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COMPARATIVE PHYTOCHEMICAL AND ANTIOXIDANT PROFILING OF CEYLON AND CHINESE CINNAMON BARK EXTRACTS*

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In this study, the chemical composition and antioxidant activity of Ceylon cinnamon (*Cinnamomum verum L.*) and Chinese cinnamon (*Cinnamomum cassia L.*) were compared. Extracts were prepared using ethanol and water; phenolic compounds, water-soluble vitamins, and minerals were determined by HPLC and ICP-OES methods. The results showed that the ethanol extract of *C. verum* exhibited the highest antioxidant activity (average 43.4%), whereas aqueous extracts sometimes demonstrated pro-oxidant properties. HPLC analysis revealed the presence of quercetin (62.7 mg/100 g), apigenin (68.2 mg/100 g), and rutin (6.3 mg/100 g) in *C. verum*. Among vitamins, C. verum contained higher levels of B1 (37.5 mg/100 g) and B3 (22.3 mg/100 g). Regarding mineral composition, potassium (484.8 mg/100 g) and magnesium (75.4 mg/100 g) were predominant. These findings suggest that Ceylon cinnamon is a promising source of bioactive compounds and antioxidant activity, supporting its potential use in the development of functional foods and dietary supplements.

Keywords: Cinnamomum verum L., *Cinnamomum cassia L.*, antioxidant activity, polyphenols, flavonoids, vitamins, ICP-OES, HPLC.

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Introduction

The increasing prevalence of chronic diseases and the global emphasis on preventive healthcare have prompted growing interest in plant-based compounds with antioxidant and therapeutic potential. Bioactive compounds found in plants, particularly antioxidants, play a crucial role in neutralising free radicals, reducing oxidative stress, and enhancing immune function [1, 2]. Their ability to slow ageing and combat chronic illnesses makes them vital in both nutrition and medicine.

One such plant is the cinnamon tree (*Cinnamomum*), a tropical evergreen from the *Lauraceae* family, traditionally cultivated in Sri Lanka, India, and China. Historical records indicate that cinnamon was highly valued in ancient Rome and England, where it was prized both as a spice and a medicinal plant [3, 4]. Two primary species are commercially important today: *Cinnamomum verum* (Ceylon cinnamon) and *Cinnamomum cassia* (Chinese cinnamon). While both are widely used, Ceylon cinnamon is often considered superior due to its milder flavour and lower coumarin content, which makes it safer for long-term consumption [5].

Cinnamomum species are rich in biologically active compounds, including flavonoids, essential oils (e.g., cinnamaldehyde, eugenol, linalool), and polyphenols, which contribute to their diverse pharmacological properties. These include antioxidant, antimicrobial, anti-inflammatory, anticancer, antidiabetic, and neuroprotective effects [6–8]. Flavonoids such as quercetin, apigenin, and kaempferol have demonstrated strong antioxidant and cardioprotective activities, supporting their increasing use in health supplements [6, 9].

In terms of nutritional composition, *C. verum* and *C. cassia* show broadly similar levels of proteins, fats, vitamins, and minerals, with most differences falling within the margin of experimental error. However, some

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distinct variations are noteworthy: carbohydrate content is markedly higher in *C. verum* (38.3% more than in *C. cassia*), while coumarin concentration is substantially greater in *C. cassia*, a factor of toxicological relevance. Additionally, *C. verum* contains β-carotene and vitamin B4 (*choline*), which are absent in *C. cassia*. Regarding minerals, *C. verum* is richer in manganese, whereas *C. cassia* contains higher levels of calcium and magnesium [10, 11].

Beyond their nutritional value, both species exhibit hepatoprotective properties, and ongoing studies continue to validate their traditional uses in treating gastrointestinal, metabolic, and inflammatory conditions [12, 13]. With growing scientific interest, Ceylon cinnamon is being increasingly explored for use in functional food products, nutraceuticals, and pharmaceutical applications [14, 15].

In this study, we conducted a comparative analysis of the bioactive compounds, vitamin and mineral content, and antioxidant properties of *C. verum* and *C. cassia*, with a focus on their potential applications in preventive healthcare.

Materials and methods

Cinnamon samples collected. In this study, we utilised cinnamon samples grown in India and China and imported to Uzbekistan as food products. *C. verum* and *C. cassia* were purchased directly from local food stores in Andijan, Uzbekistan, after the import certificate for foreign agricultural products was confirmed. The sample obtained, specifically *C. verum* and *C. cassia*, was selected based on which type exhibited higher antioxidant properties for use in subsequent experiments.

Preparation of extracts. Three types of extracts were prepared as follows:

Phenolic Compounds – Ethanol ultrasonic extraction: 1 g of the sample was mixed with 25 mL of 96% ethanol and subjected to ultrasonic extraction at 60 °C for 20 minutes.

Water-soluble Vitamins – Extraction with 0.1 N HCl under ultrasonic conditions: 1 g of the sample was treated with 25 mL of 0.1 N HCl and extracted using ultrasonic conditions.

Antioxidant Activity – Extracts were prepared in two solvents: aqueous (by boiling the sample in distilled water) and ethanol, both under the same ultrasonic extraction conditions.

Reagents and standards. Analytical grade reagents were used. Standards included gallic acid (Macklin, China), quercetin, apigenin, kaempferol (Regal, China), rutin (isolated from natural sources), and vitamins C, B1, B2, B3, B6, B9, and B12 (Carl Roth GmbH, Germany; DSM Nutritional Products GmbH, Germany; BLDPharm, China). All solvents were of HPLC grade purity.

Spectrophotometric Analysis. Total polyphenols and water-soluble vitamins were quantified by high-performance liquid chromatography (LC-40 Nexera Lite, Shimadzu, Japan) following established methods [16].

Elemental composition was analysed by inductively coupled plasma optical emission spectroscopy (ICP-OES, iCAP PRO X Duo, Thermo Fisher Scientific, USA).

Antioxidant activity was assessed spectrophotometrically by monitoring the oxidation of adrenaline in 0.2 M carbonate buffer (Na_2CO_3–$NaHCO_3$, pH 10.65) at 347 nm. A volume of plant extract was added to the buffer and adrenaline solution, and the change in optical density was recorded over time [7]. The detailed experimental results are presented in Supplementary Table 1.

All measurements were performed in triplicate, and results were expressed as mean ± standard deviation.

Determination of Antioxidant Activity of the Samples. The antioxidant activity of the provided samples was assessed using the inhibition of adrenaline autoxidation under in vitro conditions. This method evaluates the ability of the samples to inhibit the autoxidation reaction of adrenaline and, consequently, to prevent the formation of reactive oxygen species (ROS). The antioxidant activity of the tested samples is expressed as a percentage of inhibition of adrenaline autoxidation (AA%) using the following formula:

$$AA(\%) = \frac{(A_0 - A_s)}{A_0} \cdot 100$$

Where A_0 is the absorbance of the control, and A_s is the absorbance of the sample.

Elemental Analysis (ICP-OES). The analysis was carried out using an iCAP PRO X Duo ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometer) manufactured by Thermo Fisher Scientific (USA). Method development and data analysis were performed using the QTegra ISDS software. The main instrumental settings were as follows: pump speed – 30 (around/s); spray chamber – glass cyclonic; nebulizer – concentric glass; nebulizing gas flow –

0.6 L·min^{-1}; cooling gas flow – 12.5 L·min^{-1}; auxiliary gas flow – 0.5 L·min^{-1}; central tube diameter – 2 mm; RF power – 1150 W. Measurements were performed in triplicate with an analysis time of 15 s (radial mode).

Chromatographic Conditions and Determination of Phenolic Compounds. Standard solutions and sample extracts were analysed using a reversed-phase Shim-pack GIST C18 column (150 × 4.6 mm; 5 μm, Shimadzu, Japan) with a gradient mobile phase consisting of acetonitrile and 0.5% aqueous acetic acid solution. The injection volume was 10 μL, the flow rate was maintained at 0.5 mL/min, and the column temperature was set to 40 °C. The analytical signal of phenolic compounds was recorded at 300 nm (Supplementary Figure 1).

Phenolic compounds in cinnamon extracts were quantified based on calibration curves obtained from standard solutions, and the results were expressed as mg per 100 g of dry weight (DW).

The amount of phenolic compounds (mg/100 g of sample) was calculated using the standard formula (see Supplementary Material).

Chromatographic Conditions and Determination of Vitamins. Standard solutions and sample extracts were analysed using the LC-40 Nexera Lite HPLC system (Shimadzu, Japan), equipped with an LC-40D pump, SIL-40 autosampler, and SPD-M40 photo-diode array detector (PDA), controlled by LabSolutions ver. 6.92 software. The analysis was carried out using a Shim-pack GIST C18 column (150 × 4.6 mm; 5 μm, Shimadzu, Japan) with a gradient mobile phase consisting of acetonitrile (A) and 0.5% aqueous acetic acid solution (B) (see Supplementary Tables 2 and 3 for the gradient programs).

The injection volume was 10 μL, the flow rate was set to 0.6 mL/min, and the column temperature was maintained at 40 °C [17]. The analytical signals for each vitamin were recorded at 265, 291, and 550 nm, depending on the compound. For Vitamin C, a 15-minute gradient program was applied, and detection was carried out at 265 nm (Supplementary Figure 2). Chromatograms of other vitamins are provided in Figures 2, 3.

Vitamin contents were calculated from calibration curves using standard solutions and expressed as mg per 100 g DW of cinnamon samples (see Supplementary Material).

Results and discussion

The antioxidant activity of the tested samples was expressed as the percentage of inhibition of adrenaline autoxidation (%AA) (Table 1).

The antioxidant activity analysis revealed a stark contrast between the ethanol and aqueous extracts of both cinnamon types. The ethanol extract of *C. verum* consistently demonstrated the highest inhibition of adrenaline autoxidation (average 43.44%), indicating a significant ability to scavenge reactive oxygen species (ROS). In contrast, the aqueous extracts of both species exhibited negative inhibition values, suggesting a potential prooxidant behaviour, possibly due to the instability or poor solubility of certain compounds in water at elevated temperatures. These findings underscore the critical role of solvent polarity in the extraction efficiency of phenolic antioxidants. As a polar organic solvent, ethanol facilitates the effective extraction of flavonoids, which exhibit limited solubility in water. Conversely, the relatively low antioxidant activity observed in aqueous extracts may be attributed to the thermal degradation of heat-sensitive bioactive compounds during the boiling process [17, 18]. Furthermore, the consistently lower antioxidant activity of *C. cassia* in both solvent systems highlights the superior biochemical composition of *C. verum*.

Quantitative analysis of macro- and microelements in *C. verum* was performed using ICP-OES, and the results showed a wide range of essential minerals. Particularly high concentrations were detected for potassium (484.8±0.5 mg/100 g), magnesium (75.4±0.14 mg/100 g), and sodium (27.6±0.02 mg/100 g), which exceeded reported literature values. Among trace elements, notable amounts of manganese (33.81±0.164 mg/100 g), calcium (15.5±0.2 mg/100 g), and iron (2.50±0.023 mg/100 g) were observed, while heavy metals such as lead, cadmium, and nickel were present only in trace concentrations (<0.2 mg/100 g). These macroelements are essential for maintaining electrolyte balance, muscle contraction, and enzyme activation, whereas the trace minerals contribute to metabolic regulation. The elevated potassium levels position *C. verum* as a potential dietary supplement for populations at risk of hypertension. Magnesium plays a role in over 300 enzymatic reactions and supports cardiac and neuromuscular health. The sodium content, while higher than expected, remains within safe dietary limits for spice use. These results indicate that regular consumption of *C. verum* in culinary or supplement form may contribute to meeting daily mineral requirements, particularly in mineral-deficient diets [12, 19].

The calculated results are presented in Table 2, which shows the amount of phenolic compounds in the sample (aqueous extract of *Cinnamomum verum*) per 100 grams of the sample.

Table 1. Antioxidant activity (% inhibition of adrenaline autoxidation) of cinnamon extracts over time

Tested Extract	AA%			
	Cinnamomum Verum alcoholic extract	*Cinnamomum cassia* alcoholic extract	*Cinnamomum Verum* water extract	*Cinnamomum cassia* water extract
1 min	47.42	8.2474	-84.5361	-42.268
3 min	46.9	7.5221	-67.6991	-34.9558
5 min	44.51	6.5282	-52.5223	-28.1899
10 min	34.92	4.1667	-26.9841	-15.2778
Average	43.44	6.6161	-57.9354	-30.1729

Table 2. Amount of polyphenols in the extract and retention times

Phenolic Compound	Retention Time (s)	Concentration (mg/L)	Amount in 100 g sample (mg)
Gallic Acid	Not Detected	–	–
Rutin	18.381	2.532	6.330
Salicylic Acid	Not Detected	–	–
Quercetin	24.373	25.065	62.663
Apigenin	27.53	27.297	68.243
Kaempferol	Not Detected	–	–

This figure 1 shows the chromatographic peaks corresponding to the polyphenolic compounds present in the sample extract. Each peak would represent a specific polyphenol, and the retention times (the time it takes for each compound to elute from the chromatograph column) would be indicated on the x-axis. The area under the peaks can be used to quantify the amount of each polyphenolic compound in the extract.

The phenolic profile of *C. verum* was determined by HPLC (Table 2), revealing three key flavonoids: quercetin (62.66 mg/100 g), apigenin (68.24 mg/100 g), and rutin (6.33 mg/100 g).

The HPLC analysis confirms that these flavonoids contribute significantly to antioxidant and anti-inflammatory effects. Apigenin modulates glucose metabolism and induces apoptosis in tumour cells, while quercetin is widely studied for anti-atherogenic and antihypertensive properties. Rutin, although less abundant, supports vascular protection and may enhance the bioavailability of other flavonoids [20–22]. The absence of gallic acid, salicylic acid, and kaempferol might be due to species differences or degradation during processing. The high cumulative concentration of flavonoids (137.23 mg/100 g) in *C. verum* supports its superior therapeutic potential compared to *C. cassia*, which showed no detectable levels in the chromatograms.

The vitamin profile of *C. verum* is presented in Table 3.

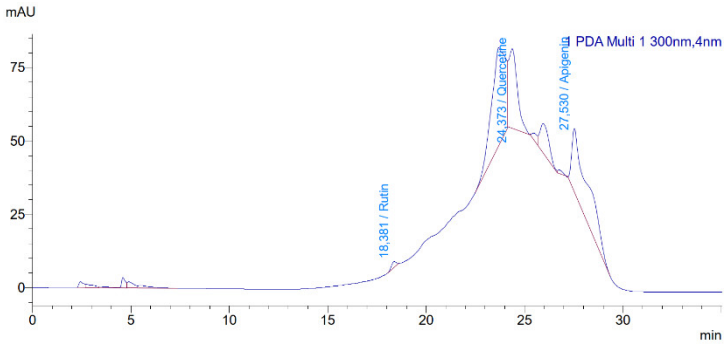


Fig. 1. Chromatogram for the determination of polyphenols in the sample extract

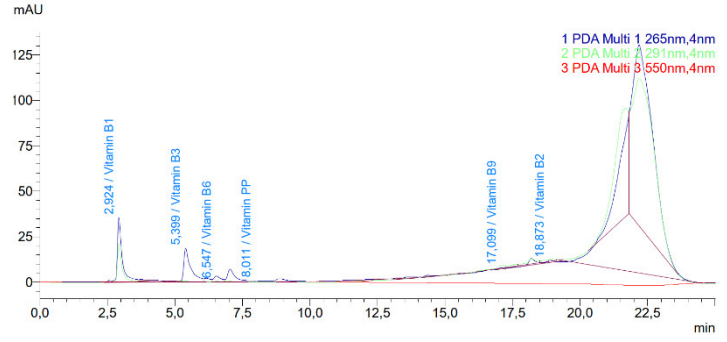


Fig. 2. Chromatogram for the determination of vitamins in the sample (aqueous extract of *Cinnamomum verum*)

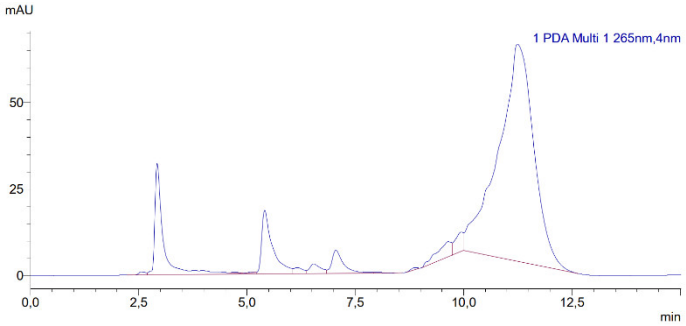


Fig. 3. Chromatogram for the determination of Vitamin C in the sample (aqueous extract of *Cinnamomum verum*)

Table 3. Amount of vitamins in the extract and retention times

Vitamin	Retention Time (min)	Concentration (mg/L)	Amount in 100g extract (mg)
Vitamin B_1	2.924	14.991	37.478
Vitamin B_3	5.399	8.93	22.325
Vitamin PP	8.011	0.234	0.585
Vitamin B_9	17.099	0.277	0.693
Vitamin B_2	18.873	0.53	1.325
Vitamin B_6	6.547	0.164	0.410
Vitamin B_{12}	Not Found	–	–
Vitamin C	Not Found	–	–

The vitamin composition is dominated by thiamine (B1, 37.48 mg/100 g) and niacin (B3, 22.33 mg/100 g), both of which are essential for energy metabolism and nervous system function. These concentrations far exceed typical values reported in dried plant materials, suggesting that *C. verum* is a rich and underutilised source of B vitamins. Vitamins B2, B6, and B9 were present in smaller amounts, while B12 and C were not detected, consistent with expectations due to their instability in dried botanical matrices [23, 24]. The presence of B vitamins alongside flavonoids suggests potential synergistic effects in enhancing bioavailability and therapeutic outcomes.

Overall, these findings demonstrate that *C. verum* possesses significantly higher antioxidant capacity, mineral richness, and bioactive compound content compared to *C. cassia*. The ethanol extracts of *C. verum* showed the strongest ROS-scavenging ability, while its high levels of potassium, magnesium, B vitamins, and flavonoids confirm its functional food potential. These results highlight *C. verum* not only as a culinary spice but also as a valuable nutraceutical candidate for preventing oxidative stress-related disorders such as metabolic syndrome, diabetes, and cardiovascular disease.

Limitation. The study focused on commercially available cinnamon products. The absence of data on cultivation conditions and processing methods limits generalizability. Future research should include controlled cultivation and broader sample collection to confirm these findings.

Conclusion

This study demonstrated that *Cinnamomum verum* (Ceylon cinnamon) possesses a richer chemical profile and stronger antioxidant activity than *C. cassia*. The ethanol extract of *C. verum* showed the highest antioxidant capacity (43.4%), corresponding to elevated levels of flavonoids (quercetin, apigenin, rutin), B-group vitamins (B1 and B3), and essential minerals (potassium and magnesium). These findings confirm the superior nutritional and functional potential of Ceylon cinnamon for use in functional foods and dietary supplements. Further studies are required to explore its effects under controlled experimental or clinical conditions.

Supplementary Information
The electronic supplement to the article (DOI: http://www.doi.org/10.14258/jcprm.20260317740s) provides additionalexperimental material that reveals the main points set out in the article.

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Conflict of Interest
The authors of this work declare that they have no conflicts of interest.

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