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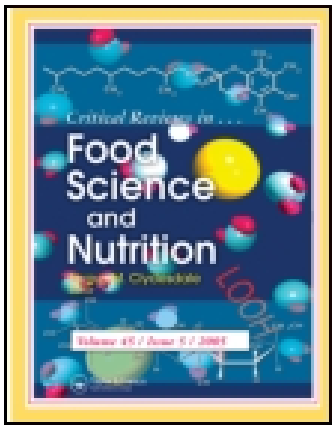

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An Overview on Chemical Composition, Bioactivity and Processing of Leaves of Cinnamomum tamala

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An Overview on Chemical Composition, Bioactivity and Processing of Leaves of *Cinnamomum tamala*

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Dried leaves of Cinnamomum tamala*, also known as Indian bay leaves, are a lesser-known spice used in the Indian subcontinent. It imparts a warm, peppery, clove-cinnamon like flavor to a variety of food preparations. Besides food applications, the leaves have also been traditionally used for curing a number of ailments and for other perceived health benefits. They find mention in the Aurvedic, Yunani, and other traditional medicinal literature. This review summarizes the effect of* Cinnamomum tamala *leaves on biological systems such as immune system, gastro-intestinal tract, liver and its antioxidant, antidiabetic, anti-inflammatory, anticancer, and antimicrobial activity. Chemical components that may be responsible for its flavor as well as bioactivity, have also been discussed.*

Keywords Lauraceae, *Cinnamomum tamala*, chemical composition, essential oil, bioactivity, flavonoids

INTRODUCTION

Cinnamomum tamala (Buch-Ham.) Nees and Eberm. is a small evergreen tree that belongs to Lauraceae. It is commonly known as Indian cassia. The tree grows up to 7.5 m height and about 1.4 m girth. Its distribution is tropical and subtropical so is found throughout India but more so in Himalayan region (3000–7000 ft) and Sylhet and Khasia hills in N.E. India (3000–4000 ft). The bark of the tree is dark brown or blackish and is slightly rough. Blaze is about 1.3 cm, pinkish or reddish brown in color, with whitish streaks toward exterior. The leaves may be opposite, sub-opposite or alternate. They are ovate, lanceolate or oblong, acuminate, coriaceous, slightly shining above and three-nerved from close above the base almost to the apex. Leaves are commonly known as Indian bay leaves and have several traditional names such as Tejpat, Tejpatta, Tamalpatra, etc. (Kirtikar and Basu, 1935). The Sanskrit name "Tamalpatra" means dark leaf. Leaves are mentioned in a first century Greek text as one of the major exports of Malabar coast (present day Kerala, India). Greek traders included the name in their language as Malabathra, which later became Malabathron. From there, Romans modified it to Malabathrum or Malobathrum (http://www.uni-graz.at/∼katzer/engl/Cinn_tam.html).

It is cultivated in Nainital (Uttarranchal), Kangra (H.P.), and in North East India (Tripura, Meghalaya, Arunachal Pradesh, and Sikkim) and Nepal for its leaves which have a clove like taste and pepper like odor. It is also common to harvest leaves from trees growing in the wild (Bradu and Sobti, 1988).

Preliminary processing: Dried leaves of the tree are used as a spice. In Nepal, the plantations are established from seedlings collected from the forest and afterwards by self-germination from seeds dispersed from older plants. Harvesting usually begins when trees are five years old. A productivity of more than 200 kg on fresh weight basis for 15 years and older trees is considered good yield. It is about 100 kg for 5–10 year old trees and between 100 and 200 kg for 10–15 year old trees. Leaves are harvested in dry and mild weather, mostly in the period from October to December and in some places till March. The leaves are collected once in a year from young trees and every other year from older and weaker trees. During harvest, small branches are cut along with leaves, which are then dried in shade for 3–4 days. On an average, 13 kg of dry leaves may be obtained from a tree, but quantity varies depending on many

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Table 1 Trade figures for Indian bay leaves in the period 1992–1995

	Import		Export	
Year	Quantity (kg)	Value ₹	Quantity (kg)	Value ₹
1992–93	21,350	643,378	562,829	2,598,122
1994–95	4874	18,440	1,430,635	6,189,103

(The wealth of India, 2000).

factors and falls in the range of 8–20 kg. The leaves are usually collected before flowering. Early or late harvesting may result in lower quality of leaves or essential oil. High rainfall tends to reduce the aroma (Lamichhane and Karna, 2010).

Tejpat is exported from India as a whole spice and powdered spice. In Meghalaya, area under Tejpat cultivation was 6,140 (in hectares) during year 2006–2007 and the production stood at 15,961 tons. (Spices Board India, website). Trade figures for Indian bay leaves in the period 1992–1995 are given in Table 1. Chemical/physical specifications, nutritional value, and calorific value are not specified for *C. tamala* leaves. Although no particular specifications are available for Tejpat essential oil, specifications for physical properties of Cinnamon leaf oil were available on the website (Table 2).

C. tamala leaves have a potential use as source of chemical isolates. World demand for Cinnamon leaf oil in 1987–1992 was 120–150 tons per annum, which was largely met by Sri Lanka (*C. verum*). The United States and Western Europe were the largest markets. China was the major exporter of cassia oil in the same period and the United States and Japan were the major importers. India produces very small amounts of Cinnamon leaf oil for domestic use. Different chemotypes of *C. tamala* produce oils rich in different components such as cinnamaldehyde and eugenol but existence of other cheaper sources (e.g., eugenol rich clove- leaf oil) limit the prospective use of *C. tamala* oil (Flavours and Fragrances of Plant Origin, 1995).

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FOOD USES AND OTHER APPLICATIONS

Dried leaves are predominantly used as a spice in India, especially in North Indian and Moghul cuisine. Indian bay leaves are also popular in Terai plains of southern Nepal, where they form a key ingredient of many vegetarian recipes. Besides, the leaves are used to flavor pickles, conserves, and sweet preparations. The leaves were known to Romans as Malobathrum and were used in both cooking and perfumery. In recipes, they were referred to as "folia" or leaves, which sometimes is mistaken for bay (Laurel) leaves, different from *C. tamala*. The leaves continued to be used through Middle Ages and for brewing beer in the 16th century, but after that their importance diminished in comparison to other spices. (http://www.unigraz.at/∼katzer/engl/Cinn_tam.html)

Table 2 Indian specifications for physical properties of Cinnamon leaf oil

Specific gravity (20°C)	1.037–1.055″
Refractive index (20°C)	1.529–1.535
Optical rotation (°)	1°36′–0°40′
Solubility	Soluble in 1.5 volumes or more of 70% alcohol, sometimes with opalescence or paraffin separation.
Remarks	Aldehyde up to 4%, phenol: 77.3–90.5%.

(Source: Spices board India, website).

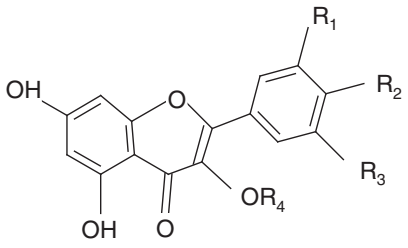
In Nepal, the leaves are used as fodder in addition to culinary uses. It is also used as a clarifier in dyeing along with myrobalan and for the manufacture of vinegar. Essential oil from leaves is used as a flavoring agent in confectionary and other processed food items, and in perfumery. The bark has been commonly used as a substitute of, or to adulterate true cinnamon bark (*Cinnamomum zeylanicum*) (Lamichhane and Karna, 2010).

Besides these, the leaves are recommended in traditional medicinal systems for a number of ailments. In the Ayurveda, the leaf is considered to have heating and alexiteric properties and is considered useful in scabies, disease of anus and rectum, piles, heart troubles, ozoena, bad taste, etc. In the Yunani system also, brain stimulating, antihelminthic, diuretic, good for liver and spleen, useful in inflammation, useful in soothing sore eyes and salivation reducing, etc., properties have been attributed to it. In Punjab, leaves are used to treat rheumatism, colic trouble, diarrhoea, and for suppression of lochia after childbirth. Bark is considered useful in treatment of gonorrhea. In folk medicine, it was also used as an antidote for snake venom and scorpion venom but scientific studies have disproved its effectiveness against both (Kirtikar and Basu, 1935).

CHEMICAL COMPOSITION

Several reports are available on the chemical composition of essential oil from leaves of *Cinnamomum tamala*; however, nonvolatile components have not been very extensively investigated. Polyphenolic components of *C. tamala* reported are 3,4′, 5,7-tetrahydroxyflavone (kaempferol), 3,3′,4′,5,7 - pentahydroxyflavone (quercetin) nonglycosidic components, kaempferol-3-O-glucopyranoside, kaempferol-3-O-sophoroside, kaempferol 3,7 di-O-rhamnopyranoside, and quercetin 3-O-rutinoside glycosidic components (Bhardwaj et al., 1983). In addition to kaempferol and quercetin, Singh et al. (2002), reported myricetin, kaempferol-3-O- rhamnoside and quercetrin (quercetin 3-rhamnoside). The structures of major nonvolatiles identified in *Cinnamomum tamala* leaves are given in Fig. 1. Devi et al. (2007) quantified the total phenolic content of methanolic extract of *C. tamala* by Folin ciocalteau method and it was found to be 6.7 mg GAE/100 g (Gallic Acid Equivalents/ 100 g).

Prasad et al. (2009) have quantified three flavonoid compounds—quercetin, kaempferol, and quercetrin in *C. tamala* leaves. Chaurasia et al. (2010a) have estimated the



$R_1 = R_2 = R_3 = R_4 = OH$: Myricetin

$R_1 = R_3 = R_4 = H,\ R_2 = OH$: Kaempferol

$R_1 = R_4 = H,\ R_2 = R_3 = OH$: Quercetin

$R_1 = R_3 = H,\ R_2 = OH,\ R_4 =$ Glucose : Kaempferol-3-O-Glucoside

$R_1 = R_3 = H,\ R_2 =$ OH, $R_4 =$ Sophoroside :Kaempferol-3-O-Sophoroside

$R_1 = R_3 = H,\ R_2 = OH,\ R_4 =$ Rhamnose : Kaempferol-3-O-Rhamnoside

$R_1 = H,\ R_2 = R_3 = OH,\ R_4 =$ Rhamnose :Quercetin-3-O-Rhamnoside

$R_1 = H,\ R_2 = R_3 = OH,\ R_4 =$ Rutinose : Quercetin-3-O-Rutinoside

Figure 1 Structures of selected nonvolatile components of *Cinnamomum tamala* leaf.

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hexane extract of the leaves to be 5.25 ± 1.5%. Concentration of flavones was found to be 20.90 ± 2.42 μg/mg extract equivalent to quercetin. Qualitative estimation carried out by Mishra et al. (2010) indicates presence of terpenoids, tannins, phenols/polyphenols, flavonoids, alkaloids, and saponins. Chakraborty and Das (2010) have reported antioxidant components of *C. tamala* leaves (mg/kg dry weight) as phenols (20.83), ascorbate (22.30), and carotenoids (0.82).

The essential oil content obtained after hydrodistillation in a Clevenger type apparatus or steam distillation varies between 0.7–1.5% (Nath et al., 1999). The composition of the essential oil is highly variable depending on many factors, major one being geographical region of growth. Many chemotypes of *C. tamala* exist, e.g., eugenol type (eugenol- 66–70%), cinnamic aldehyde type ((E)-cinnamaldehyde- 79.4%), linalool type (linalool- 54.66%), trans sabinene hydrate-β-ocimene type (trans- sabinene hydrate- 28.8%, β-ocimene- 17.9%), etc., named after the main constituents present (Sood et al., 1979; Upadhyaya et al., 1994; Mir et al., 2004; Baruah et al., 2007; Kapoor et al., 2009; Joshi et al., 2009). Rana et al., 2009, reported eugenol type essential oil (eugenol- 34–94%) from cinnamomum tamala leaves from North-East India. Besides trans- Cinnamaldehyde, 5-(2-propenyl)-1,3- benzodioxole is also reported as the major constituent of *C. tamala* leaves essential oil (Wang et al., 2009). Major components of *C. tamala* leaf essential oil from different sources to indicate the extent of variability in composition are given in Table 3. Structures of selected volatile components are given in Fig. 2.

BIOACTIVITY OF Cinnamomum tamala *LEAVES*

Antioxidant Activity

The antioxidant activity and total polyphenols content of methanol and water extract of leaves of *Cinnamomum tamala* were reported (Bajpai et al., 2005). Total phenolic content of combined extracts is 12.5 ± 0.1 mg/g GAE. The antioxidant activity as determined by β-Carotene linoleic acid auto-oxidation assay was 52.3 ± 1.7%. In this study, *Cinnamomum tamala* was concluded to have low total phenolic content but high antioxidant activity indicating presence of active constituents other than phenols.

Volatile oil and acetone extract of *Cinnamomum tamala* leaves are reported to show strong radical scavenging activity (Singh et al., 2007). Radical scavenging activity of the volatile oil fraction determined by DPPH method at concentrations 5 and 25 μL was 50.31% and 70.29%, respectively, as against 86% and 96% for BHA. For acetone extract the corresponding values were 56.11 and 74.44%. Reducing power was determined to be 44.1–64.7% for volatile oil and 64.3-3-81.2% for acetone extract for concentrations between 5 and 25 μL. Chelating effect on ferrous ions in concentration range of 5–25 μL was found to be 24.61–45.6% for volatile oil and 24.71–49.56% for acetone extract as against 50.61–90.4% for EDTA. Antioxidant activity determined by conjugated diene method was in range of 53.6–72.3% for volatile oil and 65.3–83.5% for acetone extract as compared to 69.34–87.98% for BHA.

Table 3 Major components (%) of *C. tamala* leaf essential oil from different sources

S. no.	Component	Cinnamic aldehyde type (Joshi et al., 2009)	Eugenol type (Kapoor et al., 2009)	β- Caryophyllene-Linalool type (Ahmed et al., 2000)	Trans- Sabinene hydrate-β- ocimene type (Mir et al., 2004)	Eugenol- Linalool type (Baruah et al., 2005)
1	Benzaldehyde	0.3	—	—	—	—
2	α-Thujene	—	0.02	—	—	—
3	6-Methyl 5 Heptene-2- one	—	Trace	—	—	—
4	Camphene	—	—	0.1	1.8	0.2
5	α-Pinene	—	0.07	0.5	3.1	0.43
6	β-Pinene	1.3	0.03	0.2	0.7	0.35
7	Myrcene	Trace	0.02	0.1	4.6	0.16
8	α-Phellandrene	—	0.4	—	—	4.84
9	β-Phellendrene	—	—	0.3	—	—
10	3-Carene	—	0.02	—	—	—
11	Sabinene	—	—	—	2.3	—
12	(Z)-β-ocimene	—	—	—	17.9	—
13	Trans-Sabinene hydrate	—	—	—	29.8	—
14	*p*-cymene	0.6	0.6	1.4	0.2	4.2
15	Limonene	0.8	Trace	0.3	—	—
16	1,8-cineole	Trace	0.4	0.3	—	0.6
17	*p*-Mentha 2,4 (8) diene	—	Trace	—	—	—
18	*p*-Cymenene	—	Trace	—	—	—
19	γ-terpinene	0.5	—	—	—	—
20	Linalool	5.4	0.04	13.4	—	24.45
21	Linalyl acetate	—	—	—	—	1.40
22	Borneol	0.3	0.1	—	—	—
23	Terpinen-4-ol	0.1	0.1	0.7	0.9	—
24	α-Terpineol	—	0.5	1.6	1.2	—
25	α-Terpinyl acetate	—	—	3.2	—	—
26	(Z)-Cinnamaldehyde	0.6	Trace	—	—	—
27	(E)-Cinnamaldehyde	79.4	0.5	—	—	—
28	α-Copaene	1.0	—	0.8	0.4	—
29	α-Cubebene	—	—	0.1	—	—
30	β-Cubebene	0.5	0.06	—	—	—
31	(E)-Cinnamyl acetate	3.7	—	—	—	—
32	Spathulenol	0.2	4.8	2.8	1.1	—
33	Caryophyllene oxide	0.5	Trace	10.3	1.9	—
34	α-Ylangene	—	—	0.9	—	—
35	β-Bourbonene	—	—	0.1	—	—
36	Trans-Pinocarveol	—	Trace	—	0.2	—
37	Camphor	—	Trace	—	—	—
38	cis-Verbenol	—	Trace	—	—	—
39	Trans Verbenol	—	—	—	0.5	—
40	*m*-Cymen-8-ol	—	Trace	—	—	—
41	*p*-Cymen-8-ol	—	0.08	0.1	—	—
42	*p*-Cymen-7-ol	—	Trace	—	—	—
43	Trans-Piperitol	—	Trace	—	—	—
44	Carvone	—	Trace	—	0.5	—
45	Chavicol	—	Trace	—	—	—
46	Anethol	—	0.2	—	—	—
47	Thymol	—	0.2	—	—	—
48	Carvacrol	—	Trace	—	—	—
49	Methoxyacetophenone	—	0.1	—	—	—
50	β-Elemene	—	0.3	0.6	0.4	—
51	Eugenol	—	66.1	0.1	—	56.56
52	α-Gurjumene	—	0.1	—	4.7	—
53	Aromadendrene	—	1.5	1.5	1.1	—
54	α-Guaiene	—	0.1	—	1.2	—
55	Guaiol	—	0.5	—	—	—
56	α-Humulene	—	0.4	6.2	0.2	—
57	Humulene epoxide II	—	—	1.7	—	—
58	Alloaromadendrene	—	0.5	—	—	—
59	Ethyl vanillin	—	Trace	—	—	—
60	γ-Muurolene	—	0.6	1.6	—	—
61	α-Muurolene	—	—	0.8	—	—
62	D-Germacrene	—	0.5	1.0	0.8	—
63	Viridiflorene	—	2.9	—	—	—

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Table 3 Major components (%) of *C. tamala* leaf essential oil from different sources *(Continued)*

S. no.	Component	Cinnamic aldehyde type (Joshi et al., 2009)	Eugenol type (Kapoor et al., 2009)	β- Caryophyllene-Linalool type (Ahmed et al., 2000)	Trans- Sabinene hydrate-β- ocimene type (Mir et al., 2004)	Eugenol- Linalool type (Baruah et al., 2005)
64	Viridiflorol	—	0.6	0.4	0.2	—
65	γ-Cadinene	—	0.2	0.7	1.6	—
66	δ-Cadinene	—	1.1	1.4	0.9	—
67	Eugenol acetate	—	0.1	—	—	0.75
68	α-Cadinene	—	0.07	—	—	—
69	α-Calacorene	—	0.1	—	—	—
70	Elemicin	—	Trace	—	—	—
71	Globulol	—	—	0.9	0.7	—
72	α-Cadinol	—	0.6	1.5	—	—
73	T-Muuralol	—	—	0.8	0.3	—
74	Valencene	—	—	0.3	—	—
75	α-Selinene	—	—	0.2	—	—
76	Geranyl acetate	—	—	0.1	—	—
77	Cuminaldehyde	—	—	0.8	—	—
78	Nerol	—	—	Trace	—	—
79	Geraniol	—	—	0.3	—	—
80	Neral	—	—	—	0.3	—
81	β-Selinene	—	—	—	1.9	—
82	β-Bisabolene	—	—	—	0.5	—
83	Germacrene A	—	—	—	11.3	—
84	cis-Calamenene	—	—	0.7	—	—
85	β-Ionone	—	—	0.2	—	—
86	Cubenol	—	—	0.4	—	—
87	1-epi-cubenol	—	—	0.6	—	—
88	Benzylbenzoate	—	—	0.1	—	—
89	Citronellal	—	—	—	0.8	—
90	Ledol	—	—	—	1.2	—
91	Isocaryophyllene oxide	—	—	1.9	—	—
92	Isoamyl isovalerate	—	—	0.4	—	—
93	Farnesyl acetone	—	0.03	—	—	—
94	Hexahydrofarnesyl acetone	—	0.04	—	—	—
95	Coniferol	—	0.2	—	—	—
96	T-Cadinol	—	—	0.7	—	—
97	δ-Cadinol	—	0.2	0.3	—	—
98	trans Nerolidol	—	0.2	—	—	—
99	β-Eudesmene	—	Trace	—	—	—
100	Ethyl cinnamate	—	—	—	—	Trace
101	Methyl cinnamate	—	—	—	—	Trace
102	β-Caryophyllene alcohol	—	—	0.2	—	—
103	β-Caryophyllene	0.9	1.9	25.3	0.3	3.9
104	Methyl eugenol	—	1.3	—	—	—
105	Vanillaldehyde	—	0.2	—	—	—
106	Iso eugenol	—	—	—	—	0.47
107	*p*-Cumic aldehyde	—	0.03	—	—	—
108	Iso-dihydrocarveol	—	0.03	—	—	—
109	Butyl-2-methyl butyrate	—	—	0.1	—	—
110	4-Allyl 2,6-di- Methoxy phenol	—	0.2	—	—	—
111	Caryophyllenol II	—	—	0.4	—	—
112	(E)-Geranylacetone	—	—	1.3	—	—
113	Eremophilene	—	—	—	0.1	—
114	Humulene epoxide I	—	—	0.1	—	—
115	10-epi-γ-Eudesmol	—	0.3	—	—	—
116	Dodecanoic acid	—	—	1.1	—	—
117	Tetradecanoic acid	—	—	0.2	—	—
118	Hexadecanoic acid	—	—	1.1	1.2	—
119	α-Elemene	—	0.06	—	—	—
120	β-Terpineol acetate	—	Trace	—	—	—
121	Selin-11-en-4 alpha-ol	—	—	0.1	—	—
122	2,6-Dimethyl-2(3),7 octadiene	—	—	—	0.8	—
123	(E)-3 Hexenyl nonanoate	—	—	0.2	—	—
124	Caryophylladienol	—	—	0.5	—	—
125	α-Calacorene I	—	—	0.2	—	—
126	α-Calacorene-II	—	—	0.1	—	—
127	epi-Globulol	—	—	—	1.9	—

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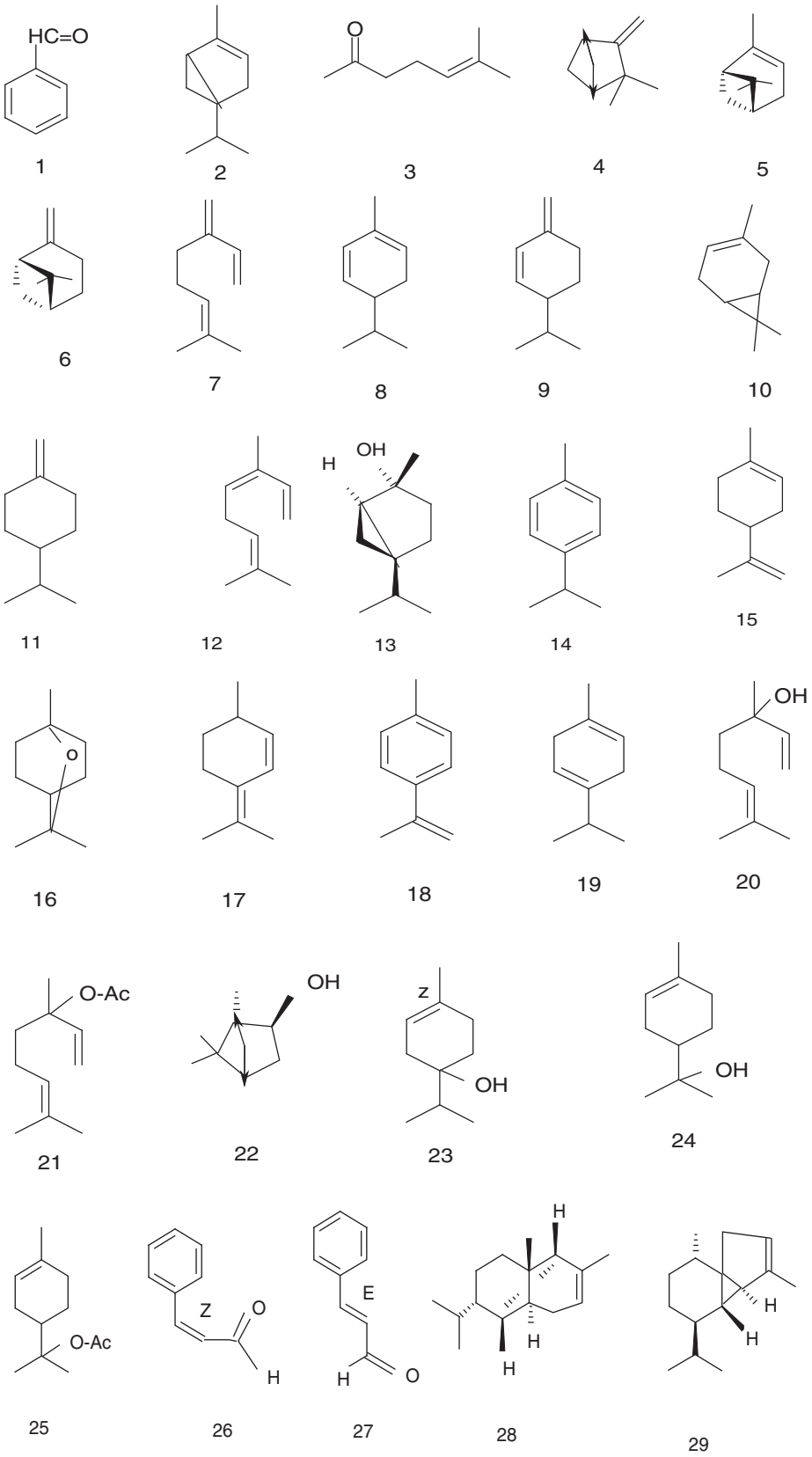

Figure 2 Structures of volatile compounds present in the essential oil of *Cinnamomum tamala* leaves (Numbers indicate the serial no. in Table 3). (Continued)

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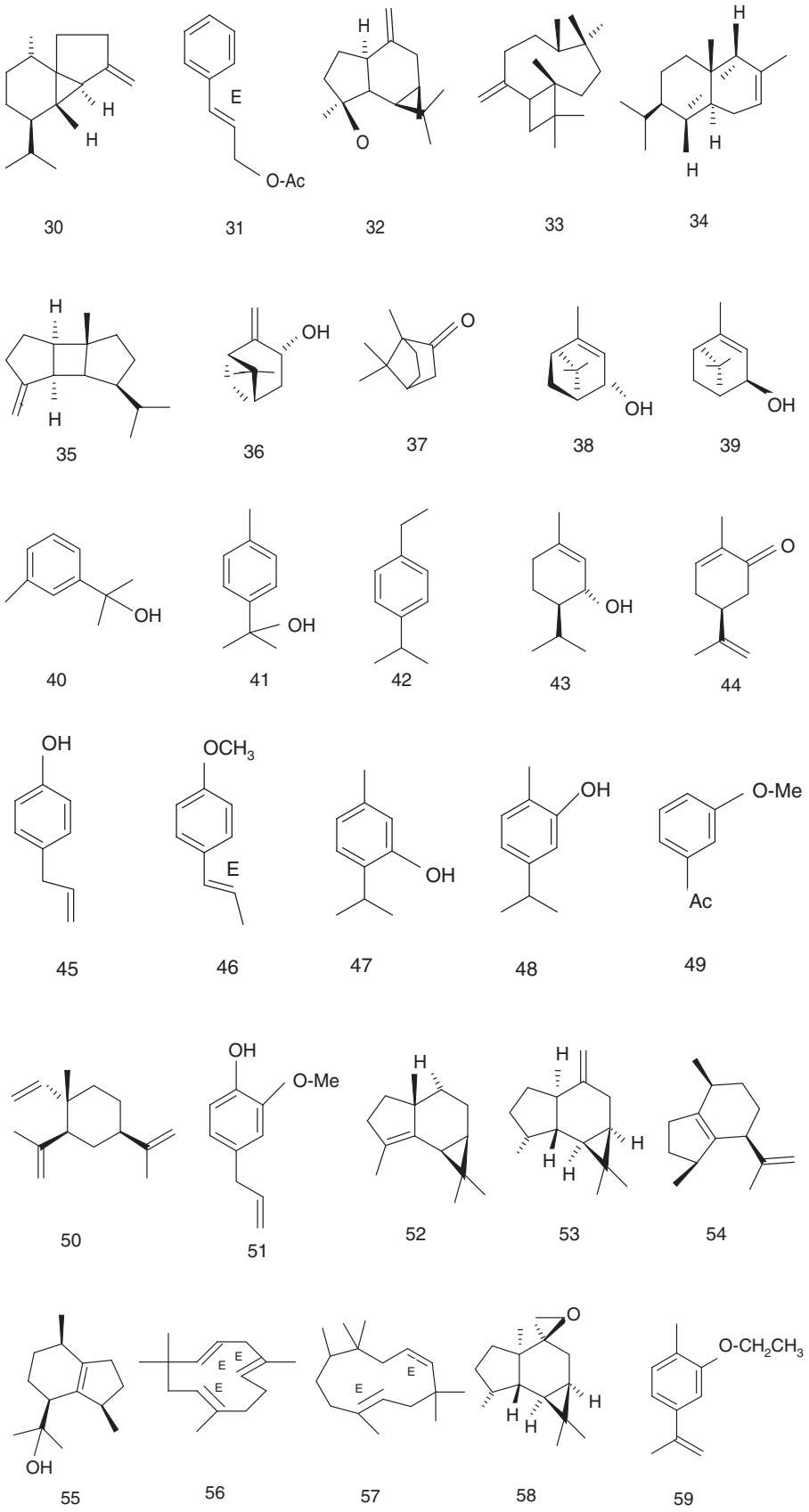

Figure 2 (Continued)

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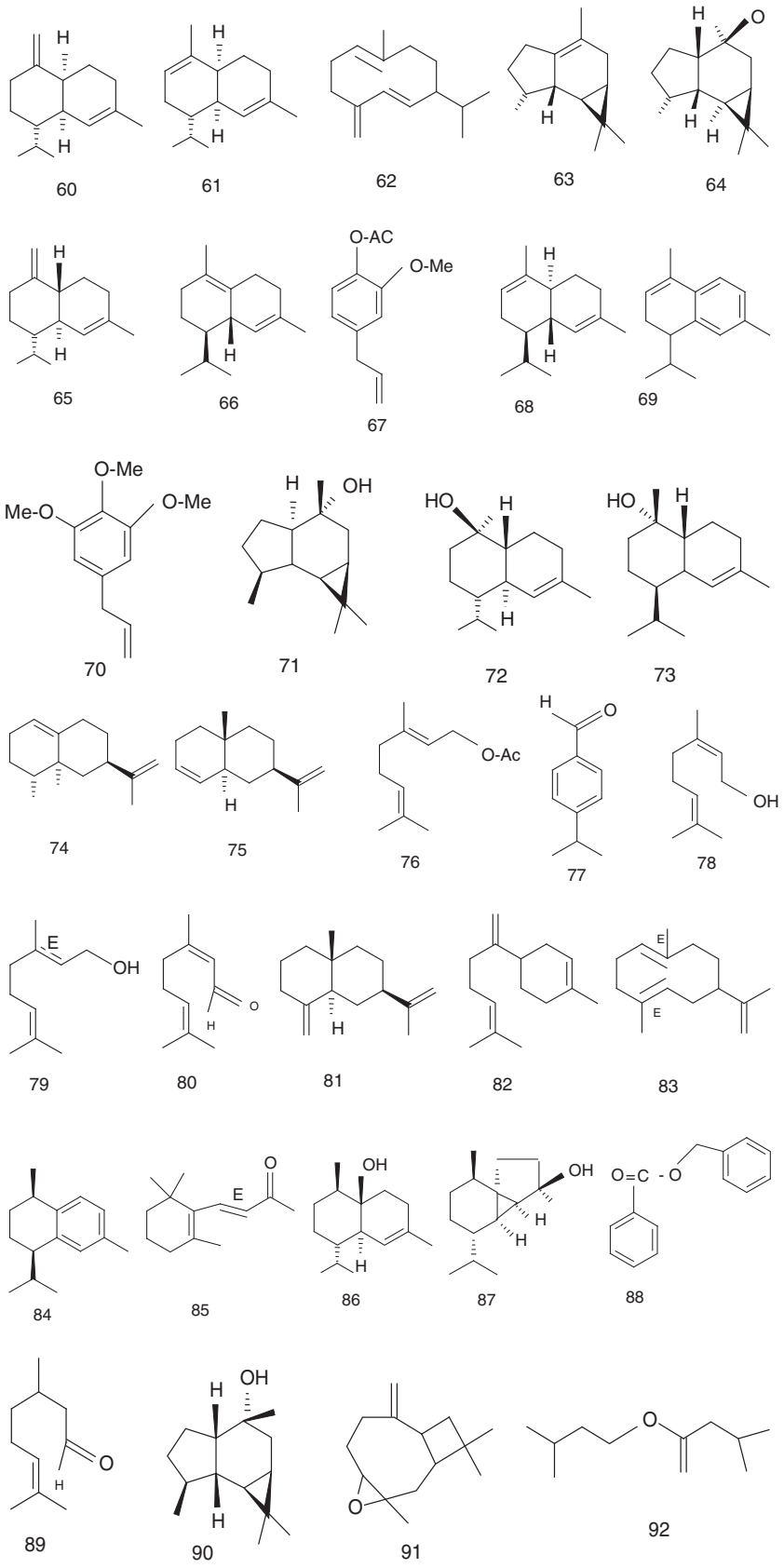

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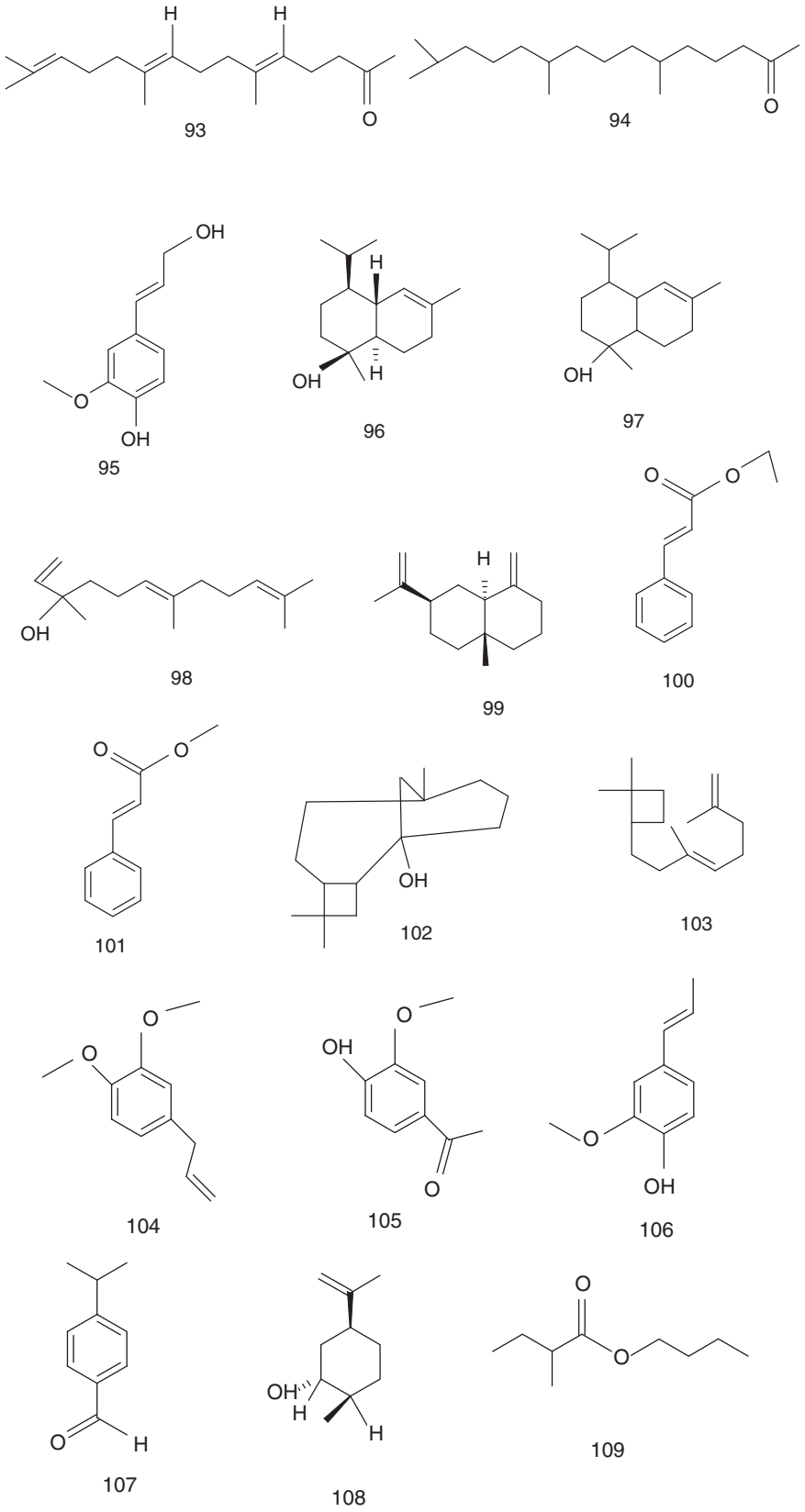

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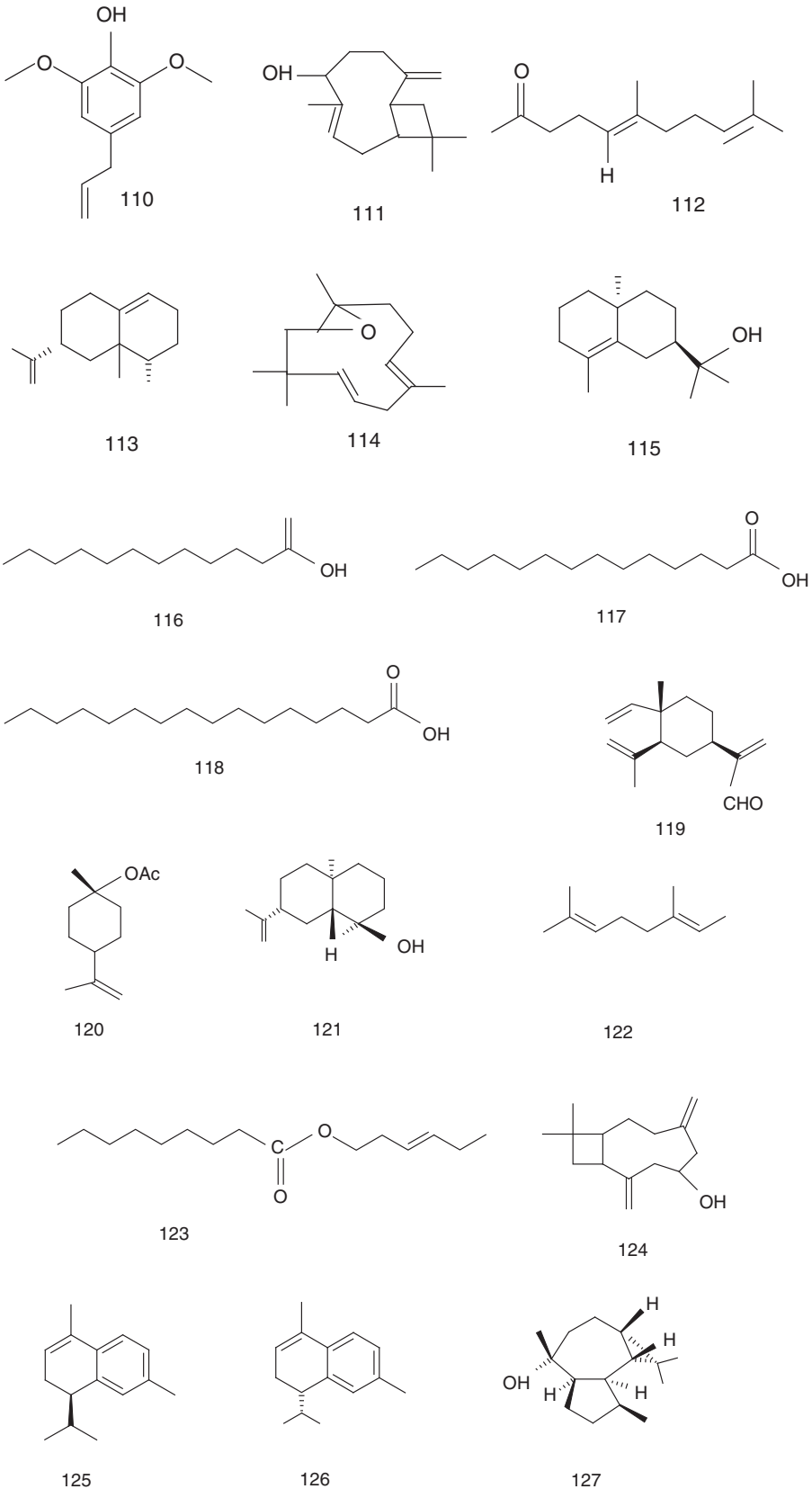

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In vitro antioxidant activity of *C. tamala* extract in rat brain synaptosomes has been investigated (Devi et al., 2007). It was observed that Reactive Oxygen Species (ROS) generation/lipid peroxidation in brain synaptosomes of diabetic rats is higher than in controls and the scavenging capacity is also comparatively low. Methanolic extract of *Cinnamomum tamala* effectively scavenges ROS and suppresses ferrous-ascorbate-induced lipid peroxidation in brain synaptosomes of diabetic rats. A 70% inhibition of lipid peroxidation was observed at a dose of 220 μg GAE.% hydroxyl radical scavenging activity, DPPH radical scavenging activity, and superoxide anion scavenging activity of *C. tamala* extract and BHT were found to be similar with no significant difference between the two and varied in a dose-dependent manner. Approximately 80% inhibition was observed in the above mentioned assays for *C. tamala* at a concentration of 220 μg GAE and for BHT at 1000 μg. However, the reductive potential values of BHT were found to be higher than those for *C. tamala* extract. The total polyphenolic content of the extract was determined to be 6.7 mg GAE/100 g.

In another study (Prasad et al., 2009), leaves of five species of Cinnamomum (including *C. tamala*) were investigated for their antioxidant activities. While *C. zeylanica* showed highest DPPH radical scavenging, total antioxidant activity and reducing power, *C. tamala* exhibited the highest superoxide anion scavenging activity. The antioxidant activity is attributed to the phenolic and flavonoid content in these species.

Sultana et al. (2010), have also reported antioxidant activity of methanolic extract of leaves of *Cinnamomum tamala* as determined by DPPH method. Ascorbic acid was used as the standard with IC_{50} (50% reduction) concentration of 22.78 mg/mL. Activity of *Cinnamomum tamala* extract was found to be low with an IC_{50} concentration of 157.58 mg/mL. Much better results were obtained in the same study for *Cuminum cyminum*, *Zinziber officinale,* etc.

Gupta and Sharma (2010), have reported antiperoxidative effect of ethanolic extract (cold percolation) of *Cinnamomum tamala* leaves on ferrous sulfate-induced lipid peroxidation in isolated rat liver homogenate as determined by TBARS assay (Thiobarbituric Acid Reactive Substances assay). The test involves quantification of end products of lipid peroxidation, especially malondialdehyde. TBA reacts with malondialdehyde to yield a fluorescent product. Ferrous sulfate-treated rats had 405.69 units of TBARS, which decreased to 400.09 and 250.68 in presence of *C. tamala* extract at concentrations 0.33 and 5.60 mg/mL, respectively.

Antidiabetic Activity

Sharma et al. (1996) have studied the hypoglycemic and antihyperglycemic activity of 50% ethanolic extract of *C. tamala* leaves in normal and streptozotocin-induced hyperglycemic rats. The blood glucose level of normal untreated rats decreased from 69.3 to 64.2 mg/100 mL after a period of 12 hours, and for those treated with extract at doses 100, 250, and 500 mg/kg, the blood glucose declined from 68.1–69.5 to 42.9–49.1 mg/100 mL over the same period. In diabetic rats, a reduction in blood glucose from 285.2 to 258.7 mg/100 mL was observed on treatment with the extract at a dose of 250 mg/kg as against an increase in blood glucose of untreated rats from 278.8 to 311.3 mg/100 mL after 10 days. Decrease in blood glucose on treatment with standard antidiabetic, glibenclamide (10 mg/kg) over the same period was from 271.9 to 204.3 mg/100 mL. In hyperglycemic condition, blood cholesterol and triglyceride levels have been observed to rise. Administration of *C. tamala* extract was found to reduce the rate of increase in total cholesterol and triglycerides in blood of diabetic rats. Blood cholesterol level of rats treated with 250 mg/kg extract was 81.0 ± 7.1 mg/100 mL after 10 days of treatment against 95.4 ± 5.3 for untreated controls. Cholesterol level of Glibenclamide (10 mg/kg) treated rats was 68.1 ± 2.9. Similarly, blood triglyceride level of treated rats was 110.2 ± 3.5 mg/100 mL after 10 days against 155.5 ± 4.8 mg/100 mL for controls. Corresponding value for Glibenclamide treated rats was 112.6 ± 2.1 mg/100 mL.

An antidiabetic formulation having (−) epicatechin and gymnemic acid as major active constituents and also containing *Cinnamomum tamala* leaves along with some other plant components has been prepared. The composition results in regeneration of pancreas cells which regain their ability to produce insulin, thus the treatment can be discontinued once normal pancreatic function is restored (Dhaliwal, 1999).

Ethanolic (95%) extract of *C. tamala* leaves has also been found to lower blood glucose in alloxan diabetic albino rats after two weeks of treatment (Kar et al., 2003). Significant reduction in blood glucose levels has been reported on treatment with 250 mg/kg body weight dose, once twice or three times daily. Although *C. tamala* was in the list of 24 out of 30 medicinal plants screened in the study which showed effect on blood glucose level of diabetic rats, much higher activity was reported for some other plants such as *Coccinia indica, Tragia involucrata,* etc.

Pushpangadan and Prakash (2006) patented a herbal nutraceutical formulation to provide health benefits to diabetes patients and also to obviate the symptoms of diabetes. The preparation includes powder/extract of *C. tamala* leaves as an essential component along with other herbs.

Chakraborty and Das (2010) reported antidiabetic and antioxidant activity of aqueous extract of *Cinnamomum tamala* leaves. Diabetes was induced in albino rats by treatment with streptozotocin. Diabetic rats had reduced body weight and showed presence of glucose in the urine. Administration of extract (250 mg/kg body weight) for three weeks resulted in weight gains comparable to normal controls. Also, no urine sugar was detected in the animals. Some sugar was detected in urine of rats administered a dose of 125 mg/kg body weight, which was less as compared to the control animals. A marked decline in levels of fasting blood glucose was also observed on treatment with the extract.

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Effect on Immune System

Many antidiabetic drugs have been found to have immunosuppressive effect. Hexane fraction of leaves of *C. tamala* has been shown to have immunosuppressive activity in rats (Chaurasia et al., 2010a). Action was found to be both direct and indirect (through modulation of innate immunity) on function of lymphocytes. Animals were sensitized with Sheep Red Blood Cells (SRBC) and administered *C. tamala* extract at 400, 800, and 1600 mg/kg body weight. Cyclophosphamide (250 mg/kg body weight) was used as a standard immunosuppressant for comparison. Later foot-pad swelling (as a measure of delayed type hypersensitivity), antibody production against SRBC and mitotic index in bone marrow of femur were determined. *C. tamala* extract inhibited delayed type hypersensitivity response measured after seven days of sensitization, in a dose-dependent manner. Treatment with 1600 mg/kg extract showed an inhibition of 54.2% as against 65.7% for cyclophosphamide. Antibody production in rats after eight days of treatment was also inhibited at higher concentrations. No inhibition was observed at a dose of 400 mg/kg but a dose of 1600 mg/kg showed an inhibition of 10% as compared to 45% for cyclophosphamide. A reduction in cell division in bone marrow cells (mitotic index) was observed after 10 days of treatment. 3.7% inhibition was observed at 40 mg/kg dose and the value was 20.4% at 1600 mg/kg. Treatment with *C. tamala* extract for 30 days caused reduction in rate of increase of body weight, bone marrow cellularity and also weight of organs related to immune system (thymus and spleen). A reduction in total white blood-cell count and percentage of lymphocytes in peripheral blood was also observed. The immunosuppressive activity could be due to flavones and monoterpene constituents.

In a separate study, (Chaurasia et al., 2010b) effect of *C. tamala* hexane extract on macrophage function was studied. Macrophage function was found to be suppressed in both in vivo and in vitro conditions. Oral administration of extract for 10 days was found to suppress phagocytotic activity (EC_{50} - 2355 $\pm$ 52.45 mg/kg), reduce superoxide production (EC_{50}- 275.91 $\pm$ 10.21 μg/mL and reduce NADPH content (EC_{50}- 384.95 $\pm$ 4.85 μg/mL) in a dose-dependent manner in albino rats, with maximum effect at a dose of 1600 mg/kg body weight. It was also found to inhibit nitric oxide production induced by LPS (Lipopolysaccharide) and expression of iNOS (inducible Nitric Oxide Synthase) protein. Phagocytosis causes a respiratory burst by suddenly producing a large amount of free radicals to kill the engulfed pathogen. In the process oxygen is reduced to superoxide, which is responsible for activation of iNOS. The mechanism of action of *C. tamala* constituents may be through free radical scavenging property.

Anti-inflammatory Activity

Gambhire et al. (2009) have reported the anti-inflammatory effect of aqueous extract of leaves of *C. tamala*. The extract was found to significantly inhibit carrageenan-induced paw edema in mice at a dose of 400 mg/kg body weight. Inhibition of 54.4% was observed against 62.7% for the standard anti-inflammatory agent indomethacin (10 mg/kg body weight). Acetic acid-induced increase in vascular permeability was also inhibited (54.78%) at a dose of 400 mg/kg against 68.45% for indomethacin (10 mg/kg). The extract was also found to have a protective effect against erythrocyte membrane lysis caused by hypotonic solution. *C. tamala* extract at 1 mg/mL resulted in 43.83% inhibition of RBC haemolysis as compared to 54.79% inhibition by indomethacin (0.1 mg/mL). The membrane stabilizing property may be due to interference with phospholipase activity, which is involved in formation of inflammation mediators. Inhibition of prostaglandin release involving arachidonic acid metabolites may have a role. It was concluded that purification of chemical constituents and study of effect on biochemical pathways may yield a potent anti-inflammatory agent.

Anticancer Activity

Saluja et al. (2010)studied anticancer activity of *Cinnamomum tamala* leaf extracts against Ehrlich ascites carcinoma (EAC) in Swiss albino mice. The mean survival time (in days) for tumor bearing mice increased by 42.93% and 40.75%, respectively, on administration of ethanolic and acetone extracts (500 mg/kg/day) for nine days. The increase in life span observed for 5-Fluorouracil, an antitumor agent (20 mg/kg) was 53.01%. A decrease in tumor volume was observed for mice treated with *C. tamala* extract. The solid tumor volumes on 30th day for acetone (625 mg/kg/day) and ethanolic extract (500 mg/kg/day) were found to be 8.1 mL and 7.5 mL, respectively, as against 3.66 mL for 5-Fluorouracil and 11.66 mL for untreated controls. Treatment also enhanced the peritoneal exudate cell count, which indirectly reflects inhibition of tumor cells. High in vitro cytotoxic activity, 98% and 84%, respectively, for ethanolic and acetone extracts (200 mg/kg) was observed against EAC. Extract was also found to ameliorate degenerative changes in liver and kidney tissues of tumor bearing mice. The mode of action may be through facilitation of macrophage activation or cytokine production. Flavonoids may be responsible for the cytotoxic and antitumor properties of the extract.

Hepatoprotective Activity

Hepatoprotective effect of methanolic extract of *C. tamala* leaves against paracetamol-induced toxicity in Swiss albino mice has been reported (ThamizhSelvam et al., 2010). Hepatic injury results in rise of cellular enzymes in plasma and their estimation gives the measure of hepatocellular damage. On administration of 2.5 g/kg dose of paracetamol, abnormally high levels of liver function parameters in serum—serum glutamate pyruvate transaminase (SGPT), serum glutamate oxaloacetate

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transaminase (SGOT), alkaline phosphatase (ALkP), bilirubin, and certain proteins—were observed. Treatment with *C. tamala* extract at doses of 100 and 200 mg/kg for eight days, before paracetamol intoxication reduced the extent of liver damage. Higher activity was observed at the dose of 200 mg/kg, which was similar to the effect of standard hepatoprotective agent silymarin. Structural damage to liver tissue caused by paracetamol was also found to be reduced in treated animals. Further research on isolation and characterization of active constituents is required.

Effect on Gastro-intestinal Tract

Gastroprotective activity of *C. tamala* leaf extract in rats has been investigated (Eswaran et al., 2010). Treatment with the extract orally (50, 100, and 200 mg/kg) twice daily for five days was found to protect against ethanol, cold restraint stress, and pylorus ligation-induced ulcers. Effect on ethanol-induced ulcers was observed by estimation of H^+ K^+ ATPase activity and gastric wall mucous. For cold restraint stress-induced ulcers activity of antioxidant enzymes was measured, and for pylorus ligation-induced ulcers volumes of gastric juice, acid output, and pH were measured. A significant decrease in lesion index was observed for treated rats as compared to the controls. H^+ K^+ ATPase activity, volume of gastric juice, and acid output were found to decrease significantly. Level of gastric wall mucous and pH were found to increase in a dose-dependent manner. Level of lipoprotein oxidase and superoxide dismutase decreased while that of catalase was found to increase. The gastroprotective activity of extract was attributed to its free radical scavenging capability.

Rao et al. (2008) have reported the antidiarrhoeal activity of 50% ethanolic extract of *C. tamala* leaves in rats. The extract at 25, 50, and 100 mg/kg, given orally, caused a dose-dependent reduction in castor oil-induced diarrhoea. A dose of 100 mg/kg resulted in a significant reduction in gastrointestinal fluid accumulation (by 32.5–65.0%). The extract was also found to significantly reduce lipid peroxidation and increase catalase activity. A high dose of extract (15 mg/mL) did not show any effect on mast cell degranulation; however, lower doses (5 and 10 mg/mL) had a significant protective effect.

Antimicrobial Activity

Antifungal activity: *Cinnamomum tamala* has been reported to have fungicidal/fungistatic activity. Essential oils of *Cinnamomum tamala* leaf have been found to inhibit growth of two ringworm fungi, *Trichophyton mentagrophytes* and *Microsporum audounil* (Yadav and Dubey, 1994). The minimum concentration at which essential oils of *Cinnamomum tamala* inhibited fungal growth in poisoned food method was 500 ppm. In this method, the test dose is mixed in the culture medium. The essential oil showed better effectiveness as compared to some synthetic antifungal agents.

Mehmood et al. (1999) found moderate activity of alcoholic extract of *C. tamala* leaves at a concentration of 200 mg/mL against *Trichophyton rubrum, Microsporum gypseum*, and *Epidermophyton floccosum* with <10 mm diameter zone of inhibition. A 16–19 mm zone of inhibition was observed against *Candida albicans* with alcoholic extract but no activity was detected with aqueous extract.

In another study (Kapoor et al., 2009), the volatile oil and oleoresins from *Cinnamomum tamala* leaf have been found to be effective against a number of fungi, although the oleoresins were less effective as compared to the volatile oil. Complete inhibition of fungal growth by volatile oil has been reported in this study at a dose of 6 μL against *Aspergillus niger, A. flavus, A. solani,* and *Fusarium moniliforme* in the inverted petriplate assay. In this method, the dose is soaked on a piece of filter paper, which is placed on the lid of a petriplate, and the petriplate is then kept in an inverted position. A 100% inhibition of *A. oryzae* was observed even at a dose of 2 μL. However, *A. awamori* could not be completely inhibited and showed 87.6% inhibition at a dose of 6 μL. In the poisoned food method experiment, 100% inhibition was observed for *A. niger* and *Fusarium monoliforme* at 6 μL. For other fungi, inhibition ranged from 56 to 83%.

Antibacterial activity: De et al. (1999) tested antimicrobial activity of 35 Indian spices and found 15 of them to have potent activity. Alcoholic extracts of different spices were tested at doses of 1 mg/mL, 25 mg/mL, and 100 mg/mL. *C. tamala* leaf extract has been found to inhibit growth of *Saccharomyces cervisiae*, in a test tube at a dose of 100 mg/mL. It was, however, found to be ineffective against *Bacillus subtilis* and *E. coli*.

Singh et al. (2007) studied antibacterial activity of volatile oils and acetone extract of *C. tamala* leaves against *E. coli, Salmonella typhi, Pseudomonas aeruginosa, Bacillus cereus, Bacillus subtilis,* and *Staphylococcus aureus* by disc diffusion and plate count methods. Volatile oil was found to have high activity against all organisms tested. The activity of acetone extract was lower than that of volatile oil. The oil/extract were found to be equally, or in some cases, more effective as compared to standard antibiotics at very low concentrations. A 100% inhibition was observed in plate count method with volatile oil fraction at concentrations of 2 and 6 μL which was better than results obtained at 10 mg/petriplate with antibiotics penicillin-G, amilkacin, and gentamycin. In the disc diffusion method, approximately equal to or greater than 40% zone inhibition was reported at 10 μL concentration. Here again, results for volatile oil were better as compared to antibiotics.

Kapoor et al. (2008), have used essential oil and oleoresins of *Cinnamomum tamala* leaf, obtained by hydro-distillation using a Clevenger type apparatus and solvent extraction using soxhlet apparatus, respectively, as preservatives in pineapple fruit juice. Peroxide values of the samples containing the essential oil (9.3 meq/kg) were found to be lower than control samples (14.3 meq/kg) after 28 days. Yeast and mold count after seven days of storage was 62 with volatile oil as compared to control values

of 162 and 103. Corresponding values for total microbial count are 53 for volatile oil and 95 and 52 for controls. After 28 days of storage, the volatile oil containing juice samples had a yeast and mold count of 176 as against 265 and 190 for controls, and a total microbial count of 90 as against 178 and 138 for controls.

Mishra et al. (2010) reported antibacterial effect of *C. tamala* leaf against *E. coli, Pseudomonas vulgaris, Streptococcus pneumoniae,* and *Staphylococcus aureus*. The minimum inhibitory concentration (MIC) of solvent extracts and oil from *C. tamala*, when inhibition in growth tubes was observed for the organisms tested, varied between 0.60 and 2.40 mg/mL. Also, minimum inhibitory disc concentrations (MIDC), which is the lowest concentration of volatile oil, loaded onto a disc and put over a petriplate containing microbial culture, that inhibits visible microbial growth around the disc, ranged from 0.90 to 2.25 μg/disc.

Miscellaneous

Dried *Cinnamomum tamala* leaf powder/extract along with several other plant components has been used in a novel nicotine free herbal product that acts against poisonous effect of tobacco smoking and addiction to tobacco related products (Karerat et al., 2006).

Palpu et al. (2006) have patented an ayurvedic herbal soft drink with immunity enhancing, antioxidant, hepatoprotective, antifatigue, and antistress properties. The preparation includes decoction of leaves of *Cinnamomum tamala* among the ingredients.

Nematicidal effect of *Cinnamomum tamala* leaf extract has also been reported. Ethanolic extract of leaves at a concentration of 1000 ppm was found to significantly inhibit egg hatching of the nematode, *Meloidogyne javanica*. Ethanolic extract gave better results as compared to aqueous extract (Abbas et al., 2009).

Insecticidal effect of *Cinnamomum tamala* leaf powder against *Callosobruchus maculatus* in black gram has been studied (Hussain et al., 2008). The values for day of 100% mortality at doses of 25 g/kg and 30 g/kg were reported to be 14 and 13, respectively. The values, although lower, are close to the control values of 15.7 and 16 at same doses. Much better results have been obtained in the same study for clove, black pepper, and Ceylon cinnamon, etc., powders.

Semwal et al. (1999) have reported pro-oxygenic effect of *Cinnamomum tamala* leaf powder and different solvent extracts of *C. tamala* in sunflower oil. Peroxide values and thiobarbituric acid values of different samples were determined, and ratio of peroxide value of control to treated sample was expressed as pro-oxygenic activity. The pro-oxygenic activity values for *C. tamala* fractions ranged from 0.62 for chlorophyll to 1.00 for water extract and spice residue. (Values <1 indicate pro-oxygenic effect and >1 indicate antioxygenic effect.) Value for leaf powder was 0.81. Further, chlorophyll-free fractions were found to be devoid of any pro- or antioxygenic activity, on basis of which it was concluded that chlorophyll was the sole pro-oxygenic constituent of *C. tamala*. Capsaicin and chilli powder were found to have antioxygenic effect in the same study. However, in another study (Kapoor et al., 2009) the antioxidant effect of essential oil and oleoresins of *C. tamala* in mustard oil has been reported. Peroxide values of samples containing *C. tamala* essential oil/solvent extract were found to be lower than controls. Peroxide values for sample containing essential oil of *C. tamala* was 20 against 80 for control after seven days and 30 against 160 after 28 days. Volatile oil had higher activity than solvent extracts. TBARS (Thiobarbituric Acid Reactive Substances) formation was inhibited by volatile oil and other fractions showed moderate inhibition at 0.02% concentration, which was comparable to BHA and PG. Results obtained for anisidine and total carbonyl values and linoleic acid system scavenging also indicated antioxidant effect.

BIOACTIVITY OF STEM- BARK OF C. tamala

Antidiabetic Activity

In a study, (Kumanan et al., 2010) α-amylase inhibitory activity of bark of *C. tamala* has been reported. Inhibition of α-amylase causes reduction in rate of starch digestion and subsequent carbohydrate uptake, and therefore may play a role in management of diabetes. The inhibition values of methanol and successive water extract of *C. tamala* bark at a concentration of 1 μg/mL were reported to be 97.49% and 93.78%, respectively. IC_{50} values of methanol extract is one-third of successive water extract.

Antibacterial Activity

Antibacterial potential of extracts from stem-bark of *C. tamala* has been investigated (Goyal et al., 2009). The extent of inhibition depended on procedure of extraction, plant part used, whether fresh or dry material was used, solvent used, and the microorganisms tested. Variable extent of inhibition was observed for different bacteria (*E. coli, Salmonella typhi, Bacillus cereus, Bacillus subtilis, Staphylococcus aureus and Streptococcus pyrogenes*) in agar well diffusion assay by all extracts except hexane extract, which was inactive. Significant activity was observed for ethanol, methanol, and ethyl acetate extracts against all bacteria except *E. coli*, which was found to be totally resistant to all extracts. Gram-positive bacteria were found to be more susceptible as compared to Gram negative ones. MIC value of methanolic extract against *S. aureus* was 256 μg/mL and for ethanolic extract was 512 μg/mL. The MIC values were found to be four to eight-fold for some other bacteria. Methanol extract was found to be most effective and organic extracts had higher activity than aqueous extracts.

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CONCLUSION AND FUTURE PROSPECTS

Leaves of *Cinnamomum tamala* exhibit significant biological activity by virtue of its active constituents. Most reported research on effect of solvent extracts and essential oil of *Cinnamomum tamala* on biological systems is very recent (2006–2010). Further research may bring out other effects of this spice on biological systems. Although the profile of volatile fraction of *C. tamala* leaves is fairly well characterized, it is highly variable due to the presence of different chemotypes in different geographical regions. A systematic evaluation of odor impact constituents of the volatile oil may be helpful in promoting its use as an additive in food formulations. As far as characterization of non-volatile components is concerned, there is ample scope for further work on this aspect. Future research is also required for identification of specific components of *C. tamala* leaves, which are responsible for its specific biological effects to facilitate its use in nutraceuticals or drug development.

Epidemiological studies on average daily consumption and effect of short-/long-term consumption as spice or otherwise on health has not been reported. Nature and bioavailability of active constituents present in *Cinnamomum tamala* has also not been thoroughly investigated. Acute toxicity study for animal system has indicated that consumption of at least up to 2 g/kg body weight is safe without any adverse health effects. Toxicity level for human subjects has not been reported. Investigation in these areas would also generate useful information.

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