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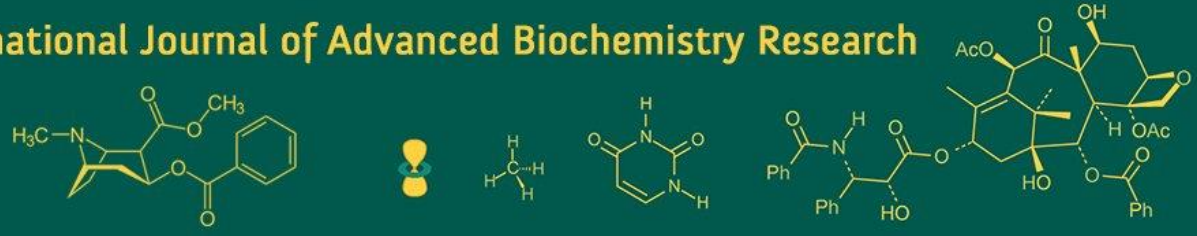

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Economic viability and production challenges of black turmeric in Odisha's Eastern Ghats Highlands: A focus on its therapeutic potential

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Abstract
Curcuma caesia Roxb. is a family member of Zingiberaceae commonly known as black turmeric. It is characterized by its distinctive dark purple to black rhizomes, The leaves and rhizomes of this plant are extensively used in Ayurvedic medicine and as traditional remedies for various ailments. The biological effects of *C. caesia*, such as antioxidant, antimicrobial, anticancerous, antiulcer, anti-inflammatory properties, anthelmintic, anxiolytic and CNS depressant activity and many other miscellaneous activities, which are due to the presence of various bioactive components. The diverse chemical composition contained in this plant contributes to various biological activities, which may be beneficial for the health, food, and cosmetic industries. However, its cultivation, conservation, and commercial exploitation remain constrained. This study investigates the challenges encountered by black turmeric farmers in the Koraput region of Odisha, with a particular focus on the Dasmantpur block. The most significant issue identified is the consistently low yield, which directly limits production potential. In addition to this, difficulties in market accessibility and a lack of awareness regarding high-yield black turmeric varieties exacerbate the situation. This article explores the phytochemical composition, traditional uses, medicinal properties, and potential health benefits of black turmeric. It also examines the challenges related to its cultivation and conservation efforts. The study emphasizes the need to address these systemic barriers through targeted policies and support mechanisms, which are essential for promoting the sustainable development of black turmeric cultivation. Farmers can enhance their income by cultivating black turmeric, which offers health benefits and is highly marketable to pharmaceutical companies, Ayurvedic practitioners, herbal medicine dealers, and Ayurvedic retail outlets. By tapping into this lucrative market, farmers not only contribute to the growing wellness sector but also secure a steady revenue stream by supplying a product that is both valuable and versatile in its application.

Keywords: Black turmeric, cultivation challenges, health benefits, production and marketing. Garrett's score

Introduction
Black turmeric (*Curcuma caesia* Roxb.), popularly called as Kali Haldi a perennial rhizomatous plant belonging to the Zingiberaceae family. This underutilized medicinal herb, holds significant value across Asia for its potent therapeutic properties and is increasingly recognized for its potential in traditional healing practices with a diploid chromosome number (2n = 42), is endangered in Southeast Asia. It is native to North-East and central India, distributed to Java, Myanmar and rarely found in Madhya Pradesh, Jharkhand, Chhattisgarh, Orissa and other parts of South India. This species is commonly found along with the coastal areas and river alluvial soils extending up to midlands of Kerala and South Karnataka in wild form (Sabu, 2006) [28].

It is characterized by its distinctive dark purple to black rhizomes, which set it apart from the more common yellow turmeric (*Curcuma longa*). This plant contains various bioactive compounds, particularly in its rhizomes and leaves, which are used in traditional medicine as natural alternatives to pharmaceutical treatments for various diseases Due to its therapeutic properties, black turmeric is often referred to as "Chemical Goldmine" and holds significant economic value (Joy *et al*., 1998) [15].

Kanglom *et al.* (2023) investigated the phytochemical composition, antioxidant, and antibacterial properties of black turmeric (*Curcuma caesia*) and found it to be a rich source

of antioxidants and antimicrobial compounds, making it valuable for health benefits and applications in the pharmaceutical and food industries. Additionally, black turmeric possesses a range of therapeutic properties, including antioxidant, anti-tumor, anti-inflammatory, hepatoprotective, and carminative effects (Gantait *et al.*, 2011) [11], contributing to its significant economic value. All parts of the plant—leaves, roots, bulbs, and rhizomes—are used in Ayurvedic, Unani, and Siddha medicine (Pandey & Chowdhary, 2003) [23].

The rhizomes of *C. caesia* are traditionally used in the treatment of various ailments and metabolic disorders like leukoderma, asthma, tumors, piles, bronchitis, rheumatic arthritis/joint pain, gastric problem, cut/injury to stop bleeding, inflammation, fever, cough, infection, allergy, snake bite, insect bite, toothache, vomiting, impotency, cancer, relax muscle, menstrual disorder, aphrodisiac, inflammation, gonorrheal discharges etc. in Indian system of medicine (Das *et al.*, 2013; Pathan *et al.*, 2013) [8, 24]. The rhizome is also known for its antioxidant and antimutagenic (Devi *et al.*, 2015) [9]. Its pungent smell is due to essential oil rich in camphor and starch, with the volatile oil containing 30 components, including camphor (28.3%) and ar-turmerone (12.3%) as major constituents. The rhizomes are used for a range of therapeutic effects, such as smooth muscle relaxation, treating hemorrhoids, leprosy, asthma, epilepsy, and cancer, as well as for their anti-inflammatory and aphrodisiac properties (Arulmozhi *et al.*, 2006; Sasikumar, 2005) [3, 26]. The diverse chemical composition contained in this plant contributes to various biological activities, which may be beneficial for the health, food, and cosmetic industries. It is the rarest and most expensive rhizome in the Curcuma family, yet its potential remains largely underexplored, with limited awareness of its value.

The present study investigates the therapeutic uses and socio-economic impact of black turmeric in the local communities of Koraput, Odisha, emphasizing its economic potential and the challenges in production and marketing. Koraput, located in the Eastern Ghats region between 17°40' and 20°07' north latitude and 81°24' and 84°02' east longitude, is an agro-biodiversity hotspot with a predominantly tribal population. The district's altitude ranges from 1500 to 3000 meters above sea level, with an average annual rainfall of 1,567 mm, mostly received between June and September. The environment is ideal for black turmeric cultivation, which thrives in warm, humid climates and moist deciduous forests with clayey soils. Black turmeric is planted from April to August, with rhizomes (about 20 g) placed three inches deep. The crop is ready for harvest when the leaves turn yellow and fall, typically in December or January. The goal of this research is to provide a comprehensive understanding of the challenges in black turmeric cultivation, marketing, and its therapeutic benefits. This valuable information is the key that can be used for the development of drugs, functional food ingredients, and food product it can be used in fresh form or processed into different products.

Botanical characteristics

The plant is usually erect, with a height ranging from 0.5 to 1.0 m. It consists of an underground, large, ovoid, tuberous rhizome (often referred to as the rootstock) and an erect aerial shoot with leaves and reproductive parts. The leaves are broadly lanceolate or oblong with a deep violet midrib, arising from the underground stem, and have a strong camphoraceous scent. The leaves are generally found in groups of 10-20. In the middle region, the lamina displays deep ferruginous purple-colored clouds. The flowering bracts are green with a ferruginous tinge. The flower petals can be deep pink or red in colour and typically appear in June or July. The calyx is 10-15 mm long, obtuse, and 3-toothed, whereas the corolla is long and tubular with a pale yellow lip that is 3-lobed and semi-elliptical. The rhizome is sessile, covered with adventitious roots, root scars, and warts, and is laterally flattened. The inner part of the rhizome is bluish-black in color, about 2-6 cm in diameter, and emits a characteristic sweet camphoraceous odor due to the presence of essential oils like eucalyptol and camphor. It has a bitter and hot taste with a pungent smell (Pandey *et al.*, 2003; Das *et al.*, 2013) [23, 8]. The fruits are seed-bearing structures enclosed in a capsule.

Black Turmeric: Phyto-Constituents & Therapeutic Uses:

Curcuma caesia is a valuable source of unique natural products for the therapeutics development against various diseases. The multiple phtyoconstituents like curcumminoids, oil content, flavonoids, phenolics, amino acids, protein and high alkaloids, found in the rhizome, are responsible for the antimicrobial, antitumor, anxiolytic, antiinflammatory, antiulcer, CNS depressant, locomotor depressant and antioxidant activities (Karmakar *et al.*, 2013) [17]. Pharmacologically blood purifying activity (Arulmozhi *et al.*, 2006) [3], bronchodilating activity (Paliwal *et al.*, 2011), anthelmintic activity (Gill *et al.*, 2011) [13], anti-bacterial activity (Rajamma *et al.*, 2012) [25], anti-ulcer activity (Das *et al.*, 2012) [27] were reported by several workers.

The diverse chemical composition of Black Turmeric (*Curcuma caesia*) contributes to various biological activities beneficial for the health, food, and cosmetic industries. Gaikwad *et al.* (2023) [12] identified components such as alkaloids, triterpenoids, steroids, saponins, tannins, flavonoids, cardiac glycosides, proteins, amino acids, carbohydrates, fats, and fixed oils in different extracts (methanolic, chloroform, petroleum ether, and water). The unique color of black turmeric rhizomes is due to the presence of anthocyanins, specifically cyanidin, as reported by Pandey *et al.* (2003) [23].

The characteristic pungent smell of Black Turmeric (*Curcuma caesia*) rhizomes is due to the essential oil, which is rich in camphor and starch. The volatile oil components of the rhizomes were analyzed by GC-MS by Pandey *et al.* (2003) [23]. The volatile rhizomes oil of contains 30 components that make up 97.48% of the oil. Major constituents include camphor (28.3%), ar-turmerone (12.3%), (Z)-ocimene (8.2%), 1,8-cineole (5.3%), elemene (4.8%), borneol (4.4%), bornyl acetate (3.3%), curcumene (2.82%), and ar-curcumene (6.8%) as reported by Mehendra Kumar *et al.* (2014) [9].

Antioxidant response and cellular protection

C. caesia, rich in flavonoids, phenols, and curcuminoids, has demonstrated strong antioxidant properties through its free radical scavenging activity. The essential oil of its leaves and rhizome extract are considered excellent natural sources of antioxidants, which can be utilized in cosmetics and pharmaceuticals (Caleja *et al.*). Regular use of black

turmeric may help prevent cardiovascular diseases, neurodegeneration, aging, and cancer risks. Its high ORAC (Oxygen Radical Absorbance Capacity) values suggest that it can bolster cellular defenses and slow oxidative stress-related deterioration. Additionally, the ethanolic extract of black turmeric shows strong thrombolytic activity, potentially preventing blood clot formation in arteries.

Anticancer response

The methanolic extract of *C. caesia* rhizome mitigates the toxicity induced by cyclophosphamide, a chemotherapeutic agent, in bone marrow cells by reducing micronuclei formation. Additionally, it helps prevent hepatotoxicity and nephrotoxicity associated with cyclophosphamide treatment, suggesting its potential as a supportive supplement in cancer therapy with cyclophosphamide (Devi & Mazumdar, 2016) [10].

Neuro pharmacological response: A study by Karmakar revealed that the rhizome of *C. caesia* exhibits analgesic, anticonvulsant, muscle relaxant, and locomotor depressant effects, suggesting its potential as an antidepressant and a promising agent for improving brain health.

Smooth Muscle Relaxant and Anti-asthmatic Activity: Arulmozhi *et al.* (2006) [3] found that *Curcuma caesia* demonstrates smooth muscle relaxant and anti-asthmatic properties, offering potential benefits for asthma prevention.

Anti-ulcer activity: Das *et al.* (2012) [27] found that the ethanol extract of *C. caesia* rhizome reduces gastric acid and free acidity while increasing mucus production, suggesting its potential as an effective anti-ulcer agent, comparable to ranitidine.

Anti-diabetic effects: Some studies suggest that curcuminoids in black turmeric may help regulate blood sugar levels.

Aphrodisiac: In traditional systems, it is considered an aphrodisiac and is used to address sexual health issues.

Anti-fungal activity: Banerjee and Nigam (1984) [4] identified the antifungal properties of *C. caesia* rhizomes, while Borah *et al.* found that its essential oil, also present in the leaves, inhibits the growth of *Aspergillus niger*, *Saccharomyces cerevisiae*, *Aspergillus fumigatus*, and *Candida albicans*.

Anti-Bacterial activity: Kumar *et al.* (2014) [21] reported that *C. caesia* rhizome extracts exhibit antibacterial activity against Gram-positive bacteria like *Bacillus cereus*, *Bacillus subtilis*, and *Streptococcus agalactiae*. Additionally, Angel Gabriel Rajamma *et al.* (2012) [25] explored the antioxidant and antibacterial properties of oleoresins from nine *Curcuma* species, while Pandey and Gupta (47) found that rhizome extracts were more effective than stem and leaf extracts in inhibiting bacterial growth.

Black turmeric: Ayurvedic Healing Properties

The rhizomes of black turmeric have long been recognized for their wealth of health-promoting compounds, which have formed the basis of traditional medicinal practices for centuries. These medicinal plants are utilized extensively worldwide to treat a wide range of chronic as well as acute illnesses, and are considered the backbone of traditional medicine. The rhizomes are used as stimulants, anti-diarrheal, diuretic, anti-emetic, wound cleanser and in treating various skin disorders in India, Indonesia, Thailand and Malaysia (Vairappan *et al.*, 2013) [29]. In different regions, black turmeric is used to treat specific conditions, such as stomachache, typhoid, and pneumonia. Its rhizome powder is also used as a face pack, and its paste is applied to relieve migraine, snake and scorpion bites, and wounds (Chadalavada *et al.*, 2017) [6].

Black turmeric (*Curcuma caesia*) is highly valued in Ayurveda for its medicinal properties. Its fresh rhizomes are known for their effectiveness in treating diarrhea, stomach aches, and gastrointestinal disorders. It has strong anti-inflammatory, analgesic, and anti-helminthic properties, making it beneficial in treating conditions like rheumatic arthritis, epileptic seiures and worm infections. The rhizome paste is also applied to wounds for quick healing and to stop bleeding. Additionally, black turmeric is used in the treatment of respiratory issues like bronchitis, cough, fever, and tonsillitis, and is considered an aphrodisiac and remedy for leprosy, epilepsy, and even cancer. Both dried rhizomes and leaves of *Curcuma caesia* are used in treating piles, leprosy, asthma, cancer, wounds, impotency, fertility issues, toothache, vomiting, and allergies. Crushed fresh rhizomes, applied as a paste on the forehead, relieve migraines, while also aiding digestion, supporting liver and kidney function, and alleviating sprains, bruises, and menstrual disorders.

Results and Discussion

The study investigates the challenges and prospects of black turmeric cultivation in the Koraput region, focusing on the Dasmantpur block, a key area for production. Using analytical methods like percentage analysis and Garrett's ranking technique to analyze various factors affecting production. The study identifies and ranks key issues affecting growers. The factors assessed include production, marketing, social, technological, and financial challenges. Results show that the most significant constraints include low yield, inadequate storage facilities, low productivity and financial constraints. Other challenges include lack of technical knowledge, unavailability of quality planting material, limited awareness, price fluctuations, improper marketing channels, and insufficient adoption of appropriate technology. The findings suggest that low yield and Market accessibility are the most pressing constraints faced by black turmeric growers in the region, impacting their overall productivity and income potential. These issues underscore the need for targeted interventions in technology adoption, market access, and financial support to improve the socio-economic conditions of black turmeric growers in the region.

Table-1: Highlights the ranking of challenges faced by black turmeric farmers in the Koraput region, with production factors emerging as the most critical concern (Rank 1, Garrett's Score: 83). This indicates that crop yield, cultivation practices, and related issues are the primary focus for farmers. Marketing factors ranked second (Rank 2, Garrett's Score: 74), pointing to significant challenges in market access, price fluctuations, and marketing channels. Financial constraints (Rank 3, Garrett's Score: 62) followed closely, reflecting issues like limited credit access and low incomes that hinder investment in better practices.

Technological factors (Rank 4, Garrett's Score: 55) were seen as less urgent, though difficulties in accessing modern farming tools and techniques remain. Social factors (Rank 5, Garrett's Score: 49) were identified as the least critical, suggesting that while awareness and cultural barriers are important, they are not as pressing as the other challenges. The findings suggest that improving production-related factors, followed by marketing strategies, would be key to addressing the challenges in black turmeric farming in Koraput

Table-2: presents the ranking of production-related challenges faced by black turmeric farmers. The most critical challenge is Low Yield (score: 72), highlighting it as the top priority for growers. This is followed by the Non-availability of Planting Material (score: 64), which emerges as the second most significant issue. Market Access for Selling Turmeric ranks third (score: 50), reflecting the importance of reaching viable markets for sales. Lack of Technical Knowledge (score: 43) is a moderately important concern, but it is considered less urgent compared to the other issues. Lastly, Limited Processed Product Development (score: 37) is seen as the least critical challenge, suggesting that farmers prioritize other production aspects over product diversification and processing.

The data presented in Table 3 highlights the key marketing challenges faced by black turmeric farmers in koraput region. The most critical issue is market accessibility, which directly impacts farmers' ability to sell their crops and secure a stable income. Market price variation ranks second, as fluctuating prices create financial instability and hinder long-term planning. The third concern, the role of middlemen, reveals that while intermediaries assist with distribution, their involvement often results in higher costs and reduced profits for farmers. Lack of transportation ranks fourth, signaling logistical difficulties. Finally, lack of storage facilities is ranked lowest, indicating it is a concern but less critical in comparison to issues affecting market access and pricing. Overall, the rankings emphasize that the most pressing marketing challenges directly influence the profitability and sustainability of black turmeric production.

Table 1: Challenges Faced by Black Turmeric Farmers in Cultivation and Marketing.

Factor	Rank Given (R)	Percentage Position	Garrett's Score
Production Factors	1	10%	83
Marketing Factors	2	30%	74
financial Factors	3	50%	62
Technological Factors	4	70%	55
sociall Factors	5	90%	49

Table 2: Challenges in the Production Aspect of Black Turmeric Cultivation

Production Problem	Rank Given (R)	Percentage Position	Garrett's Score
Low Yield	1	20%	72
Non-availability of Planting Material	2	30%	64
Market Access for Selling Turmeric	3	50%	50
Lack of Technical Knowledge	4	60%	43
Limited Processed Product Development	5	70%	37

Table 3: Challenges in the Marketing Aspect of Black Turmeric Cultivation

Marketing factors	Rank Given (R)	Percentage Position	Garrett's Score
Market accessibility	1	10%	82.92
Market price variation	2	30%	71.82
Middleman	3	50%	62.48
Lack of Transportation	4	60%	57.02
Lack of storage facility	5	75%	47.46

Conclusion

C. caesia (black turmeric) holds significant potential as a natural complementary and alternative health therapy, offering promising applications in both the pharmaceutical and nutraceutical industries. However, its potential remains largely underexplored, with limited awareness of its value. To unlock this potential, the implementation of scientific agronomic practices is critical for optimal cultivation and enhanced production. Farmers in Koraput, who grow black turmeric, face various challenges related to production, marketing, technology, social issues, and finance. Addressing these systemic barriers through targeted policies and support mechanisms is essential for the sustainable growth of black turmeric cultivation and the improvement of farmers' socio-economic well-being. Given its bioactive compounds and therapeutic potential, *C. caesia* could become a key medicinal plant. However, further research is necessary to identify valuable germplasm and develop breeding techniques that could increase its productivity. This crop has the potential to provide financial security and improve the livelihoods of the local tribal communities in Koraput.

Conflict of Interest

All authors declared that there is no conflict of interest.

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