**Review Article**

**Phytopharmaceutical Potential of Turmeric: From Tradition to Modern Medicine**

**Abstract:**

Turmeric (*Curcuma longa*), a perennial herb belonging to the *Zingiberaceae* family, has been revered for centuries in traditional medicine systems such as Ayurveda, Unani, and Traditional Chinese Medicine. Its principal bioactive compound, curcumin, along with other curcuminoids and essential oils, has garnered significant scientific interest due to its broad spectrum of pharmacological properties. These include anti-inflammatory, antioxidant, antimicrobial, anticancer, neuroprotective, and hepatoprotective activities. The transition of turmeric from a traditional remedy to a modern phytopharmaceutical agent has been driven by extensive preclinical and clinical research demonstrating its therapeutic efficacy and safety profile. Despite its immense therapeutic potential, the clinical application of curcumin has been limited by poor bioavailability, rapid metabolism, and systemic elimination. To address these challenges, novel drug delivery systems such as nanoparticles, liposomes, phytosomes, and curcumin analogs have been developed, significantly enhancing its solubility, stability, and bio efficacy. Furthermore, the integration of turmeric-derived compounds into dietary supplements, functional foods, and topical formulations has broadened its application in preventive and therapeutic healthcare. This review highlights the journey of turmeric from its ethnomedicinal origins to its current status in modern medicine. It discusses the molecular mechanisms underlying its pharmacological effects, recent advancements in formulation technologies, and the outcomes of contemporary clinical trials. Emphasis is also placed on regulatory perspectives and future directions in turmeric-based drug development. By bridging the gap between traditional knowledge and scientific innovation, turmeric continues to emerge as a promising candidate in the development of safe, effective, and affordable phytopharmaceuticals.

Keywords:
Turmeric, Curcumin, Phytopharmaceuticals, Traditional Medicine, Bioavailability, Drug Delivery Systems, Clinical Trials, Anti-inflammatory, Antioxidant, Herbal Therapeutics

**Introduction:**

Turmeric (*Curcuma longa* L.), a perennial herbaceous plant belonging to the *Zingiberaceae* family, has been extensively utilized in traditional medicine, culinary applications, and cosmetic formulations for centuries. Native to South Asia, particularly India, turmeric is renowned for its vibrant yellow pigment and diverse pharmacological properties. The rhizome of turmeric is the most valuable part of the plant, as it contains a rich array of bioactive compounds, among which curcuminoids are the most significant. The most well-known curcuminoid, curcumin, has been identified as the primary contributor to turmeric’s therapeutic potential, exhibiting a wide range of biological activities, including anti-inflammatory, antioxidant, antimicrobial, anticancer, and neuroprotective effects (Gupta et al., 2013; Hewlings & Kalman, 2017).

*Curcuma longa* L. (*C. longa*) is the common tall herb that flourishes in tropical as well as in other Indian regions and is referred to as “Indian Saffron or The Golden Spice of India” because of its use in a broad range of diseases in Indian homes as a spice, food preservative, and coloring source (Fuloria et al., 2022). The tuberous rhizome from which *C. longa* is formed has a coarse and segmented skin. In the ground soil, the rhizomes mature underneath the foliage. The matured rhizomes have a yellowish-brown color with a dull orange from inside. Small pointed or tapered tubers sprout off the main rhizome measuring 2.5–7.0 cm (1–3 inches) in length and 2.5 cm (1 inch) in diameter (Prasad and Aggarwal, 2011). The dry rhizome is ground into a yellow powder form that has a bitter, yet sweet taste. A yellow colored substance derived from the rhizome is curcumin (1,7-bis [4-hydroxy-3-methoxyphenyl]-1,6-heptadiene-3,5 dione), a combined form of resin and oil. Rhizome powder is supposed to flavor various cuisines and treat numerous disorders, including inflammation, flatulence, jaundice, menstrual troubles, and hemorrhage. It is also a useful ointment to treat several skin disorders. *C. longa* of India is particularly popular when compared with those from other countries due to its high curcumin concentration, which is the most essential and active biological ingredient responsible for its therapeutic potential (Verma et al., 2018). Curcumin is a flavonoid having a lipophilic affinity that is practically water insoluble (Dave et al., 2017) yet quite stable at the stomach’s acidic pH. *C. longa* and curcumin show antioxidant features close to vitamins C and E in both aqueous and fat-soluble extracts.

Turmeric has played a vital role in traditional medicine systems such as Ayurveda, Traditional Chinese Medicine (TCM), and Unani medicine. Ayurvedic practitioners have long used turmeric to treat a variety of ailments, including digestive disorders, respiratory conditions, and skin diseases. In TCM, turmeric is often employed for its ability to promote blood circulation, alleviate pain, and reduce inflammation. Additionally, Unani medicine has recognized turmeric as a potent remedy for liver disorders and infections. Given its extensive historical use, turmeric continues to be a subject of scientific interest, with modern research exploring its pharmacological mechanisms and therapeutic potential.

Among the most interesting qualities of turmeric is its strong anti-inflammatory effect. Many diseases, including diabetes, cardiovascular disease, neurodegenerative disorders, and arthritis, are often caused by chronic inflammation. By blocking important molecules like nuclear factor-kappa B (NF-\u03ba), tumor necrosis factor-alpha (TNF-\u03b1), and interleukins, curcumin has been shown to modulate several inflammatory pathways (Aggarwal et al., 2007). These processes help curcumin to be effective in controlling inflammatory diseases including asthma, rheumatoid arthritis, and inflammatory bowel disease. Furthermore, studies suggest that curcumin may offer an alternative to non-steroidal anti-inflammatory drugs (NSAIDs) by providing similar benefits with fewer side effects (Gupta et al., 2013).

In addition to its anti-inflammatory activity, turmeric possesses remarkable antioxidant properties. Oxidative stress, which results from an imbalance between free radicals and antioxidants, is a major contributor to aging and various chronic diseases, including cancer, cardiovascular diseases, and neurodegenerative conditions. Curcumin demonstrates its antioxidant properties by neutralizing free radicals, augmenting the function of endogenous antioxidant enzymes like superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px), and diminishing lipid peroxidation (Hewlings & Kalman, 2017). These actions safeguard cells from harm and enhance overall well-being. Turmeric’s antimicrobial properties have also been widely recognized, making it a valuable natural remedy for bacterial, viral, and fungal infections. *Staphylococcus aureus, Escherichia coli,* and *Candida albicans* among others have all been shown to be broadly susceptible to curcumin (Gopinath et al., 2018). Several processes, including bacterial cell membrane disruption, suppression of quorum sensing, and alteration of microbial virulence factors, explain its capacity to prevent bacterial growth. Furthermore, turmeric’s antimicrobial effects extend to its potential role in managing antibiotic resistance, as curcumin has been shown to enhance the efficacy of conventional antibiotics and reduce bacterial resistance (Tyagi et al., 2015).

The anticancer potential of turmeric has garnered significant scientific interest, with numerous studies highlighting its ability to inhibit tumor growth and induce apoptosis in cancer cells. Curcumin has been found to exert anticancer effects through multiple mechanisms, including inhibition of cell proliferation, induction of cell cycle arrest, suppression of angiogenesis, and modulation of oncogenic signaling pathways (Gupta et al., 2013). Curcumin's capacity to improve the efficacy of chemotherapy and radiotherapy while lowering their adverse effects has also helped it to be a promising complementary treatment for cancer.

Another area where turmeric has shown great promise is in neuroprotection and cognitive health. Neurodegenerative disorders such as Alzheimer’s disease, Parkinson’s disease, and Huntington’s disease are characterized by progressive neuronal damage and cognitive decline. Curcumin has been reported to mitigate neurodegenerative processes by reducing oxidative stress, inhibiting neuroinflammation, and promoting the clearance of amyloid-beta plaques (Mishra & Palanivelu, 2008). Furthermore, emerging research suggests that curcumin may enhance neurogenesis and improve synaptic plasticity, thereby supporting cognitive function and mental well-being.

Beyond its medicinal benefits, turmeric is widely used in culinary applications across various cultures. In Indian cuisine, turmeric is a staple spice, used in curries, rice dishes, and beverages such as golden milk. The spice imparts a distinct flavor and color to foods while also providing health benefits. Turmeric is also used in Middle Eastern, Southeast Asian, and African cuisines, where it is valued for its aromatic and preservative properties. In addition to its culinary uses, turmeric is incorporated into traditional beauty and skincare regimens, where it is applied topically to improve skin complexion, treat acne, and reduce pigmentation.

Despite its numerous health benefits, turmeric faces challenges related to bioavailability. Curcumin has poor solubility in water and undergoes rapid metabolism and elimination, limiting its absorption and therapeutic effectiveness. Various strategies have been explored to enhance curcumin’s bioavailability, including the use of adjuvants such as piperine (a component of black pepper), nano-formulations, liposomal encapsulation, and curcumin-phospholipid complexes (Anand et al., 2007). These approaches have shown promise in improving curcumin’s systemic availability and enhancing its pharmacological effects.

Given the growing interest in natural remedies and plant-based medicine, turmeric continues to be a focal point of scientific research and clinical studies. Ongoing investigations aim to elucidate the molecular mechanisms underlying curcumin’s therapeutic actions and explore its potential applications in treating various health conditions. Moreover, the development of novel formulations and drug delivery systems is expected to further optimize the efficacy of curcumin-based therapies.

In conclusion, turmeric (*Curcuma longa* L.) is a remarkable plant with a rich history of traditional use and extensive pharmacological potential. Its bioactive component, curcumin, exhibits diverse therapeutic properties, including anti-inflammatory, antioxidant, antimicrobial, anticancer, and neuroprotective effects. While challenges such as low bioavailability remain, advancements in formulation technologies continue to enhance curcumin’s therapeutic potential. As research on turmeric progresses, it is likely to play an increasingly important role in modern medicine, offering natural solutions for a wide range of health concerns.

**Taxonomy:**

Turmeric (*Curcuma longa* L.) is classified within the plant kingdom as follows:

* **Kingdom:** Plantae
* **Clade:** Tracheophytes
* **Clade:** Angiosperms
* **Clade:** Monocots
* **Order:** Zingiberales
* **Family:** *Zingiberaceae*
* **Genus:** *Curcuma*
* **Species:** *Curcuma longa* L.

Turmeric belongs to the *Curcuma* genus, which comprises over 100 species. It is closely related to other medicinal plants such as ginger (*Zingiber officinale*). The species *Curcuma longa* is the most commonly cultivated and utilized variety for medicinal and culinary purposes.

**Botanical Description:**

Turmeric is a rhizomatous herbaceous perennial plant that grows up to 1 meter (3.3 feet) in height (Figure 1). The plant has the following distinguishing features:

* **Rhizomes:** The underground stem (rhizome) is cylindrical, orange-yellow in color, and covered with a brownish outer layer. The rhizomes have a balmy smell and bitter in taste (Puteri et al., 2020). It is highly aromatic and contains curcuminoids, the primary bioactive compounds. Table 1 represent the biochemical content in dried turmeric rhizomes (Niranjan et al., 2003).

**Table 1. Biochemical content in dried turmeric rhizomes (Niranjan et al., 2003)**

|  |  |
| --- | --- |
| Curcumin  | 3.1-3.4 % |
| Anthocyanin  | 18.9-37.0 g/g |
| Phenols | 0.15- 0.62 %  |
| Sugars | 20.5-43.4 % |
| Protein content | 3.6-6.8 % |
| Oil | 3.7-5.3 % |
| Tannins | 0.32-0.76 % |
| Ash | 6.9-9.8 % |
| Moisture  | 90.2-91.3 % |

* **Leaves:** The plant produces large, oblong, lanceolate leaves that are arranged alternately along the stem. They have a bright green color and can grow up to 70 cm in length.
* **Flowers:** The flowers are pale yellow with a reddish border, arranged in dense, spike-like inflorescences that emerge from a central shoot. They are mostly sterile, meaning the plant primarily reproduces through its rhizomes.
* **Fruits and Seeds:** Turmeric rarely produces seeds under cultivated conditions. Instead, it propagates vegetatively through rhizome division.



**Cultivation:**

Turmeric thrives in tropical and subtropical climates with well-drained, loamy or sandy soil. The turmeric plant needs a good annual rainfall and an average temperature of 20 to 30 °C to thrive. Typically, turmeric grows best under moist conditions. Typically, harvest season lasts from January through March or April. While medium varieties take 8 to 9 months to grow, early forms are ready in 7-8 months. The crop is ready to be harvested once the leaves turn yellow and start to dry out (Soudamini and Kuttan, 1989). When the rhizomes are ready, the leaves are chopped off closer to the soil's surface, the earth is ploughed, and the rhizomes are either hand-picked or gently lifted with a spade. The soil should be rich, friable, and contain only a small amount of sand for the turmeric plant. The climatic and soil conditions will decide how much irrigation is needed for turmeric. Medium-heavy soils require 15–25 irrigations, while light-texture red soils require 35–40 irrigations, depending on the soil types and rainfall. Typically, rhizomes are stacked under trees for shade or in ventilated shelters, and then they are wrapped in turmeric leaves. In sawdust pits, mature rhizomes could be preserved as seeds (Aggarwal et al., 2004).

**Geographical Distribution:**

Turmeric is believed to have originated from South or Southeast Asia, more likely in Vietnam, China, or western India. India is the biggest producer, consumer, and supplier, but it is also cultivated extensively in Cambodia, Bangladesh, Nepal, Indonesia, Thailand, Malaysia, West Bengal, Madagascar, Tamil Nadu, Maharashtra, Madras, Indonesia, and Philippines (Royal Botanic Gardens Kew, 2021) for its medicinal and commercial value.

**Nutritive Value:**

Turmeric is major source of macro and micronutrients (Mishra and Goel, 2020). Table 2 shows that it is rich in dietary fibre, vitamins, minerals content, and good source of energy. The vitamins and minerals content in the turmeric are significant. In ancient times turmeric is known as “Golden Spice” because of its various nutritional and medicinal properties, which helps in prevention of many diseases and also enriching the taste and color of the food (Longvah et al., 2017).

 **Table 2. Nutritive value of turmeric per 100 g**

|  |  |
| --- | --- |
| Constituents | Amounts |
| Carbohydrate | 49.22 g |
| Protein | 7.66 g |
| Total fat | 5.03 g |
| Total dietary fibre | 21.38 g |
| Ash | 6.13 g |
| Energy | 1174 KJ |
| Riboflavin | 0.01 mg |
| Thiamine | 0.06 mg |
| Pantothenic acid | 0.13 mg |
| Niacin | 1.55 mg |
| Iron | 46.08 mg |
| Calcium | 122 mg |
| Sodium | 24.41 mg |
| Potassium | 2374 mg |
| Copper | 0.44 mg |
| Zinc | 2.64 mg |
| Phosphorus | 276 mg |

 (Source- Indian Food Composition Table, 2017)

**Historical and Cultural Significance:**

Turmeric has played a vital role in human civilization for thousands of years. Its significance extends beyond medicinal applications to cultural, religious, and culinary domains.

**Ancient and Traditional Use:**

**Traditional Uses**

Turmeric has been an integral part of traditional healing systems across various cultures. Its applications range from medicinal remedies to cosmetic and household uses.

* **Ayurvedic Medicine:** In Ayurveda, turmeric is considered a 'Rasayana' herb, meaning it promotes longevity and overall health. It has been traditionally used for digestive disorders, wound healing, skin diseases, and as a detoxifying agent (Chattopadhyay et al., 2004).
* **Traditional Chinese Medicine (TCM):** In TCM, turmeric is used to invigorate blood circulation, relieve pain, and treat conditions such as arthritis, and menstrual disorders (Li et al., 2011). It is also used in TCM for the treatment, prevention and management of various illnesses such as cancer, coughs, diabetes, diarrhoea, inflammation, psoriasis, hepatobiliary diseases, skin disorders, gastric ulcers and peptic ulcers (Tung et al., 2019) (Figure 2).
* **Unani Medicine:** Unani practitioners have utilized turmeric for its anti-inflammatory and digestive-enhancing properties. It is used in formulations to treat jaundice, liver diseases, and respiratory ailments (Pancholi et al., 2020).
* **Folk Remedies:** In many rural communities, turmeric paste is applied to wounds and insect bites for its antibacterial and wound-healing properties. It is also consumed with milk (golden milk) to boost immunity and alleviate respiratory ailments. Turmeric has been applied as a home remedy to heal wounds and also facilitates the treatment for digestive dysfunction, hepatic problems, leukemia, atherosclerosis, osteoarthritis, menstrual problems, bacterial infections, and eye problems. Turmeric has a role in preventing inflammation in the mucous membranes that line the throat, stomach, intestine, and lungs.
* **Cosmetic Applications:** Turmeric is used as a natural skin brightener and anti-aging agent. In South Asian cultures, turmeric paste is applied to the skin to enhance complexion and treat acne.
* **Household Uses:** Due to its antiseptic properties, turmeric is used to preserve food and as a natural dye for fabrics and religious decorations.

**Figure 2. Traditional uses of turmeric (*Curcuma longa* L.)**

**Medicinal Applications:**

Turmeric has been thoroughly researched for its therapeutic properties, chiefly because of its active component, curcumin. The following are some of its key therapeutic applications:

* **Anti-Inflammatory Properties:** Curcumin is a potent anti-inflammatory agent that inhibits pro-inflammatory cytokines such as TNF-α, IL-6, and NF-κB (Aggarwal et al., 2009). It is beneficial in managing chronic inflammatory conditions such as arthritis and inflammatory bowel disease.
* **Antioxidant Effects:** Turmeric exhibits strong antioxidant activity by scavenging free radicals and enhancing the body's natural antioxidant defenses, reducing oxidative stress-related diseases (Gupta et al., 2013).
* **Antimicrobial and Antiviral Properties:** Curcumin has demonstrated antimicrobial activity against bacteria, fungi, and viruses. It is effective against *Helicobacter pylori*, *Staphylococcus aureus*, and other pathogenic microbes (Ghosh et al., 2018).
* **Anticancer Potential:** Research suggests that curcumin induces apoptosis, inhibits tumor growth, and suppresses metastasis in various cancers, including breast, lung, prostate, and colorectal cancers (Goel et al., 2010).
* **Cardioprotective Effects:** Turmeric helps lower cholesterol, reduce blood pressure, and prevent atherosclerosis, contributing to heart health (Hewlings & Kalman, 2017).
* **Neuroprotective Properties:** Curcumin has been studied for its ability to prevent neurodegenerative diseases like Parkinson's and Alzheimer's. It reduces amyloid plaque accumulation and oxidative stress in the brain (Mishra & Palanivelu, 2008).

**Turmeric in Religious and Spiritual Practices:**

Turmeric holds deep religious and spiritual significance, especially in Hindu culture. It is commonly used in rituals, ceremonies, and festivals. Turmeric paste is used on the bride and groom in Hindu weddings to signify purification and blessing (Krishna et al., 2011). Turmeric is also associated with goddess Lakshmi, the deity of wealth and prosperity, and is used to sanctify religious idols and altars.

In Buddhism, monks have traditionally dyed their robes with turmeric due to its vibrant yellow-orange color, which symbolizes renunciation and spiritual enlightenment (Kumar & Jain, 2015). Similarly, in Southeast Asia, turmeric is used in spiritual and protective rituals, often applied as a paste on newborns to ward off evil spirits.

**Culinary Importance Across Cultures:**

Turmeric is an essential ingredient in various global cuisines, particularly in South Asian, Middle Eastern, and Southeast Asian cooking. In Indian cuisine, it is a key component of curry powders, spice blends, and traditional dishes such as dal and biryani (Mehta et al., 2019). It is also used in Persian, Thai, and Indonesian cuisine for its distinct flavor and color-enhancing properties.

Beyond South Asia, turmeric has been incorporated into European diets since medieval times, where it was referred to as "Indian saffron" due to its vibrant hue (Nelson et al., 2017). In modern Western culture, turmeric-based beverages such as "golden milk" and turmeric lattes have gained popularity due to their perceived health benefits.

**Culinary Uses:**

Turmeric plays a crucial role in global cuisine, particularly in South Asian, Middle Eastern, and Southeast Asian culinary traditions. Its unique flavor, color-enhancing properties, and health benefits make it a staple in many dishes.

* **Indian Cuisine:** Turmeric is an essential component of spice blends such as garam masala and curry powder. It is used in lentil dishes (dal), rice preparations (biryani, pulao), and vegetable curries. Turmeric is also a key ingredient in pickles and chutneys.
* **Southeast Asian Cuisine:** In Thai and Indonesian cuisine, turmeric is used in soups, stews, and traditional spice pastes like Thai yellow curry paste. It is also an integral part of satay marinades and rendang dishes.
* **Middle Eastern Cuisine:** Turmeric is used in Persian and Arabic dishes such as saffron rice, kebabs, and stews. It is often combined with other spices like cinnamon and cumin for a rich, aromatic flavor.
* **Western Cuisine:** Turmeric has gained popularity in Western diets, particularly in health-conscious recipes. It is commonly used in smoothies, teas, lattes (golden milk), and salad dressings. Turmeric-infused honey and vinegar are also growing in popularity.
* **Baking and Beverages:** Turmeric is used in baking, adding color and mild spice to bread and pastries. It is also a key ingredient in health drinks such as turmeric tea and turmeric-infused juices.
* **Fermented Foods:** Turmeric is incorporated into fermented products like kimchi and sauerkraut for its antimicrobial properties, enhancing shelf life while providing health benefits.

**Historical Trade and Economic Importance:**

Turmeric has played a significant role in international trade since ancient times. It was a valuable commodity along the Silk Road and was exported from India to the Middle East, Africa, and Europe (Menon & Sudheer, 2007). The demand for turmeric increased during the colonial era when European traders recognized its culinary and medicinal value.

Today, India remains the largest producer, consumer, and exporter of turmeric, accounting for approximately 80% of the world's supply (FAO, 2020). Major turmeric-producing states in India include Andhra Pradesh, Tamil Nadu, Maharashtra, and Odisha. Other significant producers include China, Indonesia, Bangladesh, and Thailand (Jiang et al., 2018).

**General Health Benefits:**

Evidence suggests the benefits of turmeric in relieving acne, inflammation, joint pain, asthma, eczema, and tonic and acute allergies; in wound healing; in maintaining a balanced mood and blood sugar levels; and in immunomodulation (Ammon and Wahl, 1991; Reddy and Rao, 2002).

**Phytochemical Constituents of Turmeric:**

Turmeric contains protein (6.3%), fat (5.1%), minerals (3.5%), carbohydrates (69.4%) and moisture (13.1%). Phenolic diketone, curcumin (Diferuloylmethane) (3-4%) is responsible for the yellow colour, and comprises curcumin I (94%), curcumin II (6%) and curcumin III (0.3%). Other chemicals compound is copper/zinc, campesterol, stigmasterol, beta-sitosterol, cholesterol, fatty acids and metallic elements potassium, sodium, magnesium, calcium, manganese, and iron (Satruhan and Patel, 2022). Turmeric contains a diverse array of bioactive compounds that contribute to its medicinal properties (Figure 3). The major phytochemicals found in turmeric include:

* **Curcuminoids:** These include curcumin, demethoxycurcumin, and bisdemethoxycurcumin, which provide anti-inflammatory, antioxidant, and anticancer properties (Nelson et al., 2017).
* **Essential Oils:** Comprising turmerone, ar-turmerone, atlantone, and zingiberene, these oils contribute to the aromatic and therapeutic qualities of turmeric, including antimicrobial and neuroprotective effects (Li et al., 2011).
* **Polysaccharides:** Such as starch, arabinogalactan, and ukonan, which enhance turmeric’s immune-modulatory activities and metabolic functions (Menon & Sudheer, 2007).
* **Phenolic Compounds:** These provide strong antioxidant capabilities, contributing to free radical scavenging and anti-aging effects (Hewlings & Kalman, 2017).
* **Flavonoids:** Found in small amounts, these compounds further enhance anti-inflammatory and cardiovascular protective properties (Gupta et al., 2013).
* **Alkaloids and Tannins:** Present in trace amounts, these compounds contribute to antimicrobial and hepatoprotective effects.
* **Saponins and Glycosides:** These compounds play a role in cholesterol regulation and have cardioprotective benefits.



 **Figure 3. Chemical structure of phytoconstituents present in turmeric**

**Pharmacological Properties of Turmeric:**

Turmeric (*Curcuma longa* L.) is a medicinal plant and it has various therapeutic and pharmacological activities (Figure 4).

**Anti-Inflammatory Activity**

*Curcuma longa* contains volatile oils and curcumin, both of which have strong anti-inflammatory properties. Oral administration of curcumin in instances of acute inflammation was found to be as effective as cortisone or phenylbutazone. Oral administration of *Curcuma longa* significantly reduced inflammatory swelling (Cronin, 2003). *C. longa* anti-inflammatory properties may be attributed to its ability to inhibit both biosynthesis of inflammatory prostaglandins from arachidonic acid, and neutrophil function during inflammatory states. In order to reduce inflammation and itchiness brought on by inflammatory skin disorders and allergies, curcumin may also be applied topically; however, caution must be taken to avoid garment stains caused by the yellow pigment. Curcumin is a potent modulator of inflammatory pathways, inhibiting nuclear factor-kappa B (NF-κB) and downregulating pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and interleukin-1β (IL-1β) (Aggarwal et al., 2007). Several studies have demonstrated the efficacy of curcumin in managing chronic inflammatory conditions such as arthritis, inflammatory bowel disease, and cardiovascular disorders (Chainani-Wu, 2003).

**Antioxidant Properties**

Turmeric exhibits strong antioxidant activity by neutralizing free radicals and enhancing the activity of endogenous antioxidant enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase (Mishra et al., 2011). This property makes curcumin beneficial in preventing oxidative stress-related diseases, including neurodegenerative disorders and cardiovascular diseases (Hewlings & Kalman, 2017). Water and fat-soluble extracts of turmeric and its curcumin component exhibit strong antioxidant activity, comparable to vitamins C and E. A study of ischemia demonstrated that curcumin pretreatment decreased ischemia-induced changes in the heart (Dikshit et al., 1995).

**Antimicrobial and Antiviral Effects**

Curcumin has demonstrated broad-spectrum antimicrobial properties against bacteria, fungi, and viruses. Studies indicate that curcumin inhibits the growth of *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans* through mechanisms involving cell membrane disruption and inhibition of biofilm formation (Gunes et al., 2016). Additionally, curcumin has shown antiviral activity against hepatitis C virus, influenza, and SARS-CoV-2 by interfering with viral replication (Praditya et al., 2019).

**Anticancer Potential**

Curcumin exhibits anticancer properties by modulating multiple cellular signaling pathways, including apoptosis induction, inhibition of angiogenesis, and suppression of metastasis (Sharma et al., 2005). Experimental studies have demonstrated curcumin's effectiveness against various cancers, including breast, prostate, lung, and colorectal cancer (Gupta et al., 2013). Clinical trials suggest that curcumin enhances the efficacy of conventional chemotherapeutic agents while reducing their adverse effects (Ravindran et al., 2009).

**Antifungal Property**

Ether and chloroform extracts and oil of turmeric have antifungal effects (Apisariyakul et al., 1995). Crude ethanol extract also possesses antifungal activity. Turmeric oil is also active against *Aspergillus flavus, A. parasiticus, Fusarium moniliforme* and *Penicillium digitatum* (Jayaprakasha et al., 2001).

**Diabetes Mellitus**

Turmeric rhizome powder is very useful with amla juice and honey in Madhumeha (diabetes mellitus) (Acharya, 1994). The ingestion of 6 g turmeric increased postprandial serum insulin levels, but didn't seem to affect plasma glucose levels or gastrointestinal, in healthy subjects. The results indicate that *Curcuma longa* may have an effect on insulin secretion (Wickenberg et al., 2010). The active principles within the rhizome of turmeric plant namely curcuminoids lower lipid peroxidation by maintaining the activities of antioxidant enzymes like superoxide dismutase, catalase and peroxidase at higher levels. Antioxidant properties of *Curcuma longa* are due to curcumin and its three derivatives (demethoxycurcumin, bisdemethoxycurcumin and diacetylcurcumin) (Faizal et al., 2009).

**Osteoarthritis**

Researches reveal that taking turmeric extracts, alone or along with other herbal ingredients, can be helpful in pain management, and also improve the functions in people with knee osteoarthritis. In some research, turmeric worked about also as ibuprofen for reducing osteoarthritis pain. But it does not seem to work as well as diclofenac for improving pain and function in people with osteoarthritis (Mishra and Goel, 2019).

**Gastrointestinal Disorders**

Curcumin’s anti-inflammatory properties and therapeutic benefit have been demonstrated for a variety of gastrointestinal disorders, including dyspepsia, *Helicobacter pylori* infection, peptic ulcer, irritable bowel syndrome, Crohn’s disease, and ulcerative colitis (Labban, 2014).

**Neurological Disorders**

Studies in animal models of Alzheimer’s disease (AD) indicate a direct effect of curcumin in decreasing the amyloid pathology of AD (Ringman et al., 2005). Based on many studies, results have shown that curcumin possessed multiple actions in brain. Curcumin can be a future drug of therapy for the treatment of various neurological disorders such as major depression, tardive dyskinesia and diabetic neuropathy (Kulkarni et al., 2010).

**Pregnancy/Neonates**

Singh and Aggarwal 1995 studied curcumin on hepatic biotransformation system enzymes. Turmeric and curcumin induced a significant increase in hepatic levels of glutathione S-transferase (GST) and sulfhydryl (SH) levels. Cytochrome b5 and cytochrome P450 levels were significantly elevated as well. This indicates that turmeric and/or curcumin metabolites can be transferred through lactation.

**Irritable Bowel Syndrome**

In patients with irritable bowel syndrome (IBS) the most common symptoms are abdominal pain, bloating, altered bowel habits, and increased stool frequency. In an eight-week pilot study of IBS patients. After four weeks, those groups experienced a 53% and 60% reduction in IBS prevalence. In post-study analysis, abdominal pain and discomfort scores were reduced by 22 and 25% (Barbara et al., 2002).

**Skin Treatments**

Turmeric has lots of benefits for the skin including speeding up the process of healing wounds, calming pores on the face to reduce acne. Since it has antioxidant and anti-inflammatory properties, which is really use full for treating skin problems (Verma et al., 2018).

**Management of Obesity**

People who would like to lose a couple of pounds or treat obesity and other similar condition can take benefits of turmeric powder which can be very helpful in keeping one’s ideal body weight. The component in turmeric helps in boosting the flow of bile which is an essential element in the process of breaking down of dietary fats (Verma et al., 2018).

**Respiratory Disorders**

*Curcuma longa* and its constituents have a relaxing impact on tracheal smooth muscles, suggesting a possible bronchodilatory influence in individuals with obstructive lung disease. They also have a protective benefit in an animal model of respiratory disorders, involving effects on inflammatory cells and mediators, lung pathological alterations, airway responsiveness, and immunomodulatory responses (Boskabady et al., 2020). Curcumin has been shown in both in vivo and in vitro investigations to have antiasthmatic properties. Bronchitis is treated with fresh rhizome juice*. C. longa* is boiled in milk and combined with jiggery and used internally for rhinitis and cough. In cases of catarrhal cough and painful throat with infection, a rhizome decoction is gargled, and a piece of the rhizome is slightly burned and chewed. Turmerones, curcuminoids, curcumin, and tetrahydrocurcumin are chemical compounds of *C. longa* that have anti-asthmatic properties, and Haridradhumvarti (fumes wick) fumes are used in asthma and congestion.

**Cardiovascular Diseases**

Cardiovascular diseases (CVDs) seem to be a global health issue that is linked to high disease and death rates. Anti-hypercholesterolemic, anti-atherosclerotic (Gao et al., 2019), and protective capabilities against cardiac ischemia and reperfusion (Wang et al., 2018) of curcumin have been proven in preclinical and clinical trials. Curcumin has anti-CVD potential by improving the lipid profile of patients, and it might be administered alone or as a dietary supplement to traditional CV medicines (Qin et al., 2017). Curcumin is also seen in many studies to protect against coronary heart disease (Li H. et al., 2020) and also possesses anticoagulant properties. Curcumin may reduce chronic heart failure by boosting p38 MAPK, JNK, and ASK1, according to Cao et al. (2018). Curcumin and its components were used in recent research to determine the utility of nanotechnology-based medication delivery systems in CVD patients (Salehi et al., 2020).

**Hepatoprotective**

In jaundice, rhizome powder added to amla juice is utilized. *C. longa’s* hepatoprotective abilities have been proven in studies against several hepatotoxic ailments, including carbon tetrachloride, galactosamine, and acetaminophen (paracetamol) (Rao et al., 1995). The ethanolic crude extract of rhizomes was detected with curcumin, tumerone, atlantone, and zingiberene, which had substantial hepatoprotective ability at an oral dose of 250 and 500 mg/kg (Park et al., 2000). Curcumin is said to increase apoptosis in injured hepatocytes while also reducing inflammatory effects, hepatic fibrogenesis, and substantially liver injury. The hepatoprotective attribute of C. longa and curcumin might be due to direct free radical scavenging mechanisms, boosting glutathione levels, and assisting in liver detoxification. Tacrine is well-known for its hepatotoxic and T-cell-destructive properties. Curcumin was over ten times more efficient than standard therapy, ascorbic acid, in research involving human hepatocytes cells that had been disrupted by tacrine (Song et al., 2001).

**Anti-Allergic Activity**

Curcumin inhibited the degranulation and release of histamine from rat peritoneal mast cells caused by compound 48/80. Calcium uptake measurements and cAMP tests in mast cells were used to investigate the mechanism of action. Curcumin enhanced intracellular cAMP levels and inhibited both nonspecific and selective mast cell-mediated allergy reactions (Choi et al., 2010). Curcumin significantly reduced IgE/Ag-induced PSA (passive systemic anaphylaxis), as measured by serum-dependent leukotriene C4, dependent prostaglandin D2, and histamine levels, indicating that it might be useful to produce drugs for allergic inflammatory illnesses (Li et al., 2014). Curcumin can suppress expression of CD80, CD86, and class II antigens by dendritic cells and blocks the release of inflammatory cytokines like IL1β, IL-6, and TNF-α from LPS-stimulated dendritic cells.

**Dyspepsia and Gastric Ulcer**

Six hundred milligrams of curcumin five times a day for 12 weeks to individuals with peptic ulcers could prevent ulcer development but also cause symptomatic erosions, dyspepsia, and gastritis in some patients. Abdominal pain along with other symptoms has greatly decreased with curcumin within 1–2 weeks. Kim et al. (2005) found that orally administered ethanolic *C. longa* extract decreased stomach acid, gastric juice secretion, and ulcer initiation in male rats by inhibiting H2 histamine receptors, which is similar to the effects of ranitidine. Similarly, the antiulcer action of *C. longa* ethanolic extract was seen as it lowers ulcer index in addition to stomach acidity significantly. *C. longa* extract also suppressed hypothermic-restraint stress depletion of stomach wall mucus and diminished the severity of necrotizing agent-induced lesions.

**Antidepressant Properties**

*Curcuma longa* has antidepressant potential because it tends to hinder monoamine oxidase accumulation in the central nervous system (Yu et al., 2002). Curcumin has a wide range of characteristics that are important to depression pathogenesis. The ethanolic *C. longa* extract prevented the decrease in serotonin, noradrenalin, and dopamine concentrations while increasing serotonin turnover, cortisol levels, and serum corticotrophin-releasing factor levels (Xia et al., 2007). The consequences of orally administered curcumin seem on behavior under chronic stress or depression condition in the rat model. Curcumin administration showed a similar impact to imipramine, a known antidepressant drug, and it has been indicated by various authors to be a feasible alternative source in depression condition (Mohammed et al., 2019; Qi et al., 2020).

**Curcumin Prevents Drug Resistance**

Curcumin possesses a powerful anti-drug resistance agent. It has a novel capacity to suppress adriamycin-induced elevation of P-glycoprotein and its mRNA, and this ability is linked to increased intracellular drug accumulation, thereby increasing ADM lethality (Xu et al., 2011). Curcumin blocks NF-κB activation, which results in chemosensitivity in drug-resistant cancer cells. Furthermore, curcumin and tamoxifen co-therapy has also been illustrated to expose tamoxifen-resistant breast cancer cells, suggesting that it could be a viable method for either minimizing tamoxifen resistance or re-sensitizing refractory illness to tamoxifen therapy (Mimeault and Batra, 2011).

**Antifertility**

Traditional medicine has been recommended by the World Health Organization as a cost-effective substitute to manufactured antifertility medicines. Parkes mouse strain was given aqueous rhizome extract of *C. longa* via the oral route (600 mg/kg body weight/day for 8 and 12 weeks), which causes reversible spermatogenesis, decreased seminiferous tubules diameter, and loosening of germinal epithelium, thus indicating its potential in male fertility. Hembrom et al. (2015) also examined the influence of an aqueous C. longa rhizome extract in sperm count, spermatozoa motility, and seminal pH in Swiss Albino male mice leading to infertility. The combined action of curcumin and andrographolide significantly suppressed the number of implants and litter size in female Sprague–Dawley rats, changed the duration of phases involved in the estrus cycle, and lowered the number of ovarian follicles (Shinde et al., 2015). Petroleum ether in addition to aqueous extract of rhizome shows antifertility impact on rats via oral administration and results in complete inhibition of implantation. Curcumin also reduces human sperm motility, suggesting its usage as intravaginal contraceptive and its antispermatogenic activity.

**Figure 4. Pharmacological Properties of Turmeric (*Curcuma longa* L.)**

**Efficacy of Turmeric:**

Turmeric and curcumin (active component) are approved as GRAS (generally regarded as safe) by FDA (food and drug administration). So, turmeric and its components (curcumin) are mostly used in the butter, mustard, cheese, chips and other products in the United States. Turmeric helps in cardio protection and functional recovery that helps to decrease in cell death for 1 month at administration of 100 mg/kg turmeric (Mohanty et al., 2006).

**Clinical trials on the therapeutic efficacy of *Curcuma longa*:**

So far, some of the identified pharmacological activities of curcumin have been confirmed through clinical trials (Iweala et al., 2023). In treating osteoarthritis and rheumatoid arthritis, oral administration of different doses of *C. longa* has been discovered to possess an anti-arthritic effect (Dcodhar et al., 2013; Pinsornsak et al., 2012). This therapeutic effect was observed in its significant effect on pain, joint swelling, reducing inflammatory markers, and improving disease activity score (Kulkarni et al., 1991; Kuptniratsaikul et al., 2014). In Alzheimer’s patients, 12 months of oral administration of *Curcuma longa* led to increase A 𝛽40 deposits in the serum, which is an indication of the ability of curcumin to disaggregate A 𝛽-deposits-the significant cause of Alzheimer’s disease (Ringman et al., 2012). In children with recur- rent respiratory tract infections, oral doses of curcumin supplementation improved immune modulation (Zuccotti et al., 2009).

**Challenges in Turmeric-Based Therapeutics:**

Despite its vast therapeutic potential, curcumin faces significant challenges, including poor water solubility, low systemic bioavailability, and rapid metabolism (Anand et al., 2007). Several strategies have been employed to enhance curcumin's bioavailability, including nanoparticle-based formulations, liposomal encapsulation, and phytosomal technology (Sun et al., 2013). These approaches aim to improve curcumin's pharmacokinetics and optimize its therapeutic efficacy in clinical applications.

**Phytopharmaceutical Applications of Turmeric:**

Turmeric has been incorporated into various phytopharmaceutical formulations, including capsules, tablets, and topical applications. Curcumin-loaded nanoparticles have been developed for targeted drug delivery as a result of recent innovations in nanotechnology (Gera et al., 2017). The role of curcumin in the management of metabolic disorders, neurodegenerative diseases, and immune system modulation has been the subject of clinical studies (Hewlings & Kalman, 2017). Furthermore, the synergistic effects of curcumin in conjunction with other bioactive compounds have been demonstrated to improve therapeutic outcomes (Gupta et al., 2013).

**Modern Therapeutic Potential:**

Turmeric continues to be a subject of extensive scientific research for its modern therapeutic potential. Studies have identified its efficacy in various fields of medicine:

* **Chronic Disease Management:** Turmeric is used in treating metabolic disorders such as diabetes and obesity. Curcumin improves the management of type 2 diabetes and obesity-related inflammation by increasing insulin sensitivity and regulating lipid metabolism (Daily et al., 2016).
* **Gastrointestinal Health:** Research indicates that curcumin aids in the treatment of gastrointestinal conditions, including irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), and gastric ulcers, by reducing gut inflammation and oxidative stress (Chainani-Wu, 2003).
* **Chemoprevention and Cancer Treatment:** Curcumin exhibits potential in cancer treatment by inhibiting tumor growth, reducing metastasis, and inducing apoptosis. Studies have underscored its role in the suppression of a variety of cancers, such as breast, prostate, lung, and colorectal cancers(Goel et al., 2010).
* **Neurodegenerative Disorders:** Turmeric has been investigated for its neuroprotective properties in conditions such as Alzheimer's disease and Parkinson’s disease. It reduces beta-amyloid plaque accumulation, oxidative stress, and neuroinflammation, potentially delaying cognitive decline (Mishra & Palanivelu, 2008).
* **Cardiovascular Health:** Curcumin promotes cardiovascular health by decreasing cholesterol, preventing atherosclerosis, and reducing hypertension. It functions as an anticoagulant, thereby decreasing the likelihood of stroke and heart disease (Hewlings & Kalman, 2017).
* **Wound Healing and Skin Health:** Due to its antimicrobial and anti-inflammatory effects, turmeric is widely used in dermatology for treating acne, psoriasis, and wound healing (Pancholi et al., 2020).

The increasing scientific validation of turmeric's medicinal properties has led to its incorporation into modern pharmaceuticals, nutraceuticals, and functional foods. However, challenges such as curcumin's low bioavailability have prompted research into novel delivery systems, including nanoparticles, liposomes, and phospholipid complexes.

**Safety and Adverse Effects:**

While turmeric is widely recognized for its medicinal benefits, its safety profile should be carefully considered, especially in high doses or prolonged use.

* **Gastrointestinal Issues:** Excessive consumption of turmeric may lead to nausea, diarrhea, acid reflux, or stomach upset in some individuals (Lao et al., 2006).
* **Allergic Reactions:** Some individuals may experience allergic responses such as skin rashes, itching, or contact dermatitis when using turmeric topically or orally (Rahman et al., 2019).
* **Bleeding Risks:** Turmeric has mild anticoagulant properties, which may increase the risk of bleeding when taken with blood thinners like aspirin or warfarin (Chainani-Wu, 2003).
* **Liver and Gallbladder Concerns:** High doses of turmeric may exacerbate existing liver conditions or gallbladder disease by increasing bile production (Cheng et al., 2001).
* **Drug Interactions:** Curcumin may interact with medications such as antidiabetic drugs, chemotherapy agents, and immunosuppressants, potentially altering their efficacy (Sharma et al., 2005).
* **Pregnancy and Breastfeeding:** While turmeric is safe in dietary amounts, high doses should be avoided during pregnancy due to potential uterine-stimulating effects (Takahashi et al., 2009).

Although turmeric is generally well-tolerated, it is essential to consult a healthcare provider before using it as a medicinal supplement, particularly for individuals with pre-existing conditions or those on medications.

**Conclusion:**

Turmeric remains an invaluable plant with extensive medicinal, culinary, and cultural significance. Its bioactive compounds, particularly curcumin, exhibit remarkable therapeutic properties, making it a promising candidate for disease prevention and treatment. Ongoing scientific research continues to validate its efficacy in modern medicine, yet challenges such as bioavailability and standardization require further investigation. As the global demand for natural and plant-based remedies increases, turmeric’s role in pharmaceuticals, functional foods, and healthcare is expected to expand. Future studies focusing on innovative delivery methods and clinical trials will help harness its full potential, ensuring its integration into mainstream medical practice.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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