

Therapeutic and Pharmaceutical Potential of *Cinnamomum Tamala*

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Review Article

ABSTRACT

The present review explains therapeutic and pharmaceutical potential of *Cinnamomum tamala* a well-known plant grows in high altitude areas of tropical and subtropical regions. This article emphasizes important uses of *C. tamala* constituents as spice, drug, and drug carrier with its therapeutic potential. Plant is a good depository of chemical constituents most of which are found in bark essential oils showed important biological activities such as antidiarrheic, antitumor, anti-inflammatory, anti-arthritic, antiparasitic, gastrourinary, antitumor, antiparasitic, antioxidant, chemopreventive, and gastroprotective. Plant leaves are used to generate special flavor to dishes, beverages and food items. Plant bark is a good source of essential oils and its phenolic compounds show multiple beneficial effects against Alzheimer's disease, cardiac mainly arteriosclerosis. Plant also shows therapeutic effects against cancer and inflammation, cardiac, and neurological disorders. Plant bark, fruits and leaves contain essential oil that shows nematocidal, termiticidal, larvicidal, microbicidal, antipyretic and anxiolytic activity. This article suggests wider use of *C. tamala* and its associating species in generation of chemopreventive anti-cancer, antiulcer, immunomodulatory, antilipidemic, antidiabetic and hepatoprotective drugs which might show broad-spectrum biological effectiveness.

Keywords: HIV, HIV-HBV co-infection, Selected haematological markers, Umuahia.

INTRODUCTION

Cinnamomum tamala Nees and Eberm (family *Lauraceae*) is an Indian plant commonly known as Tejpat or Bay leaf. This is an important traditional medicinal plant found in various parts of India. Plant generally found in upper Himalayas at altitudes of 900 meter to 2500 meter. Genus *Cinnamomum* shows wider distribution as 350 species are reported worldwide [1]. Plant contains aromatic leaves which are major source bioactive compounds of immense therapeutic, culinary and medicinal use. Plant has many synonyms and recognized by different names based on local area [2]. In Bengali, it is called as tejpat, in Hindi tejpatta, in Marathi tamalpatra, in Telugu bagharakku, tamalapattram in Sanskrit, tejpata in Nepal, tsheringma herb that is used Bhutan in tea. Bay laurel leaves are shorter and light to medium green in color, with one large vein down the length of the leaf, while tejpat leaves are about twice as long and wider, usually olive green in color, and with three veins down the length of the leaf [3]. True tejpat leaves impart a strong cassia- or cinnamon-like aroma to dishes, while the bay laurel leaf's aroma is more reminiscent of pine and lemon. Indian grocery stores usually carry true tejpat leaves. *Cinnamomum cassia* Presl bark is commonly used as ingredient in food and cosmetic industry [4].

Cinnamomum verum (L.) dry bark is known as Dalchini'. Dried leaves of *Cinnamomum tamala* spread are used to flavor a variety of food preparations. Plant bark and leaves are good source of aromatic essential oil which possess phenolic compounds which show multiple therapeutic effects against Alzheimer's disease, diabetes, arthritis, and arteriosclerosis. Plant emits clove-cinnamon like flavor. Essential oil is golden-yellow in colour, and possesses a very hot aromatic taste. Plant bark is rich source of cinnamaldehyde that provides a pungent taste and strong aroma that after exposure with oxygen, it become dark in colour and forms resinous compounds [5]. Cinnamon essential oil contains more than 80 compounds [6] including eugenol and cinnamaldehyde as major constituents. Oil of *cinnamomum* is used in baked goods [7] and to flavor various alcoholic beverages [8]. Cinnamon is mixed during distillation process to prepare cinnamon liqueur or barndy. It is also added to flavor white wine mainly Maiwein and vodka in Europe [9]. Cinnamon bark is used as spice to flavor food. It is used in cookery as a condiment and flavouring material. It is also used to produce flavored chocolates in Mexico [10]. Cinnamon is used in preparing buns, apple pie and dough nuts and in other desert recipes.

Cinnamon mixed with sugar is used to flavored, sweet and savoury dishes, cereals, breads, toasts. It is also rubbed on fruits to provide a specific aroma. Cinnamon is used in important spices, pickling, soups, drinks, and sweets [11].

THERAPEUTIC PROPERTIES

Cinnamon is also used as a traditional medicine to alleviate pain and inflammation in patients those who suffer from arthritic rheumatism. Plant contains cinnamaldehyde, cinnamic acid, cinnamate, and numerous other components which show strong therapeutic effects against cancer and inflammatory, cardioprotective, and neurological disorders [12]. Polyphenols showed good antioxidant, anti-inflammatory, antidiabetic, antimicrobial, anticancer effects [13]. Plants leaves are nutrient rich contain a lot of manganese, iron, dietary fiber, and calcium. Besides, food applications, the dried leaves are used as medicine by local people. Leave paste is used for curing a number of ailments and has multiple health benefits. Its dried leaves and bark are prescribed for fever, anemia and body odor. People chew dried leaves to disguise bad mouth odor. Leaves and barks of cinnamon have aromatic, astringent, stimulant and carminative activities and are used in rheumatism, colic, diarrhea, and nausea and vomiting Indian system of traditional medicines. Its seeds are used after crushed and mixed with honey or sugar and administered to children for dysentery or cough [13]. *Cinnamomum tamala* leaves put strong effect on biological systems such as immune system, gastro-intestinal tract, and liver. The bark is also sometimes used for cooking and flavoring the food.

Ancient literature on Ayurveda, Yunani, reveal therapeutic use of this plant in the first century A.D. *Cinnamomum*, Cinnamon bark, essential oils, bark powder showed multiple biological activity such as antioxidant, antidiabetic, anti-inflammatory, anticancer, and antimicrobial activity [14]. *C. camphora* leaf essential oil shows antifungal and insecticidal action against gall midge and butterfly larvae, fruit flies, and fire ants. *C. camphora* oil shows effectiveness against human breast tumor cells. *C. glaucescens* fruit essential oil showed nematicidal, termiticidal and larvicidal activity. Essential oil of *C. tamala* is found toxic to mosquito larvae and fire ants [15]. It is also found therapeutically effective against Alzheimer's disease, diabetes, arthritis, and arteriosclerosis, cancer and inflammatory, cardioprotective, and neurological disorders [12].

PHARMACEUTICAL EFFECTS

Immunosuppressive Effects

Cinnamomum bark is a source of major procyanidin compounds, few of them are cinnamtannin B1, cinnamtannin D1 (CTD-1), parameritannin A1, procyanidin B2, and procyanidin C1. These showed immunosuppressive effects and regulate immune function in experimental animals [16] (Table 1).

Immunomodulatory

Ethyl and methyl alcohol extracts from *C. verum* contain trans-cinnamaldehyde and its analogues which showed good ameliorative effects ($p < 0.05$) after day 2 of treatment [17] (Table 1).

Anxiolytic, Antidepressant, and Anti-Stress Activities

Cinnamomum tamala extracts showed antidepressant activity similar to imipramine at a dose level 400 mg/kg. These cause behavioral despair, learned helplessness, and tail suspension. Plant shows significant anxiolytic activity and has therapeutic beneficial for the management of psychological ailments [18].

ANTIMICROBIAL ACTIVITY

The essential oil isolated from the bark of *Cinnamomum glanduliferum* (Wall) Meissn showed strong antimicrobial activity against gram-positive bacteria, gram-negative bacteria, and fungi [19]. Oil and its components showed strong antimicrobial activity against methicillin-resistant *Staphylococcus aureus*, *Geotrichum candidum*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Helicobacter pylori*, *Aspergillus fumigatus*. Essential oil showed growth inhibitory effects against *S. aureus* and *Mycobacterium tuberculosis*, *Escherichia coli*, and displayed minimum inhibitory concentration (MIC) in range of 0.49 µg/ml to 32.5 µg/ml). *Cinnamomum tamala* also showed antidiarrhoeal activity [20] (Table 1).

Cinnamomum tamala extract is used to biosynthesize magnetic iron nanoparticles (MFeNp) are used for sludge dewatering. The breakdown of extracellular polymeric substances (EPS) by the MFeNp leads to the significant reduction in proteins, polysaccharides, water content and heavy metals. These particles have shown maximum removal efficiency of water from the sludge was 85.9%, hence, this treated and contaminant free water can be used for irrigation of agricultural fields [21]. SNPs synthesized using aqueous leaf extract of *Cinnamomum tamala* do inhibition of antibiotic resistant haloarchaeal isolates *Haloferax prahovense* RR8, *Haloferax lucentense* RR15, *Haloarcula argentinensis* RR10 and *Haloarcula tradensis* RR13. More possible this action of particles may alter and disrupt haloarchaeal membrane

permeability, inhibit respiratory dehydrogenases and lipid peroxidation. It also imposes DNA damage that results in microbial cell death [22].

Antidiabetic, Antioxidant and Hypolipidemic Activity

Cinnamon extracts contain procyanidins (trimer procyanidins cpd3, cpd4 and cpd6) which protect pancreatic β -cells, and demonstrate anti-diabetic activity [23]. These also increase glucose-stimulated insulin secretion in PA-treated β -cells [23]. Ethanolic extract of *C. tamala* leaves showed hypoglycemic and antihyperglycemic activities [24]. It also restores blood glucose level to normal and significantly increase level of total cholesterol, TG, LDL and VLDL cholesterol levels in diabetic rats [25] and lower down chances of hyperlipidemia after regular dosage [25]. *C. tamala* leaf extract promote the insulin release from the undestroyed β -cells [26] and improve the oral glucose tolerance by increasing the availability of insulin (Table 1). Similarly, methanolic extract of *C. tamala* leaves also does significant reduction in blood glucose level, blood glycosylated haemoglobin, LPO, serum AST, and ALT, and significant increase in the antioxidant enzymes such as CAT, GSH, and SOD. It could be used as an adjunct therapy in diabetes [27]. Similarly, cinnamtannin D-1 (CD1) from *C. tamala* found to protect pancreatic β -cells from palmitic acid-induced apoptosis. It also reverses palmitic acid-induced dysfunction of glucose-stimulated insulin secretion in primary cultured islets [28]. *C. tamala* shows potent therapeutic efficacy against diabetes mellitus [29] (Table 1)

Table 1. Showing therapeutic and biological efficacy of various major and minor bioorganic natural products isolated from *Cinnamomum* plant species.

Cinnamomum species	Biochemical component/s	Plant part	Characteristics /Biological activity
<i>Cinnamomum verum</i>	Dalchini	Bark	Cinnamon-like aroma medicine to alleviate pain and inflammation
<i>Cinnamomum tamala</i>	Cinnamaldehyde	Leaves	Anti-tyrosinase activities
<i>Cinnamomum tamala</i>	cinnamon	barks	Immunosuppressive effects, anticancer
<i>Cinnamomum tamala</i>	Procyanidin B2, C1	Leaves	Immunosuppressive effects, hypoglycemic and antihyperglycemic, antioxidant
<i>Cinnamomum tamala</i>	Ethanolic extract	Leaves	Reduced prostatic enlargement and improved hyperplastic changes
<i>Cinnamomum tamala</i>	Cinnamtannin B1, cinnamon	barks	Immunosuppressive effects
<i>Cinnamomum tamala</i>	tarns-cinnamaldehyde	Leaves	Antioxidant, anti-HIV, anticancer
<i>Cinnamomum glanduliferum</i>			Antimicrobial
<i>Cinnamomum tamala</i>	trimer procyanidins	Leaves	Antidiabetic, antioxidant and hypolipidemic activity
<i>Cinnamomum tamala</i>	Cinnamic acid	Leaves/bark oil	Antiparasitic, anticancer, antioxidant
<i>Cinnamomum tamala</i>	Bornyl acetate	leaf extracts	Anticancer
<i>Cinnamomum tenuifolium</i>	Tenuifolide B	stem	Obstruct cancer cell viability, cell cycle analysis, apoptosis, oxidative stress, and DNA damage
<i>C. tamala</i>	Extracts	Leaf	Potential to prevent growth of food spoilage/pathogenic fungi
<i>Cinnamomum cassia</i>	Extracts	Leaf	Chemoprevention of peptic ulcer or gastric cancer
<i>Cinnamomum glanduliferum</i>	Essential oil	Leaf	--
<i>Cinnamomum cassia</i>	Extracts	Leaf	Protective against gastritis and inflammation
<i>Cinnamomum tamala</i>	Polyphenol	Leaf	Decreased body weight, visceral fat, liver weight and serum glucose

<i>Cinnamomum tamala</i>	polyphenols	Leaf	Antioxidant, anti-inflammatory, antidiabetic, antimicrobial, anticancer
<i>Cinnamomum camphora</i>	Essential oil	Leaf	Insecticidal activity
<i>Cinnamomum glanduliferum</i>	Eucalyptol (65.87%), terpinen-4-ol (7.57%), α -terpineol (7.39%).	Bark oil	Antimicrobial and cytotoxic activities
<i>Cinnamomum verum</i>	Coumarin	Bark, powder and dried flowers	Used in flavoring food, beverages
<i>C. loureiroi</i>	phytosterols, fatty acids	Leaf/bark oil	--
	monoterpene	Leaf/bark oil	Antioxidant
	sesquiterpene	Leaf/bark oil	Toxic, antimicrobial
	geraniol	Leaf/bark oil	Antimicrobial, antioxidant
	linolol	Leaf/bark oil	Antimicrobial, antioxidant
<i>C. citriodorum</i>	saponins	Leaf/bark oil	Antimicrobial
<i>Cinnamomum cassia</i>	β -caryophyllene 0.50%	Leaf/bark oil	Cidal, Antimicrobial
<i>Cinnamomum cassia</i>	α -pinene 2.25%	Leaf/bark oil	Antipathogenic, antioxidant
<i>Cinnamomum cassia</i>	β -pinene 0.50%	Leaf/bark oil	Antipathogenic, antioxidant
<i>Cinnamomum cassia</i>	camphene 0.34%	Leaf/bark oil	Antipathogenic, anti-parasitic
<i>Cinnamomum cassia</i>	Linalool 1.20%	Leaf/bark oil	Antimicrobial, antioxidant
<i>Cinnamomum cassia</i>	Cinnamaldehyde 0.20%	Leaf/bark oil	Analgesic, immunomodulatory, flavoring
<i>Cinnamomum cassia</i>	Eugenol 68.10%	Leaf/bark oil	Antimicrobial
<i>Cinnamomum cassia</i>	p-cymene 4%	Leaf/bark oil	Anti-parasitic
<i>Cinnamomum cassia</i>	Bark Cinnamic aldehyde 70% to 80%	Leaf/bark oil	Anti-rheumatic, anti-inflammatory
<i>Cinnamomum cassia</i>	Eugenol	Roots	Anti-parasitic, antioxidant
<i>Cinnamomum cassia</i>	Safrole	Roots	Anti-microbial
<i>Cinnamomum cassia</i>	Benzaldehyde	Roots	Surfactant, Anti-parasitic, antimicrobial
<i>Cinnamomum cassia</i>	Terpine	Roots	Antimicrobial, anti-parasitic

ANTICANCER ACTIVITY

Cinnamomum tamala leaf constituents showed anticancer activity against human ovarian cancer cells. Its leaf extracts contain bornyl acetate that exhibit strong cytotoxicity to cancer cells *in vitro* [30]. It significantly reduces prostatic enlargement and improved hyperplastic changes. It also showed mild to moderate anti-inflammatory activity [31] (Table 1). *Cinnamomum cassia* extracts reverses TGF- β 1-induced epithelial-mesenchymal transition in human lung adenocarcinoma cells and suppresses tumor growth *in vivo* [32]. *C. cassia* extracts also obstruct tumor growth of human lung adenocarcinoma cells and inhibit transforming growth factor (TGF)- β 1-induced cell motility and invasiveness. Tenuifolide B found in *Cinnamomum tenuifolium* stem also inhibit proliferation of oral cancer cells via apoptosis, ROS generation, mitochondrial depolarization, and DNA Damage [33]. It potentially suppresses cancer cell viability, obstruct cell cycle, and induce apoptosis, oxidative stress, and DNA damage. *Cinnamomum cassia* was found cytotoxic to colon (HCT-116), liver (HepG2), and breast (MCF-7) carcinoma cell lines.

Anti-Food Spoilage/Antipathogenic

Essential oil from *C. tamala* shows potent antifungal activity against *Aspergillus niger*, *A. fumigatus*, *Candida albicans*, *Rhizopus stolonifer* and *Penicillium spp.* Its various solvent extracts exhibit antioxidant activity in β -carotene bleaching

assay and reducing power assay. *C. tamala* leaf extracts significantly inhibited growth of food spoilage/pathogenic fungi. These can also mitigate the oxidative stress by antioxidant response^[34] (Table 1).

Tyrosinase Inhibitory Activity

C. tamala possess two major components cis-2-methoxycinnamic acid (43.06%) and cinnamaldehyde (42.37%). cinnamaldehyde, possess potent anti-tyrosinase activities and may be a good source for skin-whitening agents^[35] (Table 1).

Anti-Inflammatory and Cytoprotective

Cinnamomum cassia was found effective against *Helicobacter pylori* a dreadful pathogen that severely infect GI tract. *Cinnamomum cassia* extract contains bioactive candidates which could be used in chemoprevention of peptic ulcer^[36]. It also shows anti-inflammatory and cytoprotective effects^[36].

Gastroprotective Effects

Cinnamomum glanduliferum leaf essential oil shows gastroprotective effect in experimental animals. CG oil exhibited a significant modulatory effect on ethanol-induced gastritis in rats and does significant inhibition of lipid peroxidation. CG volatile oil was found effective against non-anti-ulcerative gastritis and display anti-inflammatory activity^[37].

Anti-Gout and Septic Responses

Cinnamomum cassia shows anti-gout and antiseptic responses in experimental animals. It is used to treat dyspepsia, gastritis, blood circulation, and inflammatory diseases^[38]. It suppresses inflammation-related disorders by regulating the formation of inflammasome activation and cut down interleukin-1 β secretion. Furthermore, use of CA improves survival rate of LPS-induced septic shock and gout murine model.

Anti-Hyperlipidemic

Cinnamon polyphenol cut down hyperlipidemia, slow down inflammation, and release out oxidative stress through activation of transcription factors and making antioxidative defense^[39]. It also cut down body weight, visceral fat, liver weight and serum glucose and insulin concentrations, liver antioxidant enzymes, and restore lipid profile. Cinnamon polyphenol suppress hepatic SREBP-1c, LXR- α , ACLY, FAS, and NF- κ B p65 expressions and enhance the PPAR- α , IRS-1, Nrf2, and HO-1 expressions in the HFD rat livers (P<0.05).

Cardio-Protective Effect

C. cassia plant extract contains important bioactive candidates such as coumarin, trans-cinnamic acid, cinnamaldehyde, 2-hydroxycinnamaldehyde, 2-methoxycinnamaldehyde (6), 2-hydroxy-cinnamyl alcohol, benzoic acid, (+)-syringaresinol and phenethyl (E)-3-[4-methoxyphenyl]-2-propenoate which display diverse biological activity^[40]. Its solvent extracts were found effective against gastritis, diabetes, blood circulation disturbance and inflammatory diseases^[40] (Table 1) These also showed cardio-protective effects and reduce blood pressure, plasma glucose, obesity and ameliorating dyslipidemia.

Insecticidal Activity

Cinnamomum camphora essential oil and its isolated constituents showed insecticidal activity against the stored grain pests^[41]. It also displays strong fumigant action against *Tribolium castaneum* and *Lasioderma serricornis* adults^[23]. The essential oil from the twigs of *Cinnamomum cassia* Presl alleviates pain and inflammation in mice^[23]. *Cinnamomum cassia* twigs are used to treat inflammatory processes, pain, menstrual disorders, hypertension, fever etc. Essential oil inhibits carrageenan-induced mechanical hyperalgesia and paw edema and subsequently decreased the levels of cytokines TNF- α , and IL-1 β , NO, and PGE2. *Cinnamomum cassia* Presl, plant also possesses antinociceptive and anti-inflammatory properties. The root essential oil of *C. tamala* found toxic to mosquito larvae and fire ants^[15]. Silver (Ag) and gold (Au) nanoparticles (NPs) synthesized by using the aqueous bark extract of *Cinnamomum zeylanicum* showed larvicidal activity has been tested against the malaria vector *Anopheles stephensi* and filariasis vector *Culex quinquefasciatus*. Nanoparticles AgNPs and AuNPs were found highly susceptible to *An. stephensi* than the *Cx. quinquefasciatus*. *C. zeylanicum* synthesized silver and gold nanoparticles have the potential to be used as an ideal eco-friendly approach for the control of mosquito^[42] (Table 1).

Carminative, Analgesic and Antipyretic Properties

Cinnamomum iners Reinw showed carminative, analgesic and antipyretic properties. It was found active in postpartum treatment, rheumatism and digestive ailments [43]. More often, cinnamyl derivatives isolated on organic solvent-extractable fractions of *Cinnamomum cassia* antipyretic activity [44].

Anthelmintic

Extracts from *Cinnamomum cassia* contains cinnamaldehyde and cinnamic acid that work potential candidate antiparasitic agent against *Dactylogyrus intermedius* [45] found in in goldfish (*Carassius auratus*) [46]. Similarly, trans-cinnamaldehyde successfully kills parasitic worms of the intestine i.e., *Trichuris suis* and *Oesophagostomum dentatum* larvae [47].

Anti-Parasitic

The essential oil obtained from *C. aromaticum* Cinnamon bark contains trans-cinnamaldehyde as a major component (79%) [48]. It shows anti-parasitic action against flagelated poultry parasites *Tetratrichomonas gallinarum* and *Histomonas meleagridis*. Both types of PLGA nanoparticles loaded with CBE were effective inhibitors of *Salmonella enterica* serovar *Typhimurium* and *Listeria monocytogenes* after 24 h and 72 h at concentrations ranging from 224.42 µg/mL to 549.23 µg/mL. The PLGA encapsulation shows improved delivery of hydrophobic antimicrobial to the pathogens in aqueous media [49].

Anti-Arthritic and Wound Healing

Cinnamon bark i.e., *Cinnamomum zeylanicum* is one of the oldest traditional medicines for inflammatory- and pain-related disorders. Its polyphenolic fraction shows anti-inflammatory and anti-arthritis potential or anti-rheumatic agent with disease-modifying action [50]. It put impact on cytokines (IL-2, IL-4, and IFN γ) released from Concanavalin (ConA)-stimulated lymphocytes. CPP showed a strong and dose-dependent reduction in paw volume, weight loss reversal effects against carrageenan-induced paw edema, and cotton pellet-induced granuloma models in rat's action [50]. CPP was found to inhibit cytokine (IL-2, IL-4, and IFN γ) release from ConA-stimulated lymphocytes *in vitro*. *Cinnamomum verum* extract mediated nanosilver (CENS) particles showed good antibacterial activity and accelerated wound healing with complete epithelialisation and normal re-growth of hair in animal models after topical application. CENS promotes collagen synthesis, stabilize wound besides countering oxidative stress and stimulating cellular proliferation. It could be use a novel therapeutic agent for wound management [51].

Anti-HIV

Trans-cinnamaldehyde (CA), is main essential oil constituent isolated from Cinnamomi cortex. It inhibits growth of influenza A/PR/8 virus *in vitro* and *in vivo* and is used to treat acute respiratory infectious diseases [52]. Similarly, *Cardiospermum helicacabum* (shoot + fruit) extracts were found against HIV-1 and HIV-2 [53]. The silver nanoparticles derived from Cinnamon extract enhanced the antiviral activity. Similarly, silver nanoparticles synthesized from *Cinnamomum cassia* extract were found effective against H₇N₃ Influenza A Virus. These effectively decrease HRSV-induced plaque formation and syncytium formation in respiratory mucosal cell lines. It removes off obstructions occurred in airway epithelia due to HRSV infection through inhibiting viral attachment, internalization and syncytium formation [54].

FUTURE APPLICATIONS

Cinnomom functionalized nanoparticles have vast industrial application. These are used as therapeutic drugs, carriers and metabolizables. Fe₃O₄ nanoparticles coated with bio-ingredients from isolated from *C. verum* showed strong antibacterial activity against both gram-positive and gram-negative bacteria [55]. These showed improvement in anti-adherent properties, and inhibit colonization of both Gram-negative and Gram-positive bacteria. Similarly, 1-octadecylimidazolium ionic liquid modified magnetic nanoparticles (Fe₃O₄@SiO₂@ImC₁₈) were used to isolate flavonoid compounds of myricetin, quercetin and luteolin and cinnamic acid from cinnamon. These particles have large scale use in pharmaceutical and food industry [56]. Similarly, Cinnamon-coated gold nanoparticles (Cin-AuNPs) are used for diagnosis of cancer. These nanoparticles are non-toxic and show excellent CT/photoacoustic contrast-enhancement and can be used for tumor detection [57]. Biomolecule-loaded nanoparticles (GSCNPs and CZCNs) exhibit dose-dependent cytotoxicity and induce apoptosis in a human cervical cancer (SiHa) cell line [58]. Similarly, chitosan and gold nanoparticles prepared synthesized from *Cinnamomum zeylanicum* leaf constituents displayed very high antibacterial activity against the tested gram-negative bacterium *Escherichia coli* and gram-positive bacterium *Staphylococcus aureus* [59]. These also showed antifungal activity against *Aspergillus niger* and *Fusarium oxysporum*.

Similarly, silver nanoparticles synthesised from *Cinnamomum cassia* leaf constituents showed high antimicrobial potential against *Candida albicans* [60]. Their MIC and MFC values were found in a range of 0.0006% to 0.0097% (v/v) and 0.0012% to 0.019% (v/v), respectively. Use of cinnamon acts as an antagonist of the TLR4 complex, and hydrogen and reduces the health-related effects generated due to emissions released from laser printers and photocopiers (LPandP) [61]. It dissolute irritation and hyper-responsiveness of the upper and lower respiratory tract; and slow down the process of chronic fatigue syndrome. Similarly, cinnamon oil nano-emulsion (droplet diameter of 65 nm) was found growth inhibitory to *Bacillus cereus*. It can be used for preservation of minimally processed food [62]. CoP nanoparticles (NPs) in CaCO₃ NP-templated *Cinnamomum* platyphyllum leaf extract-derived carbon also have high industrial application [63]. Similarly, gold nanoparticles synthesized by using using *Cinnamomum zeylanicum* leaf broth act as the reducing agent [64].

PHYTOCHEMISTRY

Phytochemical analysis of *C. tamala* leaf extract revealed presence of important saponins, phytosterols, fatty acids, carbohydrates, monoterpene, sesquiterpene, geraniol and linolol, bornyl acetate, caryophyllene oxide, p-coumaric acid and vanillic acid [30]. Plant leaves also contain, procyanidin oligomers compounds, mainly cinnam, tannin B1, cinnamtannin D1 (CTD-1), parameritannin A1, procyanidin B2, and procyanidin C1 in bark [16]. *C. tamala*, also contain cinnamtannin D-1 (CD1) as one of the main A-type procyanidin oligomers [28]. Tenuifolide B is isolated from *Cinnamomum tenuifolium* stem that showed therapeutic activity [33]. Twigs of *C. cassia* contain cinnamomulactone, coumarin, trans-cinnamic acid, cinnamaldehyde, 2-hydroxycinnamaldehyde, 2-methoxycinnamaldehyde, 2-hydroxycinnamyl alcohol, benzoic acid, (+)-syringaresinol and phenethyl (E)-3-[4-methoxyphenyl]-2-propenoate with strong therapeutic potential [40]. Plant bark essential oil contain some minor constituents with significant chemotypic variations i.e., p-cymene, cinnamaldehyde, eugenol, linolool, alpha and beta-pinene, limonene, 3,3,4,5,7-pentahydroxyflavone, kaempferol-3-o-saphoroside, kapeferol-3-o-glucopyranoside and quercetin-3-o-rutenoside and diverse biological activity [64]. Plant also contains steroids, terpenoids and tannins, polysaccharides [65], procyanidins cpd3, cpd4 and cpd6 [23] and glycosides, cinnacassides F and G, with a rare geranylphenylacetate carbon skeleton [66] (**Figure 1**). These compounds have shwon immunomodulatory and immunosuppressive activities against murine lymphocytes Cinnamaldehyde is major chemical constituent component (44.898%) of essential oil found in *Cinnamomum tamala* leaves that possess multiple biological activity [67]. Cinnamon contains derivatives, such as cinnamaldehyde, cinnamic acid, cinnamate, and numerous other components such as polyphenols and antioxidant, anti-inflammatory, antidiabetic, immunomodulatory and immunosuppressive antimicrobial, anticancer effects [12] (**Figure 1**).

Cinnamomum verum contains alkaloids, triterpenes, Cinnamaldehyde and other volatile oils [17]. Essential oils also found in bark of *Cinnamomum glanduliferum* (Wall) Meissn [17] contain important chemical constituent's i.e., eucalyptol (65.87%), terpinen-4-ol (7.57%), α -terpineol (7.39%), D-camphor (51.3%), 1,8-cineole (4.3%), and α -terpineol (3.8%). D-camphor (28.1%), linalool (22.9%), and 1,8-cineole (5.3%) have been isolated from fruits. Twenty-five and 20 compounds were identified from leaf and branch oils, respectively (98.85 and 99.13%). The major ones were: eucalyptol (59.44%; 55.74%), sabinene (14.99%; 7.12%), α -terpineol (6.44%; 9.81%), α -pinene (5.27%; 4.71%) [37]. These chemical components provide special flavor and fragrance to food items and beverages [68] and showed strong antimicrobial and cytotoxic activity [69]. These cinnamon phytochemicals can be used synthesize biocompatible gold nanoparticles using [70], which could be used to target gastric ulcer [71], carcinogenesis [72]. Cinnamon ingredients also showed analgesic, antipyretic [73] and hepatoprotective activity [74]

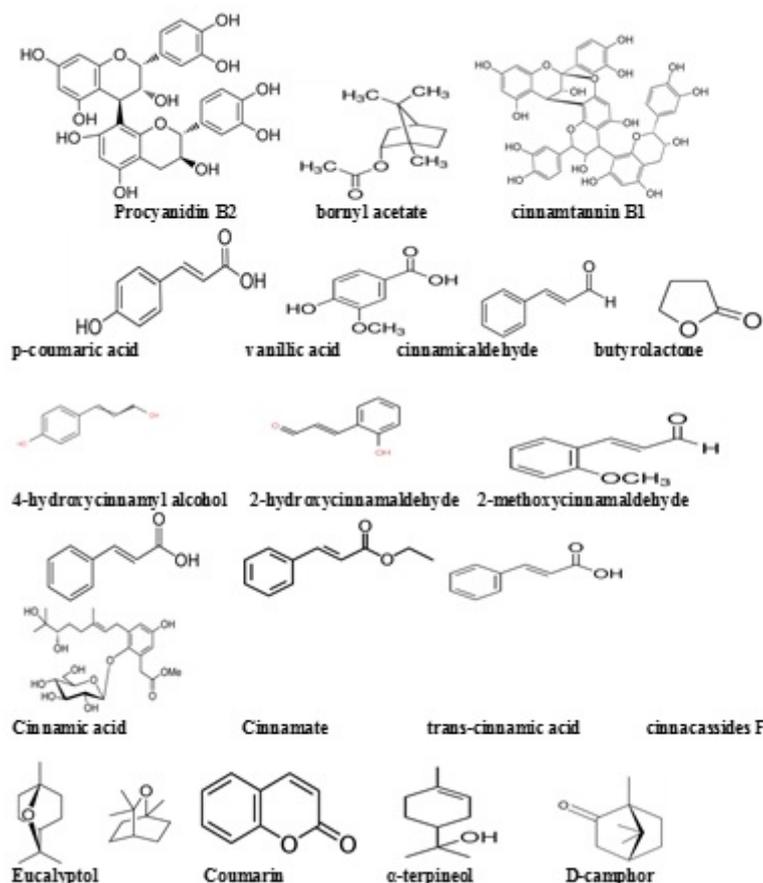


Figure 1. Showing major bio-organic compounds isolated from various *Cinnamomum* species.

CONCLUSION

C. tamala and its associating species are rich source of economically important bio-organic products which can be largely used for preparation of flavored foods, pharmaceuticals and pesticides. Both leaves and plant bark of this plant is widely used in folk medicine. *C. verum* bark is used as Dalchini a specific spice. Its leaves are used to provide a specific aroma to vegetable curries. This plant has enormous therapeutic potential as it can obstruct metastasis and lower down cancer-related mortality in patients. Its bioorganic ingredients can kill drug resistant pathogens. *Cinnamomum sp.* volatile contains alkaloids, triterpenes, cinnamaldehyde which showed antioxidant, anti-inflammatory, antidiabetic, anti-inflammatory, immunomodulatory, immunosuppressive antimicrobial, anticancer effects and anti-food spoilage/antipathogenic activity. Cinnamon polyphenol reduces the hyperlipidemia, inflammation, and oxidative stress through activating transcription factors and antioxidative defense signaling pathway in HFD rat liver. Essential oils obtained from this plant possess various active ingredients which can be used to control insects and nematodes and drug resistant bacteria and fungi. These can be processed to obtain pharmaceutical agents mainly against gastric, diabetic, high blood pressure and neurological problems. *Cinnamomum* species contain major group of biologically active chemicals that can be used to make highly efficacious broad spectrum pharmaceutical products.

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