



**Assessment of some potential health
benefits of Sri Lankan cinnamon,
Cinnamomum zeylanicum Blume
(*Cinnamomum verum* Presl)
by studying selected bioactivities**

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ABSTRACT

Cinnamon is one of the first traded, most popular and useful spices world over. Among several species of cinnamon, Ceylon cinnamon (*Cinnamomum zeylanicum* Blume) is the true cinnamon and has gained high reputation and demand in the international trade since ancient times. Besides being a spice in nature, Ceylon cinnamon had been used in medicine in the Sri Lankan traditional system of medicine. Some of the traditional medicinal claims of Ceylon cinnamon have been scientifically validated in number of research studies particularly at international level. However, reported health benefits are doubtful since the experimental cinnamon samples are not properly authenticated. Further, some reported findings are even without mentioning the *Cinnamomum* species used. Moreover, reported health benefits are mostly for the bark of cinnamon and scientific validation on health benefits of leaf of Ceylon cinnamon remains obscure. In this connection, this study was undertaken to investigate potential health benefits of both bark and leaf of Ceylon cinnamon using range of biological activities.

Ethanollic (95%) and dichloromethane:methanol (DCM:M, 1:1 v/v) extracts of bark and leaf of authenticated Ceylon cinnamon were used in the evaluation of biological activities. The investigated biological activities included antioxidant, anti-diabetic, antilipidemic, anti-inflammatory, skin anti-aging and anti-cancer related activities *in vitro* and anti-inflammatory activity *in vivo* using rat model. The concentration range of 25-3000 µg/ml was used for *in vitro* biological activities and in rat model of anti-inflammatory activity concentrations of 25, 100 and 400 mg/kg of body weight (ethanollic bark) were used. As chemical constituents of bark and leaf extracts of Ceylon cinnamon total polyphenolics, flavonoids and proanthocyanidins were quantified. Further, both bark and leaf extracts were chemically characterized for selected phenolic and non phenolic compounds using High Performance Liquid Chromatography (HPLC) technique. Based on these findings two products, a cream and a moisturizer were also developed.

The results of *in vitro* biological activities tested showed that both ethanollic and DCM:M extracts of bark and leaf of Ceylon cinnamon possess varying degrees of antioxidant, anti-diabetic, antilipidemic, anti-inflammatory, skin anti-aging and anti-cancer related activities. However, bark extracts exhibited superior biological activities compared to leaf extracts (except antioxidant, anti-glycation and glycation reversing activities). In general, ethanollic extracts demonstrated significantly high ($p < 0.05$) biological activities compared to the DCM:M extracts. The observed *in vitro* biological activities of bark and leaf extracts of Ceylon cinnamon were mediated by multiple mechanisms. The antioxidant activity was multifaceted and mediated by 1,1-diphenyl-2-picryl-hydrazyl (DPPH), 2,2-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) and oxygen radical absorbance capacity (ORAC) radical scavenging activities and presence of ferric reducing antioxidant power (FRAP). Anti-diabetic activity was mediated by inhibition of amylase, a key carbohydrate digestion enzyme, diabetes complications management through anti-glycation and glycation reversing activities and type 3 diabetes management via anti-cholinesterases activity. Antilipidemic activity was also mediated via several modes of action which included anti-HMG CoA reductase, anti-lipase, anti-cholesterol esterase, cholesterol micellization inhibitory activity and bile acids binding abilities. Inhibition of *in vitro* nitric oxide and superoxide radicals and cyclooxygenases (COX1 and COX2) were the mechanisms of anti-

inflammatory activity. Further, in rat model inhibition of production of prostaglandins and cytokines (IL1 α , IL2, IFNY, TNF α , GM-CSF) and stabilization of rat red blood cell membrane were also observed. Skin anti-aging activity was also through multiple modes of action and ascertained by inhibition of elastase, collagenase, hyaluronidase and tyrosinase and presence of sun protection ability. Anti-cancer related activities were through growth inhibition and cytotoxicity towards multiple human carcinoma cell lines (MCF7, HePG2, AN3CA cell lines). Further, glutathione *S*-transferase inhibitory activity, an essential biological activity in managing cancer patients during chemotherapy was also observed. The biological activities tested showed potent [BChE inhibitory activity (ethanolic and DCM:M bark extracts), BSA-glucose mediated anti-glycation activity (ethanolic leaf extract, ethanolic and DCM:M bark extracts), cholesterol micellization inhibitory activity (ethanolic bark extract), sodium taurocholate bile acid binding (ethanolic and DCM:M bark extracts) and anti-collagenase activity (both ethanolic and DCM:M bark and leaf extracts)] and moderate activities (rest of the biological activities) compared to the reference standards used. Interestingly, this is the 1st study to report presence of range of novel medicinal properties in bark [anti-diabetic (anti-glycation and glycation reversing), antilipidemic (anti-HMG CoA reductase, anti-lipase, anti-cholesterol esterase, cholesterol micellization inhibitory activity and bile acids binding activity), anti-cancer (growth inhibition and cytotoxicity against human endometrial cancer cell line), anti-inflammatory (COX1 and COX2 inhibition) and anti-aging (anti-elastase, anti-collagenase, anti-hyaluronidase, anti-tyrosinase) activities] and leaf [antioxidant (ORAC), anti-diabetic, antilipidemic, anti-cancer, anti-aging, and anti-inflammatory activities] of Ceylon cinnamon. Results of chemical constituents of Ceylon cinnamon showed that it is a rich source of polyphenols, flavonoids and proanthocyanidins and cinnamaldehyde and eugenol were the highest chemical constituents of bark and leaf extracts respectively. The products developed, cream and the moisturizer showed skin whitening and anti-aging properties and are value added cosmaceuticals. Further, they complied with Sri Lanka Standard (SLS) 743:2014 (specification for skin creams and lotions) requirements and are novel products to the cosmetic industry.

Considering all, it can be concluded that both bark and leaf of Ceylon cinnamon (true cinnamon) possess numerous health benefits. However, bark had superior biological activities than leaf. This research added value to inner bark, the main commercial product of Ceylon cinnamon and also the leaf, commercial part use in production of leaf essential oil. In addition, this study scientifically validated some of the Sri Lankan traditional health claims on Ceylon cinnamon. Findings of this study essentially contributed to the scientific advancement and strengthening the scientific knowledge on health benefits of Ceylon cinnamon, the true cinnamon world over. Finally, findings indicate the possibility of utilizing both bark and leaf of Ceylon cinnamon in development of value added functional foods, nutraceuticals, pharmaceuticals and cosmaceuticals for prevention and management of chronic diseases.