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Review Article

# Commercial Uses of Cinnamon Products

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**Abstract**

The bark of various cinnamon species is one of the most important and popular spices used worldwide not only for cooking but also in traditional and modern medicines. Cinnamon is mainly used in the aroma and essence industries due to its fragrance, which can be incorporated into different varieties of foodstuffs, perfumes, and medicinal products. The most important constituents of cinnamon are cinnamaldehyde and trans-cinnamaldehyde, which are present in the essential oil, thus contributing to the fragrance and to the various biological activities observed with cinnamon. The procyanidins extracted from cinnamon and berries also possess antioxidant activities. In addition to being used as a spice and flavoring agent, cinnamon is also added to flavor chewing gums due to its mouth refreshing effects and ability to remove bad breath. Cinnamon can also improve the health of the colon, thereby reducing the risk of colon cancer. Cinnamon is a coagulant and prevents bleeding. Cinnamon also increases the blood circulation in the uterus and advances tissue regeneration. This plant plays a vital role as a spice, but its essential oils and other constituents also have important activities, including antimicrobial, antifungal, antioxidant, and antidiabetic. Cinnamon has been used as anti-inflammatory, antitermitic, nematicidal, mosquito larvicidal, insecticidal, antimycotic, and anticancer agent. Cinnamon has also been traditionally used as tooth powder and to treat toothaches, dental problems, oral microbiota, and bad breath. Parkinson's disease (PD) is the second major widespread neurodegenerative disorder after Alzheimer's disease, with a prevalence of 2% in people 65 years and older. PD protein 7 (PARK7) is an autosomal recessive form of early-onset Parkinsonism caused by alterations in theDJ-1 gene. Sodium benzoate, a cinnamon metabolite, upregulates DJ-1 by modulating mevalonate metabolites. Cinnamon and its metabolite sodium benzoate also upregulate the neurotropic factors BDNF (brain-derived neurotropic factors) as well as neurotrophin-3 (NT-3) in the mouse central nervous system. PARK7 is one of the main neuro protective proteins that protect cells from damage and from the further detrimental effects of oxidative stress; therefore, this protein may be an effective molecule that can be incorporated into the therapeutic intervention of Parkinson's disease.

Cinnamophilin acts as a potential thromboxane synthase inhibitor and TXA 2 receipt or antagonist and may be helpful when incorporated in the treatment of diseases involving TXA 2 ndisorders, such as platelet aggregation and cancers. The ability of cinnamaldehyde in vasodilatory function may be because it impedes both Ca2+influx and Ca2+release. Cinnamaldehyde averts the progress of hypertension in types 1 and 2 diabetes by abridging vascular contractility, in addition to its insulinotropic effect in insulin deficiency. The spicy taste and fragrance are due to the presence of cinnamaldehyde and occur due to the absorption of oxygen. As cinnamon ages, it darkens in color, improving the resinous compounds. Spices and medicinal plants have received rapid consideration as sources of beneficial antioxidants against various diseases. Antioxidants have been considered the most important drivers in the progress and existence of humans, as they respond to free radicals and damage in metabolic diseases and age-related syndromes of humans and other animals.

**Kew Words:** covid-19; sars-cov-2; covid-19 testing; covid-19 self-testing; point of care testing; epidemiology; general practice

## Introduction

The bark of various cinnamon species is one of the most important and popular spices used worldwide not only for cooking but also in traditional and modern medicines. Over-all, approximately 250 species have been identified among the cinnamon genus, with trees being scattered all over the world (Sangal, 2011; Vangalapati *et al.*, 2012). Cinnamon is mainly used in the aroma and essence industries due to its fragrance, which can be incorporated into different varieties of foodstuffs, perfumes, and medicinal products (Huang *et al.*, 2007). The most important constituents of cinnamon are cinnamaldehyde and trans-cinnamaldehyde (Cin), which are present in the essential oil, thus contributing to the fragrance and to the various biological activities observed with cinnamon (Yeh *et al.*, 2013). A study on Cinnamomum osmophloeum (C. osmophloeum) indicated that the essential

oil from cin-namon leaves contains a high level of Cin. Consequently, C. osmophloeumis also used as an alternative spice for C. cassia (Chang *et al*., 2008). One of the major constituents of essential oil extracted from C. zeylanicumnamed (E)-cinnamaldehyde has an antityrosinase activity (Marongiu *et al*., 2007), while cinnamaldehyde is the principal compound responsible for this activity (Chou *et al*., 2013). The components of procyanidins include both procyanidin A-type and B-type linkages (Anderson *et al*., 2004; Peng *et al*., 2008 and Tanaka *et al*., 2008). These procyanidins extracted from cinnamon and berries also possess antioxidant activities (Maatt¨a-Riihinen *et al*., 2005). In addition to being used as a spice and flavoring agent, cinnamon is also added to flavor chewing gums due to its mouth refreshing effects and ability to remove bad breath (Jakhetia *et al*., 2010). Cinnamon can also improve the health of the colon, thereby reducing the risk of colon cancer (Wondrak *et al*., 2010). Cinnamon is a coagulant and prevents bleeding (Hossein *et al*., 2013). Cinnamon also increases the blood circulation in the uterus and advances tissue regeneration (Minich and Msom, 2008). This plant plays a vital role as a spice, but its essential oils and other constituents also have important activities, including antimicrobial (Chang *et al*., 2001; Matan *et al*., 2006 and Gende *et al*., 2008), antifungal (Wang *et al*., 2005), antioxidant (Shobana and Akhilender Naidu, 2000; Mathew and Abraham, 2006), and antidiabetic (Kim *et al*., 2006; Prabuseenivasa *et al*., 2006; Jia *et al*., 2009; Jarvill-Taylor *et al*., 2001; Lu *et al*., 2011 and Subash Babu *et al*., 2007). Cinnamon has been used as anti-inflammatory (Chao *et al*., 2011 and Tung *et al*., 2008), antitermitic (Tung *et al*., 2010), nematicidal (Park *et al*., 2005 and Kong *et al*., 2007), mosquito larvicidal (*et al*., 2004), insecticidal (Cheng *et al*., 2009), antimycotic, (Dhulasavan *et al*., 2010; Amin *et al*., 2009 and Bandara *et al*., 2012) and anticancer agent (Zhang *et al*., 2010; Kwon *et al*., 2009; 2010 and Koppikar *et al*., 2010) Cinnamon has also been traditionally used as tooth powder and to treat toothaches, dental problems, oral microbiota, and bad breath (Aneja *et al*., 2011, Gupta *et al*., 2007). Singh et al. (2011) reported that the spicy taste and fragrance are due to the presence of cinnamaldehyde and occur due to the absorption of oxygen. As cinnamon ages, it darkens in color, improving the resinous compounds (Singh *et al*., 2011). Spices and medicinal plants have received rapid consideration as sources of beneficial antioxidants against various diseases (Suhaj *et al*., 2006). Antioxidants have been considered the most important drivers in the progress and existence of humans, as they respond to free radicals and damage in metabolic diseases and age-related syndromes of humans and other animals (Halliwell, 2004; 2006).

Different flavonoids isolated from cinnamon have free-radical-scavenging activities and antioxidant properties (Okawa *et al*., 2001). A study of the inhibitory effects of cinnamaldehyde and other compounds of cinnamononnitric oxide production revealed that cinnamaldehyde possesses potential activity against the production of nitric oxide as well as the expression of inducible nitric oxide. The highest inhibitory activities were reported as 81.5%, 71.7%, and 41.2% at 1.0, 0.5, and 0.1$\mu$g/$\mu$L, respectively (Lee *et al*., 2002). Lin et al. (2003) reported the in vivo antioxidant activity of two different extracts, the ethanolic and hot water extracts of the dry bark of C. cassia. The ethanolic extract of C. Cassia exhibited significant inhibition (96.3%) compared to the natural antioxidant $\alpha$-tocopherol (93.74%) (Lin *et al*., 2003). Overall, cinnamon exhibited higher antioxidant activities compared to that of other dessert spices (Murcia *et al*., 2004). Eugenol and the essential oils were more effective than the other two com-pounds (Chericoni *et al*., 2005). In a comparative study among 26 spices, cinnamon showed the highest antioxidant activity, indicating that it can be applied as an anti-oxidant used in foods (Shan *et al*., 2005). The mixture, which consisted of 1 g/100 g cinnamon bark, showed a significant antioxidant activity compared to the fructose alone group (Suganthi et al., 2007). Volatile oils from C. zeylanicum showed significant biological activities (Jayaprakasha and Rao, 2011). Forty-one different volatile compounds in the bark oil of cinnamon have been identified and were found to vary significantly in percentage composition depending on the growth stages and segments of the C. cassia tree (Geng *et al*., 2011). All of the extracts had moderate amounts of phenolic compounds and showed potential activity against hydrogen peroxide, nitric oxide, and lipid peroxide free radicals (Aravind et al., 2012). The ethanolic extract of all of the plant parts had significant antioxidant properties compared with the extraction using the supercritical fluid (Yang *et al*., 2012).

C. tamala has potential antioxidant activities in diabetic rats (Kumar *et al*., 2012), while C. osmophloeum, a species from Taiwan, and has significant in vitro and in vivo antioxidant activities under oxidative stress (Hsu *et al*., 2012). The antioxidant activity of C. zeylanicum has been investigated using various methods. In addition to the antioxidant activity, cinnamon can be used as a preservative in cakes and other food products (Kordsardouei et al., 2013). A recent study reported that pectin film coated with cinnamon leaf extract yielded high antioxidant and antibacterial activities (Ayala-Zavala *et al*., 2013). Dong et al. (2005) reported that cinnamaldehyde (E) extracted from C. cassia is the main compound and is present in levels as high as 72.7% compared to other volatile components (Dong *et al*., 2005). Cinnamaldehyde (E) is well known for its antityrosinase activity (Shi *et al*., 2005). Hence, antityrosinase agents are associated with a wide range of applications, such as cosmetics, medicine, and food (Georgiev *et al*., 2013 and Parvez *et al*., 2007). Several studies on medicinal plants and their components have indicated the anti-inflammatory activities of cinnamon (Li *et al*., 2003; Sosa *et al*., 2002 and Matu and Staden, 2003). To date, there are several flavonoid compounds (e.g., gossypin, gnaphalin, hesperidin, hibifolin, hypolaetin, oroxindin, and quercetin) that have been isolated and have anti-inflammatory activities (Garc´ıa-Lafuente et al., 2009; Kim et al., 2004; Guardia et al., 2001; Stoner and Wang, 2013 and Cho et al., 2013).

A recent study reported that 2 –hydroxycinnamaldehyde isolated from C. cassia bark exhibited an inhibitory effect on the production of nitric oxide by inhibiting the activation of the nuclear factor kappa-light-chain-enhancer of activated B cells (NF-$\kappa$B), indicating that this substance can potentially be used as an anti-inflammatory agent (Lee et al., 2005). The ethanolic extract of C. cassia showed significant anti-inflammatory effects by reducing the activation of Src/spleen-tyrosine-kinase (Src/Syk-) mediated NF-$\kappa$B (Yu et al., 2012 and Youn et al., 2008). Various com-pounds contained in C. ramulus showed anti-inflammatory effects by suppressing the expression of inducible nitric oxide synthesis (iNOS), cyclooxygenase$^{-2}$ (COX$^{-2}$), and nitric oxide (NO) production in the central nervous sys-tem (CNS). By this mechanism, C. ramulus could be a potential source for the therapeutic treatment or prevention of inflammation-mediated neurodegenerative diseases (Hwang *et al*., 2009). Furthermore, the aqueous extract of cinnamon decreases the lipopolysaccharide-induced tumor necrosis factor-$\alpha$levels in the serum (Hong *et al*., 2012).

The effects were found to have a considerable effect (by 34–43%) on abridged brain infarction (Lee *et al*., 2009) and further enhance neurobehavioral outcomes. Cinnamophilin also dramatically condenses the oxygen glucose deprivation-induced neuronal damage in organotypic hippocampal slices in experimental rats. A sub-stance called procyanidin type-A trimer (trimer 1) isolated from cinnamon's water-soluble extract showed that trimer 1 may reduce cell swelling by controlling the movement ofintracellular calcium [$Ca^{2+}$] (Panickar *et al*., 2012). Trimer 1 also considerably alleviates the oxygen glucose deprivation-induced diminishing effects on glutamate uptake. The protective effects of trimer 1 in attenuating the diminution in glutamate uptake are possibly arbitrated via their effects on the mitochondria (Panickar *et al*., 2012). Parkinson's disease (PD) is the second major widespread neurodegenerative disorder after Alzheimer's disease, with a prevalence of 2%inpeople65years and older. PD protein 7 (PARK7) is an autosomal recessive form of early-onset Parkinsonism caused

by alterations in theDJ-1 gene (Bonifati *et al*., 2004). Khasnavis and Pahan reported that sodium benzoate, a cinnamon metabolite, upregulatesDJ-1by mod-ulating mevalonate metabolites (Brahmachari *et al*., 2009and Khasnavis and Pahan, 2012). Cinnamon and its metabolite sodium benzoate also upregulate the neurotropic factors BDNF (brain-derived neurotropic factors) as well as neurotrophin-3 (NT-3) in the mouse central nervous system (Jana *et al*., 2013). PARK7 is one of the main neuro protective proteins that protect cells from damage and from the further detrimental effects of oxidative stress; therefore, this protein may be an effective molecule that can be incorporated into the therapeutic intervention of Parkinson's disease (Khasnavis and Pahan, 2012).

A natural compound isolated from cinnamon extract (CEppt) significantly reduces the formation of toxic $\beta$-amyloid polypeptide (A$\beta$) oligomers and prevents its toxicity on neuronal pheochromocytoma (PC12) cells (Frydman-Marom *et al*., 2011). The study indicated that CEppt resolved the reduced permanence, fully improved deficiencies in locomotion, and totally eradicated the tetrameric species of A $\beta$in the brain of the flymodel of Alzheimer's disease, leading to a noticeable reduction in the 56 kDa A$\beta$oligomers, reducing plaques and improv-ing the cognitive performance of transgenic mice models (Frydman-Marom et al., 2011). The extract can also encourage the complete fragmentation of recombinant tau filaments and cause the considerable modification of the morphology of paired helical filaments from Alzheimer's disease brain (Peterson *et al*., 2009). Several studies have also revealed that cinnamon extracts lower not only blood glucose but also cholesterol levels (Blevins *et al*., 2007; Khan *et al*., 2003; Mang *et al*., 2006; Crawford, 2009 and Safdar *et al*., 2004). A study comparing the insulin-potentiating effects of many spices revealed that the aqueous extract of cinnamon was 20-fold higher than the other spices (Broadhurst et al., 2000). Methylhy-droxychalcone polymer (MHCP) is the purified polymer of hydroxychalcone with the ability to stimulate glucose oxidation (Anderson *et al*., 2006].

These polyphenols include rutin (90.0672%), catechin (1.9%), quercetin (0.172%), kaempferol (0.016%), and isorhamnetin (0.103%) (Li *et al*., 2008). Cao et al. (2007) demonstrated that the aqueous extract of cinnamon containing polyphenols purified by high performance liquid chromatography (HPLC) showed insulin-like activity (Cao *et al*., 2007). The aqueous extract of cinnamon markedly decreased the absorption of alanine in the rat intestine. Alanine plays a vital role in gluconeogenesis, is altered back to pyruvate in the liver, and is utilized as a substrate for gluconeogenesis (Kreydiyyeh *et al*., 2000). However, another study conducted on diabetic postmenopausal women supplemented with cinnamon showed poor glycemic control (Vanschoonbeek *et al*., 2006), even though cinnamon is generally believed to be useful for diabetes. In a recent study (Lee et al. (2013), suitable doses of cinnamon (5, 10, and 20mg/kg) of the linalool chemotype were found to help with glycemic control in diabetics due to enhanced insulin secretion. It is plausible that the amelioration of oxidative stress and the proinflammatory environment in the pancreas may confer protection to pancreatic$\beta$cells (Lee *et al*., 2013), which should be further investigated.

To date, several antimicrobial activities of cinnamon and its oils have been reported in various studies (Becerril *et al*., 2007).Goni et al. described the antibacterial activity of a combination of cinnamon and clove oils against Gram-positive organisms (Listeria monocytogenes, Enterococcus faecalis, Staphylococcus aureus, and Bacillus cereus), as well as against Gram-negative bacteria (Salmonella choleraesuis, Escherichia coli, Pseudomonas aeruginosa, and Yersinia enterocolitica) (Go˜ni *et al*., 2009). A recent study reported the activity of the aqueous extract of cinnamon and other plants against oral microflora. Overall, the essential oil from cinnamon is more potent than other tested plant extracts, such as Azadirachta indica and Syzygium aromaticum (Parthasarathy and Thombare, 2013).

Jeong et al. (2003) reported that CB403, a chemical that can be synthesized from 2 -hydroxycinnamaldehyde derived from cinnamaldehyde, can inhibit tumor growth. Overall, the antitumor and growth-inhibitory properties of CB403 in animal-based studies as well as in cell culture-based studies indicate the potential of cinnamon to be used as an anticancer agent (Jeong *et al*., 2003). Cabello et al. (2009) reported that cinnamic aldehyde inhibits the activity of NF-$\kappa$B and the production of tumor necrosis factor alpha (TNF$\alpha$-) induced interleukin-8 (IL-8) in A375 cells (Cabello *et al*., 2009). This inhibition provides additional support to the existing unrecognized role of cinnamic acid as a potential anticancer agent (Cabello *et al*., 2009). Fang et al. (2004) reported the anti-cancer effect of trans-cinnamaldehyde from C. osmophloeum, inding that transcinnamaldehyde showed potential effects in restraining tumor cell growth and in enhancing tumor cell apoptosis (Fang *et al*., 2004). Apreliminary study on cinnamon and cardamomagainst azoxymethane- (AOM-) induced colon cancer in Swiss albino mice has been conducted (Bhattacharjee *et al*., 2007). One of the active components isolated from C. Cassia named 2-methoxycinnamaldehyde (2-MCA) decreases the expression of vascular cell adhesion molecule-1 (VCAM-1) in TNF$\alpha$-activated endothelial cells, suggesting that ischemia/reperfusion (I/R) injury is ameliorated due to the induction of hemeoxygenase- ($HO^{-1}$) (Hwa *et al*., 2012). A recent study reported the potential effects of two compounds, cinnamic aldehyde and cinnamic acid, isolated from C. cassia against myocardial ischemia (Song *et al*., 2013), indicating that cinnamon also has the potential to be used to treat cardiovascular diseases.

Cinnamophilin acts as a potential thromboxane synthase inhibitor and TXA 2 recept or antagonist and may be helpful when incorporated in the treatment of diseases involving TXA 2 ndisorders, such as platelet aggregation (Jurasz, 2004) and cancers (Nie *et al*., 2004). A recent study showed that cinnamaldehyde expands rat vasculars mooth muscle in an endothelium-independent manner. The ability of cinnamaldehyde in vasodilatory function may be because it impedes both $Ca^{2+}$ influx and $Ca^{2+}$ release (Xue *et al*., 2011). Cinnamaldehyde averts the progress of hypertension in types 1 and 2 diabetes by abridging vascular contractility, in addition to its insulinotropic effect in insulin deficiency (El-Bassossy *et al*., 2011). Another study by (Rahman et al., 2013) found a reduction in the total cholesterol, triglycerides, and low-density lipoproteins in rats administered Cinnamomum cassia powder (15%) for 35 days. Additionally, cinnamon oils reduced the cholesterol levels in broiler chickens (Ciftci *et al*., 2010).These antiglycation activities of the phenolic compounds not only are attributed to their antioxidant activities but also are asso-ciated with the entrapping capabilities of reactive carbonyl species, such as methylglyoxal (MGO), an intermediate reactive carbonyl of AGE formation (Peng *et al*., 2010).Numerous in vitro and in vivo studies have elucidated cinnamon's effect on insulin signal transduction (Karalee *et al*., 2001; Qin *et al*., 2003; 2004 and Lee *et al*., 2003). A study in diabetic mice showed that cinnamon lowered blood glucose, total cholesterol, and triglyceride levels while raising HDL cholesterol levels (Kim *et al*., 2007). The first clinical trial to evaluate the effect of cinnamon in individuals with type 2 diabetes was conducted in Pakistan (Khan *et al*., 2003).

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