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Review Article

Evaluation of Analytical Techniques for Curcumin Quantification: A Comprehensive Review

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ABSTRACT

Turmeric (Curcuma longa) a golden-yellow spice widely used in both culinary and medicinal practices, contains curcumin as its primary bioactive compound, known for its potent anti- inflammatory, anti-oxidant and anti-cancer properties. It has been utilized for centuries in traditional medicine, particularly in Ayurveda. However, curcumin's poor bioavailability poses challenges, prompting the use of enhancers like pipeline and innovative pharmaceutical formulations to improve its absorption. Analytical techniques such as UV-Visible Spectroscopy, HPTLC and HPLC are employed for the precise quantification of curcumin in pharmaceutical products, ensuring accurate dosing. These methods play a vital role in its routine application in both traditional and modern medicinal systems.

INTRODUCTION

Turmeric, derived from the rhizomes of *Curcuma longa* (family Zingiberaceae), is an essential part of Indian culture, often called the "kitchen queen." [1-2] India, known as the "land of species", produces about 78% of the word's turmeric, growing it extensively in states like Tamil Nadu, Maharashtra and Bengal. [3-4] Turmeric, along with spices like ginger, fenugreek, cinnamon is not only key culinary ingredient but also has numerous health benefits. [5] It is known for its anti-inflammatory properties, blood-purifying abilities and cultural significance in Ayurveda. The name turmeric comes from the French word Terre-merite, meaning "merit of the earth." [6] Historically referred to as the "earthy herb of the sun" during the Vedic period, turmeric is rich in bioactive compounds such as curcumin, which helps regulate inflammation and control cellular oxidation. [7] Widely cultivated in Asia, including China, Bangladesh and Southeast Asia, turmeric plays a key role as a spice, preservative and coloring agent. [1,8] In turmeric the rhizome part is used. Turmeric is perennial, erect and leafy plant

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with very large, lily-like leaves up to 1.2 m long. It has oblong, pointed leaves and funnel-shaped yellow flowers.[9] In Hindu rituals, turmeric is still used as a natural dye for holy robes.[10]

Fig.1: Curcuma longa Linn

Introduction Of Curcumin

Curcumin, also known as diferuloylmethane, is a key polyphenol from *Curcuma longa.* It is insoluble in water but soluble in organic solvents. Curcumin, with the IUPAC name 1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione, provides turmeric's color and contains volatile oils, sugars, and proteins. Curcumin exists in two forms enolic in solvents and keto in water. Historically, turmeric has been used medicinally in India for over 4000 years. Curcumin offers health benefit like reducing inflammation, managing metabolic syndrome and supporting eye and kidney health, mainly due to its antioxidants and anti-inflammatory properties. However, curcumin's bioavailability is low due to poor absorption and rapid metabolism. [11-12] Curcumin is a yellow-orange polyphenol (C21H20O6) with a molecular weight of 368.39 g/mol. It is insoluble in water but soluble in alcohol and glacial acetic acid, with a log P of 3.0, pKa of 8.5-10.7, and a melting point of 183 ºc. [13-15] There are many pharmacological effects of Curcumin like anti-inflammatory, antioxidant and antimicrobial. It is used to manage conditions like cancer, diabetes, cardiovascular diseases and arthritis. Additionally, curcumin supports liver protection, immune modulation, and helps with obesity and premenstrual symptoms. [16]

Mechanism of action

Curcumin scavenges reactive oxygen species and inhibit lipid peroxidation and DNA damage. It modulates signaling pathways involved in inflammation, cancer, and cellular growth, inhibiting protein kinases, prostaglandin biosynthesis, and COX-2 activity. [13-15]

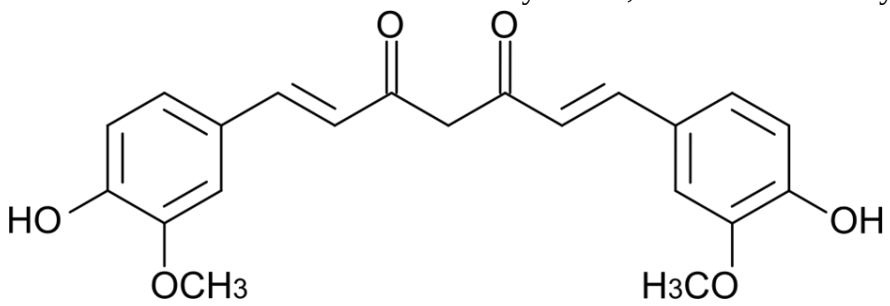

Fig. 2: Chemical structure of Curcumin

Review Of Literature

Table 1: Official Reported Method for Curcumin

Sr. No.	Official in	Method	Description	Reference No.
1	Indian Pharmacopoeia 2022	High Performance Liquid Chromatography (HPLC)	**Mobile phase:** Water: Acetonitrile (85:15 %v/v) **Stationary phase:** Octadecylsilane column (250 × 4.6 mm, 5 □m)	17

			Wavelength: 240 nm **Flow rate:** 1mL/min	
2	U.S Pharmacopoeia 2013	High Performance Thin Layer Chromatography (HPTLC)	**Mobile phase:** Chloroform: Methanol: Formic acid (96:4:1 %v/v/v) **Stationary phase:** Silica gel (0.25 mm layer) on TLC plates **Wavelength:** 365 nm	18

Table 2: Literature review on UV Spectroscopy Method.

Sr. No.	Title	Description	Reference No.
1	**UV-Visible Spectrophotometric** estimation of Curcumin in nanoformulation	**Wavelength:** 421 nm **Solvent:** Methanol **Linearity:** 5-25 µg/mL **R2:** 0.9997	19
2	Development and validation of **UV Spectrophotometric method** for the estimation of Curcumin in bulk drug and pharmaceutical dosage form	**Wavelength:** 421 nm **Solvent:** Methanol **Linearity:** 1-7 µg/mL **R2:** 0.9995	20
3	Development and validation of **UV Spectrophotometric method** for the estimation of Curcumin in cream formulation	**Wavelength:** 422 nm **Solvent:** Methanol **Linearity:** 1-7 µg/mL **R2:** 0.999	21
4	Qualitative analysis of Curcumin in marketed dosage form by using **UV Spectroscopy**	**Wavelength:** 421 nm **Solvent:** Methanol **Linearity:** 1-7 µg/mL **R2:** 0.9357	22
5	Development and validation of **UV-Visible Spectrophotometric method** for the estimation of Curcumin in bulk and pharmaceutical formulation	**Wavelength:** 429 nm **Solvent:** Phosphate buffer and ethanol (1:1) **Linearity:** 2-10 µg/mL	23

Table 3: Literature review on HPLC Method.

Sr. No.	Title	Description	Reference No.
1	Estimation of Curcumin in different turmeric samples using **High Performance Liquid Chromatography (HPLC)**	**Mobile phase: Methanol:** Water (75:25 %v/v) **Stationary phase:** Zodiac C18 column (100 × 4.6 mm, 5 µm) **Wavelength:** 225 nm **Flow rate:** 1.2 mL/min	26

2	Simple **HPLC method**for resolution of curcuminoids with antioxidant potential	**Mobile phase:** 2-Propanol: Water (95:5 %v/v) **Stationary phase:** Exil-amino column (150 × 4.6 mm, 5 µm) **Wavelength:** 425 nm **Flow rate:** 1 mL/min	27
3	Greener stability-indicating **HPLC** approach for the determination of Curcumin in-House developed nanoemulsion and *Curcuma longa* L. extract	**Mobile phase:** Ethanol: Ethyl acetate (83:17 %v/v) **Stationary phase:** Nucleodur C18 column (150 × 4.6 mm, 5 µm) **Wavelength:** 425 nm **Flow rate:** 1 mL/min	28
4	Analytical Method and Validation for Simultaneous Estimation of Curcumin and Cyclosporine by **RP-HPLC**	**Mobile phase:** Acetonitrile: Water: Methanol (50:10:40 %v/v/v) **Stationary phase:** Eclipse C18 column (4.6 × 150 mm, 5 µm) **Wavelength:** 214 nm **Flow rate:** 0.5 mL/min	29
5	A New Stability-Indicating **RP-HPLC Method** for Determination of Curcumin: An Application to Nanoparticulate Formulation	**Mobile phase:** Phosphate buffer (pH 3): Acetonitrile (50:50 %v/v) **Stationary phase:** C18 column (250 × 4.6 mm, 5 µm) **Wavelength:** 422 nm **Flow rate:** 1 mL/min	30
6	Bioanalytical **RP-HPLC method** development and validation for estimation of Curcumin in plasma samples	**Mobile phase:** Acetonitrile: Water with 0.1% formic acid (40:60 %v/v) **Stationary phase:** Qualisil BDS C18 column (250 × 4.6 mm, 5 µm) **Wavelength:** 423 nm **Flow rate:** 0.3 mL/min	31
7	A Simple isocratic **HPLC method** for the simultaneous determination of Curcuminoids in commercial turmeric extracts	**Mobile phase:** Acetonitrile: 2% v/v acetic acid (40:60 %v/v) **Stationary phase:** Alltima C18 column (150 × 4.6 mm, 5 µm) **Wavelength:** 425 nm **Flow rate:** 2 mL/min	32

Table 4: Literature review on HPTLC Method.

	Title	Description	Reference No.
1	Validated **HPTLC analysis method** for quantification of variability in content of Curcumin in *Curcuma longa* L (turmeric) collected from different geographical region of India	**Mobile phase:** Toluene: Chloroform: Methanol (50:40:10 %v/v/v) **Stationary phase:** TLC aluminium plates precoated with silica gel 60F254 **Wavelength:** 430 nm	33
2	Improved **HPTLC method** for determination of Curcuminoids from Curcuma longa	**Mobile phase:** Chloroform: Methanol (98:2 %v/v) **Stationary phase:** Precoated HPTLC aluminium plates silica gel 60F254 **Wavelength:** 366 nm	34
3	**HPTLC method** for the quantitative determination of ar-Turmerone and Tumerone in lipid soluble fraction from *Curcuma longa*	**Mobile phase:** N-Hexane: Ethyl acetate (98:2 %v/v) **Stationary phase:** TLC aluminium plates precoated with silica gel 60F254 **Wavelength:** 254 nm	35
4	Stability-indicating **HPTLC** determination of Curcumin in bulk drug and pharmaceutical formulations	**Mobile phase:** Chloroform: Methanol (92.5:7.5 %v/v) **Stationary phase:** TLC Aluminium plates precoated with silica gel 60F254 **Wavelength:** 430 nm	36
5	Qualitative analysis and quantitative determination of "Curcumin" in a siddha herbo-mineral formulation using **High Performance Thin Layer Chromatography (HPTLC)**	**Mobile phase:** Chloroform: Methanol (9.5:0.5 %v/v) **Stationary phase:** Silica gel 60F254 coated on aluminium plate **Wavelength:** 366 nm	37
6	Development of **HPTLC method** for its validation for the estimation of Curcuminoids	**Mobile phase:** Chloroform: Methanol:	38

CONCLUSION

This review highlights the significant medicinal value of turmeric, particularly its active component curcumin, known for its anti-inflammatory, antioxidant and anticancer properties. The development and validation of UV-Visible Spectrophotometry, RP-HPLC and

HPTLC methods for curcumin were found to be eco-friendly, simple, reliable and cost effective. These methods were rigorously evaluated for accuracy, precision, linearity and robustness, adhering to ICH guidelines. The study presents a comprehensive approach for the routine analysis of curcumin in bulk and pharmaceutical formulations, ensuring quality control in both Ayurvedic and modern medicinal applications. This work provides a strong foundation for further research in enhancing the bioavailability of curcumin and its potential in treating various health conditions.

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