IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 14, May 2026
Impact Factor: 8.2

Curcumin and Its Antimicrobial Activity: A Comprehensive Review

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Abstract: *Curcumin, a naturally occurring polyphenolic compound obtained from the rhizomes of Curcuma longa, has attracted substantial research interest due to its diverse biological and therapeutic properties. Among its various pharmacological effects, antimicrobial activity has emerged as an important area of investigation. This review presents an overview of the antimicrobial potential of curcumin against a wide range of microorganisms, including bacterial, fungal, viral, and multidrug-resistant species. Evidence from previous studies suggests that curcumin acts through several mechanisms, such as alteration of microbial membrane integrity, suppression of biofilm formation, induction of oxidative stress, and modulation of essential cellular processes. Different antimicrobial assessment methods, including agar disc diffusion, Minimum Inhibitory Concentration (MIC), Minimum Bactericidal Concentration (MBC), time-kill assay, Colony Forming Unit (CFU) analysis, and Live/Dead cell staining techniques, have demonstrated its effectiveness in reducing microbial growth. Research findings further indicate that the antimicrobial action of curcumin is influenced by concentration and formulation characteristics. Despite promising outcomes, factors such as poor solubility and limited bioavailability restrict its clinical application. Recent advances in nanoformulation strategies have shown potential in improving the delivery and therapeutic performance of curcumin, supporting its future development as a natural antimicrobial agent.*

Keywords: Curcumin, Curcuma longa, antimicrobial activity, multidrug resistance, nanoparticles, bioavailability, antimicrobial assays, natural therapeutic agents

I. INTRODUCTION

Curcumin is the major biologically active compound present in turmeric, which is obtained from the rhizome of Curcuma longa. Turmeric is well known for its bright yellow color, primarily attributed to curcumin. Over the years, curcumin has gained considerable scientific interest because of its diverse pharmacological properties. Studies have indicated that it possesses anti-inflammatory, antioxidant, antimicrobial, anticancer, and antidiabetic activities. These properties suggest that curcumin may have significant therapeutic potential in the prevention and management of various diseases.(1)

Turmeric has been used for centuries in different regions of the world, not only as a culinary ingredient but also as a component of traditional medicine. Its applications vary according to cultural practices and regional preferences. In India, turmeric is commonly incorporated into food preparation and Ayurvedic remedies. In Japan, it is frequently consumed in the form of tea, while in Thailand it is utilized in skincare and cosmetic products. In China, turmeric is used as a natural coloring agent in food products, whereas in Korea it is included in beverages and health drinks.(1)

DOI: 10.48175/IJARSCT-36163

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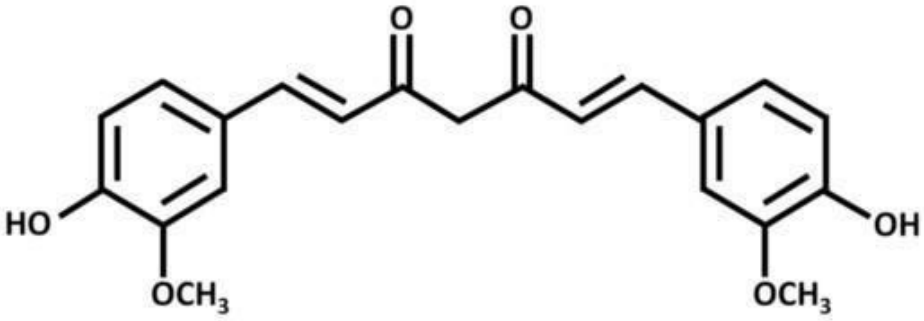
Source of curcumin

Curcumin is a natural bioactive compound derived from the rhizomes of Curcuma longa (turmeric), a flowering plant belonging to the Zingiberaceae family. Turmeric has long been valued in traditional medicinal practices because of its therapeutic significance. Among the various curcuminoids present in turmeric, curcumin is the major active constituent responsible for its bright yellow appearance and diverse biological properties. It is commonly isolated from dried turmeric rhizomes through several extraction methods, including conventional solvent extraction as well as advanced techniques such as Soxhlet extraction, ultrasound-assisted extraction, and microwave-assisted extraction.(2)

Chemical Nature:

Curcumin is a symmetrical molecule, also called diferuloyl methane. Its official name from the IUPAC system is (1E,6E)-1,7-bis(4-hydroxy-3-methoxyphenyl)1,6heptadiene- 3,5-dione. The chemical formula for curcumin is C21H20O6, and its molecular weight is
368.38. Its structure includes three parts: two aromatic rings that each have o-methoxy phenolic groups, linked together by a seven-carbon chain that has an alpha-unsaturated beta-diketone part.(2)

Structure of curcumin



Traditional Uses

: This bright yellow spice comes from the root of a plant. It has been used for a long time in the traditional medicine of China and India . The root of turmeric is crushed into a powder and has been used in Asian cooking, medicine, cosmetics, and dyeing for over 2000 years . Early European travellers to Asia brought this important spice to the West in the 14th century . People still use curcumin as a home remedy today.(3)

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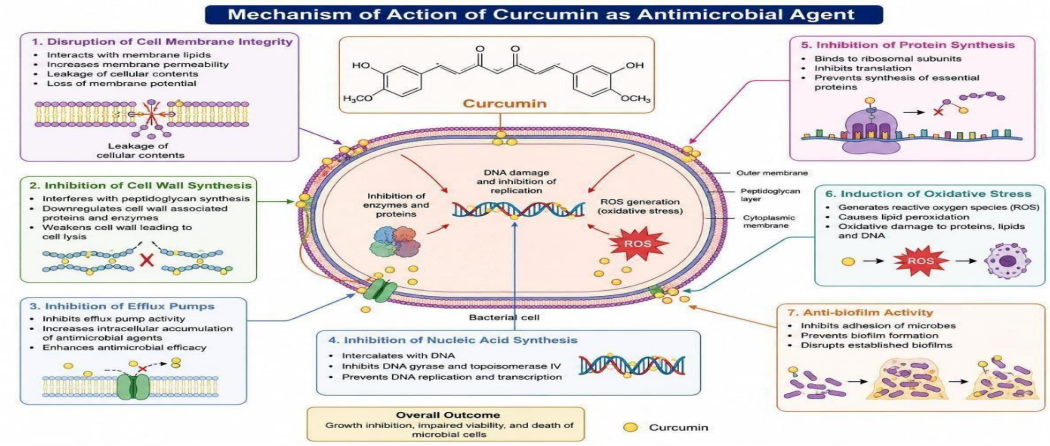
In the ancient Indian medical system called Ayurveda, a paste made from turmeric is used to treat common eye infections, wounds, bites, burns, acne, and different skin problems . The American company Johnson & Johnson also makes turmeric Band-Aids for the Indian market . In Northern India, women are given a drink made from fresh turmeric paste, powdered dried ginger, and honey in a glass of hot milk twice a day after childbirth. A turmeric poultice is also applied to the perineum to help heal any tears in the birth canal

Powdered turmeric is taken with boiled milk to help with coughs and other breathing issues and roasted turmeric is used as a remedy for children with diarrhoea.(3)

Importance as an antimicrobial agent

The antibacterial power of curcumin was first shown in the journal Nature in 1949 . In 1974, researchers from our Institute published detailed findings in the Planta Medica journal about how curcumin, an ethanol extract and essential oil from the rhizome of C. longa, worked against 65 different bacterial and fungal strains, covering 56 types of microbes. They found that curcumin was very effective in the lab against certain bacteria like Staphylococcus aureus, S. epidermidis, Streptococcus pyogenes, Micrococcus tetragenus, and M. luteus, as well as spore-forming bacteria like Bacillus and Clostridium species, some Gram-negative bacteria such as Acinetobacter lwoffii and Alcaligenes faecalis, and fungi like Candida stellatoidea, Cryptococcus neoformans, Microsporum gypseum, Saccharomyces cerevisiae, and Scopulariopsis brevicaulis. More recent studies have supported the strong antimicrobial ability of curcumin even though it is not very soluble in water, has low bioavailability, and a poor pharmacokinetic profile .(4)



Curcumin has been studied for its ability to stop bacteria from forming biofilms by stopping their communication systems and breaking down existing biofilms . Also, curcumin can work by creating toxic reactive oxygen species (ROS) that harm both free- floating and biofilm bacteria . The literature has shown that curcumin is helpful against certain Gram-negative bacteria that cause urinary tract infections like Escherichia coli, Pseudomonas aeruginosa, Proteus mirabilis, and Serratia marcescens , and it may help prevent the formation of struvite stones linked with these infections . In addition, curcumin works better with antibiotics and antifungals against a number of harmful microbes, including methicillin-resistant S. aureus , Pseudomonas aeruginosa , enterotoxigenic Escherichia coli (ETEC) , and Candida albicans . Because of its strong anti-inflammatory properties and ability to fight Helicobacter pylori, curcumin has been considered for treating H. pylori-related conditions such as gastritis, peptic ulcers, and gastric adenocarcinoma .(5)

Despite many studies looking at how curcumin can fight bacteria and fungi, there isn't enough information about how it works against different types of microbes, especially the ones found in clinical settings and those that are resistant to multiple drugs. Also, the lowest amounts of curcumin needed to stop the growth of many common bacteria in their free-floating form haven't been determined yet. Some research has looked at curcumin's effects on specific bacteria like A. lwoffi, Proteus mirabilis, Serratia marcescens, Stenotrophomonas maltophilia, and Streptococcus agalactiae, but

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these studies are not very common. In recent studies, curcumin's ability to stop microbial growth has mostly been tested against a small group of bacteria, usually E. coli, P. aeruginosa, and S. aureus, with fewer tests on Bacillus subtilis and Enterococcus faecalis. Some studies have only looked at one type of bacteria and a single strain. Sometimes, the concentrations ofcurcumin used in these studies are too low, such as up to 64, 100, 128, 156, 256, 330, or 375 micrograms per millilitre. Because of this, more research is needed to understand how curcumin affects a wide range of bacterial strains and species using a standard method.(4)

Objectives of the Review

• To study the antimicrobial properties of curcumin, the principal active compound isolated from the rhizomes of Curcuma longa.

• To review published scientific studies related to the activity of curcumin against different microorganisms, including bacteria, fungi, and resistant microbial strains.

• To understand the various mechanisms involved in the antimicrobial action of curcumin, including inhibition of microbial multiplication, damage to microbial cell structures, prevention of biofilm development, and induction of oxidative stress.

• To evaluate the combined effect of curcumin with commonly used antimicrobial agents and its possible contribution in enhancing their therapeutic activity.

• To examine the potential of curcumin as a natural alternative or supportive agent in the management of microbial infections and antimicrobial resistance. (6)

Literature Review

1. Antibacterial Activity of Curcumin

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• Tyagi P, Singh M, Kumari H, Kumari A, Mukhopadhyay K. Antimicrobial properties of curcumin. J Antimicrob Chemother. 2015.

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Aim & Objectives

Aim

To check how well curcumin fights different microorganisms in a lab and to see how effective it is at different levels of concentration and under different lab conditions.(7)

Objectives

• The study looked at how curcumin works against various types of bacteria and fungi, and found that it had mixed results, with some microbes showing less growth in lab settings.
• Standard lab methods were used to watch how the microbes behaved, and repeated tests showed that curcumin slowly stopped their growth and colony formation over time.
• The research also aimed to understand how curcumin fights microorganisms.
• Another goal was to compare how effective curcumin is against common antibiotics.
• The study also checked how well curcumin works against strains of microbes that are resistant to multiple drugs
• Earlier research on turmeric suggests that scientists are working on ways to improve its antimicrobial power through experiments and changes.

Overall, curcumin is being studied as a possible natural alternative to antibiotics, and while the results are encouraging, its use in real-world medical situations is still being developed(7)

Plan Of Work

Selection of Research Topic

The topic Curcumin as an Antimicrobial Agent was selected based on increasing interest in natural compounds and the growing problem of antimicrobial resistance.(8)

Collection of Literature

Relevant review articles, research papers, journals, and online databases were studied to gather information regarding curcumin, its properties, and antimicrobial applications.(8)

Study of Curcumin and Its Properties

Information regarding the source, chemical structure, biological activities, and pharmacological properties of curcumin was collected and analysed.(8)

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Review of Antimicrobial Activity

Published studies related to antibacterial, antifungal, antiviral, and antiparasitic activities of curcumin were reviewed.(8)

Evaluation of Mechanism of Action

Literature regarding mechanisms by which curcumin inhibits microbial growth, such as membrane disruption, oxidative stress induction, and inhibition of cellular pathways, was analyzed.(8)

Assessment of Laboratory Methods

Experimental methods commonly used to evaluate antimicrobial activity were reviewed, including:
Laboratory Methods includes:

- Agar disc diffusion method
- Minimum Inhibitory Concentration (MIC)
- Minimum Bactericidal Concentration (MBC)
- Time assay method
- Colony Forming Unit (CFU) Count Method
- Live/Dead Cell Staining Assay(8)

Comparative Analysis

Antimicrobial effects of curcumin were compared with conventional antimicrobial agents and antibiotics based on available literature.(8)
Study of Curcumin Against Drug-Resistant Microorganisms
Research regarding multidrug-resistant strains and the synergistic activity of curcumin with antibiotics was evaluated.(8)

Analysis of Advanced Formulations

Nanoformulations such as nanoparticles, liposomes, and micelles developed to improve curcumin bioavailability were reviewed.(8)
Compilation and Interpretation of Data
Information collected from different sources was organised, compared, and interpreted systematically.(8)
Conclusion and Future Scope
Final conclusions were drawn based on findings, and future perspectives regarding curcumin as a natural antimicrobial therapeutic agent were discussed.(8)

Material & Equipment

Chemicals and Reagents

- Curcumin powder or extract
- Dimethyl sulfoxide (DMSO) or ethanol (solvent for curcumin)
- Sterile distilled water
- Nutrient broth
- Nutrient agar
- Phosphate-buffered saline (PBS)
- Standard antibiotics (positive control, e.g., gentamicin, ciprofloxacin)
- Sterile saline solution
- Dyes like methylene blue or ethidium bromide
- Glass slides

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- Cover slips
- Sterile tubes
- Sterile spreader/swabs (10-15)

Equipment used :

1. Agar Disc Diffusion

- Petri plates
- Filter paper discs
- Forceps
- Incubator
- Ruler/Vernier calliper (10)

2. MIC determination

- Agar plates
- Micropipettes
- Spectrophotometer or microplate reader (10)

3. MBC determination

- Agar plates
- Incubator
- Colony counter(11)

4. Colony Forming Unit (CFU) Count Method

- Incubator
- Micropipettes
- Colony counter
- Laminar airflow cabinet
- Vortex mixer
- Autoclave
- Analytical balance (12)

5. Live/Dead Cell Staining Assay

- Fluorescence microscope or confocal microscope
- Centrifuge
- Micropipettes
- Incubator
- Vortex mixer
- Laminar airflow cabinet (13)

Experimental Work

Preparation of curcumin solution

Curcumin solution is prepared by accurately weighing the required amount of curcumin powder and dissolving it in a suitable organic solvent such as ethanol, methanol, or DMSO to obtain a concentrated stock solution. The mixture is thoroughly vortexed or stirred until complete dissolution is achieved.(9)

For experimental use, the stock solution is further diluted with sterile distilled water or appropriate culture medium to obtain the desired working concentrations. Prior to application in antimicrobial assays, the solution is typically sterilized using a 0.22 µm membrane filter to ensure aseptic conditions.(9)

1. Agar disc diffusion method

The Agar Disc Diffusion Method is a commonly applied technique for assessing the antimicrobial activity of compounds such as curcumin due to its simplicity and reliability. In this method, curcumin-loaded discs are placed on

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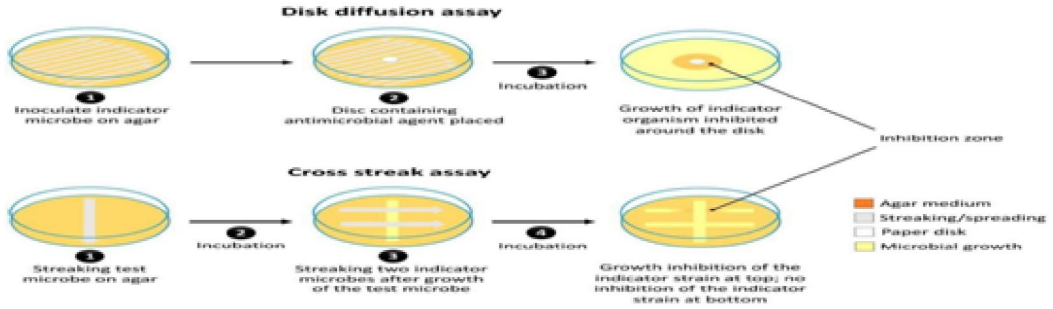
microorganisminoculated agar plates, where the compound diffuses into the medium and forms a clear inhibition zone, reflecting its ability to suppress microbial growth.(10)



Procedure

• Sterile nutrient agar medium was prepared and dispensed into Petri plates, followed by solidification under controlled aseptic conditions.

• A bacterial suspension of standardized concentration was prepared and evenly inoculated across the agar surface using a sterile swab to ensure uniform microbial growth.

• Sterile filter paper discs were treated with curcumin solutions of different concentrations and dried appropriately before use.

• The curcumin-treated discs, along with suitable positive and negative control discs, were carefully positioned on the inoculated agar surface using sterile forceps.

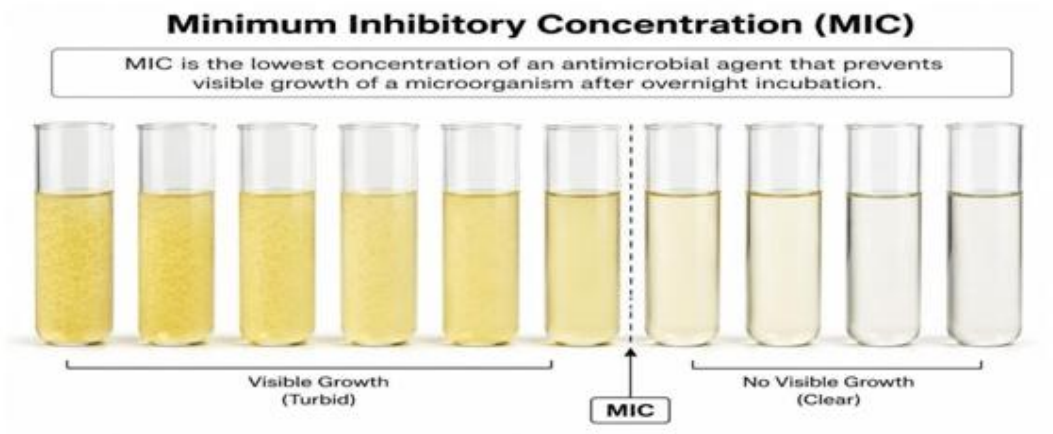
• The culture plates were incubated in an inverted orientation at 37°C for 18–24 hours to allow adequate microbial growth and diffusion of curcumin through the medium.

• After incubation, the diameter of the growth inhibition zone around each disc was measured using standard measuring tools, and larger zones were considered indicative of stronger antimicrobial activity.(10)

Observation : A larger zone of inhibition indicates stronger antimicrobial activity and greater sensitivity of microorganisms to the tested compound. Smaller inhibition zones suggest reduced effectiveness, while the absence of a clear zone may indicate microbial resistance or insufficient activity at the tested concentration.(10)

2. Minimum Inhibitory Concentration

The Minimum Inhibitory Concentration (MIC) test is used to determine the lowest concentration of an antimicrobial agent, such as curcumin, required to inhibit visible microbial growth. In this method, microorganisms are exposed to different concentrations of curcumin in a liquid medium, and the lowest concentration that prevents visible growth or turbidity after incubation is recorded as the MIC value.(10)



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Procedure:

• A stock solution of curcumin was prepared using an appropriate solvent such as DMSO or ethanol to ensure proper dissolution.

• Sterile nutrient broth was prepared and dispensed into sterile test tubes or microtiter plate wells under aseptic conditions.

• Serial dilutions of curcumin were prepared to obtain a range of concentrations for antimicrobial evaluation.

• A standardized microbial suspension equivalent to 0.5 McFarland standard was prepared and inoculated into each tube or well containing curcumin solutions.

• Appropriate positive, negative, and solvent controls were included, followed by incubation at 35–37°C for 18–24 hours.

• After incubation, microbial growth was assessed by observing turbidity, and the lowest concentration showing no visible growth was recorded as the MIC value.(11)

Observation: Following incubation, the tubes or microtiter wells were examined for visible microbial growth, typically indicated by turbidity. The lowest concentration of curcumin that showed no visible growth was identified as the Minimum Inhibitory Concentration (MIC) value.(11)

3. Minimum Bactericidal Concentration

The Minimum Bactericidal Concentration (MBC) is defined as the lowest concentration of an antimicrobial agent required to kill microorganisms completely, resulting in no bacterial growth after subculture onto fresh agar media. This method helps determine whether curcumin exhibits bactericidal activity or only inhibits microbial growth, with samples from MIC assays being transferred to agar plates for confirmation.(12)

Procedure:

• The Minimum Inhibitory Concentration (MIC) assay was initially performed using varying concentrations of curcumin to identify concentrations showing no visible microbial growth.

• Tubes or wells exhibiting no visible growth were selected for further bactericidal assessment.

• A small aliquot from each selected sample was aseptically transferred onto fresh agar plates free of curcumin.

• The inoculated agar plates were incubated at 35–37°C for 18–24 hours under appropriate conditions.

• Following incubation, the plates were examined for the presence or absence of microbial colonies.

• The lowest concentration of curcumin that resulted in complete absence of colony growth was recorded as the Minimum Bactericidal Concentration (MBC) value.(12)

Observation: After incubation, the absence of microbial colonies on the agar surface indicated a bactericidal effect, suggesting complete elimination of the microorganisms. In contrast, the presence of colonies reflected microbial survival, indicating growth inhibition rather than microbial killing. A lower MBC value represented greater bactericidal potency of the tested compound.(12)

4. Time kill assay method

The Time Kill Assay is a method used to evaluate the rate and extent of antimicrobial activity over a specific period by monitoring changes in viable microbial counts. In this method, microorganisms are exposed to different concentrations

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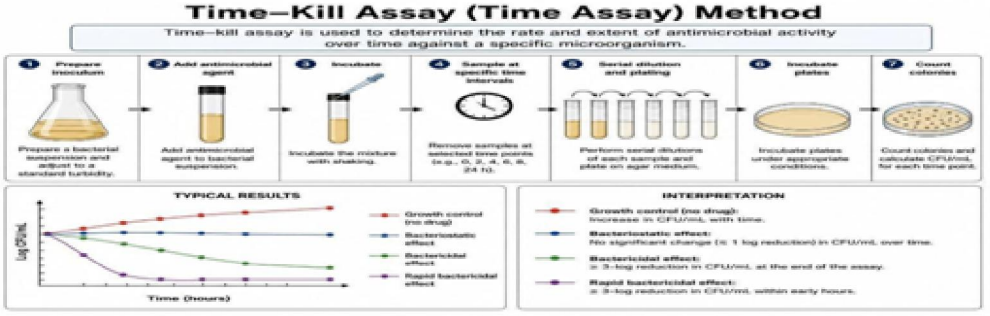
of curcumin, and samples are collected at predetermined time intervals to determine the reduction in bacterial growth and assess antimicrobial effective ness.(13).



Procedure

• Curcumin solutions of varying concentrations were prepared in sterile nutrient broth for antimicrobial evaluation.

• A standardized microbial inoculum was added equally to each preparation to maintain consistent experimental conditions.

• The inoculated samples were incubated at 35–37°C under controlled conditions.

• Aliquots (same proportion of sample) were collected at predetermined time intervals (0, 2, 4, 6, 12, and 24 hours) for analysis.

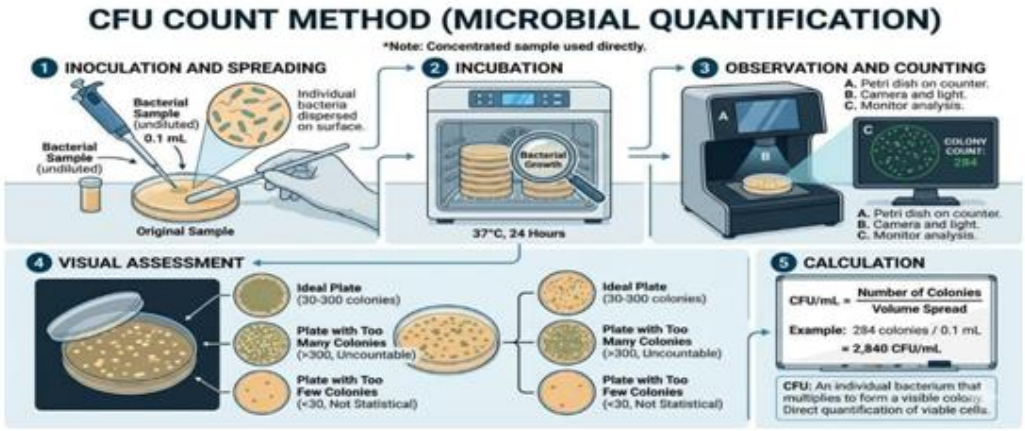
• The collected samples were serially diluted and inoculated onto agar plates using appropriate microbiological techniques.

• After incubation for 18–24 hours, the number of colonies formed was counted to determine the viable bacterial count (CFU/mL).(13)

Observation: A steady decrease in CFU values over successive time intervals reflects the antimicrobial effectiveness of the tested agent. The significant reduction in bacterial load, along with limited or no regrowth, indicates strong bactericidal activity and effective inhibition of microbial growth.(13)

5. Colony forming unit count method The Colony-Forming Unit (CFU) Count Method

is used to determine the number of viable microorganisms remaining after treatment with antimicrobial agents such as curcumin. In this method, microbial samples treated with curcumin are serially diluted, cultured on agar plates, and the resulting colonies are counted; a lower CFU count indicates greater antimicrobial effectiveness of curcumin.(14)



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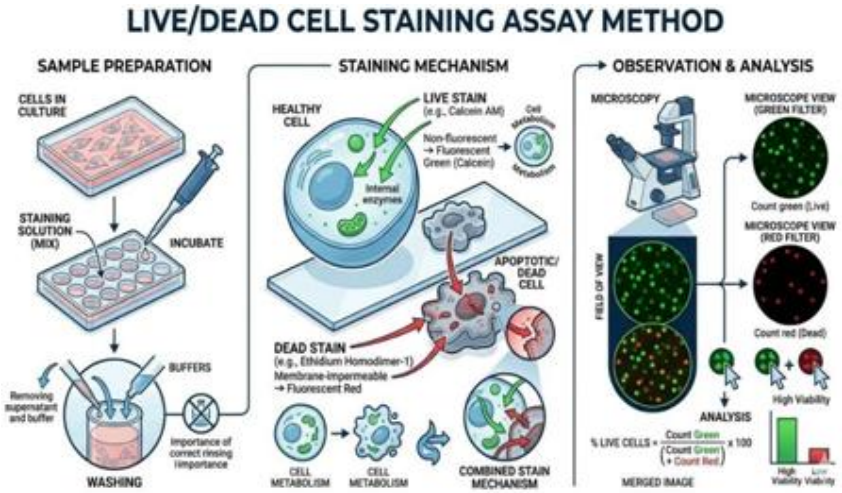
Procedure:

• A curcumin solution of the required concentration was prepared, and the microbial culture was exposed to the test compound under controlled conditions.
• Following treatment, samples were collected for microbiological analysis.
• Serial dilutions of the treated samples were prepared using sterile saline solution to obtain appropriate dilution ranges.
• The diluted samples were aseptically spread onto sterile nutrient agar plates.
• The inoculated plates were incubated at 35–37°C for 18–24 hours to allow microbial growth.
• After incubation, the developed colonies were counted and expressed as colonyforming units (CFU) to assess antimicrobial activity.(14)

Observation : A decrease in colony-forming units (CFU) with increasing concentrations of curcumin indicated enhanced antimicrobial activity. Higher concentrations producing minimal or no colony formation suggested effective inhibition or elimination of microbial growth, demonstrating the antimicrobial potential of curcumin.(14)

6. The Live / Dead cell staining assay

The Live/Dead cell staining assay is a fluorescence-based technique used to distinguish viable and non-viable microbial cells after antimicrobial treatment. It evaluates membrane integrity, where intact membranes indicate live cells and compromised membranes indicate dead cells. Based on differential dye uptake, live cells exclude or minimally absorb the stain, while dead cells take up the dye and appear distinctly stained, enabling assessment of antimicrobial efficacy.(15)



Procedure:

• Microbial cultures are prepared in nutrient broth and standardized to 0.5 McFarland turbidity.
• The cells are exposed to different concentrations of curcumin and incubated at 35– 37°C for 18–24 hours.
• After incubation, the culture is centrifuged at low speed and washed using sterile saline or phosphate-buffered saline.
• Methylene blue solution (0.1% w/v) is added to the cell suspension and allowed to stain for 1–5 minutes at room temperature.
• A wet mount is prepared by placing a drop of the stained sample on a clean glass slide and covering it with a coverslip.
• The slide is examined under a light microscope at 10× or 40× magnification, and observations are recorded based on staining, where viable cells appear unstained or lightly stained and non-viable cells appear dark blue.(15)

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Observation : A higher proportion of dark blue-stained cells indicates stronger antimicrobial activity and increased cell death. In contrast, a greater number of unstained cells reflects higher microbial viability. An increase in curcumin concentration leads to enhanced cell death in microbial cultures.(15)

Curcumin Nanoformulations

Nanoformulations of curcumin are advanced drug delivery systems developed to improve its therapeutic efficiency by overcoming limitations such as poor water solubility, low bioavailability, and rapid metabolic degradation. These nanoscale carriers enhance the stability, absorption, and targeted delivery of curcumin, thereby increasing its biological activity, including antimicrobial potential.(16)

Various nanocarrier systems have been explored for curcumin delivery, including liposomes, polymeric nanoparticles, solid lipid nanoparticles, nanoemulsions, micelles, and nanogels. These systems encapsulate curcumin, protect it from chemical and enzymatic degradation, and allow controlled and sustained release at the target site.(16)

Research findings indicate that nanoformulated curcumin exhibits improved cellular uptake and enhanced pharmacological efficacy compared to its free form, making it more effective in antimicrobial, anti-inflammatory, and anticancer applications.(17)

Advantages of Curcumin Nanoparticles:

- Increase the water dispersibility and solubility of curcumin.
- Enhance the absorption and overall bioavailability of curcumin.
- Protect curcumin from chemical degradation and rapid elimination.
- Support controlled and site-specific delivery of the active compound.
- Improve therapeutic performance and biological effectiveness.
- Strengthen antimicrobial, antioxidant, anti-inflammatory, and anticancer activities.
- Lower the required dosage while reducing the possibility of adverse effects.(17)

Discussion

This overall information provides an analysis of the outcomes obtained from various antimicrobial evaluation methods like agar disc diffusion method, MIC, MBC, time kill assay method etc applied to curcumin. These approaches assist in assessing its ability to inhibit microbial growth and determine its effectiveness against different microorganisms, thereby supporting its potential use in therapeutic applications in various microbial infections.(4)

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 14, May 2026 Impact Factor: 8.2

Sr.no	Methods	Observation	Conclusion
1	Agar disc diffusion method	Wider zone of inhibition	Curcumin shows antimicrobial activity(10)
2	Minimum inhibitory concentration	Less cloudiness in tubes	Curcumin shows antimicrobial activity(11)
3	Minimum bactericidal concentration	Absence of colonies on agar plate	Curcumin shows antimicrobial activity(12)
4	Time kill assay method	Decrease value ofcolony forming unit	Curcumin shows antimicrobial activity(13)
5	Colony forming unit count method	Decrease in colony forming	Curcumin shows antimicrobial activity(14)
6	Live/ dead cell staining assay method	Dark blue coloured cells	Curcumin shows antimicrobial activity(15)

Dose dependency The antimicrobial activity of curcumin has been widely investigated and findings indicate that its effectiveness is strongly influenced by concentrationdependent behavior. Studies have demonstrated that increasing curcumin concentration generally produces greater inhibition of microbial growth, leading to a reduction in microbial viability and colony formation.(17) This dose-dependent response suggests that higher concentrations may enhance membrane disruption, interfere with cellular metabolism, and alter essential biological processes required for microbial survival.(18)

Mechanism of action The proposed antimicrobial mechanism of curcumin involves multiple pathways. Curcumin has been reported to affect the integrity of microbial cell membranes, resulting in increased permeability and cellular damage. In addition, it may interfere with protein function, nucleic acid synthesis, and intracellular signaling pathways. Curcumin can also induce oxidative stress within microbial cells, contributing
to growth inhibition and cell death. The presence of several mechanisms may reduce the likelihood of rapid resistance development.(19)

Comparative studies curcumin vs Antibiotics Comparative studies between curcumin and conventional antibiotics suggest that antibiotics generally exhibit stronger and more rapid antimicrobial action because of their targeted mechanisms and established pharmacological properties. However, curcumin has demonstrated potential as an adjunct therapeutic agent, particularly when combined with antibiotics. Research findings indicate that curcumin may enhance antimicrobial efficacy and, in some cases, improve activity against drug-resistant microorganisms through synergistic interactions.(20)

Despite these promising findings, several limitations affect the clinical application of curcumin. Its poor aqueous solubility, low absorption, rapid metabolism, and limited systemic availability reduce its therapeutic efficiency. To overcome these limitations, advanced formulations such as nanoparticles, liposomes, and micellar systems have been explored to improve stability, absorption, and antimicrobial performance. These approaches may enhance the practical use of curcumin as a potential antimicrobial agent.
(21)

There are some laboratory conditions in which curcumin shows action on microbes:

Sr.no	Condition	Action of curcumin on microorganisms	Result on microorganisms
1	Room Temperature	Curcumin interacts with microbial cell membranes and proteins	Reduced microbial growth and cell damage
2.	Cold Temperature (4– 8°C)	Curcumin remains stable; microbial metabolism slows	Growth rate decreases and microbial proliferation is reduced
3.	Hot Temperature	High temperature can degrade curcumin and reduce activity	Lower antimicrobial action and increased microbial survival

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4.	Sunlight Exposure	Curcumin undergoes photodegradation, reducing ROS generation	Decreased inhibition of microbial cells
5.	Dark Condition	Curcumin retains stability and antimicrobial potency	Greater inhibition of bacterial and fungal growth
6.	Biofilm Condition	Curcumin disrupts quorum sensing and biofilm formation	Reduced microbial adhesion and biofilm breakdown
7.	ROS-Generating Condition	Curcumin induces production of reactive oxygen species (ROS)	Oxidative damage leading to microbial cell death
8.	Combination with Antibiotics	Curcumin acts synergistically with antimicrobial drugs	Enhanced killing of resistant microorganisms

Summary

The present review highlights the antimicrobial potential of curcumin, the principal bioactive constituent of turmeric, and summarizes its activity against a broad range of microorganisms including bacteria, fungi, viruses, and multidrug-resistant strains. Literature findings indicate that curcumin exhibits antimicrobial effects through multiple mechanisms such as disruption of microbial cell membranes, induction of oxidative stress, inhibition of biofilm formation, and interference with essential cellular functions.Different laboratory assessment methods including agar disc diffusion, Minimum Inhibitory Concentration (MIC), Minimum Bactericidal Concentration (MBC), time-kill assay, Colony Forming Unit (CFU) count, and Live/Dead cell staining assays demonstrated the antimicrobial effectiveness of curcumin. The findings also indicate a concentration-dependent response, where increased curcumin levels result in enhanced microbial inhibition. Furthermore, nanoformulation strategies such as nanoparticles, liposomes, and micellar systems have shown potential in overcoming limitations associated with poor solubility and low bioavailability, thereby improving its therapeutic effectiveness and antimicrobial activity.

II. CONCLUSION

Based on the reviewed studies, curcumin demonstrates significant antimicrobial potential and may serve as a promising natural therapeutic agent for the management of microbial infections. Its broad-spectrum activity, multiple mechanisms of action, and synergistic interactions with conventional antimicrobial agents support its potential role in addressing antimicrobial resistance. However, limitations including poor aqueous solubility, low bioavailability, and rapid metabolism continue to restrict its clinical application. The development of advanced drug delivery systems, particularly nanoformulations, has provided promising approaches to improve its pharmacological performance. Further standardized experimental and clinical investigations are necessary to establish the efficacy, safety, and practical applications of curcumin in antimicrobial therapy.

Result:

The agar disc diffusion assay indicated antimicrobial efficacy through the development of distinct growth inhibition zones, whereas absence of such zones suggested reduced activity. MIC and MBC evaluations confirmed inhibitory and bactericidal effects through decreased turbidity and lack of colony formation, while visible growth indicated lower effectiveness. Findings from time-kill, CFU count, and Live/Dead cell staining assays demonstrated reductions in microbial viability and increased cell death following curcumin treatment. Although the findings support the concentration dependent antimicrobial potential of curcumin, additional research is necessary to confirm its effectiveness and support future therapeutic applications.

Future Scope

• Further investigations should focus on overcoming limitations associated with curcumin, including poor aqueous solubility, low bioavailability, and rapid metabolic degradation.

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• Advanced delivery systems such as nanoparticles, liposomes, nano emulsions, and micellar formulations should be explored to enhance therapeutic effectiveness.
• Additional studies are required to evaluate the antimicrobial activity of curcumin against a wider range of multidrug-resistant microorganisms.
• Research should examine the synergistic effects of curcumin in combination with conventional antibiotics and antifungal agents.
• Standardization of dosage, formulation methods, and experimental protocols is necessary for reproducible outcomes.
• Comprehensive preclinical and clinical studies should be conducted to establish efficacy, safety, and long-term therapeutic potential.
• Further exploration of curcumin in targeted drug delivery and infection management may contribute to future antimicrobial treatment strategies.(22)

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