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-arthritis, antiparasitic, gastourinary, 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 nematicidal, 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, tamălapattram 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 flavor sweet and savory 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.

**THERAPEUTIC PROPERTIES**

Cinnamon is also used as a traditional medicine to alleviate pain and inflammation in patients 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. Polyphenols showed good antioxidant, anti-inflammatory, anti-diabetic, antimicrobial, anticancer effects. 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. *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*, Cinnamomum bark, essential oils, bark powder showed multiple biological activity such as antioxidant, anti-diabetic, anti-inflammatory, anticancer, and antimicrobial activity. *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 nematocidal, termiticidal and larvicidal activity. Essential oil of *C. tamala* is found toxic to mosquito larvae and fire ants. It is also found therapeutically effective against Alzheimer’s disease, diabetes, arthritis, and arteriosclerosis, cancer and inflammatory, cardioprotective, and neurological disorders.

**PHARMACEUTICAL EFFECTS**

**Immunosuppressive Effects**

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

**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.

**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.

**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. 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.

*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. SNPs synthesized using aqueous leaf extract of *Cinnamomum tamala* do inhibition of antibiotic resistant haloarchaeal isolates *Halofex prahovense* RR8, *Halofex 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.

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

**Cinnamomum camphora**
- Essential oil
- Leaf
- Insecticidal activity

**Cinnamomum glanduliferum**
- Eucalyptol (65.87%), terpinen-4-ol (7.57%), α-terpineol (7.39%)
- Bark oil
- Antimicrobial and cytotoxic activities

**Cinnamomum verum**
- Coumarin
- Bark, powder, and dried flowers
- Used in flavoring food, beverages

**C. loureiroi**
- Phytosterols, fatty acids
- Leaf/bark oil
- --

**C. citriodorum**
- Saponins
- Leaf/bark oil
- Antimicrobial

**Cinnamomum cassia**
- β-caryophyllene 0.50%
- Leaf/bark oil
- Cidal, Antimicrobial

**Cinnamomum cassia**
- α-pinene 2.25%
- Leaf/bark oil
- Antipathogenic, antioxidant

**Cinnamomum cassia**
- β-pinene 0.50%
- Leaf/bark oil
- Antipathogenic, antioxidant

**Cinnamomum cassia**
- Camphene 0.34%
- Leaf/bark oil
- Antipathogenic, anti-parasitic

**Cinnamomum cassia**
- Linalool 1.20%
- Leaf/bark oil
- Antimicrobial, antioxidant

**Cinnamomum cassia**
- Cinnamaldehyde 0.20%
- Leaf/bark oil
- Analgesic, immunomodulatory, flavoring

**Cinnamomum cassia**
- Eugenol 68.10%
- Leaf/bark oil
- Antimicrobial

**Cinnamomum cassia**
- p-cymene 4%
- Leaf/bark oil
- Anti-parasitic

**Cinnamomum cassia**
- Bark Cinnamic aldehyde 70% to 80%
- Leaf/bark oil
- Anti-rheumatic, anti-inflammatory

**Cinnamomum cassia**
- Eugenol
- Roots
- Anti-parasitic, antioxidant

**Cinnamomum cassia**
- Safrole
- Roots
- Anti-microbial

**Cinnamomum cassia**
- Benzaldehyde
- Roots
- Surfactant, Anti-parasitic, antimicrobial

**Cinnamomum cassia**
- Terpine
- Roots
- Antimicrobial, anti-parasitic

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- Safrole
- Roots
- Anti-microbial

**Cinnamomum cassia**
- Benzaldehyde
- Roots
- Surfactant, Anti-parasitic, antimicrobial

**Cinnamomum cassia**
- Terpine
- Roots
- Antimicrobial, anti-parasitic

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**ANTICANCER ACTIVITY**

*Cinnamom 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-β1-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)-β1-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* possesses 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-1β 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-κB p65 expressions and enhance the PPAR-α, IRS-1, Nr2, 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-hydroxycinnamyl 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 serricorne* 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-1β, NO, and PGE2. *Cinnamomum cassia* Presl, plant also possesses antinociceptive and anti-inflammatoryary 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 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 flagellated poultry parasites _Tetrahymena 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 IFNγ) 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 IFNγ) 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

Cinnmomum 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, _Cinnamomum zeylanicum_ leaf constituents displayed very high antibacterial activity against the tested gram-positive bacterium _Escherichia coli_ and gram-positive bacterium _Staphylococcus aureus_ [59]. These also showed antifungal activity against _Aspergillus niger_ and _Fusarium oxysporum_.

RRJPPS | Volume 6 | Issue 3 | September 2017
Similarly, silver nanoparticles synthesized 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 reduces the health-related effects generated due to emissions released from laser printers and photocopiers (LPandP) [61]. It dissolves 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 *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, caryophylyene oxide, p-coumaric acid and vanillic acid [30]. Plant leaves also contain, procyanidin oligomers compounds, mainly cinnam, tannin B1, cinnamattannin D1 (CTD-1), paramerattannin A1, procyandin B2, and procyandin C1 in bark [16], *C. tamala*, also contain cinnamattinnin 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-hydroxy-cinnamyl 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, cinnamicaldehyde, eugenol, linoolool, 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 geranylyphenylacetate 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%), a-terpineol (7.39%), D-camphor (51.3%), 1,8-cineole (4.3%), and a-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%), sabine (14.99%; 7.12%), a-terpineol (6.44%; 9.81%), a-pine (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].
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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