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Review Article

A Mini Review of *Curcuma longa*: Antimicrobial Properties

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ABSTRACT

This review discusses the antimicrobial potential of *Curcuma longa*, a plant traditionally recognized for its medicinal properties. The emerging concern over antimicrobial resistance, coupled with the adverse effects of synthetic drugs, necessitates an exploration of plant-based natural antimicrobials. *Curcuma longa*, commonly known as turmeric, provides a compelling case with its broad spectrum of antimicrobial activity. The review first delves into the phytochemical composition of *Curcuma longa*, focusing on its primary bioactive compounds, the curcuminoids, with curcumin being the most prominent. These compounds, along with essential oils and polysaccharides, contribute significantly to the antimicrobial properties of the plant.

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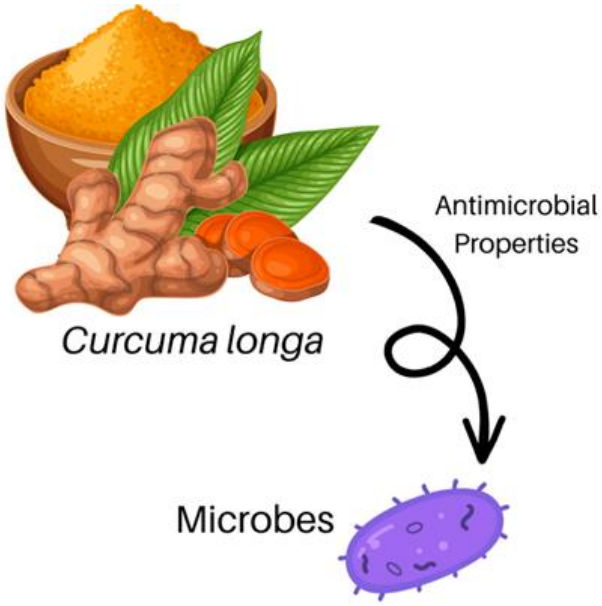
GRAPHICAL ABSTRACT



Introduction

Curcuma longa, commonly known as turmeric, is a perennial plant belonging to the *Zingiberaceae* family, native to Southeast Asia. It has been extensively used in traditional medicine for centuries, owing to its wide array of medicinal properties. The rhizome of the plant, recognized by its bright yellow colour, serves not only as a culinary spice, but also as a therapeutic agent in various traditional medicine systems [1, 2].

In recent years, the scientific community has shown growing interest in the potential health benefits of *Curcuma longa*. It has been studied for its anti-inflammatory, antioxidant, anticancer, and neuroprotective properties. One area that has garnered significant attention is the antimicrobial properties of *Curcuma longa*. In the age of increasing antimicrobial resistance, identifying new antimicrobial agents is of utmost importance, and *Curcuma longa* presents a compelling case as a potential natural source [3, 4]. This review aims to provide a comprehensive overview of the antimicrobial properties of *Curcuma longa*.

It delves into the rich phytochemical composition of the plant, highlighting the primary active compounds responsible for its antimicrobial activity. It further discusses the broad spectrum of its antimicrobial activity against various pathogens, including bacteria, viruses, fungi, and parasites [5, 6].

Understanding the mechanisms of action is key to harnessing the antimicrobial potential of *Curcuma longa*; hence, the review also focuses on elucidating the various strategies deployed by its bioactive compounds against microorganisms. These include, but are not limited to, disruption of microbial cell structures, inhibition of microbial enzymes, and modulation of the immune responses of the host [7, 8].

Finally, the review explores potential applications of *Curcuma longa* in different sectors, including pharmaceuticals, food preservation, agriculture, and animal health. It also touches on the challenges to be addressed for the effective utilization of this plant as a natural antimicrobial agent [9, 10]. Through this review, it is hoped to shed light on the untapped potential of *Curcuma longa* in the field of antimicrobial research and inspire further investigations into this promising plant.

Phytochemical composition of curcuma longa

Curcuma longa, known for its vibrant yellow colour, owes its distinctiveness and medicinal value to its rich phytochemical composition.

The plant's phytochemical profile is diverse and complex, composed primarily of curcuminoids, volatile oils, polysaccharides, and other secondary metabolites, each of which contributes to its health-promoting properties [11, 12]. Curcuminoids, a group of phenolic compounds, are the most prominent active constituents of *Curcuma longa*. The major curcuminoids include curcumin (Figure 1), demethoxycurcumin, and bisdemethoxycurcumin, with curcumin being the most abundant and biologically active. It is this compound that imparts the characteristic yellow colour to the plant and is largely responsible for its potent antioxidant, anti-inflammatory, and antimicrobial activities [13, 14].

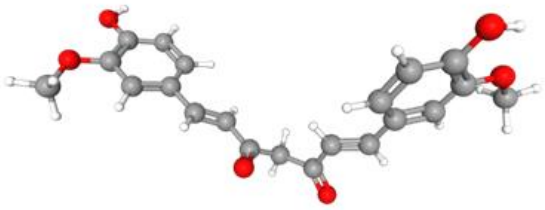


Figure 1: Structure of curcumin

In addition to curcuminoids, volatile oils contribute significantly to the bioactivity of *Curcuma longa*. These oils consist of a variety of monoterpenes and sesquiterpenes such as turmerone, atlantone, and zingiberene. These aromatic compounds not only contribute to the distinct aroma and taste of turmeric, but also have been reported to possess antimicrobial, anti-inflammatory, and antioxidant properties [15, 16]. Polysaccharides are another group of compounds found in *Curcuma longa*. These complex carbohydrates often referred to as turmeric's "ukonan" fractions, have shown promising immune-stimulatory effects. The polysaccharides have been found to activate macrophages and other immune cells, contributing to the host's immune response to pathogens [17, 18]. Lastly, *Curcuma longa* contains other secondary metabolites, such as sterols, fatty acids, and sugars, which further enhance its medicinal properties. Among these, the presence of various flavonoids and alkaloids has been noted, many of which contribute to the plant's antioxidant and anti-inflammatory actions. Collectively, the broad spectrum of phytochemicals present in *Curcuma longa* make it a plant of significant pharmacological interest. Further studies may uncover additional compounds and reveal a more detailed understanding of the interactions among these compounds that result in the broad medicinal benefits of this plant [19, 20].

Antimicrobial activity of curcuma longa

Extensive research has been conducted to ascertain the antimicrobial potential of *Curcuma longa*. Its antimicrobial activities have been tested against a diverse range of microorganisms, both *in vitro* and *in vivo*, providing ample evidence to affirm its robust antimicrobial potency. The antibacterial action of *Curcuma longa* is profound and broad-spectrum. It has been shown to be effective against both Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Helicobacter pylori*. In particular, the curcumin component appears to disrupt bacterial cell walls and interfere with the synthesis of bacterial proteins and DNA, hence leading to bacterial cell death. Moreover, *Curcuma longa* has exhibited potential in combating multidrug-resistant bacterial strains, highlighting its possible utility as an alternative to conventional antibiotics [21, 22].

Regarding its antiviral activity, *Curcuma longa* and its derivatives have been investigated against various viruses, including the human immunodeficiency virus (HIV), influenza virus, hepatitis C virus, and Zika virus. Curcumin has demonstrated potential to interfere with the replication cycle of these viruses, proving beneficial in viral suppression. Furthermore, *Curcuma longa*'s antifungal activity, exhibited against fungal species such as *Candida albicans* and *Aspergillus flavus*, adds to its antimicrobial repertoire. Finally, preliminary studies indicate an antiparasitic effect of *Curcuma longa*, seen particularly against protozoan parasites like *Plasmodium* and *Leishmania* species. However, more research is needed to understand the exact mechanism and potential uses in antiparasitic therapy [23, 24].

Mechanisms of antimicrobial action

The antimicrobial potency of *Curcuma longa* can be attributed to a complex interplay of mechanisms orchestrated by its bioactive constituents, mainly curcuminoids and essential oils. These mechanisms range from disrupting microbial cell structures to inhibiting essential microbial enzymes, and even modulating host immune responses [25, 26]. The most notable antibacterial mechanism of *Curcuma longa* is the disruption of bacterial cell membrane integrity. Curcumin and its related compounds have lipophilic properties that allow them to interact with the bacterial cell membrane. This interaction alters the fluidity and permeability of the membrane, eventually leading to leakage of cellular contents and cell death. Moreover, curcuminoids can interfere with the formation of bacterial biofilms, complex structures that protect bacteria from antimicrobial agents and the host immune system [27, 28]. Aside from structural disruption, *Curcuma longa* constituents can inhibit key microbial enzymes. For instance, some studies indicate that curcumin inhibits the bacterial DNA gyrase, an enzyme crucial for DNA replication and transcription in bacteria. By inhibiting this enzyme, curcumin prevents bacterial proliferation. Similarly, *Curcuma longa* has been found to inhibit certain viral enzymes like HIV-1 integrase and protease, crucial for the viral replication. *Curcuma longa* has also been shown to modulate the host immune system to enhance antimicrobial defences. Curcumin can regulate various signalling molecules involved in inflammation, such as cytokines, transcription factors, and enzymes, which can help the innate immune response of the body in clearing the pathogen. In addition, curcumin has antioxidant properties that can protect host cells from damage by microbial toxins [29, 30]. In terms of antifungal and antiparasitic action, *Curcuma longa* seems to disrupt the integrity of fungal cell walls and interfere with the energy metabolism of parasites, leading to their death. However, these mechanisms are not fully understood and warrant further investigation. The multi-targeted approach of *Curcuma longa* in combating microbial pathogens presents a promising path for the development of novel antimicrobial strategies, particularly in the era of increasing drug resistance [31, 32].

Potential applications and future perspectives

The broad-spectrum antimicrobial properties of *Curcuma longa* present a diverse range of potential applications. In the pharmaceutical industry, *Curcuma longa* extracts or isolated compounds could be developed into therapeutic drugs. Given the rise in antibiotic-resistant bacterial strains and the slow development of new antibiotics, *Curcuma longa* offers a promising alternative. Furthermore, its antiviral properties could contribute to treatments for various viral infections [3-7]. In the food industry, *Curcuma longa* could serve as a natural preservative. Synthetic preservatives often have adverse health effects and may lead to the development of resistant microbial strains. The antimicrobial properties of *Curcuma longa* could potentially inhibit the growth of foodborne pathogens and spoilage organisms, extending the shelf life of food products without introducing harmful synthetic compounds [1, 2, 8-10]. *Curcuma longa* could also play a significant role in agriculture. The increasing emergence of drug-resistant pathogens in crops has emphasized the need for effective and safe antimicrobials. As a natural antimicrobial, *Curcuma longa* could be used to control plant diseases, thereby reducing crop losses and contributing to sustainable farming practices [13, 15-16]. The application of *Curcuma longa* in animal health is another potential area. The widespread use of antibiotics in livestock has been linked to the emergence of antibiotic-resistant pathogens. The use of *Curcuma longa* as a feed additive could not only enhance animal health, but also reduce the need for antibiotics in animal farming, mitigating the risk of antibiotic resistance [15, 17, 19]. Despite the promising potential, the application of *Curcuma longa* is not without challenges. The bioavailability of curcumin, the main active compound in *Curcuma longa*, is relatively low due to its poor absorption, rapid metabolism, and systemic elimination. Enhancing the bioavailability of curcumin through various

techniques such as the use of adjuvants, nanoparticles, and structural analogues is a significant area of research. Furthermore, the safety and efficacy of *Curcuma longa* as an antimicrobial need to be validated through comprehensive clinical trials. It is envisaged that with advanced research and technology, the full potential of *Curcuma longa* as a natural antimicrobial agent can be realized [33-37].

Conclusion

In summary, *Curcuma longa* exhibits significant antimicrobial properties, making it a potential source for the development of new antimicrobial agents. However, further research is required to fully understand its mechanisms of action, improve its bioavailability, and explore its potential applications in different fields.

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Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the article and agreed to be responsible for all the aspects of this work.

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