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Chapter

Cinnamomum zeylanicum: Morphology, Antioxidant Properties and Bioactive Compounds

Asel Chandula Weerasekera, Kanchana Samarasinghe, Heethaka Krishantha Sameera de Zoysa, Thushara Chathuranga Bamunuarachchige and Viduranga Yashasvi Waisundara

Abstract

Cinnamomum zeylanicum is one of the oldest spices used for culinary purposes in Asian countries. Its extracts have demonstrated a positive impact on controlling the progression of disease pathologies due to antioxidant, anti-inflammatory, antimicrobial, anticancer, anti-mutagenic, anti-tyrosinase and antidiabetic characteristics. *C. zeylanicum* also has its unique variations which makes it necessary to distinguish it from other species of cinnamon. Phenolic compounds such as cinnamaldehyde, eugenol, carvacrol, cinnamic acetate and thymol are the main compounds that can be found in essential oils of *C. zeylanicum*. However, cinnamaldehyde and eugenol act as the main bioactive antioxidant compounds found in *C. zeylanicum* because of their active functional groups in the structures. There are many examples of the use of *C. zeylanicum* extracts for medicinal purposes, specifically cinnamon metabolite proanthocyanidins which suppress inflammatory compounds and help pathways such as insulin signaling. Moreover, the bioactive compounds in essential oils of this plant are used against many pathogenic (including food-borne) and spoilage bacteria.

Keywords: Alzheimer's disease, Ayurveda, cinnamaldehyde, Ceylon cinnamon, eugenol

1. Introduction

Cinnamomum zeylanicum (family Lauraceae), known as 'Ceylon cinnamon' or 'true cinnamon', grows as an ever-green tree native to Sri Lanka (earlier Ceylon), and India including other regions of tropical Indochina and Madagascar (**Figure 1**). This is one of the oldest traditional spice species used for culinary purposes in South Asian countries [1, 2]. Additionally, according to toponymical and historical evidence, *C. zeylanicum* has been used for medicinal purposes since the establishment of Aryan settlements in the Anuradhapura kingdom [3]. Moreover, the indigenous species of Ceylon cinnamon has been used in the Ayurveda system of Sri Lanka [3, 4]. Ethnopharmacological studies show that

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Figure 1.
Typical Cinnamomum zeylanicum *tree (a), leaf (b), and processed bark (c) in Sri Lanka.*

C. zeylanicum has gained more importance in Ayurveda and folklore medicine as it can be used in concoctions and decoctions. The inner bark of *C. zeylanicum* is used for medicine preparation in flatulence control, indigestion and in flu-prevention in the Sri Lankan Ayurveda system. *C. zeylanicum* has also been found in various other folklore treatments against inflammation of eyes, dyspnoea, leucorrhoea, rheumatism, neuralgia, wounds, toothache and diabetes [4–6].

C. zeylanicum and it extracts have demonstrated their ability to have a positive impact on controlling the progression of disease pathologies in modern times as well. This is mainly due to the functional properties of *C. zeylanicum* and its compounds behaving as antioxidant, anti-inflammatory, antimicrobial, anticancer, anti-mutagenic, anti-tyrosinase and antidiabetic agents [1, 2]. In fact, Ceylon cinnamon is considered one of the few plants in the world that have made it to the modern pharmacy in the form of pills, powders, oils and ointments.

A striking resemblance in terms of appearance exists between different Cinnamon varieties. In particular, *C. zeylanicum* is sometimes confused with other varieties resulting in incorrect information being disseminated about the functional properties and bioactive compounds. To avoid consequences of these similarities, as well as due to the lack of data about the antioxidant properties of the plant and the importance of this information to its folkloristic use and pharmacological activities, it was deemed necessary to address the morphological features and antioxidant properties of *C. zeylanicum* in detail in this chapter, as well as the culinary and traditional uses, and the phytochemical composition and pharmacological activities.

2. Morphological features of *Cinnamomum zeylanicum*

C. zeylanicum has its unique variations which are quite useful in distinguishing it from other species of cinnamon. It is generally grown in loamy, lateritic, and

silver sand soil and can grow up to 12 m in height. The morphological features which enable the identification of the varieties of *C. zeylanicum* from other species of Cinnamon based on leaf traits are shown in **Table 1** [7]. While the deep vein distribution appears to be common to all Cinnamon species, the color change of the

Type	Leaf shape	Leaf color	Leaf size	Venation	References
Cinnamomum zeylanicum (Sri Wijaya)	Acute	Red leaves when young And deep green when matured.	Small to medium	Deep vein distribution pattern present.	[7, 8]
Cinnamomum zeylanicum (Sri Gemunu)	Ovate to elliptic	Red leaves when young and dark green when matured.	Medium to large	Deep vein distribution pattern present	[8]
Cinnamomum cassia	Lanceolate	Red leaves when young.	Small to medium	Deep veins	[9]
Cinnamomum burmannii	Ovate-oblong	Pale greenish brown leaves.	Small to medium	Deep veins	[10]
Cinnamomum tamala	Elliptic-oblong, ovate	Slightly pinkish when young and green when matured.	Small to medium	Deep veins. Three-nerved from close above the base almost to the apex	[11]

Table 1.
Morphological traits of leaves of varieties of cinnamon.

Type of Cinnamon	Color	Texture	Layers when rolled	Fragility	Odor	Taste	References
Cinnamomum zeylanicum	Tan brown	Thin, soft and papery	Multiple layers and curls inward from both edges.	Fragile	Exotic aroma	Mild sweet	[4, 12]
Cassia Cinnamon	Reddish dark brown	Thick and rough	Few layers and curls inward from one edge.	Harder to break	Mild aroma	Spicy	[4, 12]
Cinnamomum burmannii	Light reddish brown	Thin and soft	One layer	Fragile	Strong aroma	Marginal bitter and astringent	[12]
Cinnamomum loureiroi Nees	Reddish brown	Thin and rough	Few layers	Harder to break	Strong aroma	Slightly bitter and astringent	[4, 12]

Table 2.
Significant differences in the bark of Cinnamomum zeylanicum *and in other species of cinnamon.*

Type of Cinnamon	Flower color	Arrangement	References
Cinnamomum zeylanicum	Greenish	In panicles	[10, 13]
Cinnamomum cassia	White	In panicles	[13]
Cinnamomum burmannii	Whitish Yellow	In panicles	[14]
Cinnamomum tamala	Yellow	In panicles	[13]

Table 3.
Variations of flower and inflorescence in Cinnamomum zeylanicum *and other kinds of cinnamon.*

leaves from red to deep green and a larger size help to distinguish the *C. zeylanicum* from *C. cassia*, *C. burmannii* and *C. tamala*.

The Cinnamon bark of *C. zeylanicum* is where most of the bioactive compounds exist, and, there are certain traits which help identify the plant, based on bark characteristics which are shown in **Table 2** [4, 12]. However, it is also shown that the bark of *C. zeylanicum* in powder form is practically impossible to distinguish from other wild species of cinnamon due to its identical appearance – a character which is often misused by Cinnamon producers for adulteration. In these instances, an analytical method or a microscope is essential for the identification of Ceylon Cinnamon in its powdered form. However, the aroma from *C. zeylanicum* is more fragrant and exotic than other varieties. Owing to continued exposure to the plant, traditional Cinnamon growers would have the best sense of distinguishing *C. zeylanicum* from other varieties simply based on the aroma of the bark.

Flowers of *C. zeylanicum* are greenish in color and are arranged in panicles both from the axial or apex [10, 13, 14]. Variations in the Cinnamon flowers based on the different varieties are shown in **Table 3**. *C. zeylanicum* flowers have a noticeable green hue which would set it apart from flowers of other Cinnamon varieties.

3. Antioxidant properties and beneficial effects

Antioxidants are known as substances or compounds, that delay/stop the oxidation by ceasing the damage caused by free radicals. They are able to easily interact with free radicals by oxidation, and generally, the reaction occurs either in single or multi-step fashion. Antioxidants can also react through single electron transfer, hydrogen atom transfer or by chelating transitional metals. Moreover, antioxidants in the biological systems occur as enzymatic and non-enzymatic forms at both extracellular and intracellular environments [2, 15, 16]. The balance of free radicals and antioxidant defense mechanisms is critically important in health aspects from the perspective of mitigating oxidative stress [17–20]. Oxidative stress, which is induced by free radicals, is associated with many chronic diseases such as cancer, osteoporosis, diabetes and coronary heart disease [2, 4, 16, 21]. Reactive oxygen species (ROS) induce oxidative stress and are responsible for the cumulative damage imparted on DNA, lipids, proteins and other molecules, subsequently resulting in even permanent damage [17–19, 22]. Many spices, fruits and vegetables have already been identified as rich in antioxidant compounds such as polyphenols, vitamins, flavonoids and carotenoids [23–25]. Moreover, antioxidant-rich foodstuff are good sources to combat and prevent the incidence of many chronic diseases associated with oxidative stress [23].

C. zeylanicum is rich in phenolic compounds. These compounds and their activities are defined by their structure (reactive benzene rings), which is directly linked with quenching radicals in biological systems [17, 22, 26]. Cinnamaldehyde, eugenol, carvacrol, cinnamic acetate and thymol are the main phenolic compounds

that can be found in essential oils of *C. zeylanicum* [27, 28]. Characterization of phenolic compounds in *C. zeylanicum* revealed that it can improve hyperlipidemia; possibly by lowering cholesterol production, and suppressing lipid peroxidation [1]. Among the parts used in the *C. zeylanicum* tree for various medicinal purposes, the bark demonstrated the highest antioxidant activity compared to the leaves and flowers [2]. However, essential oils appear to have the greatest antioxidant activity compared to leaves, bark and extracts from other parts of the plant [18].

Peroxynitrite (ONOO-) is a compound capable of reacting with almost every class of biomolecules due to formation of $NO2^{\bullet}$ and $OH^{\bullet}$ radicals via degradation. These radicals can promote oxidative damage to blood vessels, skin, heart, lungs, kidney, and brain. Eugenol – a component of the active oils extracted from Cinnamon was found to be effective in preventing peroxynitrite-induced damage *in vitro*. However, the concentration of eugenol present in active oil extracts differ depending on the Cinnamon variety it was extracted from, with *C. zeylanicum* activity demonstrating the highest. Therefore, from a pure peroxynitrite inhibitory standpoint, Cinnamon oil extracts with a high eugenol content can be classified as a spice to inhibit the activity of radicals $NO2^{\bullet}$ and $OH^{\bullet}$ [29].

Besides, many studies have been conducted to assess the antioxidant properties of *C. zeylanicum* with extractions from different parts of the tree, under both *in vitro* and *in vivo* conditions [2, 19]. Multiple studies have exposed the total antioxidant capacity and its beneficial results such as a decrease in blood lipid peroxide levels through the improvement of hepatic antioxidant enzyme activities [2, 19, 25], and lowered risks of male infertility, and inflammatory diseases [17]. A study done with swiss albino mice by using Cinnamon 0.25% and Cardamom 0.5%, orally administered at doses of 100 ml/mouse/day, observed that azoxymethane induced colon carcinogenesis could be significantly controlled by inhibiting lipid peroxidation and enhancing Glutathione-S-transferase (GST) activity in liver and colon [30].

In addition to the health benefits, these antioxidants have been used as a primary additive or preservative especially in food industries to prevent or delay the spoilage of food rich in fats and oils [23] and for enhancement flavor [19]. Nowadays, many food industries are concerned with producing food which is less toxic, have fewer health risks and contain a smaller number of synthetic compounds during processing. Therefore, plant-derived antioxidants, especially those coming from *C. zeylanicum*, has commanded the attention of manufacturers and consumers [2, 26, 27]. The natural compounds, which are characterized by their antioxidant properties have shown great potential in terms of their health benefits (**Table 4**) [22, 27]. Additionally, these antioxidant compounds are used as substitutes for the synthetic ones such as butylated hydroxytoluene (BHT) and butylated hydroxy anisole (BHA) [22, 27, 34]. Studies have also revealed that when *C. zeylanicum* is used as an antioxidant in food, it enhances antioxidant enzymes and remove the ROS, while decreasing malondialdehyde which is naturally present during situations of elevated oxidative stress [17]. *C. zeylanicum* compounds appear to withstand severe processing conditions as well, since a study has shown that irradiation – which is used frequently to preserve foods these days, does not affect the antioxidant properties of *C. zeylanicum* extracts [15]. This indicates its suitability as a food preservative [15, 35]. Moreover, *C. zeylanicum* is used in the pharmaceutical industry as a nutraceutical. It is also used in the essence industries due to its fragrance to produce foods, perfumes and drugs [2, 22, 23].

In terms of the bioactive antioxidant compounds present in *C. zeylanicum*, cinnamaldehyde and eugenol act as the main bioactive antioxidant compound because of their active functional groups in the structures [36]. Health benefits of antioxidant compounds present in *C. zeylanicum* are listed in **Table 5.**

C. zeylanicum plant product type or parts	Main Antioxidant compounds	Properties or benefits	Reference
Essential oils	Cinnamaldehyde, eugenol, thymol, carvacrol, safrole, menthol, 1,8-cineole, α-terpineol, p-cymene	As agro-food natural antioxidants to conserve fatty foods used in all formulations containing fats, as food additives and as a natural food preservative.	[26]
Essential oils	Cinnamaldehyde, α-pinene, eugenol, β-caryophyllene, and eucalyptol	high inhibitory effect against β-carotene discoloration, suppress lipid oxidation reaction, and as a food preservative.	[31]
Essential oils	Cinnamaldehyde, eugenol and carvacrol	As feed additives and potential alternative to antibiotics in poultry industry.	[32]
Essential oil	Cinnamaldehyde and cinnamic acetate	inhibition of 2-hexenal oxidation	[28]
Essential oil	Cinnamaldehyde and trans-cinnamaldehyde	As a drug in phytotherapy disease treatment.	[33]
Cinnamon (*C. zeylanicum*) tea	Trans-cinnamaldehyde	Decrease blood lipid peroxides, increase antioxidant capacity and total thiol molecules.	[19]

Table 4.
Antioxidant compounds of C. zeylanicum *products and their properties.*

Antioxidants compounds	Activity	Reference
Cinnacassiol, eugenol, camphene, coumarin, cinnamaldehyde, cinnamic acid and gamma-terpinene	Against high cholesterol diet toxicity	[17]
Cinnamaldehyde and other compounds of Cinnamon	Activity against the production of nitric oxide and the expression of inducible nitric oxide.	[23, 37]
Eugenol	Against peroxynitrite induced nitration and lipid peroxidation.	[23]
Essential oil rich in eugenol, (E)- cinnamaldehyde, and linalool		[37]
Cinnamaldehyde and trans-cinnamaldehyde	Anti-tyrosinase activity.	[17, 23]
Cinnamate	Improves hyperlipidemia and decrease triglyceride levels.	[1]
Cinnamaldehyde	Reduce visfatin-induced breast cancer.	[38]
Cuminaldehyde	Inhibition of proliferation and apoptosis induction.	[38]

Table 5.
Antioxidant properties of bioactive compounds present in C. zeylanicum.

There are other demonstrated beneficial properties of *C. zeylanicum*. Acetaminophen is an over-the-counter antipyretic-analgesic drug. It exhibits anti-inflammatory properties at therapeutic doses. However, it also causes hepatotoxicity

and nephrotoxicity at large doses. Trials conducted by supplementing high doses of Cinnamon with acetaminophen in four rat groups discovered that pre-treatment with Cinnamon significantly ameliorated cellular alterations and apoptosis [39].

Tauopathy neurodegeneration is a subset of diseases involving a trademark neurofibrillary tangling. Hyperphosphorylation in the microtubular protein known as tau results in the protein disassociating from the microtubules and forming insoluble aggregates. These neurofibrillary tangles of tau are believed to be one of the possible central pathologies of Alzheimer's disease. Cinnamon extract was found to effectively inhibit the aggregation of human tau *in vitro*. The activity was attributed to a proanthocyanidin trimer and cinnamaldehyde. The same study observed that while the Cinnamon extract inhibited the aggregation of tau, not all polyphenols in the Cinnamon extract are active in the inhibitory process. Therefore, the inhibitory activity cannot be linked to the general antioxidant properties of the extract. However, the studies were performed *in vitro*, raising concerns about the bioavailability of compounds. Regardless, this study has set the stage and qualified Cinnamon extract for additional testing in clinical trials [40].

Cinnamon extract also exhibited significant gastroprotective effects in a study performed with Wistar albino rats. Gastric lesions were induced via an orally administered indomethacin solution. A Cinnamon suspension was administered 30 min prior to the oral indomethacin, and the animals were sacrificed 6 hours after the treatment. The results found a significant decrease in basal gastric acid secretion and ulcer protective effects across a range of models [41].

4. Bioactive compounds

C. zeylanicum antioxidant compounds are found in many of parts of the plant such as leaves, buds, flowers, fruits, bark, root bark and oils. Additionally, *C. zeylanicum* is also rich with volatile compounds, most of which act as antioxidants. *C. zeylanicum* contains cinnamyl acetate, eugenol, trans-cinnamaldehyde (the main component of Cinnamon flavor), cymene, cinnacassiol, cineol, camphene, catechins, coumarin cinnamic acid and gamma-terpinene, terpinolene, and α-thujene, α-terpineol, linalool, l-borneol, E-nerolidol, pinene, phyllandrene, proanthocyanidins, safrole, tannins constituting polymeric 5,7,3,4-tetrahydroxy-tetrahydroxy flavan-3-4-diol units, α-cubene and resins [1, 17, 23]. In addition, most of the compounds are mainly derived from cinnamyl, hydrolyzed phenol, tannins, phenylpropanoids and terpenoids compounds [42]. There are several other bioactive compounds listed in **Table 6**, according to the type of extraction using different parts of the *C. zeylanicum* tree [26]. However, eugenol, benzyl benzoate, linalool and eugenyl acetate are reported as the common antioxidants of *C. zeylanicum* species [27].

Among the bioactive constitutes of *C. zeylanicum*, cinnamaldehyde and trans-cinnamaldehyde are considered as the major compounds, especially concerning anti-tyrosinase activity [17]. The spicy and fragrance characters of *C. zeylanicum* is mainly due to cinnamaldehyde [23]. Based on the richness of bioactive compounds and its medicinal properties, *C. zeylanicum* is used traditionally to provide aroma and essence compounds. It is also used as an antioxidant, anti-inflammatory, anti-hyperglycemic, anti-lipidemic, antidiabetic, anticancer, antitumor, anthelmintic, anti-aflatoxigenic, antifungal and antimicrobial agent medicinally [1, 29, 32, 43–47]. There are many examples of its use for medicinal purposes such as Cinnamon metabolite proanthocyanidins which suppresses inflammatory compounds helping pathways such as insulin signaling. Moreover, essential oil bioactive compounds are used against many pathogenic (including food-borne) and spoilage bacteria [17, 31, 46].

Parts of *C. zeylanicum*	**Antioxidant compounds**	**Reference**
Essential oil	• Cinnamaldehyde • Trans-Cinnamaldehyde • Camphor • Cinnamyl-acetate • Caryophyllene • Carvacrol • Caryophyllene oxide • Eugenol • E-nerolidol • b-caryophyllene • Guaiol • Terpinolene • Thymol • Safrole • Menthol • 1,8-cineole • α-terpineol • p-cymene • Trans α-bergamotene • Linalool • L-borneol • L-bornyl acetate • Geraniol • Bornyl acetate • α-cubebene • *α*-terpineol • *α*-thujene • γ-elemene • α-copaene	[23, 26, 28].
Oils from the buds	• Mono and sesquiterpenes	[28]
Leaves	• Cinnamaldehyde • Eugenol	[23, 36]
Cinnamon Bark	• Cinnamaldehyde • Eugenol • Linalool • Safrole • Pinene • Phyllandrene • Cymene • Cineol • Tannins constituting polymeric 5,7,3,4-tetrahydroxy-tetrahydroxy flavan-3-4-diol units • Catechins • Proanthocyanidins • Resins	[23, 36]

Parts of *C. zeylanicum*	Antioxidant compounds	Reference
Root Bark	• Camper	[23, 36]
Flowers and fruits and in lower amounts in buds	• Trans-Cinnamaldehyde • Terpene hydrocarbons • *alpha*-Bergamotene • *alpha*-Copaene • Oxygenated terpenoids • (E)-Cinnamyl acetate • *trans-alpha*-Bergamotene • Caryophyllene oxide	[23, 28, 36]

Table 6.
Bioactive compounds find in the C. zeylanicum *species.*

5. Conclusion

Based on the evidence presented above, it is only pertinent to identify *C. zeylanicum* as a potent disease-preventing herb due to its superior antioxidant power. While most of the bioactive compounds responsible for this functional property have been isolated and identified, it is evident that the compounds vary with the variety of the plant, environmental conditions as well as the analytical method used for the characterization process. Thus, it is inevitable that more potent antioxidant compounds can be discovered in *C. zeylanicum*. Even though currently considered as a spice and a traditional medicinal herb, *C. zeylanicum* has the potential to serve as the source for generating compounds for clinical trials for further evaluation of efficacy and ability to prevent specific diseases.

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