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Research Article

Medicinal Uses of Cinnamon Varieties: A Comprehensive Review of *Cinnamomum verum, C. cassia, C. burmannii,* and *C. loureiroi*

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ABSTRACT

Packed with anti-hyperglycaemic, antioxidant and anti-microbial property, one of the most widely used spices is cinnamon, which is derived from the inner bark of *Cinnamomum* species. This article evaluates the trajectory of research on Cinnamomum to date. The four main commercial species of *Cinnamomum* differs and flavour, intensity, colour, texture, and aroma. The four primary commercial varieties are *Cinnamomum verum* (Ceylon/True cinnamon), *C. cassia* (Chinese cinnamon), *C. burmannii* (Indonesian/Padang cinnamon), and *C. loureiroi* (Vietnamese/Saigon cinnamon). The literature reveals that while all four species possess significant therapeutic potential, their phytochemical profiles and safety margins differ greatly. *C. verum* is with lowest coumarin content. In contrast, *C. cassia, C. burmannii* and *C. loureiroi* contain significantly higher levels of coumarin, a known hepatotoxic compound, with C. *loureiroi* often exhibiting the highest concentrations. Beyond analysing solvent efficiency, this review also highlights the experimental approaches in cinnamon research, comparative phytochemical profiles, analysis of its comparative phytochemistry and therapeutic potential of Cinnamon-associated endophytic fungi. Whereas preclinical evidence is robust, the review highlights bottlenecks in large-scale human clinical trials for most varieties beyond *C. verum* and *C. cassia.*

KEYWORDS: *Cinnamomum* spp., hyperglycaemic, Cinnamon-associated endophytic fungi, coumarin, Phytochemistry.

1. INTRODUCTION

With over 250 species, the genus *Cinnamomum* belongs to the family Lauraceae, which includes evergreen trees and shrubs with culinary and medicinal importance (Kumar et al., 2019). Historically, it has been used as a carminative, antiseptic, and warming stimulant across various traditional medical systems, including Ayurveda and Traditional Chinese Medicine. They are famous for bark and oil and are used as medicines, spices and for timber (Kumar et al., 2019). Contemporary research on this genus focuses particularly on validating traditional medicinal uses, advanced biochemical analysis, and pharmacology studies. Recent studies highlight its role in managing chronic diseases such as cancer, Alzheimer's, diabetes, cardiovascular disorders and its promising role as a natural antioxidant and anti-microbial agent (Silva, 2015; Ervina et al., 2019). With remarkably distinct biological profiles and varying therapeutic and safety standards, the four species *C. verum, C. cassia, C. burmannii,* and *C. loureiroi* under review are used interchangeably in various food products (Hayward et al., 2019; Suzuki et al., 2021). For proper understanding of clinical applications and regulatory compliance, understanding of differences between the species is critical (Hayward et al., 2019; Suzuki et al., 2021).

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2. Methods and Experimental Approaches

2.1 Extraction Techniques and Solvent Influence

A diverse array of extraction techniques is used for effective extraction of bioactive compounds from cinnamon (Table 1). Extraction of cinnamaldehyde and trans-cinnamic acid heavily depends on the type of extraction technique and solvent used. With modern procedures like MAE, Microwave Assisted Extraction, rapid and superior yields are available (Salama et al., 2025). Solvents which are commonly used are water, ethanol and n-hexane. For instance, a research report highlights the choice of solvent as a critical factor affecting the output. The major potential of the extracts, where water extracts of *C. burmannii* bark display higher α-glucosidase inhibition (IC50 ≈ 0.50 µg/mL) compared to ethanol extracts, suggests that polar polyphenols play a crucial role in its antidiabetic activity (Ervina et al., 2019). Another method called Microwave Assisted Extraction (MAE) is considered to be the most efficient "Green" method, which offers high yields and higher concentration of cinnamaldehyde in less time while keeping the sensitive phenolics stable (Méchin, 2023; Ervina et al., 2023).

Table 1: Extraction Techniques for Cinnamon

Technique	Mechanism	Yield	References
1. Microwave-Assisted (MAE/MAHD)	There are a cell rupture and rapid internal pressure,	Higher Yield- Approximately 4.17% w/w in 25 min.	Kusuma et al. (2018); Mulugeta et al. (2021)
2. Ultrasound-Assisted (UAE/UAHDE)	There are microfractures in the plant matrix due to acoustic cavitation	High cinnamaldehyde yield- Approximately 92%.	Wong et al. (2020); Tiwari (2023)
3. Hydrodistillation (HD) & Steam	Using clevenger apparatus, traditional boiling/steam flow is carried out,	Moderate Yield- Approximately 1.5–2.0% w/w in 3–6 hours.	Gunarathne et al. (2019); Al-Dhubiab (2012)
4. Solvent Extraction	Solvent like Ethanol or Hexane is used.	Maximum Oleoresin- Approximately 9.0–12.0% of the crude extract.	Suryanti et al. (2020); Dawidowicz et al. (2008)

2.2 Analytical and Bioactivity Assays

Biological activity is normally assessed through standardised in vitro and in vivo assays.
(Table 2).

Table 2. Biological activity of cinnamon

Category	Assays	Targets	References
Antioxidant	DPPH, ABTS, FRAP, and Nitric Oxide Scavenging (NOSA)	Free radicals & reactive species	(Tisnadjaja et al., 2020; Liu et al., 2023; Kumar et al., 2019)
Antidiabetic	α-glucosidase and α-amylase (In vitro); glucose tolerance tests, OGTT (In vivo)	Enzyme activity & glucose homeostasis	(Ervina et al., 2019; Hayward et al., 2019)
Antimicrobial	Disc diffusion (ZOI), MIC, and MBC	S. aureus and E. coli	(Mulyani, 2023; Parisa et al., 2019)
Safety	Brine Shrimp Lethality Test (BSLT); LC-MS or qNMR	Cytotoxicity & Coumarin quantification	(Kharisma et al., 2023;

3. Phytochemical Profiles of various cinnamon species

The therapeutic efficacy of cinnamon is attributed to cinnamaldehyde, eugenol, cinnamic acid and cinnamate. Along with other bioactive compounds, cinnamon shows, antioxidant, anti-inflammatory, anti-microbial and antidiabetic actions.

3.1 Volatile Oils and Phenylpropanoids (Table 3)

Table: 3

Species	Primary active compounds	Characteristics	Reference
C. verum	(E)-cinnamaldehyde (Bark); Eugenol (Leaf)	high eugenol content in leaf oil (major component).	(Tisnadjaja et al., 2020)
C. cassia	Cinnamaldehyde	Mainly cinnamaldehyde-More than 160 chemicals isolated, including terpenoids.	(Tisnadjaja et al., 2020)
C. burmannii	Cinnamaldehyde (55–71.48%), Eugenol (4–17%)	high cinnamaldehyde levels, alpha-pinene, camphene, and eucalyptol.	(Mulyani, 2023; Parisa et al., 2019; Anwar et al., 2022)
C. loureiroi	Cinnamaldehyde	High essential oil content mediates airway smooth-muscle relaxation.	(Rehman et al., 2023; Suzuki et al., 2021)

3.2 Polyphenols and Proanthocyanidins

The majority of the medicinal, antioxidant and anti-inflammatory properties of cinnamon are attributed to the presence of polyphenols, which are non-volatile and water-soluble biocompounds. Proanthocyanidins are complex tannins, especially Type-A. catechin, epicatechin et quercitrin (Ervina et al., 2019). *C. burmannii* bark is rich in proanthocyanidins (specifically A-type polymers), catechin, epicatechin, and quercitrin (Ervina et al., 2019; Muhammad et al., 2021). The polyphenol content of *C. verum is* significantly high and contributes to its COX-inhibitory and radical-scavenging properties (Kumar et al., 2019)

4. Comparative Analysis of Biological Activities

4.1 Antioxidant Activity: Radical Scavenging and Enzyme Support

Due to high concentrations of polyphenols, flavonoids, and volatile compounds like cinnamaldehyde and eugenol, *Cinnamomum* species, is a potent natural antioxidant source These compounds provide strong radical scavenging (anti-aging/disease prevention) and enzyme support (metabolic health) by neutralizing reactive oxygen species (ROS) and regulating enzymes involved in glucose metabolism. (Table 4).

Table 4: Radical Scavenging and Enzyme Support.

Species	Plant Part and Extract Type	Mode of action	Value (IC50)	Reference
C. verum	Leaf Extract	NitricOxide Scavenging	40.26 mg/mL	(Kumar et al., 2019)
C. verum	Leaf Extract	Superoxide Scavenging	696.24 mg/mL	(Kumar et al., 2019)
C. burmannii	Bark-Ethanol Extract	DPPH Scavenging	1.939 - 8.533 ppm	(Méchin, 2023; Antasionasti et al., 2021)
C. burmannii	Bark	DPPH Scavenging	3.45 mg/mL	(Méchin, 2023; Antasionasti et al., 2021)
C. cassia	Bark	General Antioxidant	High Polyphenol Levels	(Hayward et al., 2019)
C. loureiroi	Bark	AGEs Inhibition	High Potential	(Hayward et al., 2019)

4.2 Antimicrobial and Antifungal Activity

The presence of high concentrations of cinnamaldehyde accounts for the species' high efficacy as an antimicrobial and antifungal agent. (Table. 5)

Table. 5: Antimicrobial and Antifungal Activity.

Species	Extract/Part Type	Targeted Microorganism	Activity/Result	Reference
C. burmannii	Ethanol Extract (40%)	*Staphylococcus aureus*	15.69 mm inhibition zone; 5% MBC	Parisa et al., 2019)
C. burmannii	Ethanol Extract (40%)	*Escherichia coli*	9.63 mm inhibition zone	Parisa et al., 2019)
C. burmannii	Essential Oil (Leaves)	*Micrococcus luteus*	Positive inhibition	Liu et al., 2023)
C. burmannii	Essential Oil (Leaves)	*Pseudomonas putida*	Positive inhibition	Liu et al., 2023)
C. verum	Various Extracts	*General Pathogens-* *Candida sp., P. aeruginosa, E. coli*	broad spectrum in microbial, Antiseptic, antifungal, and antibacterial properties	(Kumar et al., 2019)
C. loureiroi	Various extracts	*General Bacteria-* *E. coli, S. aureus, C. albicans*	Disruption of bacterial cell membranes	(Hayward et al., 2019)

4.3 Antidiabetic and Anti-hyperglycemic effects

All four varieties demonstrate anti-hyperglycemic potential Table 6) primarily through the inhibition of carbohydrate-digesting enzymes. They show this action by enhancing insulin sensitivity and slowing carbohydrate absorption.

Table 6: Anti-diabetic and Anti-hyperglycemic effects

Species	Primary Mechanism(s) of Action	Efficacy	Reference
C. burmannii	Inhibition of α-glucosidase, Insulin stimulation	i. IC50 of 0.49-0.50 g/mL ii. outperformed acarbose iii. decreased glycemia in rat models	(Ervina et al., 2019; Fadilah, 2017; Silva, 2015)
C. loureiroi	Inhibition of species-specific α-amylase & α -glucosidase	During simulated digestion, the effective reduction of starch breakdown	(Hayward et al., 2019)
C. cassia	Most effective α -amylase inhibition in comparative assays	most effective species in specific comparative a-amylase assays	(Hayward et al., 2019)
C. verum	Innovation of α-glucosidase and GLUT4 translocation	Improved metabolic markers and glucose transport in animal models	(Kumar et al., 2019)

4.4 Anti-inflammatory and Analgesic potential

Leaf extracts of *C. verum* possess a high amount of anti-inflammatory and analgesic potential due to excellent photochemical content and work by limiting enzymes and cytokines that drive inflammation and swelling. Cinnamon acts as a powerful inhibitor of the NF-κB signalling pathway

and reduces the COX-1 (IC50 6.62 µg/mL) and COX-2 (IC50 44.91 µg/mL) enzymes (Kumar et al., 2019). Based on in-vivo and in-vitro studies regarding *C. cassia* and *C. burmannii,* both possess therapeutic properties but vary widely in their mode of action. While C. cassia shows suppression of pro-inflammatory cytokines, *C. burmannii* bark extract suppresses the key mediators and inhibits enzymes involved in inflammation (Al-Dhubiab, 2012; Kumar et al., 2019).

5. Safety, toxicity, and coumarin content

Safety and toxicity of cinnamon differ significantly between the species due to varying levels of coumarin (Table 7). Cassia cinnamon contains the highest level of coumarin, while Ceylon cinnamon contains trace amounts of coumarin, making it the safest choice for regular long-term use.

Table 7: Coumarin content of various cinnamon species.

Species	Common Name	Coumarin Content	Safety Profile	Reference
C. verum	Ceylon Cinnamon	Low, 0.0017%	Highly safe- Suitable for regular dietary and medicinal intake.	(Tisnadjaja et al., 2020; Suzuki et al., 2021)
C. cassia	Chinese Cinnamon	Approximately 916.71 mg/kg	Moderate Risk-regulated consumption.	(Kharisma et al., 2023).
C. burmannii	Korintje Cinnamon	0.0030% to 1.7% (approximately 16,980 mg/kg)	Variable Risk-High regional variance sometimes can reach very high levels.	(Tisnadjaja et al., 2020); Kharisma et al., 2023.
C. loureiroi	Saigon Cinnamon	Highest among species	Highest Risk and regular exposure may cause a significant risk of liver toxicity.	(Suzuki et al., 2021)

Prolonged use of coumarin consumption exceeding the Tolerable Daily Intake (TDI) can lead to neurotoxicity, liver inflammation and damage by inducing hepatitis. Brine Shrimp Lethality Test (BSLT) for *C. burmannii* reflects LC50 values (341.95–826.10 µg/mL) that indicate relative safety for moderate consumption but highlight the risk of cumulative exposure from "cassia" cinnamons (Kharisma et al., 2023). Furthermore, *C. burmannii* demonstrate prolong, bleeding, and coagulation time, which is a threat to a person taking anticoagulant therapies or with bleeding disorders (Sandhiutami et al., 2023).

6. Innovative Research Areas: Endophytic Fungi and Nanotechnology

Research is increasingly combining nanotechnology with cinnamon-associated endophytic fungi, which enhances the stability, delivery and bioactivity of cinnamon-derived compounds, particularly cinnamaldehyde and polyphenols. Various nano-formulations like polymeric nanoparticles, liposomes, solid-lipid nanoparticles and nano-emulsions are developed to protect these biochemicals from degradation and to enhance their bioavailability and targeted delivery of their antidiabetic components (Sukaim et al., 2023). Another investigation demonstrated significant inhibition of alpha-glucosidase and antioxidant activity, suggesting that the cinnamon plant microbiome could be a source of pharmaceutically active compounds and can lead to the development of novel therapeutic agents (Septiana et al., 2019).

7. Research Gaps and Future Directions

Despite the wealth of in vitro and animal data, several gaps remain:

There are some complications regarding the standardisation of the therapeutic dosage due to variations in the phytochemical content attributed to the geographic origin of cinnamon species and method of extractions (Kharisma et al., 2023; Mahmudati et al., 2022). Apart from this, there is a lack of notable, large-scale, long-term human clinical trials, which can confirm the safety and efficacy of *C. burmannii* and *C. loureiroi* (Kumar et al., 2019). Further, for the sensitive group, such as children and those with pre-existing liver conditions, detailed studies are required to well define the safe chronic intake levels for high-coumarin varieties (Kumar et al., 2019).

8. Conclusion

In the culinary world, cinnamon is treated as a single ingredient, distinguishing between varieties- Ceylon and the Cassia. A rich spectrum of medicinal benefits, particularly in the management of oxidative stress and glycemic control, is offered by four primary cinnamon varieties—*C. verum, C. cassia, C. burmannii,* and *C. loureiroi*. Due to high levels of coumarin, *C. cassia* is commonly used in food for its strong flavour. However, it comes with high hepatotoxic risks. In contrast, *C. verum* displays a safer profile with minimal levels of coumarin, making it the best choice for chronic therapeutic uses despite being an expensive option. In specific antidiabetic contexts, C. burmannii and *C. loureiroi* may offer stronger enzyme inhibition than *C. verum*. The rapidly evolving research area in cinnamon-associated endophytes and microbiome, driven by the demand for sustainable agriculture, novel drug discovery, and functional health products, is promising. Integrating multi-omics with AI- guided modelling to elucidate the biosynthetic pathway of biotic compounds in cinnamon is promising. This will map the therapeutic efficacy

of cinnamon, optimising its pharmacological role for managing chronic metabolic disorders.

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