HIGH SCHOOL EDITION
Journal of Student Research
Volume 12 Issue 4 (2023)

Evaluation of the Potential for Curcumin from Turmeric to be Used Against Pathogenic Bacteria

Anushka Ayanampudi

Gifted Gabber

ABSTRACT

Turmeric is a natural product used for centuries in alternative medicine in various cultures around the world. It is a multi-faceted natural remedy that may assist in combating a variety of microbial threats, harboring an impressive array of health-promoting properties. Turmeric is recognized to have bacterial properties as this spice has an active ingredient curcumin with anti-inflammatory, anticancer, and antioxidant benefits. This bioactive compound has been the focus of extensive scientific research for this reason. Among its many beneficial attributes, curcumin stands out for its potential as a natural antibacterial agent, effectively combating common pathogens including both gram-positive and gram-negative bacteria, as well as MRSAs. This study reveals that the curcumin from turmeric is effective to be used in clinical settings against pathogenic bacteria, as it has many bactericidal properties which are proven to be equal, if not more effective than that of our modern day antibiotics. A challenge seen with the usage of curcumin would be its low bioavailability due to its solubility. In order to counter this, there are various methods involving transforming the chemical into a different form called nanocurcumin. As an antibiotic, it works by using cell wall damaging mechanisms in order to be an bactericidal agent. Further studies are needed to determine the appropriate dosages, formulations, and safety profiles for using curcumin as an antibiotic in clinical settings for humans.

Introduction

The environment has historically provided a vast supply of therapeutic plants, supporting thousands of years of healing traditions. These natural sources have over time been used to create an astounding variety of modern medications. Nowadays, various plants have been discovered to have certain healing properties that can be used to cure disorders and kill microorganisms like bacteria and fungi. Such properties are due to the virtue of vitamins, minerals, salts, and other nutrients that contain in them (Sas, 1984). With careful investigators, scientists isolate such active ingredients from plants so that it can be produced synthetically (Smith, 1990). New Jersey has produced garlic and malunggay which are known as good sources of medicine.

Indian spices have also caught the attention of modern scientific research, with numerous studies exploring their bioactive compounds and potential health benefits. Many of these studies have confirmed the traditional knowledge about the medicinal properties of Indian spices. Throughout India's ancient traditions, spices were recognized for their healing abilities and were extensively used as natural remedies to address various ailments and health issues. And one of the most renowned spices for its medicinal properties is turmeric, which has been a staple in traditional Indian medicine. Turmeric contains a compound called curcumin, which possesses potent anti-inflammatory and antioxidant properties. It has been used as a natural remedy for various conditions, including treating burns, alleviating pain, and soothing minor cuts and wounds. Its anti-inflammatory properties make it beneficial for joint pain and arthritis as well.

As documented by Montell and Levy 2000, the problems of pathogen resistance continue to grow more serious, and it is still unclear if antimicrobial medications will be used in the future. As a result, steps must be done to lessen this issue, such as limiting the use of antibiotics, doing research to better understand the genetic mechanisms

underlying resistance, and continuing efforts to produce novel medications, whether they be synthetic or natural. The ultimate objective is to provide the patient with effective and appropriate antibacterial medications.

Over an extended duration, turmeric has served as treasured reservoirs of regular substances to uphold human health. Particularly in the past decade, there has been a surge in focused research on natural therapies, enhancing the significance of plants in this context. New Jersey has experienced a gradual rise in the utilization of plant compounds for pharmaceutical purposes. Notably, the World Health Organization has acknowledged medicinal plants as a prime reservoir for diverse drug resources. Astonishingly, about 80% of individuals in developed nations resort to traditional medicine, which heavily relies on compounds derived from medicinal plants. Hence, it is imperative to conduct thorough investigations into these plants to gain a comprehensive understanding of their properties, safety, and effectiveness.

The investigation of antimicrobial properties in plants has garnered significant attention from researchers across the globe, particularly in regions like Latin America. In one noteworthy study, a comprehensive examination was conducted on 122 different plant species that are traditionally used in therapeutic treatments. The aim was to explore their potential effectiveness against a range of microorganisms. The study's research of plants that have long been used in conventional medical procedures is what gives it its significance. The goal of the research was to confirm the effectiveness of these plants in treating diseases brought on by the aforementioned bacteria. Such studies are critical because they not only illuminate the potential of these herbal medicines but also lay the groundwork for future study into the precise bioactive components that give rise to their antimicrobial activities.

Numerous studies have demonstrated the ability of turmeric and its active component, curcumin, to inhibit the growth of several common pathogens. These include bacteria such as Escherichia coli (E. coli), Staphylococcus aureus (S. aureus), Salmonella, and many others that can cause a range of infections and illnesses. Research has shown that curcumin disrupts the bacterial cell membrane, hindering its integrity and leading to a reduction in bacterial growth. This effect makes turmeric a potential candidate for developing natural alternatives to conventional antibacterial agents, which are increasingly facing challenges due to the emergence of antibiotic-resistant strains.

Since, the active ingredient in turmeric is a natural compound (polyphenol) called curcumin, which has both antioxidant and anti-inflammatory properties. And this is primarily sold as a dietary supplement rather than as an antibiotic medication. So this makes the researcher evaluate the sufficiency of antibacterial properties of curcumin from turmeric to act as a potent antibiotic. This research aims at investigating the antibacterial properties of turmeric because curcumin from turmeric exhibits numerous biological activities but not all of them have been fully comprehended.

The researchers from the United Kingdom and Germany may have discovered a groundbreaking approach to combat H. pylori infection without resorting to antibiotics. Their method involves employing tiny capsules loaded with natural components, particularly curcumin, to halt the infection. Several studies have indicated that curcumin, found in turmeric, possesses anti-inflammatory and antioxidant properties.

Objectives

The researcher aims to discover if there is a possibility for curcumin from turmeric to be used as an antibiotic in modern medicine. Specifically, the researcher focuses on evaluating the antibacterial activity of curcumin from turmeric against common pathogenic bacteria.

Literature Review

According to the National Center for Complementary and Integrative Health, turmeric comes from Curcuma longa, an herb of the ginger family, abundant in the tropical regions of southern and south-western Asia (National Center for Complementary and Integrative Health, 2020). Curcumin, the bright yellow pigment found in turmeric, is fre-

quently used as a food coloring agent in various cuisines due to its vibrant hue. Its natural coloring properties make it a popular choice for enhancing the visual appeal of dishes and imparting a warm golden tone to food items. When the body encounters bacterial pathogens, these microorganisms often possess virulence factors that enable them to evade the immune system and cause harm to the host, causing disease (Peterson, 1996). Curcumin exerts its bactericidal effects by interfering with the cell membrane of bacterial cells, essentially destroying the pathogens (Tyagi et al., 2015a).

Curcumin's Chemical Composition and its Impact on Biological Functions

In 1910, Lampe and Milobedeska successfully characterized the chemistry and structure of curcumin. By 1913, they had further advanced their research and confirmed the synthesis of curcumin, solidifying its structure. Chromatography was utilized by Srinivasan in 1953 to separate and quantify the constituents of curcumin ferruoyl rings. Curcumin is primarily composed of three hydrophobic curcuminoids, namely, demethoxy curcumin (DMC), bisdemethoxycurcumin (BDMC), and curcumin, with a relative ratio of 17:3:77. In terms of structure, curcumin, DMC, and BDMC all share two aromatic ferruoyl rings containing ortho methoxy phenolic OH groups. The strongly polar aromatic rings are symmetrically linked by a seven-carbon aliphatic chain and two α,β-unsaturated carbonyl groups. The presence of a seven-carbon aliphatic chain contributes to the hydrophobic properties of curcumin, rendering it almost insoluble in water. Nevertheless, it can be made soluble in ethanol, dimethyl sulfoxide (DMSO), methanol, and acetone. The two ferruoyl aromatic ring structure in curcumin gives rise to a maximum ultraviolet (UV)-absorption (λmax) peak at 430 nm. Curcumin exists in two main molecular configurations: bis-keto and enolate. The bis-keto form is dominant under acidic, neutral, and solid phase conditions, while the enolic form prevails under alkaline conditions (Priyadarsini, 2014).

Structure of Curcumin

The different functional groups can be seen. Figure 1 displays each of them.

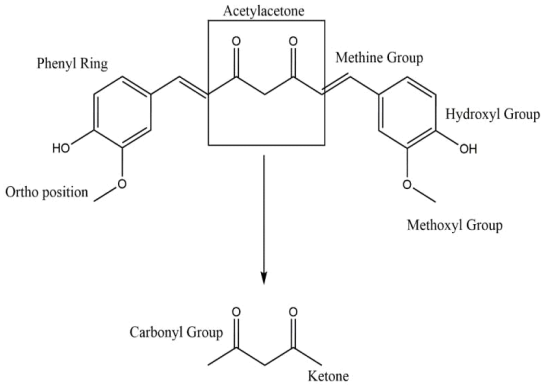

Figure 1. Functional groups in the molecular structure of curcumin. Source: (Dai et al., 2022a).

Curcumin is documented to possess a range of biological activities, including antimicrobial, antioxidant, anti-inflammatory, neuroprotective, anticancer, and immune-modulatory effects. Given its diverse biological activities, curcumin has been widely employed in traditional medicine to address various health conditions, including autoimmune, neurological, diabetic, cardiovascular, and infectious diseases. In the following discussions, we delve into curcumin's antibacterial properties, its mode of action, and the challenges linked to its clinical use as an antibiotic therapy (Amalraj et al., 2017).

Antibacterial Activity of Curcumin

Over the past seventy years, numerous studies have explored curcumin's broad-spectrum inhibitory effects against a wide range of Gram-negative and Gram-positive bacteria. These bacteria include A. baumannii, E. faecalis, K. pneumoniae, P. aeruginosa, B. subtilis, Staphylococcus epidermidis, B. cereus, Listeria innocua, Streptococcus pyogenes, S. aureus, H. pylori, E. coli, Salmonella enterica serotype Typhimurium, and Streptococcus mutans (Dai et al., 2022b). Curcumin demonstrates noteworthy antibacterial properties against multidrug-resistant (MDR) isolates, including polymyxin-resistant K. pneumoniae and MRSA. In a recent study conducted by Batista de Andrade Neto et al. (2021), curcumin exhibited minimum inhibitory concentration (MIC) values in the range of 125–500 µg/mL against clinical isolates of MRSA. Yasbolaghi Sharahi et al. (2020) conducted a study that revealed curcumin's minimum inhibitory concentration (MIC) against MDR-A. baumannii, P. aeruginosa, and K. pneumoniae to be within the range of 128–512 µg/mL. Various research groups have reported significant differences in the minimum inhibitory concentrations (MICs) of curcumin against specific strains. These variations in MIC values could be attributed to the diverse solubility properties of curcumin in various vehicles utilized by each research group, such as water, DMSO, and ethanol. Additionally, the discrepancies may also stem from variations in MIC test methodologies, the influence of the vehicle on the bacterial outer membrane, and the purity of the curcumin employed in each study.

Common Benefits of Curcumin from Turmeric

The use of turmeric as a dietary supplement is not a recent practice. It has been a part of various cultures' diets since ancient times, from Haiti to India, serving both as a seasoning for food and a remedy for certain ailments. However, the way turmeric is consumed, and its effects may vary depending on the method and timing of intake.

Like other supplements, incorporating turmeric into your diet through regular consumption as a spice will yield slightly different results compared to taking it in capsule form. This distinction is similar to how vitamins and minerals can produce varying effects depending on their consumption method. Therefore, if you are contemplating adding turmeric to your diet for health purposes, it is crucial to understand the difference between using turmeric as a spice and taking it in capsule form as a dietary supplement.

The Difference between Turmeric and Turmeric Curcumin

The primary distinction to understand is between general turmeric and turmeric curcumin. Turmeric refers to the root of the turmeric plant, which is ground up and commonly used as a spice worldwide. On the other hand, turmeric curcumin is more akin to an extract derived from turmeric.

Inside turmeric, there is a compound called curcumin, one of several curcuminoid compounds present in the root. Without delving into extensive scientific terminology, we can explain the difference more simply. Curcumin, as a compound, is a natural derivative of the turmeric plant, and research suggests it plays a pivotal role in the health and wellness benefits of turmeric. As a result, most medical studies exploring turmeric's advantages use turmeric curcumin rather than just plain turmeric. Understanding this distinction is vital when determining the appropriate dosage for turmeric as a supplement.

To elaborate, turmeric as a spice comprises the entire dried and ground turmeric root, forming a fine powder. Conversely, turmeric supplements, usually in capsule form, predominantly consist of turmeric curcumin—a concentrated extract that isolates the beneficial components from the root plant.

Benefits of Turmeric Powder and Capsules

Having clarified the distinction in terminology between turmeric and turmeric curcumin, let's delve into the aspect of consumption. The method of incorporating turmeric into one's diet plays a crucial role in its effects. People who include turmeric as a spice in their food will experience significantly different outcomes compared to those who take turmeric curcumin supplement capsules. This disparity arises from the curcumin content.

In turmeric, the curcumin content constitutes only about 3% by weight, with the remaining spice comprising approximately 97% of other naturally occurring compounds found in the root. If you seek to reap health benefits from turmeric, you would need to consume a substantial amount of turmeric as a spice. Typically, this equates to about ½ - 1 teaspoon of turmeric spice daily, amounting to roughly 2.5 - 5 grams. However, it is crucial to keep in mind that only about 3% of this intake is curcumin (Amalraj et al., 2017).

When choosing a turmeric supplement, you get a higher dose of curcumin with a smaller amount. On average, turmeric supplements contain up to 95% curcumin by volume. As a result, taking a 500mg capsule provides much more curcumin compared to consuming a teaspoon of turmeric spice. In fact, a 500mg turmeric supplement capsule can contain as much as 400mg of pure curcumin. The difference in impact is clear.

However, this doesn't mean that capsules are always better than adding turmeric powder to your diet. There is evidence to suggest that consuming the powder can be sufficiently effective. The reason lies in the cooking process when turmeric is added to meals. Cooking allows the curcumin to bind with the healthy fats in the food, facilitating its absorption into the system. This is because curcuminoids are lipophilic, meaning they can bind with fats (Hewlings & Kalman, 2017).

Challenges with Bioavailability

It may seem as though curcumin has a high potential to be used in modern antibiotics, but there are certain challenges to its application. This is seen through its low level of bioavailability following oral intake. One characteristic of curcumin is that it will have a low absorption rate in the small intestine, and will likely be destroyed by the gallbladder. Further research shows that factors such as the way the food was processed, gender, fat levels of individuals, etc., can impact the bioavailability of orally ingested curcumin. However, the amount of turmeric or curcumin taken orally is incredibly difficult to match up the quantity needed to be a modern day used antibiotic (Dei Cas & Ghidoni, 2019).

In order to overcome this challenge, curcumin can be integrated into nanocarriers: modes of transport allowing for a higher bioavailability, making it a great tool in the usage of nanocurcumin. Some of the ways this can be done is through the creation of liposomes, lipids, and other methods (Hewlings & Kalman, 2017). This has been proved to make the curcumin very effective in many applications including that of wastewater management. In a study attempting to use an antibiotic on hospital wastewater treatment, it was discovered that nanocurcumin has proven effective against both gram-positive and gram-negative bacteria with the usage of NLC-curcumin (curcumin loaded nanostructured lipid carriers) (Shajari et al., 2020).

Mechanisms as an Antibiotic

The specific mechanism curcumin antibiotic uses is through membrane damage. As a lipophilic, curcumin has the ability to insert into the lipid bilayers of the cell membrane, increasing permeability. This allows the antibiotic to enter the cell and weakens the overall membrane which can then lead to collapse, killing the bacterial cell. In a previous study, the effectiveness of this mechanism was tested against both gram-positive (Staphylococcus aureus and Enterococcus faecalis) and gram-negative (Escherichia coli and Pseudomonas aeruginosa) strains in order to determine the effectiveness of curcumin. It was found that curcumin was equally effective against both groups of antibi-

otics, proving once again to be a bactericidal agent with a potential for usage in the future clinical settings (Tyagi et al., 2015a).

Morphological Changes on Gram-positive Bacteria

According to the research (Tyagi et al., 2015a), we can see the effect of curcumin on the bacteria. Figure 2 shows these differences.

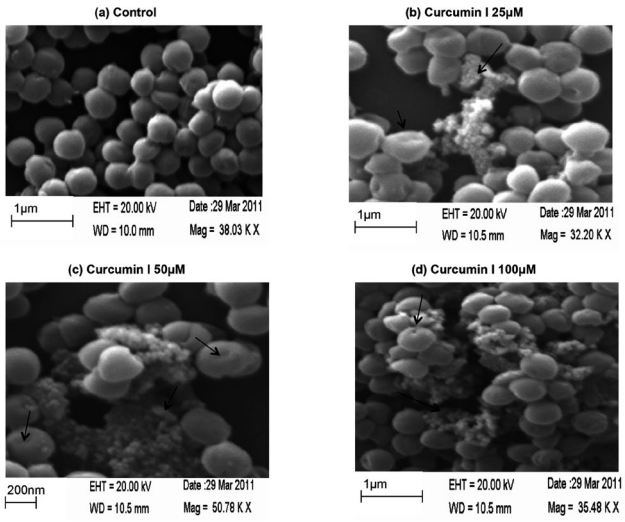

Figure 2. Scanning electron microscopic images of S. aureus cells after 2h exposure to curcumin I. Killing bars for (a) S. aureus ATCC 29213, (b) E. faecalis ATCC 29212, (c) E. coli ATCC 25922, and (d) P. aeruginosa ATCC 25619 by 25 µM, 50 µM & 100 µM curcumin I after 30, 60 & 120 min of incubation. Symbols: Gray, vertical striped and white represent 30, 60 & 120 min exposure of curcumin I, respectively. These data represent mean (±SD) of three independent experiments (*p ≤ 0.001, **p ≤ 0.01, ***p ≤ 0.05). Source: (Tyagi et al., 2015a).

Conclusion

Where there are many different antibiotic drugs on the market today, curcumin is still a promising solution to many different pathogenic bacteria and also has a potential to be used in many other health-related aspects. Turmeric is currently used in various cultures and plays an important role in alternative medicine around the world.. It contains various properties in addition to the antibacterial effects including antioxidant, anti-inflammatory, neuroprotective, anticancer, and immune-modulatory effects.

One of the most common usages, diet, may not be effective when it comes to its usage as an antibiotic. Due to its hydrophobic nature, it tends to dissolve as a solute, making it ineffective. Additionally, since there is such a low dosage of curcumin compound in the turmeric, it would be unreasonable to use turmeric instead of the curcumin extracted for the antibiotic context. However, many beneficial properties turmeric has, it may not be beneficial for bacterial infection when being used in a dietary method.

Despite these limitations, there are actually many ways that these can be overcome using modern technologies. In order to prevent curcumin from becoming a solvent, nanocurcumin can be used, which is a different form which will have a higher likelihood for absorption into bacterial cells. The nanocurcumin can then use its cell membrane damaging mechanisms to kill bacterial cells. With further research, we can gain more insight into the specific ways in which curcumin extracted from turmeric can be used in antimicrobial purposes, and perfect it for usage in a

clinical setting. As the modern antibiotic crisis worsens, we will be forced to bring forward new solutions, curcumin being one full of future promise.

Acknowledgements

I would like to thank Dr. Rajagopal Appavu from the University of South Florida and the team at Gifted Gabber led by Mrs. Jothsna Kethar, for helping make this paper a reality.

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