

Testing based on Chemical parameters of *Curcuma Longa* (Turmeric): A Comprehensive Review

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Abstract: *Curcuma longa* (Turmeric) is referred to as "Haridra" in Hindu religious terminology, which is Sanskrit for "effective medicine for jaundice". Many studies have been conducted on the chemical components of different turmeric (*Curcuma longa*). 22 diarylheptanoids and diarylpentanoids, eight phenylpropene and other phenolic compounds, 68 monoterpenes, 109 sesquiterpenes, 5 diterpenes, 3 triterpenoids, 4 sterols, 2 alkaloids, and 14 other compounds, and among at least 235 compounds, mostly phenolic compounds and terpenoids, that have been identified from the species earlier. Essential oils and curcuminoids (diarylheptanoids) are important bioactive components that exhibit a range of bioactivities in vitro and in vivo bioassays. Turmeric's curcuminoids mostly accumulate in the rhizomes. Monoterpenes often predominate in essential oils from leaves and flowers, whereas sesquiterpenes predominate in essential oils from roots and rhizomes. While the composition of turmeric rhizome's essential oils varies significantly with varieties and geographical regions, the curcuminoid concentration of turmeric rhizomes varies frequently with varieties, locations, sources, and growth conditions. Additionally, the concentrations of essential oils and curcuminoids vary depending on the extraction technique used, and they are unstable during the extraction and storage processes. Consequently, there might be significant differences in the quality of commercial turmeric products. *Ar-turmerone* (99), *-turmerone* (100), and *-turmerone* (101) can be used to control the quality of turmeric oil and oleoresin products, while *curcumin* (1), *demethoxycurcumin* (2), and *bisdemethoxycurcumin* (5) have been used as marker compounds for the quality control of rhizomes, powders, and extract ("curcumin") products. Chromatographic and NMR methods, DNA markers, morphological and anatomical data, GAP, and other information can all be used to authenticate turmeric products.

Keywords: Turmeric, Haridra, curcuminoids, diarylheptanoids, sesquiterpenes, monoterpenes, ar-turmerone, rhizomes, bioactivity, terpenoids

I. INTRODUCTION

Amomum curcuma Jacq. and *C. domestica* Valetton are scientific synonyms for turmeric (*Curcuma longa* L. Zingiberaceae), a rhizomatous herbaceous perennial plant. Originally from Southeast Asia, this plant is widely grown throughout the world's tropical and subtropical climates. It is one of the most significant spices in India and a number of other nations. It is also utilized in herbal treatment and as a natural yellow food pigment. Turmeric has been used in ancient Asian medical systems to treat a variety of conditions, including digestive disorders, diarrhea, epilepsy, wound healing, fever, allergies, bronchial asthma, chronic cough, jaundice, and arthritis. In recent decades, turmeric's biological properties have been studied. The pharmacological properties of turmeric powder and crude extracts, including hepatoprotective, antifungal, neuroprotective, and memory-enhancing properties, have been assessed (AK Mishra et al., 2015).



Curcuminoids and sesquiterpenes are the two main secondary metabolite classes in terms of its chemical makeup. Turmeric contains 3%–5% curcumin and is essentially a commercially accessible mixture of curcuminoids consisting of 72%–78% curcumin, 12%–18% demethoxycurcumin, 3%–8% bisdemethoxycurcumin, and organic solvent residue. Another issue is curcumin's low bioavailability, which has been the focus of numerous studies. A few effective ways to raise serum curcumin levels have been investigated by researchers: nanotechnology, structural analogues, 4 association with sesquiterpenes derived from essential oil, extraction with water and enzymes from fresh rhizomes, encapsulation of curcumin into chitosan, and association with piperine, the main ingredient in black pepper that increases bioavailability by 2000%.^{16, 19} Additionally, curcuminoids are sensitive to oxygen and light (Noorafshan et al., 2013). Sesquiterpene concentrations rise as the plant ages, but monoterpene concentrations fall in the rhizomes. The overall curcumin concentration decreased after the age of about nine months following planting, when the maximum curcumin level was discovered. (Funk, Jolad et al., 2006)

1. Chemical Constituents

Curcuma longa, also known as turmeric, is well-known for a variety of chemical components, primarily a class of compounds known as curcuminoids. The most well-known of these is curcumin, which makes up 2 to 5% of the dried rhizome and is mostly in charge of the therapeutic properties and yellow color of turmeric. Curcumin is a diarylheptanoid that comes in three main forms: Curcumin I (demethoxycurcumin), Curcumin II (bisdemethoxycurcumin), and Curcumin III (curcumin). In addition to curcuminoids, which give turmeric its unique aroma and potential health benefits, it also includes additional bioactive compounds like turmerone and essential oils. Other notable components include sesquiterpenes like α -turmerone and β -turmerone, which are believed to have distinct pharmacological effects. The synergistic interactions between these components boost turmeric's overall therapeutic potential, making it a pertinent research issue in both modern pharmacology and traditional medicine. (Kokate et al., 2006; Soudamini et al., 1989). Turmeric (*Curcuma longa* L.) essential oils are well known for their unique aroma and medicinal qualities. Their chemical composition is diverse and intricate. Sesquiterpenes and monoterpenes are abundant in turmeric essential oil. Three important sesquiterpenes— α -, β -, and γ -turmerone—contribute significantly to the composition of the oil. α -turmerone is especially noteworthy because of its possible anti-inflammatory and neuroprotective properties. Other noteworthy ingredients are camphene, which lends a crisp, herbaceous tone, and zingiberene, which adds a warm, spicy smell. The complex relationships between these constituents affect the essential oil's pharmacological properties, including as its antibacterial, antioxidant, and anti-inflammatory properties, in addition to its scent. Turmeric essential oil's strength and usefulness can be increased by optimizing its use in medicinal and cosmetic combinations through an understanding of its chemical makeup (Leela et al., 2002; Khanna et al., 1999).

1. Curcuminoids

The main bioactive phenolic chemicals in *Curcuma longa* rhizomes, curcuminoids, are what give turmeric its yellow hue and medicinal qualities. They primarily consist of three structurally related diarylheptanoids: bisdemethoxycurcumin, demethoxy curcumin, and curcumin (major). (Aggarwal et al., 2025)

1.1 Structure and Properties

Curcumin (diferuloylmethane; C₂₁H₂₀O₆) is mainly found in enol form in organic solvents and keto form in water. It has two aromatic rings connected by a seven-carbon chain with α , β -unsaturated β -diketone groups. Bisdemethoxycurcumin (C₁₉H₁₆O₄) is less polar and more stable than demethoxycurcumin (C₂₀H₁₈O₅), which lacks methoxy groups on both rings. These variations affect activity, bioavailability, and solubility.

Curcumin (60–94%), demethoxycurcumin (6–24%), and bisdemethoxycurcumin (0.3–14%) make up several rhizomes. Research indicates that curcumin ranges from 1.06 to 5.65%, demethoxycurcumin from 0.83 to 3.36%, and



bisdemethoxycurcumin from 0.42 to 2.16% among samples. 70–95% of curcuminoids are found in extracts (Sasikumar et al., 2005).

2. ESSENTIAL OILS

The determination of volatile oil in a haldi is made by distilling the spice with water, collecting the distillate in a graduated tube in which the aqueous portion of the distillate is automatically separated and returned to the distilling flask, and measuring the volume of the oil. The content of volatile oil is expressed as % v/w (Mao et al., 2022).

3. MOISTURE

The moisture content showed a significant effect on change in bulk density, true density, the angle of repose, the coefficient of friction and rupture force because too much water encourages mold development, enzyme activity, and curcumin breakdown during storage, dried turmeric rhizomes and powders need to be carefully managed. For long-term stability, quality standards aim for 8–12% moisture on a wet basis. This is accomplished by carefully regulated drying that strikes a balance between color and volatile preservation (Benslimane et al., 2020).

Sun drying: Reaches 9–10%, however if humidity is higher than 60%, contamination may occur.

4. ASH VALUES

Ash levels are important markers of inorganic residue in *Curcuma longa* rhizomes and powders because they show physiological minerals in addition to possible impurities like silica or soil particles that affect purity. In order to detect adulteration, researchers frequently analyze total ash in conjunction with acid-insoluble and water-soluble fractions; standards limit total ash to 7–12% to guarantee market-grade quality (Jayaprakasha et al., 2014).

5. Quality significance

Curcumin potency and microbiological stability are correlated with higher extractive yields; low values (<10%) indicate starch-heavy bulking or trash devoid of curcumin. While balanced ratios (alcohol:water ~0.8-1.0) show fresh, unadulterated rhizomes appropriate for oleoresin production, water values above 18% suggest incorrect drying or fungal gums.

Chromatographic fingerprint/TLC

By separating curcuminoids into discrete bands, high-performance thin-layer chromatography produces distinctive chemical signatures for *Curcuma longa* rhizomes that allow verification against synthetic dyes or *C. aromatica*. With Chhattisgarh samples exhibiting 15–25% variation in curcumin peak intensity compared to national standards, this fingerprinting technique uncovers processing and regional variables that are unseen to proximate analysis.

During curcumin isolation, flash-TLC-MS hybrids resolve co-eluting minors and verify fraction purity >95%.

FOREIGN MATTER

Testing for foreign matter in *Curcuma longa* focuses on non-turmeric debris that compromises purity, including both inorganic particles (dust, stones, clay) and organic fragments (stems, leaves, chaff). Because larger levels indicate poor harvesting or post-processing contamination, regulatory restrictions at 1-2% by weight protect against bulk dilution while guaranteeing safe consumption.

Under intense lighting, inspectors distribute 100–250g representative samples among glazed trays and manually classify obvious flaws as biological or inorganic. Fines are quantified by sieving through 500µm (No. 35 mesh) or 1mm apertures, with quartered sections guaranteeing homogeneity in accordance with AOAC 970.24. Supplemental microscopy for cellular mismatches caused by *C. aromatica* or starch fillers that are imperceptible to the unaided eye (Liu et al., 2017).



According to US surveys, 15% of imported turmeric exceeds 2%, which frequently results in a 25–40% reduction in curcumin output. Indian export grades deduct 10–20 USD/MT for every 0.5% extra foreign matter. Aflatoxin limitations at 30 ppm and strict zero-tolerance for visible mold and insects are explained by lead chromate-adulterated batches (negative spot test required), which increase toxicity concerns.

Untrimmed fingers and soil splash are examples of field operations that generate 60% of debris, whereas milling contributes 0.5–1% metal particles if screens don't work. Boiling or curing causes organic matter to swell by 15–20%, necessitating re-sieving before drying to achieve $\leq 1\%$ compliance.

Limitations and Interpretation

Bright reactions indicate therapeutic promise; terpenoids support antibacterial action, while flavonoids/phenolics promote antioxidant capability. However, solubility biases favor polar methanol extracts over non-polar volatiles that are missed by traditional screens. Screening is positioned as authentication triage rather than a potency measure due to the weak quantitative

II. CONCLUSION

Curcuminoids like curcumin, demethoxycurcumin, and bisdemethoxycurcumin, as well as essential oils dominated by sesquiterpenes like ar-turmerone, α -turmerone, and β -turmerone, are among the bioactive ingredients that make turmeric (*Curcuma longa*) unique.

While essential oils contribute scent and bioactivity through more than 50 volatiles discovered by GC-MS, curcuminoids, which make up 2–5% of dried rhizomes, are responsible for the yellow color and medicinal benefits of turmeric. Antioxidant, neuroprotective, and anti-inflammatory properties are strengthened by synergistic interactions. To avoid deterioration, adulteration, and microbiological hazards, standards place a strong emphasis on moisture, total ash, acid-insoluble ash and foreign matter ($\leq 1-2\%$).

HPLC separates curcuminoids at 425-430 nm. Phytochemical screening uses color reactions to verify the presence of phenolics, terpenoids, and flavonoids. The use of turmeric in food, pharmaceuticals, and traditional medicine is supported by these measurements.

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