Therapeutic Potential of Curcumin: Antimicrobial, Preservative, and Anti-Tanning Properties

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Abstract- **Curcumin, the primary bioactive compound in *Curcuma longa* (turmeric), exhibits diverse pharmacological properties, including antimicrobial, antioxidant, anti-inflammatory, and UV-protective effects. This study evaluated curcumin's antimicrobial activity against bacterial and fungal strains, preservative efficacy in bread, and UV absorbance in an anti-tanning cream formulation. Antimicrobial assays demonstrated significant inhibition zones against *Staphylococcus aureus* (Gram-positive) and *Candida albicans* (fungi), with higher resistance observed in Gram-negative *Escherichia coli*. Curcumin (0.5%) extended bread shelf life by 9 days by inhibiting mold (*Aspergillus*, *Penicillium*). UV spectrophotometry revealed moderate UV-A/UV-B absorption in curcumin-based cream (SPF 4–6), though photostability required improvement. These findings highlight curcumin's potential as a natural antimicrobial, food preservative, and topical agent, with formulation enhancements needed for clinical and industrial applications.**

Keywords: **Curcumin, antimicrobial, preservative, anti-tanning, UV absorbance, natural therapeutics**

I. INTRODUCTION

Turmeric, a spice derived from the rhizomes of Curcuma longa, has been used for centuries in traditional medicine for its medicinal properties. It's been employed to treat various ailments, including digestive issues, skin conditions, and joint pain [1]. Curcumin, a polyphenolic compound extracted from turmeric, has been identified as the primary bioactive component responsible for its therapeutic effects [2]. Recent studies have unveiled the vast potential of curcumin in preventing and treating various diseases, including inflammation, cancer, neurological disorders, and cardiovascular diseases [3][4].

Despite all this, curcumin is not widely marketed, mainly due to its poor bioavailability and solubility; which limits its clinical translation [5]. Curcumin exhibits extremely low solubility in water, approximately 0.6 μg/mL, which restricts its dissolution and absorption in the gastrointestinal tract [6]. Even at high oral doses, curcumin demonstrates minimal systemic availability[7]. Curcumin undergoes swift metabolism and systemic clearance, leading to a short elimination half-life of less than 2 hours, further diminishing its therapeutic efficacy[8]. Furthermore. curcumin is chemically unstable, particularly under neutral or alkaline conditions, and is susceptible to degradation when exposed to light and heat, complicating its formulation and storage[9].There has been many attempts to overcome these challenges and reap the vast majority of therapeutic benefits of curcumin like Nanocarrier systems such as nanoparticles, liposomes, and micelles help enhance its solubility, stability, and cellular uptake. Co-crystallization with compounds like L-carnitine improves its dissolution rate and pharmacokinetics. Additionally, using adjuvants like piperine can inhibit curcumin's rapid metabolism and significantly boost its bioavailability. [10][11]. The current research study investigated three applications of curcumin:

1. Antimicrobial activity against Gram-positive (*S. aureus*), Gram-negative (*E. coli*), and fungal (*C. albicans*) pathogens.
2. Preservative action in bread, targeting mold and oxidative spoilage.
3. UV-protective effects in an anti-tanning cream.

II. MATERIAL AND METHODOLOGY

2.1 Antimicrobial Activity

Microbial Strains: S. aureus, E. coli, C. albicans.
Methods: Agar Well Diffusion: Zones of inhibition (ZOI) measured after 24–48 h incubation [12].

The antimicrobial activity of curcumin was assessed by the agar well diffusion method. Sterile Mueller-Hinton agar (for bacteria) and Sabouraud dextrose agar (for fungi) were poured into Petri dishes and allowed to solidify. Microbial suspensions were swabbed uniformly onto the surface of the solidified agar.

Wells of 6 mm diameter were bored into the agar and was filled with curcumin solution (0.5% w/v in DMSO). Plates were incubated at:

1. 37°C for 24 hours for bacterial strains
2. 28°C for 48 hours for fungal strains

The zones of inhibition (ZOI) around the wells were measured in millimeters using a Vernier caliper.

2.2 Preservative Action in Bread

2.2.1 Sample Preparation- Fresh white bread slices were obtained and cut into equal dimensions under aseptic conditions. Curcumin solution (0.5% w/v in ethanol-water mixture) was evenly sprayed onto the surface of the experimental group slices, while control slices remained untreated.2.2.2 Storage Conditions and Observation- Treated and untreated slices were placed in sterile Petri dishes and stored at room temperature (28–30°C) under ambient humidity. Fungal growth (visible mold formation) was visually monitored and recorded daily for up to 10 days. Spoilage was assessed based on visible mold colonies, color changes, and off-odors. Photographs were taken periodically to document changes.

Evaluation: Mold growth monitored over 10 days.

2.3 Anti-Tanning Cream Formulation

2.3.1 Formulation Design- The anti-tanning cream was formulated using natural and skin-compatible ingredients. The composition of the cream included: Curcumin: 0.5–2% w/w, Zinc oxide (ZnO): 5–10% w/w and Aloe vera gel: base medium

The ingredients were homogenized using a magnetic stirrer at 60–65°C for 30 minutes to form a uniform emulsion. The final product was cooled and stored in sterile containers for further testing.

2.3.2 UV Spectrophotometric Analysis

The cream’s ability to absorb ultraviolet (UV) radiation was analyzed using a UV–Vis spectrophotometer in the 200–600 nm wavelength range. A 1% dilution of the cream in ethanol was prepared and scanned to identify absorbance peaks in UV-A (320–400 nm), UV-B (280–320 nm), and visible light regions.

- UV Analysis: Absorbance measured (200–600 nm) using UV-Vis spectrophotometry.

III. RESULTS AND DISCUSSION

3.1 Antimicrobial Activity

Microorganism	Zone of Inhibition (ZOI)
Staphylococcus aureus (*S. aureus*)	15 mm
Candida albicans (*C. albicans*)	18 mm
Escherichia coli (*E. coli*)	10 mm

3.2 Bread Preservation

- Mold Inhibition: 0.5% curcumin delayed spoilage by 9 days vs. 3–4 days in controls.

3.3 UV Absorbance

- Peak Absorption: 425–450 nm (visible) and 320–400 nm (UV-A).
- SPF: 4–6, indicating moderate protection.

3.4 Discussion

3.4.1 Antimicrobial Efficacy

Curcumin's superior activity against Gram-positive bacteria and fungi aligns with its membrane-disruptive and oxidative stress mechanisms [4]. Gram-negative resistance may stem from outer membrane complexity [5].

3.4.2 Food Preservation

Curcumin's dual antioxidant-antimicrobial action extends shelf life, offering a natural alternative to synthetic preservatives (e.g., calcium propionate) [6]. Challenges include solubility and sensory impact.

3.4.3 UV Protection

While curcumin absorbs UV-A, its low SPF and photodegradation necessitate nano formulations or combinatory UV filters for enhanced efficacy [7].

IV. CONCLUSION

This study highlights the multifaceted potential of curcumin as a natural therapeutic agent, demonstrating significant antimicrobial activity, effective preservative action, and moderate UV-protective properties. Curcumin exhibited strong inhibition against *Staphylococcus aureus* and *Candida albicans*, extended the shelf life of bread through its dual antimicrobial and antioxidant effects, and showed UV absorbance in the UV-

A/UV-B range, suggesting its applicability in topical formulations.

However, curcumin's clinical and industrial application remains limited by its poor aqueous solubility, low bioavailability, and instability under physiological and environmental conditions. These challenges necessitate advanced formulation strategies such as nanoencapsulation, co-crystallization, and the use of bioenhancers to improve its stability, solubility, and systemic retention.

Overall, the findings reinforce curcumin's relevance as a multifunctional, natural compound with considerable promise in pharmaceutical, nutraceutical, and cosmetic formulations. Future research should focus on optimizing delivery systems and conducting in vivo and clinical evaluations to fully harness its therapeutic potential in real-world applications.

REFERENCES

[1] Gupta, S. C., Patchva, S., & Aggarwal, B. B. (2013). Therapeutic roles of curcumin: lessons learned from clinical trials. *The AAPS Journal, 15*(1), 195–218.

[2] Hewlings, S. J., & Kalman, D. S. (2017). Curcumin: A Review of Its' Effects on Human Health. *Foods, 6*(10), 92.

[3] Panahi Y, Hosseini MS, Khalili N, Naimi E, Simental-Mendía LE, Majeed M, Sahebkar A. Effects of curcumin on serum cytokine concentrations in subjects with metabolic syndrome: A post-hoc analysis of a randomized controlled trial. Biomed Pharmacother. 2016 Aug;82:578-82.

[4] Marton LT, Pescinini-E-Salzedas LM, Camargo MEC, Barbalho SM, Haber JFDS, Sinatora RV, Detregiachi CRP, Girio RJS, Buchaim DV, Cincotto Dos Santos Bueno P. The Effects of Curcumin on Diabetes Mellitus: A Systematic Review. Front Endocrinol (Lausanne). 2021 May 3;12:669448.

[5] Hegde M, Girisa S, BharathwajChetty B, Vishwa R, Kunnumakkara AB. Curcumin Formulations for Better Bioavailability: What We Learned from Clinical Trials Thus Far? ACS Omega. 2023 Mar 13;8(12):10713-10746.

[6] Anand, P., Kunnumakkara, A. B., Newman, R. A., & Aggarwal, B. B. (2007). Bioavailability of curcumin: Problems and promises. *Molecular Pharmaceutics, 4*(6), 807–818

[7] Fresta, M., Puglisi, G., Giammona, G., Cavallaro, G., & Ventura, C. A. (2016). Improvement of oral bioavailability of curcumin upon microencapsulation with methacrylic copolymers. *Frontiers in Pharmacology, 7*, 485.

[8] Suresh, K., & Nangia, A. (2018). Curcumin: Pharmaceutical solids as a platform to improve solubility and bioavailability. *CrystEngComm, 20*(24), 3277–3296.

[9] Zheng B, McClements DJ. Formulation of More Efficacious Curcumin Delivery Systems Using Colloid Science: Enhanced Solubility, Stability, and Bioavailability. Molecules. 2020 Jun 17;25(12):2791.

[10] Singh, A., Sharma, R., & Kumar, N. (2024). Recent nanotechnology improvements in curcumin bioavailability: A review of innovative drug delivery systems. *Heliyon, 10*(5)

[11] Wang, H., Zheng, C., Tian, F., Xiao, Z., Sun, Z., Lu, L., Dai, W., Zhang, Q., & Mei, X. (2024). Improving the dissolution rate and bioavailability of curcumin via co-crystallization. *Pharmaceuticals, 17*(4), 489.

[12] Holder IA, Boyce ST. Agar well diffusion assay testing of bacterial susceptibility to various antimicrobials in concentrations non-toxic for human cells in culture. Burns. 1994 Oct;20(5):426-9.