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Phytochemistry and Pharmacology of *Curcuma angustifolia*: An updated Review

***Nidhi Likhitkar**

Department of Botany, Sam Global University, Raisen Road, Bhopal-464551 (India)

Abstract

Curcuma angustifolia Roxb., also known as East Indian arrowroot, is characterized by the presence of narrow, green, glabrous leaves with small inflorescences bearing yellow flowers with pink coma bracts distributed throughout India and Asian countries. The starch from the plant has been a rich source of food product used ethnobotanically. The objective of the present review is to compile and update the published data on traditional uses, pharmacological potential, and phytochemistry of compounds isolated from the plant *C. angustifolia*. The leaf, flowers and rhizomes of the plant find utility in several pharmacological actions like anticancer, antioxidant, anti-inflammatory, antimicrobial and anti-ulcer. The starch obtained from the plant is also used as a rich source of food. Many phytochemicals have been identified from *C. angustifolia* and many more are yet to be identified and isolated. Further investigations to confirm the underlying mechanisms by which the extracts of phytoconstituents of *C. angustifolia* elicit the pharmacological actions is warranted.

Key words : *Curcuma angustifolia*, antioxidant, antiproliferative, anti-ulcer, antimicrobial, anti-inflammatory.

Humans' search for drugs from natural sources dates from ancient times and there is abundant evidence from various sources, such as written documents, preserved monuments, and even original plant medicines. People have been fighting against several diseases for many years, resulting in creating an awareness of medicinal plant usage. Thus, they learned to pursue drugs from various plant parts, including barks, seeds, fruit bodies, as even the whole plant[43].

Herbal medicines are important tools in the management of health from the ancient days; traditional medicines and folk medicinal systems utilized these plants and plant products[65]. Among the various plants, the predominant ones include the spices that are the part of the daily diet[39]. Several such spices are widely utilized in Ayurvedic and Chinese traditional

*Priyanka Tiwari, EWS/D 248, Ayodhya Extension, Bhopal, Contact 7987008905

medicines as dietary agents in the management of infectious and chronic illness[27,28]. Various examples describe the importance of medicinal plants as drug sources, such as aspirin, which has been used for millennia to treat pain and fever, where salicylic acid is the active metabolite of aspirin that was extracted from the bark of willow trees[34]. In every period, during every successive century from the development of humankind to advanced civilizations, the healing properties of certain medicinal plants have been identified, noted, and conveyed to the successive generations. This perpetual interest in medicinal plants for providing drug molecules has brought about today's modern and sophisticated fashion of their processing and usage as lead compounds for drug discovery[42].

Bioactive compounds and extracts from various aromatic plants are known for their biological and medicinal activities. Well known spices belonging to Zingiberacea family especially the *Curcuma* genus have been widely investigated for their pharmacological potentials[26]. The Curcuma genus is a rhizomatous annual or perennial herb in the Zingiberaceae family. Almost all of the 120 species of this genus have already been included in many works of literature[29]. Most of the species of *Curcuma* are naturally present in tropical evergreen areas. Malaysia, Indochina, northern Australia, Thailand, India, etc. are the most favorable places to grow *Curcuma* species[32,33,63]. The chromosome number of these genus ranges from 2n = 20 to 105 [5]. The morphological features of various species in the Curcuma genus have been examined by several authors[11,16,17,35,56]. As reported by Xia *et al*.,[62] the genus *Curcuma* comprises of 70 perennial rhizomatous species, which are distributed widely throughout tropical and subtropical regions of the world. The rhizome of *Curcuma* is a source of a yellow dye and has been historically used as spices, food preservatives, flavoring agent, and household remedy for treatment of many diseases[63]. In terms of traditional medicinal uses, they have been used for the treatment of enlarged liver, spleen, stomach ulcer, diabetes, cough, hepatic disorders, chest pain, skin diseases, boils, blood purifier, and rheumatism[1,12,48,49]. The plants of *Curcuma* genus are also considered as nutritionally rich food products since the plants are a rich source of starch, carbohydrates, proteins, fats, vitamins, and minerals[3,6,21,25]. Several reports concerning the phytoconstituents, essential oils, and pharmacological actions have been published earlier[2,10,18,22,39,41]. The essential oils are very important compounds that are produced from the Curcuma rhizomes and leaves. The predominant compounds present in the rhizome essential oils of different species of *Curcuma* include Curzerenone and 14-hydroxy-δ-cadinene[23]. Primarily, the rhizomes of these plants are utilized in medicine and food; however, the leaves of the plants are usually considered and left alone as an agrowaste.

The present study aims to summarize the pharmacognostical, phytochemical and pharmacololgical properties of the *Curcuma angustifolia* species.

Relevant literature for this review on *C. angustifolia* has been obtained from PubMed, ScienceDirect, Web of Science, PubChem, Google Scholar, and Scopus database. The articles published in English

before December 2022 on traditional uses, pharmacology of extracts, and various phytoconstituents isolated from different parts of *C. angustifolia* have been included in this review.

Data inclusion criteria was (a) published/peer-reviewed scientiûc articles; (b) ethnopharmacological studies; (c) extracts with different solvents; (d) studies on the mechanism of actions of the extracts and their phytoconstituents; (e) *in silico, in vitro,* and *in vivo* studies.

Studies performed on other species of *Curcuma* genus or any unpublished data, and reports have been excluded from being taken into account for this review.

Curcuma angustifolia :

Curcuma angustifolia Roxb., also known as East Indian arrowroot, is characterized by the presence of narrow, green, glabrous leaves with small inflorescences bearing yellow flowers with pink coma bracts[52]. Flowers usually appear near to the ground in the beginning of the rainy season before the leaves are fully developed and the leaves later reach up to about 1.5 m. It is endemic to northwestern, central, and south India, where the plants are utilized for its medicinal purposes by local herbalists[61].

Synonyms :

The vernacular names of *C. angustfolia* are reported to be Tavakshira, tavaksheera, payaksheera, tavakshiri, vamsalocana in Sanskrit; Tekhur, tikhur, theksura, thavsasheera, thikora, thavakheera in Hindi; East Indian arrow root, Curcuma starch in English; Kaadu arrow root, kovegida, kove hitting gida, thavakeela in Kannada; Gaddalu in Telugu; Kisangu, araukizhangu, kooa, artimavu, kookai, kua in Tamil; Koova, kuva-kizhanna in Malayalam; (Konkani)-Koovyajhaad in Konkani; Tavakira, thavakheera, Thavakil in Marathi; Tavkhir, tikhu in Gujarati; Tikkur, keturihalodhi in Bengali[8,37].

Taxonomical Classification :

Kingdom: Plantae
Class: Liliopsida
Subclass: Commelinidae
Order: Zingiberales
Suborder: Zingiberanae
Family: Zingiberaceae
Genus: *Curcuma* L.
Species: *Curcuma angustifolia*

Traditional uses :

Traditionally and primarily *C. angustifolia* has nutritional value as a source of starch for Indian foods. The rhizomes are ground into flour which can then be mixed together with milk or water to form a nutritious meal[47]. Root powder used with milk to treat burning micturition or urination, difficulty in micturition, fever, acidity, gastric reflux disorder, treat diarrhea to take with hot water and with honey to treat cough, dyspnea. As per Ayurveda it is used to improve strength and immunity, aphrodisiac, improves vigor, nourishing, coolent, blood/skin/ bleeding disorders, jaundice, excessive thirst, liver diseases, asthma, TB, wt. loss, anemia. Tuber powder used as reducing intestinal inflammation, carminative,

astringent, dysentery, flatulence, cardiotonic[30]. Root stock is used as tonic. It is useful in leprosy, burning sensation, dyspepsia, asthma, jaundice, anemia, leucoderma, stones in kidney and disease of blood[53]. Rhizome is used in intestinal diseases, peptic ulcers, colitis, demulscent, bone fracture and swelling of body[19,47]. The essential oil extracted from different parts of this species is used for antifungal and antibacterial activities[15], antimycotic activity[55] antioxidant activity[23]. *C. angustifolia* have been reported to be a rich source of proteins and carbohydrates and are used in culinary preparations as vegetables and food appetizers[49]. Ethnobotanically it is used as tonic, dysentery, gastrointestinal disorders, body pain, inflamed mucous membranes, and stop bleeding of cattle injured by leech[12,22,43].

Morphology :

C. angustifolia is a rhizomatous, slender branched herb grows 90-180 cm in height with fleshy cylindrical rhizome and small rootstock. Its stem is typically short, replaced by pseudo stems formed by leaf sheaths. The leaves are simple, distichous, green, glabrous and lanceolate with margins that are entire (Figure 1, 2). They appear in an opposite arrangement and are deciduous. They display fine parallel venation off of a central midrib. The upper surface of the leaves is usually a darker shade of green than the lower surfaces. Leaves may grow to about 36-37 cm (14-15 in) length and 8- 10 cm (3.1-3.9 in) in width. The leaves also smell and taste similar to turmeric[15]. Its flowers are bisexual, epigenous, zygomorphic with modest and small spiked inflorescences of three or four yellow, funnel-shaped flowers within tufts of pink terminal bracts. The bracts are boat-shaped and encase the entire perianth of the flower. As is common to the genus, the flowers of *C. angustifolia* have double anthers, a slender style and a globular stigma. Flowers are usually seen at the beginning of the monsoon (rainy) season from July to August, before the leaves have had the chance to fully develop and they continue to flower even after the leaves have fully developed. The calyx of the flower is usually 1 cm (0.39 in) long and very hairy, tubular, thin, split on 1 side, sometimes and spathe like, Apex 3-toothed or lobed that may appear to be triangular or obtuse. The corolla is white, and usually grows to be about 1.5–2 cm (0.59–0.79 in) long that are also hairy, proximally tubular, distally 3- lobed; lobes varying in size and shape, Stamens or staminodes, into whorls. Lateral 2 staminodes of outer whorl petaloid, or forming small teeth at base of labellum, Ovary inferior, 3- loculed initially, 1- or 3-loculed when mature; ovules ± numerous perlocule[46]. Its rhizome is strong and can grow to be up to 1.5 m (4.9 ft) in length.

Phytochemistry :

Extraction and gas chromatographic studies have revealed several volatile components in the essential oil obtained from the leaves of *C. angustifolia*. The major compounds detected in the essential oil include Eucalyptol, α-Curcumene, Curzerenone, Boldenone, α-Elemenone, Longiverbenone, 14-hydroxy-δ-cadinene[4]. The other components reported in the leaf essential oil are α-pinene, camphene, 2-Bornanone, α-terpineol, α-bourbonene, Caryophyllene, cis- α-farnesene, α-acorenol, β-elemene, Caryophyllene oxide, Spathulenol and Alloaromadendrene oxide-(2).

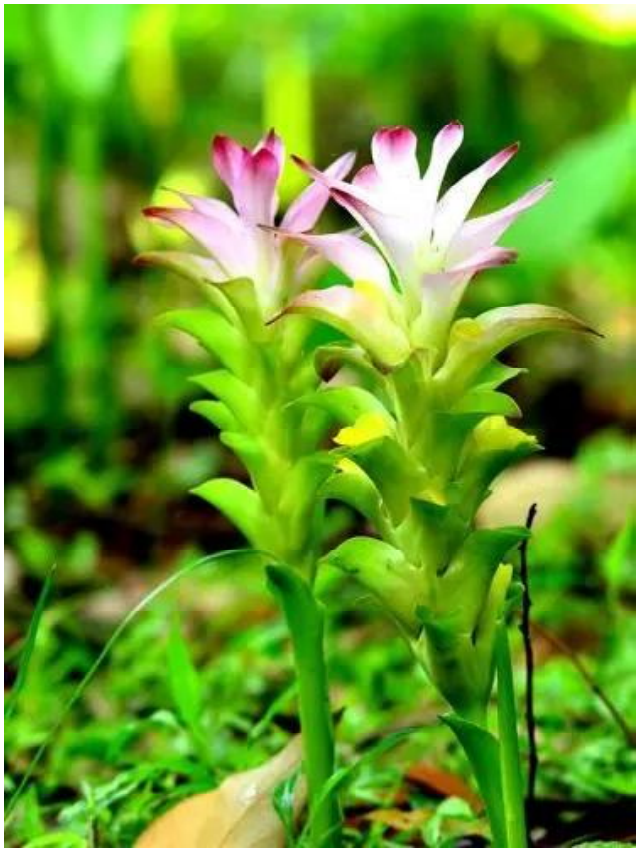

Figure 1 *Curcuma angustifolia* Roxb. [48]

Figure 2. *Curcuma angustifolia* rhizome

Oxygenated sesquiterpenes were the predominant class of compounds in rhizome oil of *C. angustifolia*. The rhizomes were found to contain Curzerenone, camphor, germacrone, xanthorrhizol and β-eudesmol in major amounts[23]. Palmitic acid, isoborneol and methyl eugenol have also been found in the rhizome essential oil of *C. angustifolia*[57].

Pharmacology :

Various pharmacological activities of *C. angustifolia* leaves, rhizomes and essential oils have been explored by the scientific community. A pictorial summary of the pharmacological actions of *C. angustifolia* has been presented in Figure 3.

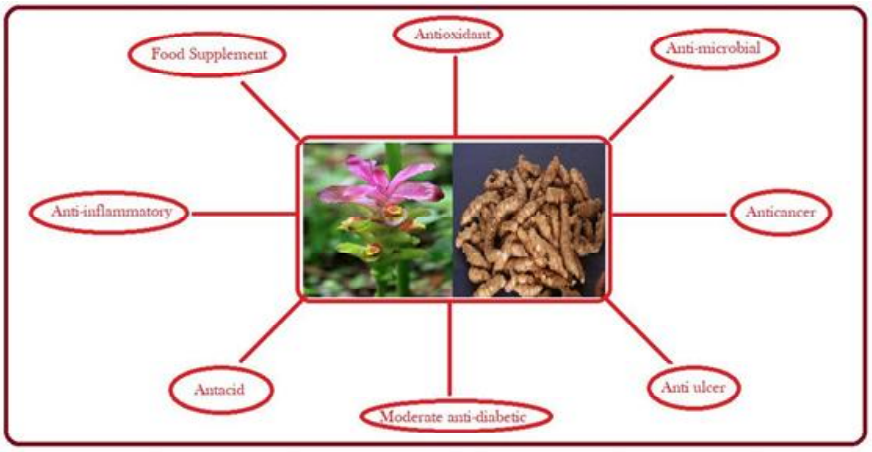

Figure 3 Pharmacological potential of *Curcuma angustifolia*

Hepatoprotective :

Methanol extract of rhizome of Curcuma angustifolia (MECA) has been reported to exhibit strong antioxidant activity and attenuated carbon tertrachloride (CCl_4)-induced decrease in the viability of HepG2 cells. MECA also restored ALT, AST, ALP, TP and albumin level. The pretreatment with MECA also improved the effects of SOD, CAT and GSH and reduced lipid peroxidation on induction of hepatotoxicity[24] by CCl_4.

Antioxidant activity :

The antioxidant activity of the essential oil extracted from leaf and rhizome of *C. angustifolia* has been reported to have antioxidant action in various oxidation models viz. DPPH, ABTS and RPA. The leaf oil has been reported to exhibit better antioxidant potential as compared to rhizome oil and reference standards (ascorbic acid and butylated hydroxytoluene (BHT))[23]. In another report, various parts of *C. angustifolia* were triturated in ethanol and water to obtain ethanolic and aqueous extracts. The ethanolic extract of the mixed parts was found to contain 76.59 mg GAE/100 g of total phenolics, 85.24 mg CE/ 100 g of flavonoids and 46.24 (mg AEAC/100 g DPPH scavenging action, suggesting role of phenolics and flavonoids in the significant

antioxidant action of the plant[7]. The essential oil extracted from the leaf of *C. angustifolia* were tested for antioxidant potential in terms of DPPH, ABTS, and hydrogen peroxide radical scavenging activities. The IC50 values of the essential oil was found to be 16.08, 12.81 and 8.08 µg/ml against the DPPH, ABTS, and hydrogen peroxide radical respectively[4]. A comparative study on the antioxidant activity of enzymatic and non-enymatic extracts of *C. angustifolia* and a few other Curcuma species exhibited and IC_{50} value of 54.21 and 40.6 µg/ml in DPPH assay for the non-enymatic and enzymatic extracts respectively whereas 47.24 µg/ml as the IC_{50} for hydroxyl radical scavenging[13]. Another study evaluated antioxidant potential of saponins extracted from *C. angustifolia* in DPPH, hydrogen peroxide (H_2O_2), and nitric oxide (NO) assays. At 100 µg/mL concentrations, the maximum antioxidant percentages for DPPH, H_2O_2, and nitric oxide were found to be 83.05 %, 65.93%, and 85.16%, respectively. In addition, the IC_{50} values for these assays were discovered to be 62.65, 77.27, and 55.30 µg/mL, respectively[9]. In another investigation, the methanolic rhizome extract of *C. angustifolia* was tested for antioxidant action using DPPH assay revealing 66.82% inhibition of the DPPH radical[37]. In a separate investigation, the methanolic extract of *C. angustifolia* were evaluated for DPPH scavenging activity followed by *in silico* study by docking process to identify suitable molecules at the protein-binding sites through annealing and genetic simulation algorithms. The extract exhibited 537 mg GAE/g of phenolics and 38 mg QUE/g of flavonoids[58].

Antiproliferative activity :

The anti-proliferative activity of aqueous extracts of budding flowers, leaves, full bloomed flowers and mixture of all parts of *C. angustifolia* was studied using MDCK, Vero and HeLa cell lines. he inhibitory activity in all the three cell lines was found to be dose dependent. The extract of leaves and budding flowers exhibited higher inhibitions in MDCK and Vero cells while the full bloomed flowers extract showed higher inhibitory activities in HeLa cells[7]. The antineoplastic potential of the leaf essential oil from *C. angustifolia* was evaluated on human breast cancer lines, MCF-7 and MDA-MB-231. The oil exhibited significant cytotoxicity on MCF-7 and MDA- MB-231with IC_{50} value of 64.17 and 70.31 µg/ml respectively[4]. The crude saponins extracted form *C. angustifolia* rhizomes have been found to exhibit significant anticancer activity against MCF-7 cell line as 79.20% at a concentration of 320 g/mL, with an IC_{50} value of 166.66 g/mL [9]. Methanolic extract of the rhizomes was studied for anticancer activity against HeLa cells by MTT assay revealing 66.55% cell viability[37].

Antibacterial activity :

The essential oil extracted from *C. angustifolia* was tested for its antibacterial action using the disc diffusion method against *Escherichia coli, Pseudomonas aeruginos, Staphylococcus aureu* and *Salmonella enterica*. The MIC was also calculated and was found to be 1.00, 0.750, 1.00 and 1.250 mg/ml respectively on the above strains[4]. The antimicrobial properties of methanolic extract of *C. angustifolia* Roxb. rhizomes were

assayed in vitro against human pathogenic bacteria represented by *Pseudomonas aeruginosa, Salmonella typhi, Staphylococcus aureus, Escherichia coli* and *Shigella flexneri* by 96 well-plate method. The result shows MIC at 2 µl for *P. aeruginosa, S. typhi, S. arueus* and *S. flexneri* whereas it was 8 µl for *E. coli* [20]. In yet another study antimicrobial activity of chloroform rhizome extracts of *C. angustifolia* against *Escherichia coli* and *Bacillus subtilis* using agar diffusion method revealed dose dependent antibacterial action with a zone of inhibition of 6.0, 7.0 and 8.0 mm at 25, 50 and 100 mg/ml dose respectively[64]. The methanol soluble extract of *C. angustifolia* collected from Nepal was found to inhibit the growth of *Staphylococcus aureus, Bacillus subtilis, Salmonella typhi* and *Escherichia coli* with zone on inhibition 14.4, 15.26, 15.06 and 14.03 mm respectively. The antibacterial action was significant when compared to the standard drugs used in the study[52]. Various extracts of *C. angustifolia* leaf and rhizomes were tested for antimicrobial activity against *Staphylococcus aureus, Pseudomonas aeruginosa, Bacillus subtilis, Streptococcus pneumonia* and *Escherichia coli*. The ethanol extract of the leaves exhibited maximum zone of inhibition was 20mm at 80mg/ml, against *P. aeruginosa* and minimum was 10mm at 20 mg/ml against *B. subtilis* and *S. aureus*. For acetone extract of maximum zone of inhibition was 20mm at 80mg/ml against *P. aeruginosa* and minimum was 10mm at 20mg/ml, against *S. aureus*. The ethanol extract of rhizome displayed maximum zone of inhibition of 9 mm at 80mg/ml against *B. subtilis* and minimum was 0 mm at 20 mg/ml against *P. aeruginosa*. In acetone extract maximum zone of inhibition was 10mm at 80mg/ml against *E. Coli* and minimum zone of inhibition was 1mm at 20mg/ml against *S. pneumonia*[40]. In a separate study, the methanolic extract of rhizomes of *C. angustifolia* exhibited moderate antimicrobial activity against four pathogenic bacterial strains out the six strains tested[37]. The root extracts of *C. angustifolia* evaluated against four UTI causing bacterial isolates by well diffusion method. The extract was found to be ineffective against *P. aeruginosa* whereas only moderately effective against *E. coli, Klebsiella pneumonia* and *S. aureus*[14].

Anti-inflammatory activity :

The hydro-alcoholic extract of the rhizomes of *C. angustifolia* have been assessed for anti-inflammatory action using the carrageenan induced rat paw edema method. The total phenolics content 0.456 mg/100mg while the flavonoids was 1.091mg/100mg. The anti-inflammatory action was found to be dose dependent reducing inflammation by 57.40 % at 200 mg/kg dose[54]. In yet another report hydroalcoholic extract of rhizomes of C. angustifolia, administered at doses of 200 mg/kg p.o. and 400 mg/kg p.o. inhibited carrageenan-induced paw oedema by 61.36 percent and 70.45 percent, respectively[31].

Other pharmacological actions :

The rhizome starch of *C. angustifolia* was studied on 67 patients at dose of 4g TID for 30 days. The starch was found to be highly effective in treatment of amlapitta (systemic acidosis) and significantly relieved the cardinal symptoms viz., Avipaka, Tikta-amlodgara, Daha, Shoola, Chhardi and the associated

symptoms viz., Aruchi, Gaurava, Udaradhmana, Antrakujana, Vit bheda, Shiroruja, Angasada, and Trit[44]. In another study by the same authors, the acute toxicity and anti-ulcer effects of the rhizome starch of *C. angustifolia* was evaluated to obtain a maximum dose of 4400 mg/kg and the gain in weight in 50% of the tested animals[45].

The ability of *C. angustifolia* rhizome extract to act as a reducing agent for synthesis of silver nanoparticles has been reported. These nanoparticles were also found to be effective antimicrobial agents *Klebsiella pneumonia, Staphylococcus aureus, Aspergillus niger, Mucor indicus* and *Rhizopus stolonifer*[59].

The discovery of disease fighting potential of nature and the bioactives from it has been an area of interest in the scientific community. The immense pool of literature available suggests and affirms the role of phytochemicals in designing new drugs. Plants from the family Zingiberaceae have been used since ancient times for cure of several diseases. *C. angustifolia* is a species of the Curcuma genus (Zingiberaceae) that has been least explored scientifically for its pharmacological potential. The available literature on scientific studies of *C. angustifolia* suggest its wide applicability as a food product. Nevertheless studies on establishing the phytochemicals in the essential oil of the plant have been done and a few compounds like Eucalyptol, α-Curcumene, Curzerenone, Boldenone, α-Elemenone, Longiverbenone, 14-hydroxy-δ-cadinene *etc.* have been found in the oil. A few studies have also been directed towards establishing the pharmacological potential of the plant as antimicrobial, anticancer, anti-inflammatory and antioxidant. The underlying mechanisms for the pharmacological actions has not been explored yet and in future it shall be the focus of investigations paving way for new perspectives for disease management.

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