Review Article

Curcuma caesia Roxb. (Black Turmeric): A brief Literature review

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Abstract

Curcuma caesia Roxb., commonly known as black turmeric, is a medicinally important rhizomatous herb belonging to the family Zingiberaceae and widely distributed in Northeast and Central India. Traditionally, the species has been valued in Ayurveda, Siddha, and folk medicine for its diverse therapeutic properties, including anti-inflammatory, analgesic, antimicrobial, antiasthmatic, wound healing, and neuroprotective actions. The article aims to bridge traditional knowledge with scientific evidence to encourage further exploration of black turmeric as a potential source for novel drug discovery and therapeutic development. This review provides a comprehensive overview of the botanical characteristics, ethnomedicinal relevance, phytochemistry, pharmacological activities, and future research prospects of *Curcuma caesia*. The plant is characterized by its distinctive bluish-black rhizome, rich aromatic profile, and the presence of bioactive constituents such as curcumin, camphor, ar-turmerone, germacrone, and various essential oils. In vitro and in vivo studies have demonstrated significant antioxidant, cytotoxic, antidiabetic, antiepileptic, adaptogenic, and anti-ulcer activities, suggesting promising applications in modern therapeutics. Despite its high medicinal value, *Curcuma caesia* remains underutilized and is categorized as a threatened species in several regions due to overharvesting and limited cultivation practices.

***Keywords*:** Black turmeric; *Curcuma caesia*, phytochemistry, pharmacological activities, conservation strategies

Introduction

Plants play a vital role in the food chain, offering a wealth of nutrients and biochemical compounds beneficial to humans and other organisms. The use of herbal plant products is growing in many segments of the population (Dev et al., 2017). One such plant, *Curcuma caesia* Roxb., belonging to the Zingiberaceae family and commonly known as black turmeric, is extensively utilized in Ayurvedic medicine and traditional remedies. Its leaves and rhizomes are rich in essential oils, including camphor, ar-turmerone, (Z)-β-ocimene, and others. Research indicates diverse biological activities of *C. caesia*, such as antioxidant, antimicrobial, and anti-inflammatory properties, attributed to its bioactive components. This plant's chemical makeup holds promise for various industries, including health, food, and cosmetics. Recent studies have focused on its in vitro and in vivo activities and ongoing clinical investigations. Summarizing these findings offers insights into potential health benefits and mechanisms, facilitating the development of drugs, functional foods, and cosmetics (Ibrahim, 2023).

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Used as functional food

The study investigated the health benefits of Curcuma spp. rhizomes, including *Curcuma caesia*, *Curcuma zedoaria*, and *Curcuma aeruginosa,* through antioxidant, anti-inflammatory, and anti-tumor cell proliferation assays. *C. caesia* (black turmeric) demonstrated the most significant biological activities, including inhibition of lipid peroxidation (LPO) and cyclooxygenase (COX-1 and COX-2) enzymes, as well as tumor cell growth. Hexane and methanolic extracts of C. caesia showed notable inhibition of LPO and COX-2 enzymes. Eleven terpenoids were identified from the extracts. The antioxidant assay revealed comparable activity to positive controls, and both extracts and isolates showed inhibition of COX enzymes. These findings support the traditional medicinal use of *C. caesia* rhizome (Liu, 2013).

Pharmacognostic parameters of *Curcuma caesia*

Ethnomedicinal practices often utilize Curcuma species for treating ailments, yet *Curcuma caesia* Roxb. remains largely unexplored. This study aims to establish pharmacognostic standards for evaluating *Curcuma caesia* Roxb. by examining its morphology, microscopy, physicochemical properties, and phytochemical profiles. Salient diagnostic features, major chemical constituents, extractive values, and other relevant characteristics are documented for comprehensive analysis (Paliwal, 2011).

Phytochemical Constituents of *Curcuma caesia* Roxb:

1. Pakkirisamy et al. (2017) studied phytochemical screening, GC-MS and FT-IR analysis of methanolic extract of *Curcuma caesia* Roxb (black turmeric) were identified compounds as: α-Santalol, retinal, ar-turmerone, alloaromadendrene, megastigma-3,7(E),9-triene, etc (Pakkirisamy et al., 2017).

2. Baghel et al. (2013) studied **p**harmacological activities of *Curcuma caesia* Roxb. a review of traditional uses and phytochemical study reported major constituents include camphor, ar-turmerone, (Z)-ocimene, ar-curcumene, 1,8-cineole, elemene, borneol, bornyl acetate, and curcumene.

3. Leela et al., (2024) *Curcuma caesia* Roxb. were updated phytochemicals and pharmacological properties. They reports major rhizome oil constituents: 1,8-cineole, camphor, ar-turmerone, linalool, ocimene, ar-curcumene, zingiberol, curzerenone and tropolone.

4. Lenka et al. (2025) unlocked terpenoid treasures of rhizome and leaf volatiles of *Curcuma caesia* Roxb through GC-GC TOFMS analysis. They identified 151 volatile constituents in rhizome and leaf oils, including curzerenone, eucalyptol, curzerene, epicurzerenone, camphor and ar-turmerone.

5. Jose et al. (2021) reported phytochemicals, antioxidants and antimicrobial components in leaf extracts of *Curcuma caesia* Roxb. They reported diverse phytochemicals in leaf extracts (phenolics, flavonoids, alkaloids, etc.).

6. Lawand et al. (2013) studied about comparison of *Curcuma caesia* Roxb. with other Curcuma species by HPTLC. They identified phenolics, alkaloids, tannins, and terpenoids; noted the presence of camphor in *C. caesia*.

7. Pandey et al. (2025) studied that medicinal potential of *Curcuma caesia* Roxb.: phytochemical composition and TLC profile of hydroalcoholic rhizome extract for identification of flavonoids, phenolics, alkaloids, terpenoids, saponins and glycosides through TLC profiling.

Analytical Advancements in *Curcuma* Species

Recent research has prioritized the development of precise methods to quantify active compounds in the *Curcuma* genus. A validated High-Performance Thin-Layer Chromatography (HPTLC) method demonstrated that curcumin levels vary significantly across species with Soxhlet extraction yielding higher concentrations than sonication (Gangal et al., 2025). Notably, while curcumin is abundant in *C. longa*, it is absent in *C. caesia*.

To address this, researchers have turned to 1H-NMR and GC×GC-TOFMS to map the complex profile of *C. caesia*, identifying over 151 compounds, including thermolabile sesquiterpenes like curzerenone and zederone (Lenka et al., 2025; Mahanta, 2020).

Therapeutic Applications of *Curcuma caesia*

Curcuma caesia exhibits diverse pharmacological and preservative properties:

Anticancer Potential: Derivatives from black turmeric have shown promise in modulating **Mis-Match Repair (MMR)** pathways in hematologic malignancies (Bhattacharya, 2021). Furthermore, gold nanoparticles synthesized from *C. caesia* extracts demonstrate selective toxicity against aggressive breast cancer cells (MDA-MB-231) while remaining safe for healthy cells (Das et al., 2024).

Biotransformation: The endophytic fungus *Ovatospora brasiliensis* found in the plant can successfully convert curcumin into **calebin-A**, a bioactive compound found in mature rhizomes (Majeed, 2019).

Food Preservation: Essential oils from the rhizome serve as effective edible coatings for fruits like mangoes, reducing weight loss and extending shelf life by preserving firmness and antioxidant levels (Kotha et al., 2025).

The integration of advanced HPTLC and NMR techniques has standardized the quality assessment of *Curcuma* species, highlighting the chemical uniqueness of *C. caesia*. While it lacks curcumin, its rich sesquiterpene profile and the efficacy of its nanoparticle formulations position it as a potent candidate for targeted cancer therapies and natural food preservation.

Bhattacharya, (2021) reported computational analysis of Curcuma derivatives in MMR-pathway-driven cancers.

Das et al. (2024) prepared Gold nanoparticle formulations of *C. caesia* in breast cancer therapy.

Gangal et al. (2025) performed HPTLC technique for routine analysis of curcumin in *Curcuma* species.

Kotha et al. (2025) identified Tropolone-related compounds in *C. caesia* for mango shelf-life extension.

Lenka et al. (2025) investigated GC×GC-TOFMS profiling of *C. caesia* rhizomes and leaves.

Mahanta (2020) performed 1H-NMR identification of chemical markers in black turmeric essential oil.

Majeed (2019) reported Biotransformation of curcumin to calebin-A via endophytic fungi.

Rathi et al. (2024) performed pharmacognostical and elemental screening of *C. caesia* rhizomes

Genetic Diversity and Evolutionary Insights

Molecular characterization of Zingiberaceae species in eastern India has revealed high levels of genetic polymorphism. Using a combination of RAPD, ISSR, and SSR markers, researchers identified significant genetic distinction between wild and cultivated species, with *C. caesia* exhibiting the highest number of genetic loci (Mohanty et al., 2014).

Complementary meiotic analysis indicates that *Curcuma* species function as an allopolyploid complex. Species are typically categorized into two groups based on chromosome counts:

- **Group I ($2n = 42$):** Predominantly displays bivalent configurations, seen in species like *C. comosa* and *C. mangga*.
- **Group II ($2n = 63$):** Shows complex trivalents and quadrivalents, characteristic of *C. caesia* and *C. longa*.

The high basic chromosome number ($x = 21$) suggests that the genus likely evolved through hybridization between species with $2n = 24$ and 18, forming dibasic amphidiploids (Lamo & Rao, 2017).

Agricultural Development and Stability

To address the endangered status of *C. caesia*, systematic selection trials have led to the identification of high-yielding, stable genotypes. **Jor Lab KH-2** emerged as a superior strain, maintaining high yield consistency across diverse environments (Lal et al., 2022). This variety represents the first registered high-yielding cultivar of Black Turmeric, providing a vital resource for commercial cultivation and conservation (Lal et al., 2022).

Environmental Influence of UV-B Radiation

Ultraviolet-B (UV-B) radiation acts as both a stressor and a metabolic regulator. Exposure impacts carbon-nitrogen dynamics, often leading to:

- **Biomass Shifts:** Increased tuber biomass but reduced rhizome weight (Jaiswal & Agrawal, 2022).
- **Phytochemical Induction:** Enhanced production of essential oils and active compounds like D-camphor and 1,8-cineole.
- **Species-Specific Responses:** *C. caesia* typically shows higher enzymatic stimulation (e.g., PAL and CHI) and a greater increase in essential oil (16%) compared to *C. longa* (9%) under elevated UV-B (Jaiswal & Agrawal, 2021). The integration of molecular markers and cytogenetic data confirms that *Curcuma* is a genetically diverse, polyploid genus shaped by hybridization (Lamo & Rao, 2017; Mohanty et al., 2014). While environmental factors like UV-B radiation can be leveraged to boost secondary metabolites, the development of stable genotypes like Jor Lab KH-2 is essential for sustainable pharmaceutical production and species preservation (Jaiswal & Agrawal, 2022; Lal et al., 2022).

Therapeutic Potential of Curcuma caesia (Black Turmeric)

Bioactives compounds from the plant origin are considered more secure as they produce less harmful metabolites (Srivastava et al. 2022). *Curcuma caesia* Roxb., commonly known as **Black Turmeric**, is a rare medicinal herb of the Zingiberaceae family. Its distinct bluish-black rhizomes contain a high concentration of bioactive compounds, including curcuminoids, essential oils (camphor, eucalyptol), and sesquiterpenes, which contribute to its broad pharmacological profile (Borah et al., 2021; Chande et al., 2023).

Biological Activities

Antioxidant & Anti-inflammatory: Rhizome extracts exhibit potent free radical scavenging abilities. Methanol and chloroform extracts are particularly effective due to high phenolic and flavonoid content, which helps mitigate oxidative stress and inflammation (Ain Ibrahim, 2023; Reenu, 2015).

Antimicrobial & Antibacterial: The essential oil and extracts demonstrate significant activity against various

pathogens, including *B. subtilis*, *S. aureus*, and *M. smegmatis*. Supercritical fluid extraction (SFE) has been shown to enhance its antimycobacterial potential, validated through molecular docking studies (Chaturvedi, 2020; Paw et al., 2020).

Antidiabetic Potential: Recent studies highlight its ability to inhibit alpha-glucosidase and alpha-amylase enzymes, suggesting a role in managing postprandial glucose levels (Singh et al., 2025).

Genotoxicity: Studies indicate that *C. caesia* essential oil has minimal genotoxic effects, supporting its safety for potential commercial and pharmaceutical applications (Paw et al., 2020).

Skin Protection and Wound Healing

Traditionally used to treat cuts and bruises, *C. caesia* contains specific **serine proteases** that exhibit procoagulant and fibrinogenolytic properties. These enzymes facilitate hemostasis (halting bleeding) and initiate the healing process by promoting collagen deposition and tissue remodeling (Shivalingu, 2016). Additionally, its extracts are utilized in herbal sunscreens for their photoprotective qualities, improving skin hydration and viscoelasticity (Saraf, 2012).

Neuroprotective Roles

Research into brain function indicates that Zederone, a compound found in *C. caesia*, can enhance memory and reduce amyloid plaque formation in dementia models (Borah, 2022). Furthermore, the rhizome's essential oil and specific fractions have shown: **Anxiolytic effects** (reducing anxiety).

Antidepressant properties by modulating neuroinflammation and oxidative stress (Borah et al., 2021).

Curcuma caesia is a versatile therapeutic agent with validated antioxidant, antimicrobial, and neuroprotective properties. Its ability to aid in wound healing and metabolic regulation makes it a valuable candidate for future phytopharmaceutical development.

Anti-diabetic activity

Curcuma caesia has exhibited due to its potent antioxidant and anti-inflammatory properties, C. caesia has been found ability to alleviate the oxidative stress and neuronal inflammation that drive nerve damage in diabetic patients (Grover 2019).

As muscle relaxant

In respiratory health, hydroalcoholic extracts of *Curcuma caesia* act as an effective smooth muscle relaxant. The mechanism behind of this activity through the modulating calcium channels rather than interacting with specific biochemical receptors, suggesting a non-specific mechanism that could benefit asthma treatments (Arulmozhi 2006).

Anticancer property

The anticancer efficacy of *Curcuma caesia* nanoparticles was assessed on HT-29 human colon cancer cells via the sulforhodamine B (SRB) assay. The yields for C. longa, C. aromatica, and C. caesia were 11.34g, 15.45g, and 12.67g, respectively, with resulting nanoparticles exhibiting smooth, spherical morphology. The nanoparticles demonstrated varied degrees of cytotoxicity against HT-29 cells, indicating potential as cancer therapeutics with low toxicity (Jain 2023). Nanoparticles are biodegradable, non-toxic lyotropic systems show promise for use in eco-friendly therapeutic, cosmetic, and advanced material applications (Gangal et al., 2025). It has been found that phytochemicals derived from Aristolochia tagala (AT) and Curcuma caesia (CC) possess significant therapeutic potential, specifically acting as anticancer agents by modulating inflammatory pathways (Hadem 2015).

Curcuma caesia Roxb., popularly known as Black Turmeric, is a medicinal plant native to India with a robust history in traditional medicine for treating tumors, asthma, and inflammation (Borah et al., 2020; Karmakar et al., 2013). Recent scientific evaluations have validated its therapeutic potential through various bioactive fractions and molecular mechanisms.

Researchers have identified several key chemical constituents through bioassay-guided fractionation. Hexane and chloroform extracts have shown efficacy against breast cancer cell lines (MCF-7 and MDA-MB-231). Specifically, compounds such as germacrone, zerumbone, and curcuzederone have been isolated; curcuzederone, in particular, significantly inhibits the migration of MDA-MB-231 cells, suggesting potential in preventing metastasis (Al-Amin, 2021).

Antioxidant and Antimutagenic Properties

C. caesia exhibits potent antioxidant activity, with ethanolic extracts reaching up to 86.91% scavenging efficiency in DPPH assays (Devi et al., 2015). These antioxidant properties contribute to its antimutagenic effects, protecting against DNA damage induced by mutagens like cyclophosphamide (Devi et al., 2015; Mukunthan et al., 2017, Karmakar et al., 2013, Hadem et al., 2014). Furthermore, in liver cancer models induced by diethylnitrosamine (DEN), C. caesia extracts lowered serum cancer markers (AST, ALT, ALP, and AChE) while boosting endogenous antioxidant enzymes like SOD and Catalase (Hadem et al., 2014).

Scientific evidence confirms that Curcuma caesia possesses significant anticancer potential driven by its rich phenolic content and specific terpenoids. It induces apoptosis through mitochondrial-mediated pathways and causes cell cycle arrest at the G2/M phase (Mukunthan et al., 2017).

These findings support its transition from traditional remedy to a source for targeted phytotherapy in modern oncology.

Protective Effects of *Curcuma caesia* Roxb against Cyclophosphamide Toxicity

Cyclophosphamide (CP) is a anti cancer drug, its metabolic breakdown induce liver toxicity, oxidative stress and damage to healthy tissues (Devi & Mazumder, 2016). Research indicates that methanolic extracts of Curcuma caesia Roxb. (MECC), commonly has known as black turmeric, possess potent antioxidant properties that can mitigate these adverse effects (Devi 2016).

Anti-Mycobacterial Activity and Agricultural Innovation

Tuberculosis (TB) remains a significant global health challenge caused by Mycobacterium tuberculosis (Mtb) (Gupta, 2018). In Madhya Pradesh, India, traditional knowledge from tribal healers has identified 35 plant species used to treat TB-related symptoms (Sieniawska et al., 2020). Scientific validation revealed that 11 of these species, including Alstonia scholaris, Glycyrrhiza glabra, and Curcuma caesia, possess significant anti-mycobacterial activity against both standard (H37Rv) and multidrug-resistant (MDR) strains (Gupta, 2018). Cytotoxicity assays confirmed that these extracts are safe for human macrophages at effective inhibitory concentrations (Logesh et al., 2020).

Beyond direct medicinal use, plants like Curcuma caesia serve as hosts for beneficial endophytic bacteria such as Paenibacillus sp. CCB36 (Panichikkal, 2021). Research into agricultural productivity shows that supplementing these bacteria with chitosan nanoparticles (CNPs) can modulate biofilm formation and enhance biocontrol efficacy against pathogens like Rhizoctonia solani (Panichikkal, 2021). While zinc oxide nanoparticles (ZnONPs) tend to reduce biofilm development, CNPs improve the colonization and functional persistence of endophytes in soil environments (Mburu et al., 2021; Dev et al., 2018; Garg et al., 2016). The integration of traditional tribal knowledge with modern ethnopharmacology and nanotechnology offers a dual pathway for progress: identifying novel treatments for drug-resistant TB and developing sustainable "green" solutions for agricultural productivity. These studies provide the first documented scientific evidence for the anti-Mtb potential of specific Indian flora and demonstrate the power of nanoparticles in optimizing microbial biological controls (Dev et al., 2018; Garg et al., 2016).

Conclusion

The plant has distinctive bluish-black rhizome, rich aromatic profile, and the presence of bioactive constituents such as curcumin, camphor, ar-turmerone, germacrone, and various essential oils. *In vitro* and *in vivo* studies demonstrated significant antioxidant, cytotoxic, antidiabetic, antiepileptic, adaptogenic, and anti-ulcer activities, suggesting promising applications in modern therapeutics. Due to high medicinal value, *Curcuma caesia* remains underutilized and is categorized as a threatened species in several regions due to overharvesting and limited cultivation practices.

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