory properties. Studies have shown that compounds from the *Cinnamomum tamala* can inhibit the activity of pro-inflammatory mediators that trigger the inflammatory response, such as prostaglandins, cytokines, and nitric oxide. The plant stops the production of inflammatory chemicals by inhibiting enzymes like COX and LOX (Cyclooxygenase and Lipoxygenase) respectively. Chemicals found in essential oils, such as eugenol, are recognised as potent anti-inflammatory agents because they reduce the level of inflammatory mediators and inhibit the expression of inflammatory genes [32]. This is

further supported by data showing that *Cinnamomum tamala* can lessen inflammatory chronic diseases like arthritis by reducing joint stiffness, pain, and oedema. The plant's antioxidant properties also serve the dual purpose of scavenging free radicals, which would otherwise increase tissue damage and inflammation. *Cinnamomum tamala* has been found to be an effective anti-inflammatory agent in a number of animal models of inflammation, including inflammation induced by formalin and carrageenan. Because of its wide-ranging effects on inflammation, the plant may be thought of as a naturally occurring medication with potential for the treatment of inflammatory bowel disease, arthritis, and even skin irritation. Human clinical trials must be carried out in order to better understand the drug's potential and level of anti-inflammatory properties [33].

- Antioxidant Activity Various studies have examined the antioxidant properties of *Cinnamomum tamala* also known as Indian bay leaf, which have been attributed to its high bioactive content of tannins, phenolics, flavonoids, and essential oils. These substances help in the detoxification of free radicals, which are unstable molecules linked to oxidative stress and the development of chronic illnesses such as cancer, heart disease, and neurological conditions [34]. Scientific studies have shown that *Cinnamomum tamala* extracts have strong antioxidant activity through scavenging free radicals and inhibiting lipid peroxidation, which kills cell membranes. Because they can stabilise free radicals and lessen their toxicity by supplying electrons, the plant's eugenol and phenolic fractions are in charge of preventing oxidative damage. *Cinnamomum tamala* has also been shown to boost the activity of antioxidant enzymes that protect cells from oxidative damage, including catalase (CAT) and superoxide dismutase (SOD). By shielding essential organs like the liver and kidneys from oxidative stress, its antioxidant potential also enhances the general health of cells [35]. Also *Cinnamomum tamala* encourages the suppression of inflammation, which is typically brought on by high levels of oxidative stress. Because of its strong antioxidant activity, the plant can be used to prevent and treat conditions brought on by oxidative damage. Further clinical trials are required to evaluate its long-term safety and efficacy in humans. All things considered, *Cinnamomum tamala* does hold potential as a natural antioxidant with therapeutic value for prevention of oxidative damage [36].
- Antidiabetic activity Many research investigations have looked into the potential of *Cinnamomum tamala* to control blood sugar and prevent diabetic complications. Flavonoids, phenols, and volatile oils are among the bioactive substances found in the plant that give it its antidiabetic properties. *Cinnamomum tamala* extracts have been shown to improve insulin sensitivity and regulate blood glucose levels in Type 1 and Type 2 diabetes models. By promoting the uptake of glucose into cells and causing the release of insulin from pancreatic cells, it is believed to reduce blood glucose levels [37]. Also, its antioxidant activity is crucial in reducing oxidative stress, which is a significant factor in the endemicity of diabetes and its complications. Additionally, studies have demonstrated that *Cinnamomum tamala* can delay the consumption of sugar and prevent the highest blood sugar levels after meals by blocking the activity of the enzyme α-glucosidase, which converts carbohydrates into glucose. Also, the herb's anti-inflammatory and antioxidant properties have been demonstrated to reduce the risk of complications from diabetes, including neuropathy and renal damage. Furthermore, it has been noted that *Cinnamomum tamala* helps in lipid profiles by reducing cholesterol and triglyceride levels, which are often elevated in diabetics. Although encouraging, additional clinical research is required to prove its effectiveness and establish the optimal dosages for human use. Yet *Cinnamomum tamala* shows great promise as a natural supplement to diabetes treatment, enhancing glucose control and overall metabolic health [38].
- Anticancer activity Indian bay leaf or *Cinnamomum tamala* anticancer activity has been under the spotlight due to the presence of bioactive compounds with strong bioactivity in the form of essential oils, flavonoids, and phenolic acids with more than one mechanism of action against cancer cells. Experiments have proved that *Cinnamomum tamala* extracts could stop growth and proliferation of different cancer cell lines such as those of breast, liver, and colon cancers [39]. The plant's essential oil, especially eugenol, was thought to promote apoptosis, or programmed cell death, in cancer cells through induction of different pathways, of which are caspase activation-related and mitochondrial dysfunction-related pathways. Besides this, *Cinnamomum tamala* has also shown anti-inflammatory activity, reducing chronic inflammation generally beneficial in the progression of cancer growth and development. Its antioxidant activity is also important in order to defend cells against oxidative stress that results in the deterioration of DNA and causes cancer [40]. Additionally, *Cinnamomum tamala* has been beneficial in preventing tumour growth by preventing tumour angiogenesis, in which tumours stimulate new vessel formation for their sustenance. In addition, the plant contains metabolites with anti-metastatic properties to suppress cancer cell metastasis to the rest of the body. Preclinical trials are promising but additional research and clinical trials would be needed in order to ultimately determine *Cinnamomum tamala* anticancer value and potential as a natural anticancer therapeutic adjuvant. The plant is, nevertheless, a drug candidate for new drugs against cancer according to its apoptotic, anti-inflammatory, antioxidant, and anti-metastatic activity [41].
- Analgesic and Anti-inflammatory Activity Analgesic activity of Indian bay leaf, *Cinnamomum tamala* was studied in different pharmacological tests, and it was seen that it has pain-reducing activity. The plant's pain-relieving activity is founded on its bioactive constituents including essential oils, flavonoids, and phenolic acids that have been discovered to affect pathways of pain in the body. Based on animal studies, *Cinnamomum tamala* extracts have been found to possess the potential to block pain in a range of disorders like neuropathic, nociceptive, and inflammatory pain. The plant's essential oils, particularly eugenol, are said to be locally anaesthetic in nature, reducing sensation of pain through anaesthesia of the painful area [42]. In addition to this, *Cinnamomum*

tamala possesses anti-inflammatory activities that reduce pain caused by inflammation, like arthritis. The plant reduces pain and oedema by inhibiting the formation of inflammatory mediators like prostaglandins and cytokines. The anti-oxidant activity of the plant also reduces oxidative stress that is a cause of tissue damage and pain. In addition, the phytochemicals in the plant can modulate pain receptors like opioid and TRPV1 receptors that transmit pain. Encouraging as this is, further clinical trials will be required to fully determine *Cinnamomum tamala* mechanism of action and medicinal use to human pain treatment. In totality, *Cinnamomum tamala* is a good candidate for the preparation of natural analgesic pharmaceuticals based on its anti-inflammatory, antioxidant, and local anaesthetic activities [43].

- Cardioprotective Effects *Cinnamomum tamala* (Indian bay leaf) has been targeted in a number of pharmacological studies with special focus on its cardioprotective effect that signifies its potential to guard the heart against several types of insults. The cardiovascular protective effect is attributed to bioactive molecules like flavonoids, essential oils, and phenolic acids found in the plant. *Cinnamomum tamala* is capable of decreasing blood pressure, which is one of the main causes of the prevention of cardiovascular disease such as hypertension and stroke, based on research. Since oxidative stress plays an important role in the development of atherosclerosis and other cardiovascular diseases, antioxidant activity is required in decreasing the level of oxidative stress. The plant suppresses the threat of vascular inflammation and plaque formation by safeguarding against the endothelial lining cells of the blood vessels through free radical scavenging. The anti-inflammatory activity of *Cinnamomum tamala* also suppresses chronic inflammation, which can lead to damage in the heart and blood vessels [44]. The cardioprotective activity of the plant, which reduces vulnerability to heart disease, is also due to it having the ability to rectify lipid profiles, such as reducing triglycerides and cholesterol. Additionally, studies have shown that it can enhance myocardial contractility and reduce ischaemic damage in conditions like myocardial infarction (heart attack), which would enhance the function of the heart. In addition, *Cinnamomum tamala* can reduce the rate of diabetic complications, which tend to lead to cardiovascular complications, by regulating blood sugar. Though encouraging, more clinical trials are required to better identify its cardioprotective mechanisms and ascertain its therapeutic utility in human populations. Nevertheless, *Cinnamomum tamala* lipid-lowering, anti-inflammatory, and antioxidant effects position it as an encouraging natural drug for cardiovascular illnesses [45].
- Diuretic The diuretic property of *Cinnamomum tamala* (Indian bay leaf) has been apparent in most pharmacological investigations, demonstrating its efficacy in urination stimulation and fluid balancing within the body. Diuretic effect is given mainly by the bioactive constituents of flavonoids, phenols, and essential oils, which are purported to enhance renal function. Studies have illustrated that *Cinnamomum tamala* extracts induce natriuresis, sodium excretion, and thus increased water loss through osmotic processes. Further, the herb enhances renal flow and glomerular filtration rate (GFR) to promote urine formation [46]. The diuretic activity of *Cinnamomum tamala* has also been attributed to the property of the plant in modulating electrolytes, i.e., sodium and potassium, which produce an optimal fluid and electrolyte equilibrium. Antioxidant activity of the plant decreases oxidative stress in the kidneys, thus enhancing kidney function and excretion of waste products. The extracts of the plant have also been found, in animal experiments, to cure conditions such as edema (water retention) and mild high blood pressure through the reduction of water retention in tissues. But although *Cinnamomum tamala* has potential diuretic activity, care should be taken in patients with renal impairment or diuretic drugs as there may be excessive loss of fluid and electrolyte imbalance. More clinical studies need to be conducted to determine the full safety, dosage, and long-term effects of the plant's diuretic action on the human body. Yet, it is optimistic as a drug from nature in the management of water retention and kidney protection [47].
- Hepatoprotective the hepatoprotective activity of Indian bay leaf, *Cinnamomum tamala*, has been well researched and has been shown to possess the ability to safeguard the liver against damage by a number of toxins and oxidative stress. *Cinnamomum tamala* leaf extracts have been shown in studies to be significantly protective against chemically induced liver injury, for example, carbon tetrachloride (CCl_4)-induced liver injury, a liver toxin. Hepatoprotection is largely due to the antioxidant nature of the plant because it alleviates oxidative stress via free radical scavenging and induction of activities of endogenous antioxidant enzymes such as superoxide dismutase (SOD) and catalase (CAT). Antioxidants inhibit oxidative damage to hepatocytes (liver cells), which is the major reason for liver impairment. In addition, *Cinnamomum tamala* can return the normal range of liver enzymes, including aspartate aminotransferase (AST) and alanine aminotransferase (ALT), increased in liver injury [48]. The plant has anti-inflammatory effects by regulating inflammatory markers and inhibiting the release of pro-inflammatory cytokines that lead to fibrosis and cirrhosis in the liver. Also, *Cinnamomum tamala* assists in enhancing liver regeneration by inducing mechanisms of cell repair and preventing fibrosis. It is further recommended by several studies to be hepatoprotective against alcohol through the prevention of lipid peroxidation and enhanced detoxification potential of the liver. The plant's action to reduce hepatotoxicity along with enhanced liver function demonstrates that it could be a fine subject to be considered for its application in liver disorder, yet clinical trials are to be undertaken in order to demonstrate its effectiveness and safety among human beings [49].
- Antidiarrhoeal Activity *Cinnamomum tamala*, antidiarrhoeal activity has been researched in various studies, and its effectiveness in curing diarrhea and indigestion has been proven. The plant has been traditionally used in Ayurvedic medicine for the

treatment of stomach disorders, and recent studies also prove its effectiveness. Antidiarrhoeal activity of leaf extracts of *Cinnamomum tamala* is highly effective in animal models by decreasing the incidence and severity of loose stools. The bioactive constituents of the plant, i.e., flavonoids and essential oils, are attributed with this effect by regulating gut motility and blocking excess secretion of fluid into the intestines. Research has established that plant extracts function in the role of inhibiting intestinal transit time, and thus increased water absorption with a decrease in stool liquidity [50]. Anti-inflammatory activity, which suppresses irritation and inflammation of the gastrointestinal tract, which usually follows diarrheal states, is also displayed by *Cinnamomum tamala*. Besides that, its antimicrobial activity can assist in fighting the viral or bacterial infection that leads to diarrhea [51]. The ability of the plant to regulate contractions of the gut smooth muscles also assists in regulating excessive peristalsis, a fundamental mechanism in diarrheal attacks. Its antioxidant activity also assists in avoiding oxidative stress on the intestinal lining, which could lead to diarrhea. Although *Cinnamomum tamala* appears to be promising as herbal remedy against diarrhea, additional investigations by way of clinical trials need to be undertaken to prove its efficacy and safe doses to administer in human patients. Yet, its antimicrobial, anti-inflammatory, and gut-modulating activity makes it a candidate to determine if it might be an effective therapy for treating diarrhea [52].

Conclusion

In Summary, the phytochemical and pharmacological studies of Indian Bay Leaf (*Cinnamomum tamala*) underscore its enormous medicinal value, based on its profuse array of bioactive compounds. Chemicals such as eugenol, cinnamaldehyde, and terpenoids, flavonoids, and phenolic compounds are but a few among the reasons for its curative properties, which include antimicrobial, anti-inflammatory, antioxidant, and analgesic activities. The findings are consistent with the traditional practices in Ayurveda, in which the plant has been employed medicinally for the healing of numerous diseases. *Cinnamomum tamala* effectiveness against inflammation, blood glucose levels, and the prevention of chronic diseases like cancer and cardiovascular diseases has been demonstrated by pharmacological studies. In the context of type 2 diabetes, the plant's antidiabetic potential to improve insulin sensitivity and maintain a stable blood glucose level is noteworthy and clinically significant. Also, the plant analgesic, curative, and antioxidant properties make it deserving of use as a natural medication to treat a variety of illnesses. Even though the preclinical findings are encouraging, more extensive research and clinical trials are needed to determine the plant's safety, effectiveness, and modes of action in people. All things considered, *Cinnamomum tamala* is a potent medicinal herb with a wide range of pharmacological activity. Its future use as a natural medicine to treat a variety of illnesses is justified by the potential for curing and mitigating the effects of its bioactive compounds, which may open up new therapeutic drug avenues in modern medicine. Even though there are encouraging preclinical results, larger-scale clinical trials and comprehensive research are necessary to fully appreciate the plant's safety, effectiveness and mechanisms in human subjects. A traditional medicinal plant with a wide range of pharmacological properties is *Cinnamomum tamala*. Additional research on its bioactive principles may open the door to novel plant-based therapeutic interventions in modern medicine.

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