Curcumin-A Review of Its Antibacterial Effect

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ABSTRACT
Curcumin is the main active component in Curcuma longa rhizome that is being recognized and used worldwide in many different forms for its multifunctional properties. A range of studies have reported the antimicrobial activity of curcumin, including antibacterial, antiviral, and antifungal activities. Here, we discuss the antibacterial activity and the action mode of curcumin, as well as the strategies to improve its bioavailability.

Keywords: Curcumin; Antibacterial Activity; Bioavailability

Mini Review
Curcumin, a polyphenol extracted from the rhizome of Curcuma longa, is in interest of researchers worldwide in recent years due to its various biological activities. It has been traditionally used in Asian countries in different products, including colorants, curries, tea, and cosmetics [1]. In some area, it is also used as medicine, due to its antioxidant, anti-inflammatory [2], antimicrobial [3], and anticancer activities [4]. Curcumin has been reported to have broad-spectrum antimicrobial activity against bacteria [5], viruses [6], and fungi [7]. In this review, we provide a brief overview of the studies regarding the antibacterial activity and the antibacterial action mode of curcumin, as well as the approaches for the improvement of its bioavailability.

Inhibitory Effect of Curcumin on Pathogenic Bacteria
Curcumin inhibits endodontic bacterial strains of Streptococcus mutans, Actinomyces viscosus, Lactobacillus casei, Porphyromonas gingivalis, Prevotella intermedia, Enterococcus faecalis, with MIC values of 333.33, 167.67, 125, 125, and 208.33 mg/L, respectively [8]. The S. mutans biomass and its biofilm formation can be effectively inhibited by the application of curcumin [9]. Similar results are also observed on several periodontopathic bacteria, including Fusobacterium nucleatum and Treponema denticola, which were suppressed by curcumin in a dose dependent manner [10]. Curcumin is 32-fold more potent than fluconazole in the inhibition of the growth of Paracoccidioides brasiliensis [11], which is the pathogen that causes one of the most prevalent systemic mycoses in Latin America - paracoccidioidomycosis [12]. Curcumin shows an inhibitory property against some food borne pathogenic and spoilage bacteria such as Escherichia coli, Versinia enterocolitica, Streptococcus aureus, Bacillus subtilis, and B. cereus [13]. The inhibitory effect is also observed on Listeria monocytogenes and Salmonella typhimurium [14].

Using the curcumin as a complementary compound in combination with other existing medicines to control bacteria growth has attracted attentions from researchers. The application of the combination of subtilosin with curcumin on L. monocytogenes infection reaches a lower effective dose compared with the utilization of subtilosin alone [15]. Synergistic effect of curcumin and antibiotics oxacillin, ampicillin, ciprofloxacin, or norfloxacin used against methicillin-resistant S. aureus infection is confirmed by Mun et al. [16]. Curcumin combined with (-)-epigallocatechin gallate notably reduces the biofilm formation in wastewater bacteria [17].

The activation of photosensitive substances by light in the presence of oxygen results in the production of reactive radicals, which are capable of inducing cell death. The effect of photosensitization mediated by curcumin on bacteria inhibition
has been investigated. Curcumin at the concentration of 75 μM in combination with a blue LED effectively inhibits the growth of *S. aureus*, *Aeromonas hydrophila*, *S. typhimurium*, *E. coli*, and *Pseudomonas aeruginosa* [18]. *S. mutans* and *Lactobacillus acidophilus* are reported to be sensitive to curcumin in the presence of blue light; however, the utilization of curcumin in the dark was not toxic to the bacteria [19].

**Action Mode of Curcumin against Bacteria**

**Membrane Disruption:** Studies show that curcumin inhibited bacteria by damaging bacterial membrane. A membrane permeabilization assays confirms that the addition of curcumin results in membrane leakage in both Gram-negative and Gram-positive bacteria, including *S. aureus*, *Enterococcus faecalis*, *E. coli*, and *P. aeruginosa* [5]. However, according to the study of Yun et al. [20], curcumin induces membrane damage at relatively high concentrations, but there is no effect at the MIC.

**Reactive Oxygen Species (ROS) Induction:** Curcumin significantly inactivates *B. cereus* and *E. coli* by inducing significant production of ROS, including singlet oxygen and hydroxyl radicals [21]. At the MIC (12 μg/mL), curcumin-treated cells display various apoptotic markers, including ROS accumulation, membrane depolarization, and Ca²⁺ influx [20].

**Efflux Pump Inhibition:** Curcumin is reported to function as an efflux pump inhibitor in a multi drug resistant pathogenic bacteria *P. aeruginosa* [22]. Similar result was also been observed by Eshra et al. [23]. Joshi et al. [24] also suggested that curcumin inhibits several bacterial efflux pumps in *s. aureus* effectively.

**Cell Division Interuption:** Curcumin has been shown to inhibit bacterial cell proliferation by perturbation of FtsZ assembly in the *B. subtilis* 168, suggesting that it inhibits bacterial cytokinesis [25]. The study on *E. coli* and *B. subtilis* by Kaur et al. [26] also demonstrated that curcumin suppress the FtsZ assembly, leading to disruption of prokaryotic cell division. Moreover, curcumin decrease the production of extracellular polysaccharide in the short term. The expression of genes related to extracellular polysaccharide synthesis, carbohydrate metabolism, adherence decreased after curcumin in treatment [9].

**Enhancement of the Bioavailability of Curcumin**

Though curcumin has been considered as a promising antibacterial agent and has the potential to be used for clinical treatment, one of the major problems with ingesting curcumin by itself is its poor bioavailability, which appears to be primarily due to poor absorption, rapid metabolism, and rapid elimination [27]. Enhancing the bioavailability of curcumin has received rather concerns in recent years. Using some agents to form a curcumin complex has been tested to improve the bioavailability of curcumin. For instance, piperine enhances the bioavailability of curcumin by 20 folds [28]. Microemulsions of curcumin fabricated from food-grade ingredients, such as Tween 20, lecithin, vitamin E, and ethanol, increase the water dispersibility of curcumin by 1,000 to 10,000 folds [29]. Nanocurcumin has also been considered as an alternative to improve the bioavailability of curcumin [30]. Curcumin nanoparticle with the size of 2–40 nm exhibits more significant antimicrobial activity against *S. aureus*, *E. coli*, and *P. aeruginosa* [31]. Encapsulation of curcumin in liposomes enhances its water dispersibility and increases its chemical stability, water dispersibility and antioxidant and anti-inflammatory properties [29].

**Conclusion**

The extensive antimicrobial effects of curcumin against pathogenic bacteria suggest it has the potential to be considered as a candidate for the clinical therapies of bacterial infections. Exploration of the action mode of curcumin against bacteria and strategies that are developed to enhance the curcumin bioavailability to improve its application effects become the focuses of researches.

**Conflicts of Interest**

The authors declare no conflict of interest.

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