ANTIMICROBIAL PROFILE ON CLINICAL NASAL ISOLATES AND ANTIOXIDANT PROPERTIES OF ETHANOL AND AQUEOUS EXTRACTS OF *Curcuma longa* RHIZOMES

BY

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FACULTY OF LIFE SCIENCES

UNIVERSITY OF BENIN,

BENIN CITY

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A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF SCIENCE LABORATORY TECHNOLOGY, FACULTY OF LIFE SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE DEGREE (B.SC) IN SCIENCE LABORATORY TECHNOLOGY (MICROBIOLOGY TECHNIQUE).

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CERTIFICATION

This is to certify that this project work was carried out by Faith Ekemeihen OISAMAYE with matriculation number, LSC2006830 Department of Science Laboratory Technology (Microbiology Technique), Faculty of Life Sciences, University of Benin, Benin City.

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DEDICATION

With profound gratitude, I dedicate this work to the Almighty God, whose grace, wisdom, and unwavering support have guided me through this journey. His blessings have been my strength, providing me with perseverance and direction even in challenging times.

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ABSTRACT

This study investigates the antimicrobial and antioxidant properties of ethanol and aqueous extracts of *Curcuma longa* (turmeric) rhizomes against clinical nasal isolates. The research aims to evaluate the efficacy of these extracts in combating microbial infections and their potential as natural antioxidants. The chemical composition of the extracts was characterized using Gas Chromatography-Mass Spectrometry (GC-MS), revealing a diverse array of bioactive compounds, including terpenes, fatty acids, phenolic compounds, and sterols. Antimicrobial activity was assessed using the broth dilution method, while antioxidant potential was determined through the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay. The results indicate that the ethanolic extract exhibited significant antimicrobial activity against nasal isolates, including *Micrococcus species*, *Moraxella catarrhalis*, and *Streptococci species*. Additionally, the aqueous extract demonstrated strong antioxidant properties, with a linear increase in activity correlating with concentration. The findings suggest that *Curcuma longa* extracts, particularly the ethanolic extract, hold promise as natural antimicrobial agents, while the aqueous extract shows potential as a potent antioxidant. This study underscores the therapeutic potential of *Curcuma longa* in addressing antibiotic resistance and oxidative stress-related conditions, providing a scientific basis for its traditional use in medicine and its application in modern healthcare.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Curcuma longa, commonly known as turmeric, is a flowering plant in the Zingiberaceae family, which is native to Southeast Asia. Its rhizomes, which are harvested, dried, and ground, are widely recognized for their distinctive yellow color and their use in cooking and traditional medicine (Patel and Goyal, 2015). Turmeric's broad application can be attributed to its bioactive components, primarily curcumin, which is responsible for many of its pharmacological effects, including anti-inflammatory, antioxidant, and antimicrobial activities (Sharma *et al.,* 2019). In modern times, turmeric has gained global recognition not only for its culinary uses but also for its potential therapeutic properties, leading to a surge in scientific research aimed at understanding its medicinal benefits. With the rise of antibiotic-resistant pathogens and the growing demand for natural products, *Curcuma longa* has garnered considerable attention as a source of novel antimicrobial and antioxidant agents (Nazzaro *et al.,* 2013).

The key bioactive components of turmeric are curcuminoids, with curcumin being the most prominent. Curcumin, a polyphenolic compound, constitutes about 2–5% of the dried rhizome, though this concentration can vary depending on the cultivation conditions (Calo *et al.,* 2015). Other curcuminoids, such as demethoxycurcumin and bisdemethoxycurcumin, are present in smaller amounts but contribute to the herb's overall medicinal properties. In addition to curcuminoids, turmeric contains volatile oils, such as turmerones, which also exhibit therapeutic effects, including anti-inflammatory, antioxidant, and antimicrobial

activities (Calo *et al.,* 2015). The medicinal properties of *Curcuma longa* are attributed to its ability to act on various biological pathways. Curcumin, for instance, has been shown to modulate multiple signaling molecules involved in inflammation, oxidative stress, and cell survival. These effects make turmeric a potent candidate for treating conditions such as arthritis, cardiovascular diseases, neurodegenerative disorders, and cancer (Jiang *et al.,* 2014).

Turmeric has long been used in traditional medicine to treat a variety of ailments, ranging from digestive issues to skin disorders. In Ayurveda, turmeric is considered a "heating" herb that is used to balance the doshas (Vata *et al.,*) and promote overall health. Its anti-inflammatory and antioxidant properties are central to its therapeutic uses. Turmeric has been traditionally used to treat conditions such as arthritis, indigestion, liver disease, wounds, and respiratory infections (Ghani *et al.,* 2020). Scientific studies have substantiated many of these traditional uses, particularly in the context of its anti-inflammatory and antioxidant properties. Curcumin, the active compound in turmeric, has been shown to inhibit the activity of inflammatory cytokines, such as TNF-α and interleukins, and to reduce oxidative stress by scavenging free radicals (Sharma *et al.,* 2019). This makes turmeric particularly useful in the management of chronic inflammatory conditions like rheumatoid arthritis and inflammatory bowel diseases. Furthermore, the antimicrobial activity of turmeric has become an area of significant interest, particularly in the face of increasing antibiotic resistance. Numerous studies have demonstrated that turmeric extracts, especially those containing curcumin, possess antimicrobial properties against a wide range of pathogens, including bacteria, fungi, and viruses (Nazzaro *et al.,* 2013).These findings suggest that

Curcuma longa could serve as an alternative or adjunct to conventional antimicrobial treatments, particularly in managing infections caused by multidrug-resistant organisms.

In addition to its antimicrobial properties, *Curcuma longa* is renowned for its antioxidant activity. Antioxidants are substances that can neutralize free radicals and prevent oxidative damage to cells, which is a key factor in the aging process and the development of chronic diseases such as cancer, cardiovascular disease, and neurodegenerative disorders (Duan and Wu, 2016). The antioxidant activity of turmeric is primarily attributed to curcumin, which has been shown to inhibit oxidative stress by scavenging reactive oxygen species (ROS) and enhancing the body's own antioxidant defenses (Patel and Goyal, 2015). Turmeric's antioxidant properties make it a valuable dietary supplement for reducing oxidative damage and inflammation. Several studies have shown that turmeric extract can increase the levels of antioxidant enzymes such as superoxide dismutase (SOD) and catalase, while reducing markers of oxidative stress in tissues (Jiang *et al.,* 2014). This has led to its widespread use as a health supplement aimed at promoting general well-being and preventing the onset of chronic diseases.

The growing global health crisis related to antibiotic resistance and the rise of chronic diseases has sparked a renewed interest in natural products with antimicrobial and antioxidant properties. Turmeric, particularly due to its bioactive compound curcumin, has shown significant potential as a natural alternative to synthetic pharmaceuticals (Nazzaro *et al.,* 2013). This study aims to contribute to the growing body of evidence supporting the medicinal benefits of *Curcuma longa*, particularly in the context of its antimicrobial and antioxidant activities. By examining the properties of turmeric extracts, this research may

provide valuable insights into the plant's therapeutic potential and its application in healthcare

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1.2 Aim of the Study

The aim of this study is to evaluate the antimicrobial and antioxidant properties of *Curcuma longa* extracts, specifically focusing on the effectiveness of ethanol and aqueous extracts.

The specific objectives of the study were to

1. characterize the plant extracts using GC-MS (Gas Chromatography-Mass Spectrometry):
2. determine the antimicrobial properties of the plant using broth dilution and agar well diffusion methods:
3. determine the antioxidant properties of the plant using the DPPH (2,2-diphenyl1-picrylhydrazyl) assay:

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction to Curcuma longa (Turmeric)

Curcuma longa, commonly known as turmeric, is a perennial herb belonging to the Zingiberaceae family, native to Southeast Asia, particularly India. It is cultivated primarily for its rhizomes, which are the underground stems of the plant. These rhizomes, characterized by their vibrant yellow-orange color, have long been revered not only for their culinary uses but also for their wide range of medicinal properties. The turmeric plant grows to a height of about one meter, with large, lance-shaped leaves and yellow flowers. The rhizomes, which resemble ginger root but are distinguished by their distinct color, are harvested, dried, and ground to produce the turmeric powder commonly used in cooking and in the production of health supplements, cosmetics, and pharmaceuticals (Patel and Goyal, 2015). Turmeric is often referred to as “Indian saffron” due to its deep yellow hue, which is also used as a natural dye in textiles and food products. Historically, turmeric has held immense importance in several ancient civilizations. In India, it has been used for over 4,000 years in Ayurvedic medicine, one of the world’s oldest healing systems, where it is believed to balance the three doshas (Vata, Pitta, and Kapha). Turmeric is considered a sacred herb, often used in religious rituals and ceremonies. It has been used to treat a wide variety of ailments, including digestive disorders, skin diseases, and inflammatory conditions (Ghani *et al.,* 2020). In addition to its medicinal uses, turmeric has been a key component of traditional cooking in Southeast Asia, where it imparts a unique flavor and vibrant color to dishes. In modern times, turmeric has gained global recognition not only for

its culinary applications but also for its pharmacological properties. The active compounds in turmeric, particularly curcumin, are responsible for much of its therapeutic effects. Curcumin, a polyphenolic compound, has been the subject of extensive scientific research due to its proven anti-inflammatory, antioxidant, anticancer, antimicrobial, and neuroprotective properties (Sharma *et al.,* 2019). These bioactive compounds have made turmeric a highly sought-after natural remedy for managing chronic diseases, reducing oxidative stress, and promoting overall health.

With increasing interest in natural alternatives to synthetic pharmaceuticals, *Curcuma longa* has become a focal point in the field of nutraceuticals and herbal medicine. Its bioactive compounds have shown potential in the treatment of conditions ranging from arthritis and diabetes to cardiovascular diseases and neurodegenerative disorders (Jiang *et al.,* 2014). Furthermore, the growing concern over the rise of antibiotic-resistant pathogens has further spotlighted turmeric as a potential natural antimicrobial agent, as it has demonstrated efficacy against a broad spectrum of bacteria, fungi, and viruses (Nazzaro *et al.,* 2013). The therapeutic potential of turmeric is not limited to its active compound curcumin. The plant also contains other important constituents such as turmerones, zingiberene, and volatile oils, which enhance its biological effects. These compounds work synergistically to provide a broad range of benefits, making turmeric an essential part of both traditional and modern medicine. As scientific research continues to uncover the full spectrum of turmeric's medicinal properties, its role in modern healthcare is poised to expand, providing a valuable alternative or adjunct to conventional treatments.

2.2 Botanical and Chemical Composition

Turmeric belongs to the Zingiberaceae family, which also includes ginger, cardamom, and galangal. Its botanical classification is as follows:

Kingdom: Plantae

• Division: Angiosperms

• Class: Monocots

• Order: Zingiberaceae

• Family: Zingiberaceae

• Genus: Curcuma

• Species: C. longa

The most notable chemical constituents of *Curcuma longa* are the curcuminoids, with curcumin being the most significant. Curcumin is a polyphenolic compound that imparts the characteristic yellow color to turmeric and is largely responsible for its medicinal properties. Curcumin is derived from the rhizomes of the plant and is present in varying concentrations depending on the plant's growing conditions and the extraction method used (Patel and Goyal, 2015). Other curcuminoids, such as demethoxycurcumin and bisdemethoxycurcumin, also contribute to the plant's pharmacological effects, although curcumin is the most extensively studied and most abundant. Turmeric essential oil is another important source of bioactive compounds. The essential oil contains compounds such as turmerones (α- and β-turmerone) and zingiberene, which also possess various biological activities, including anti-inflammatory, antimicrobial, and antioxidant properties (Calo *et al.,* 2015). These

compounds work synergistically with curcumin to enhance the overall therapeutic effects of turmeric, making it a multifaceted plant with a diverse range of bioactive components.

2.3 Geographical Distribution and Cultivation

Curcuma longa is predominantly cultivated in tropical and subtropical regions. India is the largest producer of turmeric, accounting for approximately 80% of the world's supply. Other countries where turmeric is cultivated include Indonesia, the Philippines, China, and some parts of Africa (Ghani *et al.,* 2020). The plant thrives in well-drained, fertile soils and requires a warm, humid climate with regular rainfall. It is usually grown at altitudes ranging from sea level to 1,500 meters in areas with rich, loamy soil. In India, turmeric cultivation is primarily concentrated in the states of Andhra Pradesh, Tamil Nadu, Karnataka, Odisha, and West Bengal. The production of turmeric is seasonal, with harvesting typically occurring between March and May. After harvesting, the rhizomes are boiled, dried, and ground into powder for sale in both domestic and international markets. The rhizomes are also used in the production of turmeric essential oils and extracts for medicinal and cosmetic purposes (Sharma *et al.,* 2019). Turmeric cultivation is not only an important agricultural activity in these regions but also a significant part of the local economy. The demand for turmeric continues to rise, both as a spice in cooking and as a raw material for pharmaceutical, cosmetic, and health supplement industries. The increasing interest in the medicinal properties of turmeric has led to efforts to improve cultivation practices, enhance curcumin yield, and develop new processing methods to preserve its bioactive compounds.

2.4 Historical and Cultural Significance

Turmeric's significance extends far beyond its culinary and medicinal applications. It has been an integral part of cultural rituals and religious ceremonies in India and other parts of

Southeast Asia for centuries. In India, turmeric is considered auspicious and is used in various religious and social rites, including weddings, festivals, and housewarming ceremonies. The bright yellow color of turmeric symbolizes purity, fertility, and auspiciousness, and it is often used in the application of tilak (a mark on the forehead) during religious rituals. In Ayurvedic medicine, turmeric is regarded as a "heating" herb that stimulates digestion, improves circulation, and balances the doshas. It is prescribed in a variety of forms, including powders, pastes, teas, and oils, for a wide range of ailments, such as digestive issues, skin diseases, and joint pain. In Traditional Chinese Medicine (TCM), turmeric is also used for its therapeutic properties, particularly for improving blood circulation and relieving pain (Ghani *et al.,* 2020). With the increasing popularity of herbal remedies and natural healing in the West, turmeric has gained widespread attention as a "superfood." It is used in various dietary supplements, skincare products, and functional foods, capitalizing on its perceived health benefits. Modern research has now substantiated many of the claims made by traditional practitioners, affirming turmeric's place in the contemporary medical landscape as a powerful natural remedy.

2.5 Medicinal Properties of *Curcuma longa*

Turmeric has long been recognized for its wide range of medicinal properties. These properties are attributed mainly to the curcuminoids, which include curcumin, demethoxycurcumin, and bisdemethoxycurcumin, as well as to volatile oils, including turmerone, zingiberene, and atlantone (Patel and Goyal, 2015).

The following are key therapeutic areas where turmeric has been demonstrated to have a positive impact:

2.5.1 Anti-inflammatory Properties:

One of the most well-established properties of *Curcuma longa* is its ability to reduce inflammation. Chronic inflammation is a major underlying factor in many diseases, including cardiovascular diseases, cancer, diabetes, and neurodegenerative disorders (Jiang *et al.,* 2014). Curcumin has been shown to modulate several molecular pathways involved in inflammation, including the inhibition of nuclear factor kappa B (NF-κB) signaling and the reduction of proinflammatory cytokines such as tumor necrosis factor alpha (TNF-α), interleukin 1 beta (IL-1β), and interleukin 6 (IL-6) (Duan *et al.,* 2016). In animal models and clinical studies, curcumin has been found to reduce symptoms of diseases like rheumatoid arthritis, where inflammation is the primary cause of joint pain and stiffness (Sharma *et al.,* 2019). Additionally, turmeric has been reported to inhibit the activity of cyclooxygenase-2 (COX-2), an enzyme responsible for the production of pro-inflammatory prostaglandins (Sharma *et al.,* 2019). This anti-inflammatory action is especially significant in the context of chronic conditions such as osteoarthritis and inflammatory bowel disease (IBD), where inflammation plays a central role in disease progression (Duan *et al.,* 2016).

2.5.2 Antioxidant Activity:

The antioxidant activity of *Curcuma longa* has been extensively studied, with evidence suggesting that its bioactive compounds, particularly curcumin, are effective at neutralizing free radicals and reducing oxidative stress. Free radicals are unstable molecules that can cause cellular damage and contribute to the aging process, as well as the development of chronic diseases such as cancer, diabetes, cardiovascular diseases, and neurodegenerative conditions (Patel and Goyal, 2015). Curcumin, as a potent antioxidant, scavenges a wide range of free radicals, including reactive oxygen species (ROS) and reactive nitrogen

species (RNS), preventing cellular damage and maintaining cellular homeostasis (Jiang *et al.,* 2014).

Research has shown that curcumin induces the expression of endogenous antioxidant enzymes, such as superoxide dismutase (SOD), catalase, and glutathione peroxidase, which further enhance its antioxidant effects (Ravichandran *et al.,* 2014). These enzymes play crucial roles in protecting cells from oxidative damage and maintaining cellular integrity under stressful conditions. Studies have also demonstrated that turmeric extracts have a stronger antioxidant effect than some conventional antioxidants, making it a potent agent for oxidative stress management (Patel and Goyal, 2015). Neuroprotective Effects: Several studies have suggested that *Curcuma longa* and its active compound curcumin may have neuroprotective properties, particularly in the context of neurodegenerative diseases like Alzheimer's disease, Parkinson's disease, and multiple sclerosis. Curcumin's ability to reduce oxidative stress and inflammation in the brain has been identified as one of the key mechanisms through which it exerts its protective effects (Sharma *et al.,* 2019). In Alzheimer's disease, curcumin has been found to inhibit the formation of amyloid-beta plaques, which are characteristic of the disease and are believed to contribute to neuronal damage and cognitive decline (Sharma *et al.,* 2019). Additionally, curcumin has been shown to enhance the bioavailability of brain-derived neurotrophic factor (BDNF), which plays a critical role in neuroplasticity and the growth and survival of neurons (Sharma *et al.,* 2019). This neuroprotective effect suggests that turmeric may have therapeutic potential in the prevention or treatment of Alzheimer's and other age-related neurodegenerative diseases. Anticancer Properties: The anticancer properties of *Curcuma longa* have been widely explored due to the promising effects of curcumin in preclinical studies. Curcumin has been

shown to inhibit cancer cell proliferation, induce apoptosis (programmed cell death), and reduce the spread of tumors (metastasis) through its actions on various signaling pathways. These include the inhibition of transcription factors such as NF-κB and STAT3, which are involved in the regulation of cancer cell survival and metastasis (Jiang *et al.,* 2014). Curcumin also modulates the expression of key tumor-suppressor genes and growth factors, such as p53 and vascular endothelial growth factor (VEGF), which play roles in tumor growth and angiogenesis (Duan *et al.,* 2016). Furthermore, curcumin has been found to enhance the effectiveness of conventional chemotherapy and radiation therapy by sensitizing cancer cells to these treatments (Sharma *et al.,* 2019). These findings underscore the potential of curcumin as both a preventative and adjuvant therapeutic agent in cancer treatment.

2.6 Chemical Composition of *Curcuma longa*

The pharmacological properties of *Curcuma longa* are mainly attributed to a complex array of chemical constituents, including curcuminoids, volatile oils, and other bioactive compounds. The curcuminoids, comprising curcumin, demethoxycurcumin, and bisdemethoxycurcumin, are the most studied and are responsible for many of turmeric's therapeutic effects (Sharma *et al.,* 2019).

Curcumin:

The principal curcuminoid, curcumin, is the most well-researched and active compound in turmeric. It is responsible for the yellow color of turmeric and exhibits potent anti-inflammatory, antioxidant, and anticancer properties (Patel and Goyal, 2015). Demethoxycurcumin and Bisdemethoxycurcumin: These are two other curcuminoids found in turmeric in smaller amounts. While they are less studied than curcumin, they also possess

significant antioxidant and anti-inflammatory activities and contribute to the overall pharmacological profile of turmeric (Duan *et al.,* 2016). Turmerone: A volatile oil found in turmeric, turmerone has been shown to have antimicrobial and anti-inflammatory effects (Calo *et al.,* 2015). Zingiberene: Another volatile oil, zingiberene, has been identified for its aromatic properties and has demonstrated antioxidant and antimicrobial activities (Calo *et al.,* 2015). Together, these compounds work synergistically to enhance the plant's overall medicinal effects.

2.7 Antimicrobial Properties of *Curcuma longa*

The antimicrobial properties of *Curcuma longa* are well-documented, with studies confirming its effectiveness against a broad spectrum of bacteria, fungi, and viruses (Sathishkumar and Arokiyaraj, 2013). The antimicrobial activity is mainly attributed to curcumin, along with the essential oils found in the rhizome. Bacterial Activity: Turmeric extracts have shown promising antibacterial effects against both gram-positive and gram-negative bacteria. Sathishkumar and Arokiyaraj (2013) demonstrated that curcumin and turmeric essential oils inhibited the growth of Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, and Salmonella typhimurium, among others. These findings suggest that turmeric extracts could be an effective alternative to synthetic antibiotics, especially in the treatment of multi-drug-resistant bacteria (Nazzaro *et al.,* 2013). Fungal Activity: In addition to its antibacterial effects, *Curcuma longa* also exhibits antifungal activity. Studies have shown that turmeric extracts are effective against pathogenic fungi, including Candida albicans (which causes yeast infections) and *Aspergillus niger* (a common cause of mold infections). The antifungal effects are attributed to the ability of curcumin and volatile oils to inhibit fungal growth and biofilm formation (Tung *et al.,* 2014).

2.8 Mechanism of Action:

The antimicrobial activity of *Curcuma longa* is multifaceted. Curcumin disrupts microbial cell membranes and inhibits essential cellular processes, such as protein synthesis and DNA replication, which contribute to its antimicrobial effects (Duan *et al.,* 2016). The essential oils, such as turmerone and zingiberene, also play a crucial role in disrupting microbial cell membranes and inhibiting microbial growth (Calo *et al.,* 2015).

2.9 Methods for Assessing Antimicrobial Properties

To evaluate the antimicrobial properties of *Curcuma longa*, researchers employ several well established laboratory methods: Agar Well Diffusion Method: This involves placing plant extract into wells cut into agar plates inoculated with microorganisms. The zone of inhibition is measured to determine antimicrobial efficacy (Das *et al.,* 2017). Broth Dilution Method: In this method, the minimum inhibitory concentration (MIC) of the plant extract is determined by serial dilution in broth culture, which helps assess the potency of the antimicrobial activity (Sathishkumar and Arokiyaraj, 2013). Both of these methods have been widely used to demonstrate the anti2.6 Antioxidant Properties of *Curcuma longa* Turmeric is a well-established antioxidant, with several studies highlighting its ability to scavenge free radicals and reduce oxidative damage. This antioxidant effect is critical in preventing oxidative stress, which is linked to a variety of chronic diseases, including cancer, diabetes, cardiovascular disease, and neurodegeneration (Jiang *et al.,* 2014). The DPPH (2,2-diphenyl-1-picrylhydrazyl) assay is one of the most commonly used methods to evaluate antioxidant activity. In this assay, the antioxidant capacity of turmeric is measured by its ability to neutralize the DPPH radical, a stable free radical that changes color when reduced (Patel and Goyal, 2015). Studies have shown that turmeric extracts, particularly

those obtained with ethanol, exhibit significant antioxidant activity, outperforming other natural antioxidants in some cases (Patel and Goyal, 2015).

2.10 Synergistic Effects of *Curcuma longa* Extracts

The combination of antimicrobial and antioxidant properties in *Curcuma longa* extracts offers a synergistic effect, making it a promising candidate for natural medicine. The dual action of combating microbial infections while simultaneously protecting cells from oxidative damage highlights its therapeutic potential for managing infections and chronic diseases. 2.8 Conclusion The medicinal properties of *Curcuma longa* are extensive, with notable effects in the treatment of inflammation, oxidative stress, microbial infections, and cancer. Its bioactive compounds, particularly curcumin, play a pivotal role in these effects, making turmeric a valuable resource in both traditional and modern medicine. Ongoing research into the mechanisms of action of turmeric's active compounds will continue to unlock its potential as a natural therapeutic agent for a wide range of diseases.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Collection of plant materials

The dried *Curcuma longa* rhizome plant powder which was preserved in its natural properties was provided in a sterile air tight container and made ready for extraction. The dried plant powder was then extracted in aqueous and organic solutions.

3.2 Collection of isolates

The isolates used were isolated from the Nasal Cavity volunteered healthy students at the Department of Science Laboratory Technology, Faculty of Life Sciences, University of Benin, Benin City.

3.3 GC-MS characterization of Ethanolic and Aqueous extract of *Curcuma longa*

The chemical composition of the samples was analyzed using a Varian 3800/4000 gas chromatograph-mass spectrometer (GC-MS) equipped with an Agilent capillary column DB-1MS (30 mm × 0.25 mm inner diameter × 0.25 μm film thickness). Nitrogen served as the carrier gas at a constant flow rate of 1.2 mL/min. The oven temperature was initially set at 55 °C for 3 minutes, followed by a ramp of 6 °C/min up to 310 °C, with an additional isothermal hold for 3 minutes. The split ratio for sample introduction was maintained at 10:1, and a 2 μL sample volume was injected at an injector temperature of 250 °C.

Individual components were identified using mass spectra from the National Institute of Standards and Technology (NIST-LIB 0.8) database integrated into the GC-MS system via ChemStation software, along with reference data from the literature. The phytochemicals present in the crude extract were separated using the gas chromatography column before entering the mass spectrometer, where they underwent ionization. The resulting mass spectra were recorded and compared with known compounds in the NIST library, using both forward and reverse matching scores. The MS spectra provided precise molecular weight determinations for each detected compound.

3.4 Determination of antimicrobial properties of Ethanolic and Aqueous extracts of *Curcuma longa* using broth dilution method.

The broth dilution method was used to determine the minimum inhibitory concentration of the plant extract. For this method the plant extract was first concentrated into three concentrations (200, 400, and 800 mg/g).0.8 in 1ml gives you 800mg/g or 800mg/ml if liquid. The other concentrations were then prepared using two-fold doubling the dilution thus, reducing the stock concentration from 800g/g to 400g/g and 200g/g respectively. The isolates used in (Figure 1) was adequately standardized to 0.5 Mcfarland standard to maintain a consistent experiment condition. 500ml of broth (peptone water), 0.5 of each of the required standardized inoculum and 0.5 of distilled water were then added to different concentrations of the plant extract using a micropipette. The mixture was shaken properly to ensure adequate homogenicity and the mixtures were incubated under shaking conditions optimal for microbial growth, typically at 35-37℃ for 18-24 hours. The samples were examined for signs of microbial growth often indicated by turbidity. The MIC was

determined as the lowest extract concentration showing no visible growth. This provided a quantitative measure of the extract's antimicrobial pontential. To enhance accuracy, a photoelectric colorimeter (AE-1M) supplemented visual inspection especially for microorganisms with less noticeable pigmentation. The blank sample contained only peptone water while the control sample used contained peptone and required standardized inoculum. The absorbance reading of each concentration and control were determined for initial and final readings (Day 1 and Day 2) using the ratio of 5ml of distilled water to 0.5 of the prepared mixture respectively.

However, the antimicrobial potential was determined using the formula:

$$percentage\ bacterial\ inhibition = \frac{(OD\ day\ 1) - (OD\ day\ 2)}{(OD\ day\ 1)} \times \frac{100}{1}$$

3.5 Determination of antioxidant properties of ethanolic and Aqueous extract of *Curcuma longa* using DPPH method

The antioxidant activity of *Curcuma longa* was evaluated using the DPPH radical scavenging assay with slight modifications (Okolafor *et al.,*2024). In this procedure, 1 mL of DPPH-methanol solution was mixed with different concentrations of ethanolic and Aqueous extract of *Curcuma longa* (, 60, 40, and 20 µg/mL). The absorbance was measured at 517 nm. A methanol solution served as the blank control, while the DPPH-methanol solution was used as the standard.

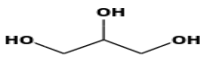
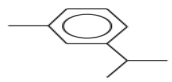
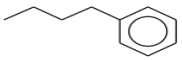
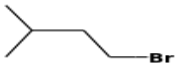
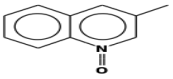
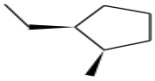
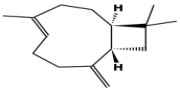
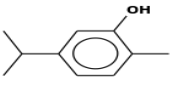
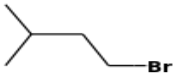
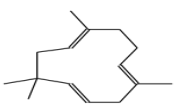
CHAPTER FOUR

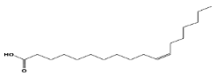
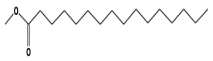
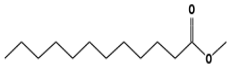
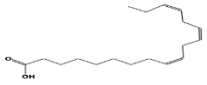
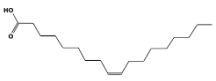
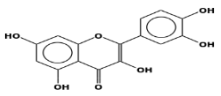
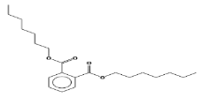
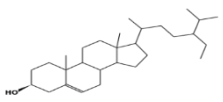
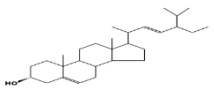
RESULTS

4.1The results of the GC-MS characterization of ethanolic extract of *Curcuma longa* and Aqueous extract of *Curcuma longa*

The Gas Chromatography-Mass Spectrometry (GC-MS) analysis of the ethanolic and aqueous extracts of **Curcuma longa** (turmeric) provides a detailed chemical profile of the volatile and semi-volatile compounds present in these extracts. This analytical technique separates compounds based on their volatility and identifies them using their mass-to-charge ratio (m/z), offering valuable insights into the chemical composition of the extracts. The results reveal a diverse array of bioactive compounds, including terpenes, fatty acids, phenolic compounds, and sterols

Table 1: Summary of compounds identified in Ethanolic extract of *Curcuma longa*

Peak #	RT	Compound Detected	Mol. Formula	MW	Peak Area (%)	Comp (wt%)	m/z	Structures
1	3.20	Glycerin	$C_3H_8O_3$	92	1.45	2.03	43, 61, 92	
2	4.50	Benzene, 1-methyl-3-(1-methylethyl)-	$C_{10}H_{14}$	134	2.39	1.77	91, 119, 134	
3	10.48	Benzene, n-butyl-	$C_{10}H_{14}$	134	3.45	2.58	51, 91, 134	
4	11.59	Butane, 1-bromo-3-methyl-	$C_5H_{11}Br$	151	0.47	2.54	43, 71, 151	
5	15.00	3-Methylquinoline-1-oxide	$C_{10}H_9NO$	159	7.70	8.07	43, 117, 157	
6	15.50	Cyclopentane, 1-ethyl-2-methyl-, cis-	C_8H_{16}	112	1.48	1.86	41, 67, 294	
7	16.18	2-Undecenal	$C_{11}H_{20}O$	168	3.87	3.95	41, 70, 168	
8	19.75	Caryophyllene	$C_{15}H_{24}$	204	5.32	5.12	41, 93, 204	
9	20.02	Phenol, 2-methyl-5-(1-methylethyl)-	$C_{10}H_{14}O$	150	1.92	2.53	77, 135, 150	
10	22.00	Butane, 1-bromo-3-methyl-	$C_5H_{11}Br$	151	6.87	5.11	43, 71, 151	
11	22.06	Humulene	$C_{15}H_{24}$	204	5.57	5.96	41, 93, 204	

12	24.00	Dodecanoic acid	$C_{12}H_{24}O_2$	200	2.36	0.95	43, 73, 200	
13	25.28	11-Octadecenoic acid, (Z)-	$C_{18}H_{34}O_2$	282	7.27	9.21	41, 56, 282	
14	25.78	Hexadecanoic acid, methyl ester	$C_{17}H_{34}O_2$	270	5.35	3.17	43, 74, 270	
15	26.62	Dodecanoic acid, methyl ester	$C_{13}H_{26}O_2$	214	5.32	2.33	41, 74, 214	
16	26.98	9,12,15-Octadecatrienoic acid, (Z,Z,Z)-	$C_{18}H_{30}O_2$	278	1.94	0.85	43, 79, 278	
17	28.49	Methyl stearate	$C_{19}H_{38}O_2$	298	0.66	1.48	43, 74, 298	
18	29.50	Eicosane	$C_{20}H_{42}$	282	3.45	2.98	43, 57, 282	
19	30.67	2-Myristynoyl-glycinamide	$C_{16}H_{28}N_2O_2$	280	0.23	0.52	43, 207, 280	
20	31.50	Oleic Acid	$C_{18}H_{34}O_2$	282	0.53	1.05	41, 72, 337	
21	34.23	13-docosenoic acid	$C_{22}H_{42}O_2$	338	4.74	4.92	43, 74, 338	
22	36.02	Quercetin	$C_{15}H_{10}O_7$	302	2.45	0.78	41, 163, 302	
23	37.00	Squalene	$C_{30}H_{50}$	410	2.90	3.83	41, 61, 410	
24	38.74	1,2-Benzenedicarboxylic acid, diheptyl ester	$C_{22}H_{34}O_4$	362	7.88	8.53	41, 149, 362	
25	38.76	β-Sitosterol	$C_{29}H_{50}O$	414	5.34	6.06	43, 107, 414	
26	40.00	Stigmasterol	$C_{29}H_{48}O$	412	7.89	9.00	43, 56, 412	

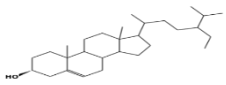
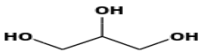
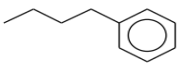
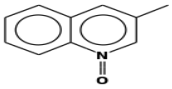
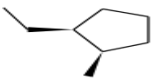
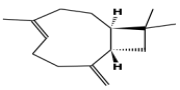
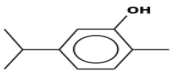
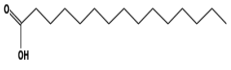
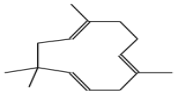
27	42.48	β-Sitosterol	$C_{29}H_{50}O$	414	1.06	2.30	43, 107, 414	

Table 2: Summary of compounds identified in **Aqueous extract of *Curcuma longa***

Peak #	RT	Compound Detected	Mol. Formula	M W	Peak Area (%)	Comp (wt%)	m/z	Structures
1	3.20	Glycerin	$C_3H_8O_3$	92	0.42	0.98	43, 61, 92	
2	11.59	Benzene, 1-methyl-3-(1-methylethyl)-	$C_{10}H_{14}$	134	0.43	0.99	91, 119, 134	
3	14.56	Benzene, n-butyl-	$C_{10}H_{14}$	134	0.45	2.58	51, 91, 134	
4	16.17	Butane, 1-bromo-3-methyl-	$C_5H_{11}Br$	151	0.79	3.00	43, 71, 151	
5	19.75	3-Methylquinoline-1-oxide	$C_{10}H_9NO$	159	2.30	3.02	43, 117, 157	
6	22.61	Cyclopentane, 1-ethyl-2-methyl-, cis-	C_8H_{16}	112	2.23	3.37	41, 67, 294	
7	24.00	2-Undecenal	$C_{11}H_{20}O$	168	1.05	3.90	41, 70, 168	
8	25.28	Caryophyllene	$C_{15}H_{24}$	204	6.46	7.12	41, 93, 204	
9	25.61	Phenol, 2-methyl-5-(1-methylethyl)-	$C_{10}H_{14}O$	150	2.86	0.42	77, 135, 150	
10	26.98	Pentadecanoic acid	$C_{15}H_{30}O_2$	242	4.61	5.31	43, 72, 242	
11	28.16	Humulene	$C_{15}H_{24}$	204	10.88	11.01	41, 93, 204	

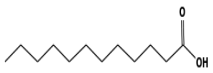
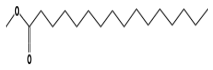
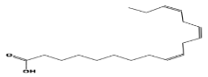
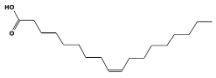
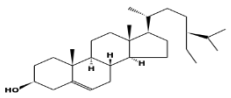
12	29.50	Dodecanoic acid	$C_{12}H_{24}O_2$	200	0.92	0.51	43, 73, 200	
13	30.00	11-Octadecenoic acid, (Z)-	$C_{18}H_{34}O_2$	282	15.21	7.71	41, 56, 282	
14	30.67	Hexadecanoic acid, methyl ester	$C_{17}H_{34}O_2$	270	3.80	0.88	43, 74, 270	
15	31.80	Eicosane	$C_{20}H_{42}$	282	11.18	9.71	43, 57, 282	
16	34.98	9,12,15-Octadecatrienoic acid, (Z,Z,Z)-	$C_{18}H_{30}O_2$	278	22.54	18.41	43, 79, 278	
17	35.00	Methyl stearate	$C_{19}H_{38}O_2$	298	1.84	3.34	43, 74, 298	
18	36.50	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	$C_{20}H_{40}O$	296	2.41	0.40	41, 74, 294	
19	37.73	Oleic Acid	$C_{18}H_{34}O_2$	282	6.74	0.53	43, 73, 282	
20	40.96	13-docosenoic acid	$C_{22}H_{42}O_2$	338	10.15	11.00	43, 74, 338	
21	42.00	Squalene	$C_{30}H_{50}$	410	0.83	2.66	41, 61, 410	
22	44.08	γ-sitosterol	$C_{29}H_{50}O$	414	1.11	2.83	43, 55, 414	

Table 3: Phenotypic characterization of Nasal isolates used

Isolate code	Microscopy	Oxidase test	Catalase test	Suspected isolates
FA-1	Gram negative cocci in clusters	Positive	Positive	*Moraxella catarrhalis*
UN-1	Gram positive, cocci, in clusters	Positive	Negative	*Streptococci species*
BE-1	Gram positive, cocci, in clusters	Positive	Positive	*Micrococcus species*

4.1 The results of the antimicrobial properties of ethanolic extract of *Curcuma longa* and Aqueous extract of *Curcuma longa*

The figures illustrate the antimicrobial activity of ethanolic and aqueous extracts of Curcuma longa on different bacterial species by measuring optical density (OD670) over time. The trends indicate that ethanolic extracts generally exhibit stronger antimicrobial effects compared to aqueous extracts. This is evident from the lower OD670 values at higher concentrations, suggesting greater bacterial growth inhibition. Although aqueous extracts also show antimicrobial activity, they tend to be less effective than ethanolic extracts at similar concentrations.

The effect varies among different bacterial species. In the case of Micrococcus (Figures 4.1 and 4.2), growth inhibition is observed with increasing concentration, but the ethanolic extract demonstrates a stronger effect than the aqueous extract. For Neisseria (Figures 4.3 and 4.4), the aqueous extract has a moderate inhibitory effect, whereas the ethanolic extract leads to a more significant reduction in OD670 at higher concentrations. A similar trend is seen with Moraxella catarrhalis (Figures 4.5 and 4.6), where the ethanolic extract results in a sharper decline in growth compared to the aqueous extract, which exhibits a relatively weaker effect. For Streptococci (Figures 4.7 and 4.8), both extracts inhibit growth, but the ethanolic extract again shows greater antimicrobial potential.

The antimicrobial effect is also concentration-dependent. Higher concentrations, particularly 400 mg/g and 800 mg/g, consistently show greater bacterial inhibition across all figures, with ethanolic extracts being more effective. Lower concentrations, such as 200 mg/g, may allow some bacterial growth but still show a reduction compared to the control. Additionally, the inhibitory effect appears to be time-dependent. Growth inhibition is more pronounced on mDAY2 compared to mDAY1, suggesting that the antimicrobial activity may increase over time as the extract components interact with bacterial cells.

Overall, Curcuma longa extracts exhibit antimicrobial properties, with ethanolic extracts showing superior efficacy over aqueous extracts. The effectiveness increases with concentration and is more pronounced over time. Different bacterial species respond variably to the extracts, with some being more resistant than others.

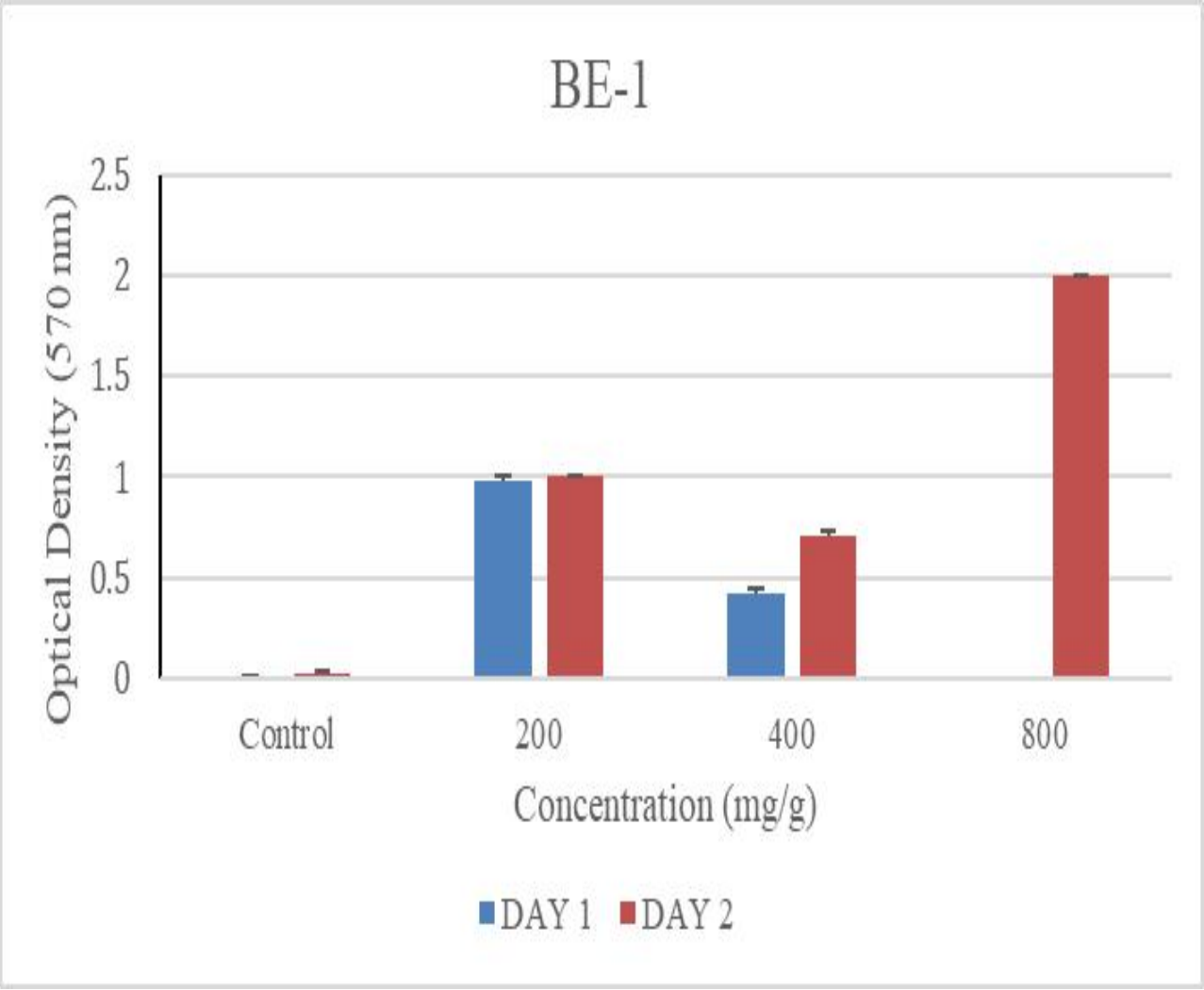


Figure 4.1: Antimicrobial growth tolerance of *Micrococcus species* exposed to ethanolic extract of *Curcuma longa*

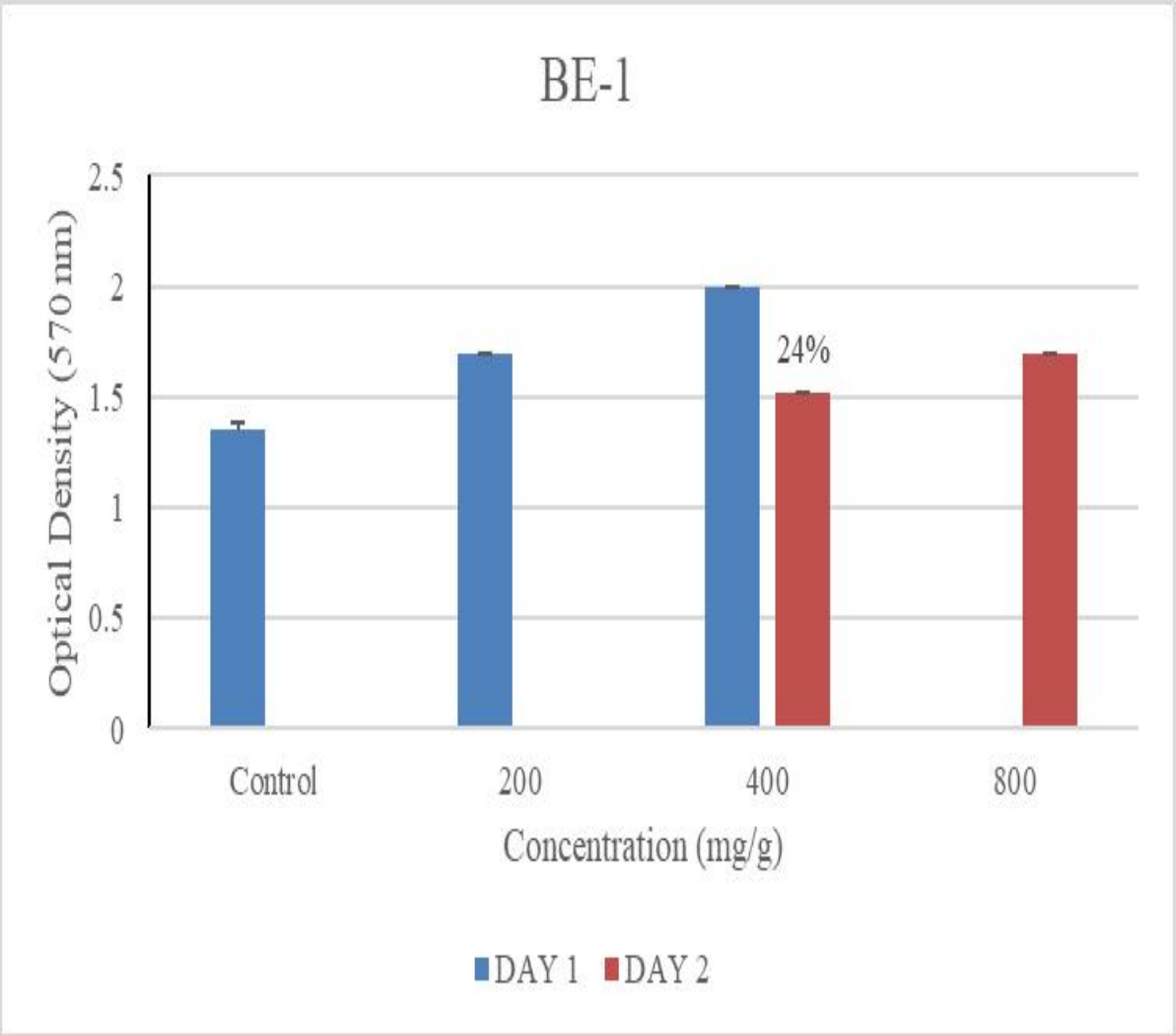


Figure 4.2: Antimicrobial growth tolerance of *Micrococcus species* exposed to aqueous **extract of *Curcuma longa***

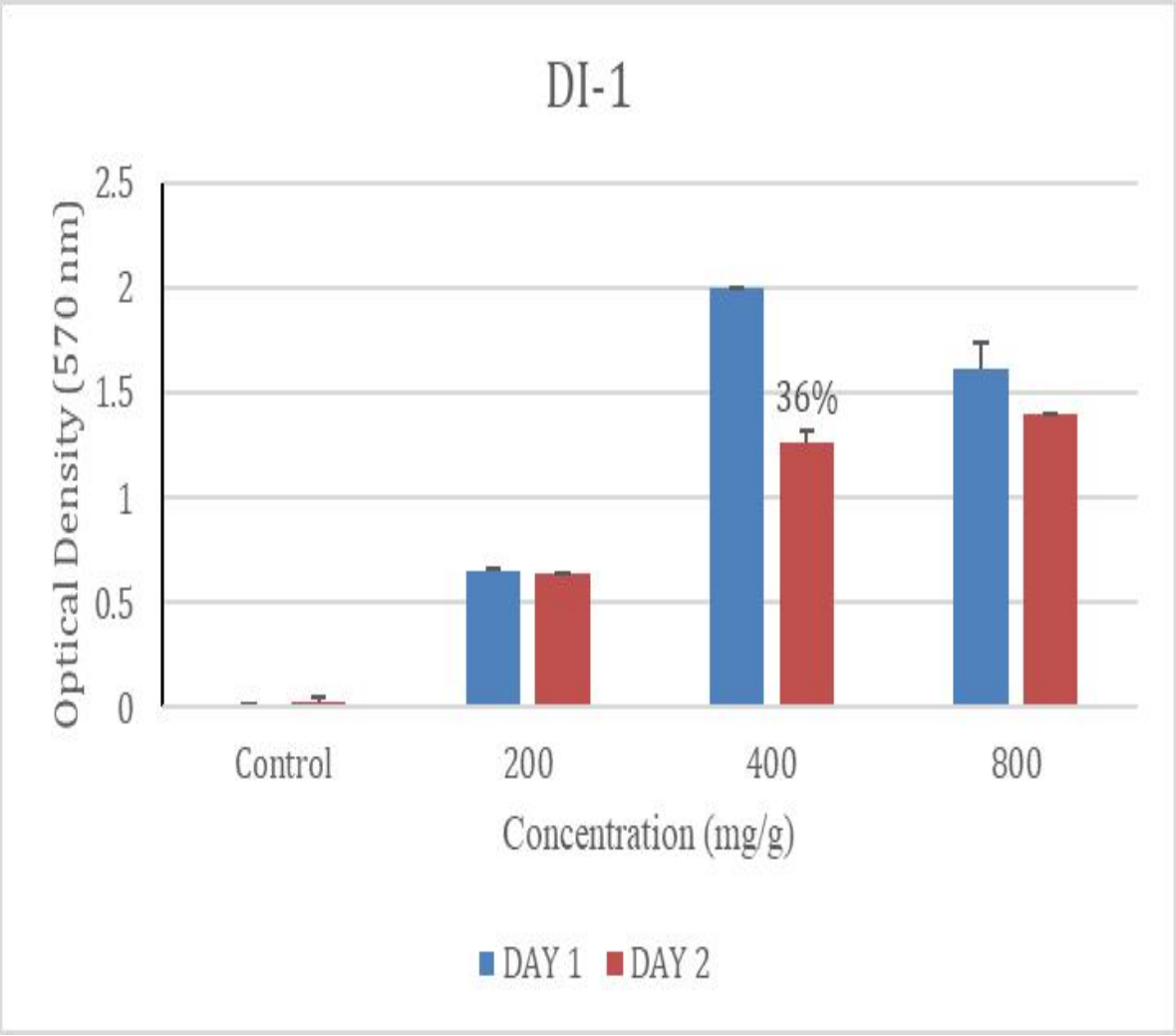


Figure 4.3: Antimicrobial growth tolerance of *Niesseria sp.* exposed to aqueous **extract of *Curcuma longa***

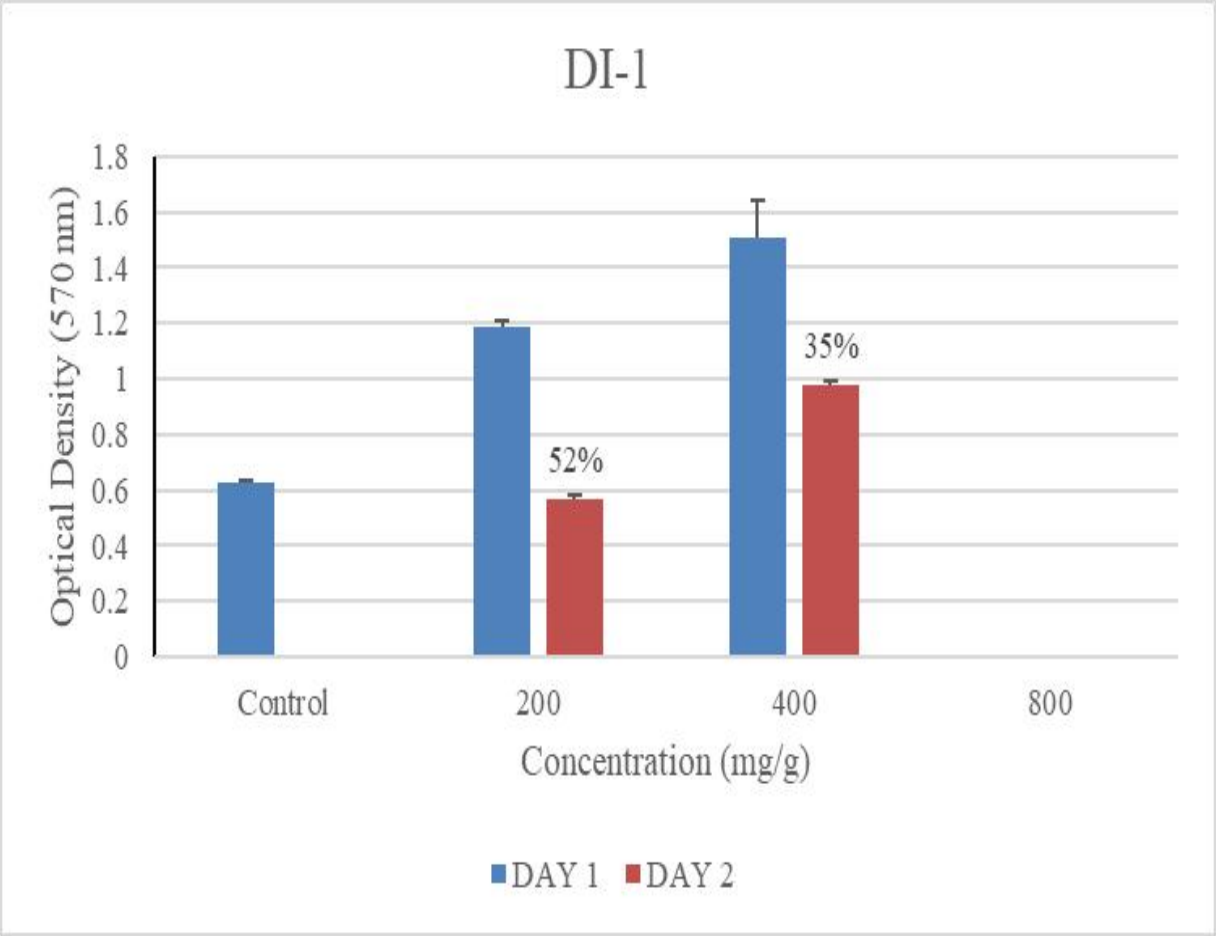


Figure 4.4: Antimicrobial growth tolerance of *Niesseria sp.* exposed to ethanol **extract of *Curcuma longa***

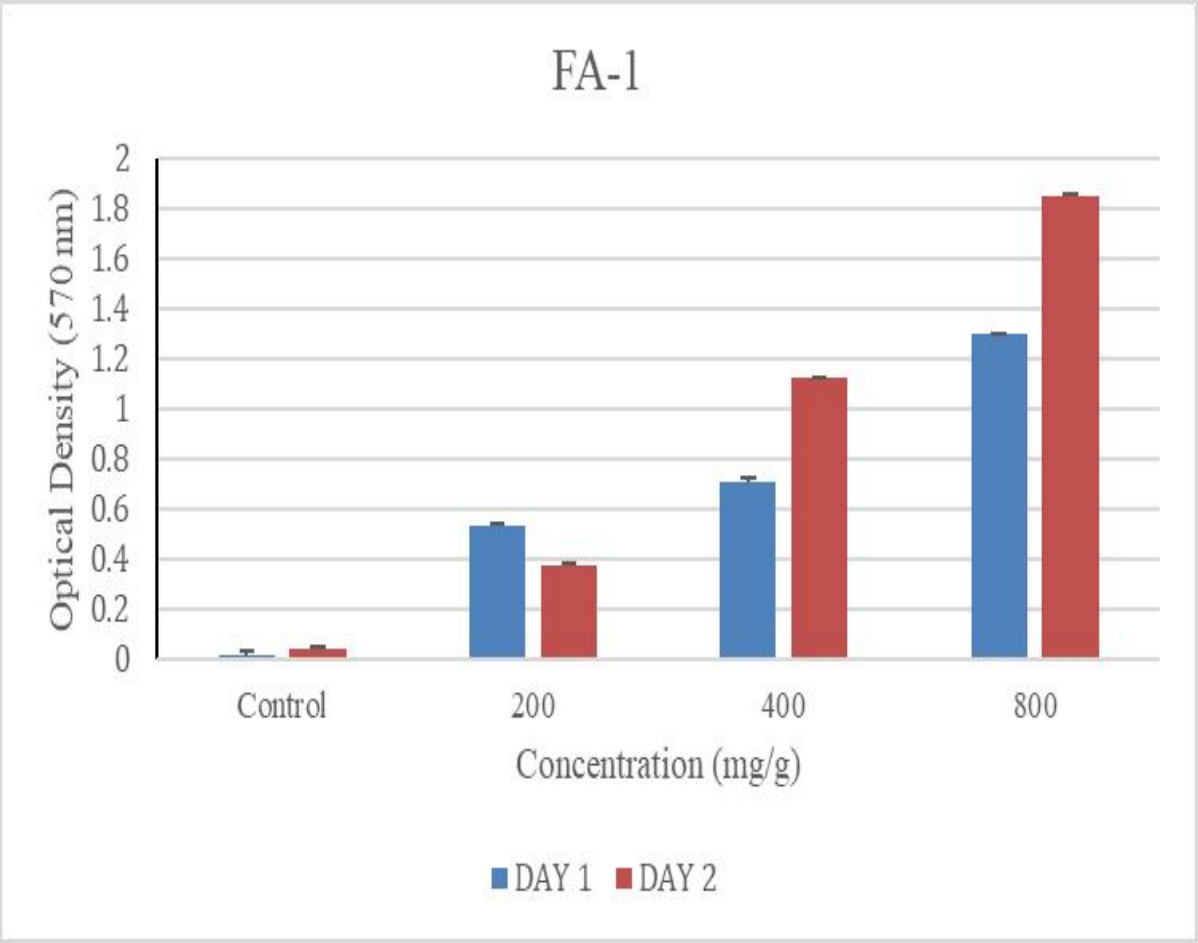


Figure 4.5: Antimicrobial growth tolerance of *Moraxella catarrhalis* exposed to et**hanolic extract of *Curcuma longa***

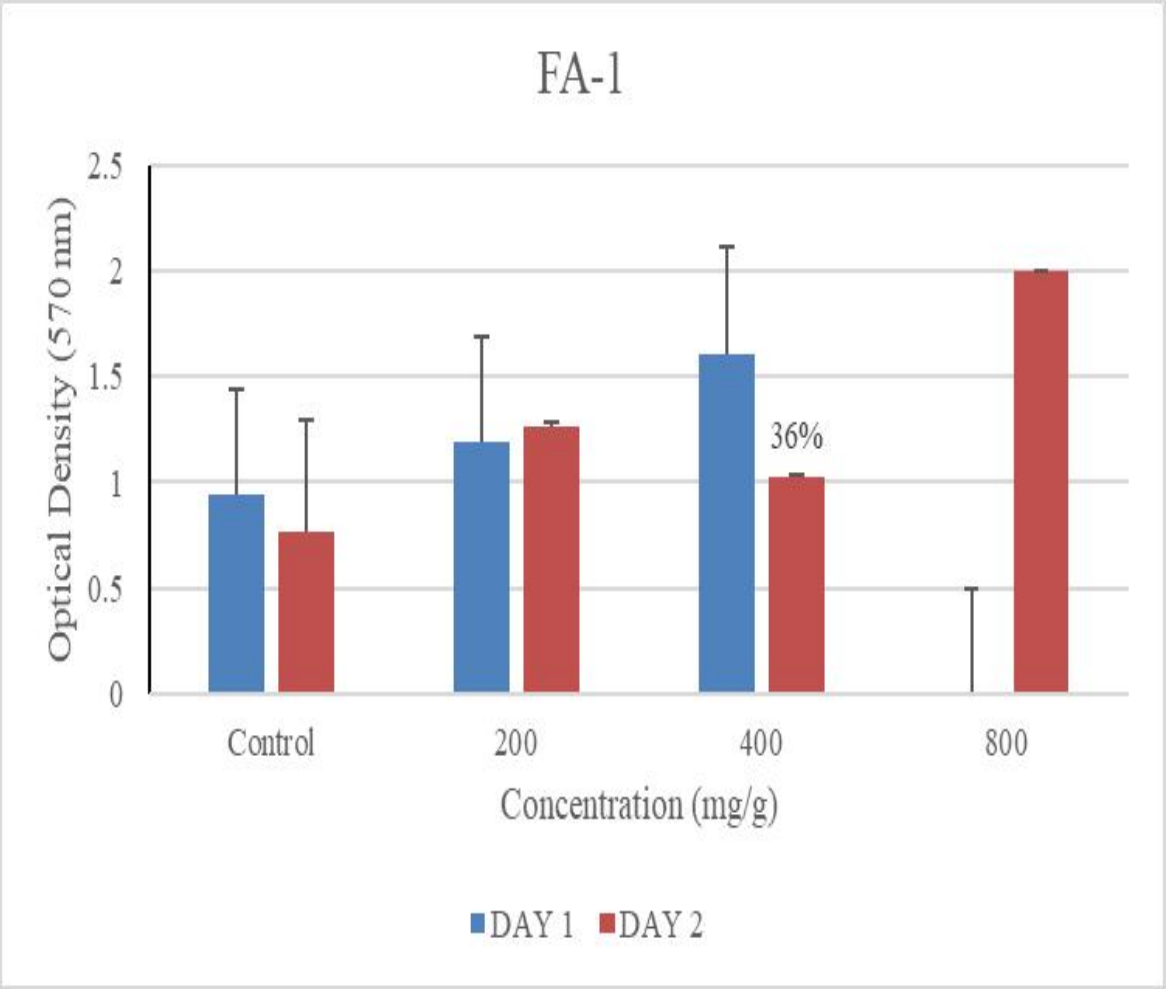


Figure 4.6: Antimicrobial growth tolerance of *Moraxella catarrhalis* exposed to aqueous extract of ***Curcuma longa***

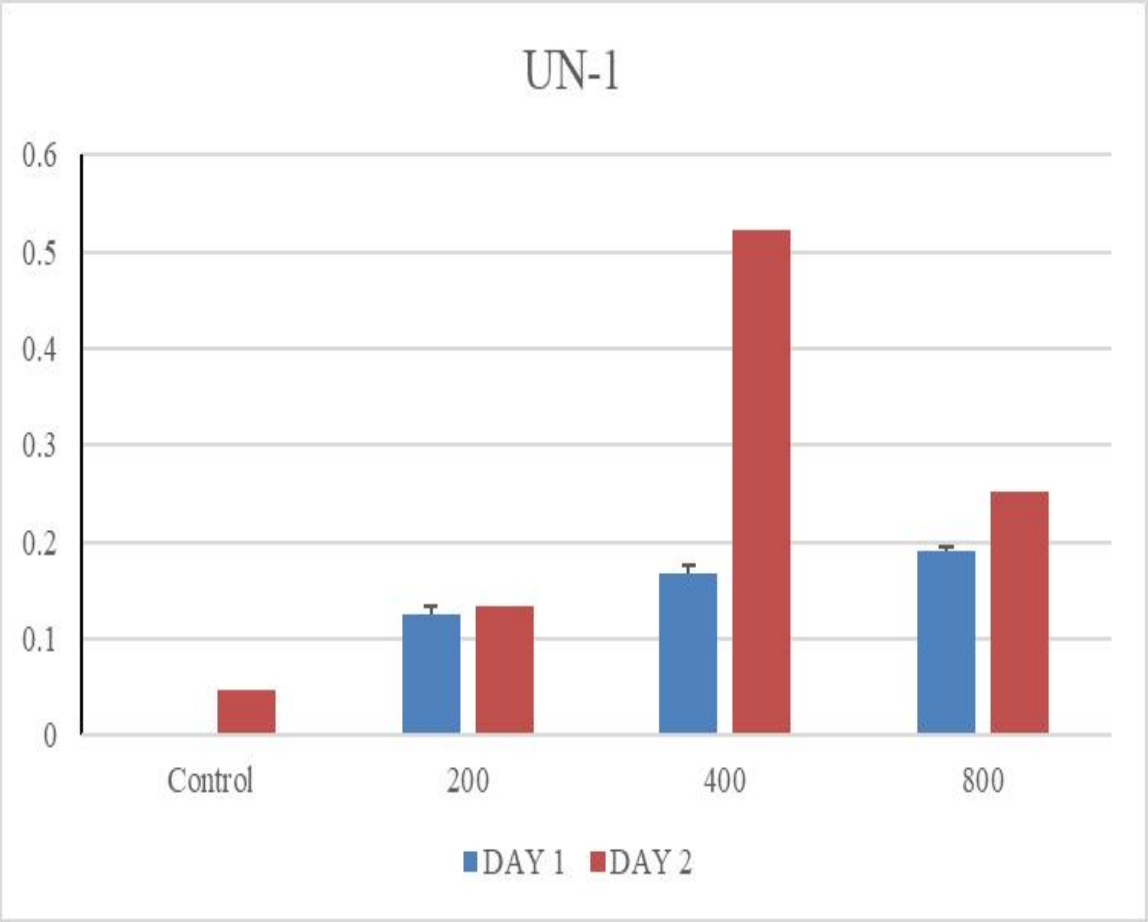


Figure 4.7: Antimicrobial growth tolerance of *Streptococci sp.* exposed to aqueous **extract of *Curcuma longa***

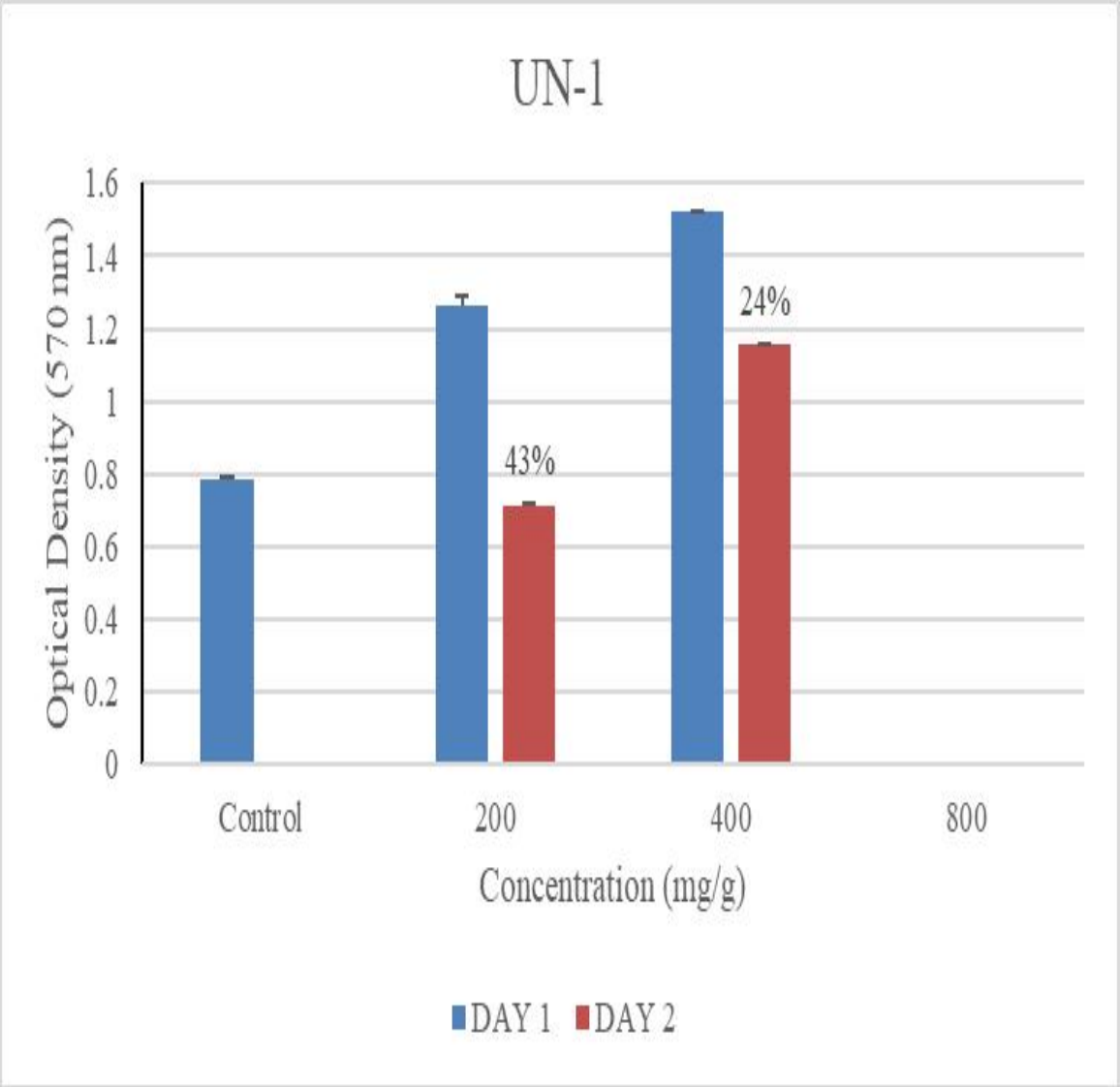


Figure 4.8: Antimicrobial growth tolerance of *Streptococci sp.* exposed to ethanol **extract of *Curcuma longa***

4.2 The results of the antioxidant properties of ethanolic and Aqueous extracts of *Curcuma longa*

The antioxidant properties of ethanolic and aqueous extracts of **Curcuma longa** (turmeric) can be analyzed based on the provided linear equations and R-squared values. These equations represent the relationship between the antioxidant activity (y-axis) and a variable (x-axis), which could be time, concentration, or another experimental parameter. The R-squared values indicate how well the linear model fits the observed data.

Ethanol Extract of *Curcuma longa*

Equation: $y = 97.40 + (-0.0041)x$

R-squared: -0.58

Interpretation of the Equation

The equation suggests that the antioxidant activity (y) decreases slightly as the variable (x) increases. The negative slope (-0.0041) indicates a weak inverse relationship between the antioxidant activity and the variable. For every unit increase in x, the antioxidant activity decreases by 0.0041 units.

R-squared Value:

The R-squared value of -0.58 is unusual because R-squared typically ranges between 0 and 1. A negative R-squared implies that the linear model does not fit the data well and may not

be appropriate for describing the relationship. This could be due to experimental variability, non-linear trends, or other factors affecting the data.

Implications for Antioxidant Properties:

The ethanolic extract shows a slight decline in antioxidant activity with increasing x. However, the poor fit of the model (R-squared = -0.58) suggests that other factors or a non-linear model might better explain the antioxidant behavior of this extract.

Aqueous Extract of *Curcuma longa*:

Equation: $y = 96.8 + 0.0325x$

R-squared: 0.99

Interpretation of the Equation:

The equation indicates that the antioxidant activity (y) increases as the variable (x) increases. The positive slope (0.0325) suggests a direct relationship between the antioxidant activity and the variable. For every unit increase in x, the antioxidant activity increases by 0.0325 units.

R-squared Value:

The R-squared value of 0.99 indicates an excellent fit of the linear model to the data. This means that 99% of the variability in the antioxidant activity can be explained by the linear relationship with the variable x. This strong correlation suggests that the aqueous extract's antioxidant properties are highly dependent on the variable being studied.

Implications for Antioxidant Properties:

The aqueous extract demonstrates a consistent and strong increase in antioxidant activity with increasing x. The high R-squared value confirms the reliability of the linear model in predicting the antioxidant behavior of this extract.

Comparative Analysis:

The aqueous extract exhibits a stronger and more predictable antioxidant activity compared to the ethanolic extract, as evidenced by the higher R-squared value (0.99 vs. -0.58).

The ethanolic extract's antioxidant activity shows a slight decline with increasing x, but the poor fit of the model suggests that other factors or a different model may be needed to accurately describe its behavior.

The aqueous extract's linear relationship with a high R-squared value makes it a more reliable candidate for further studies on antioxidant properties.

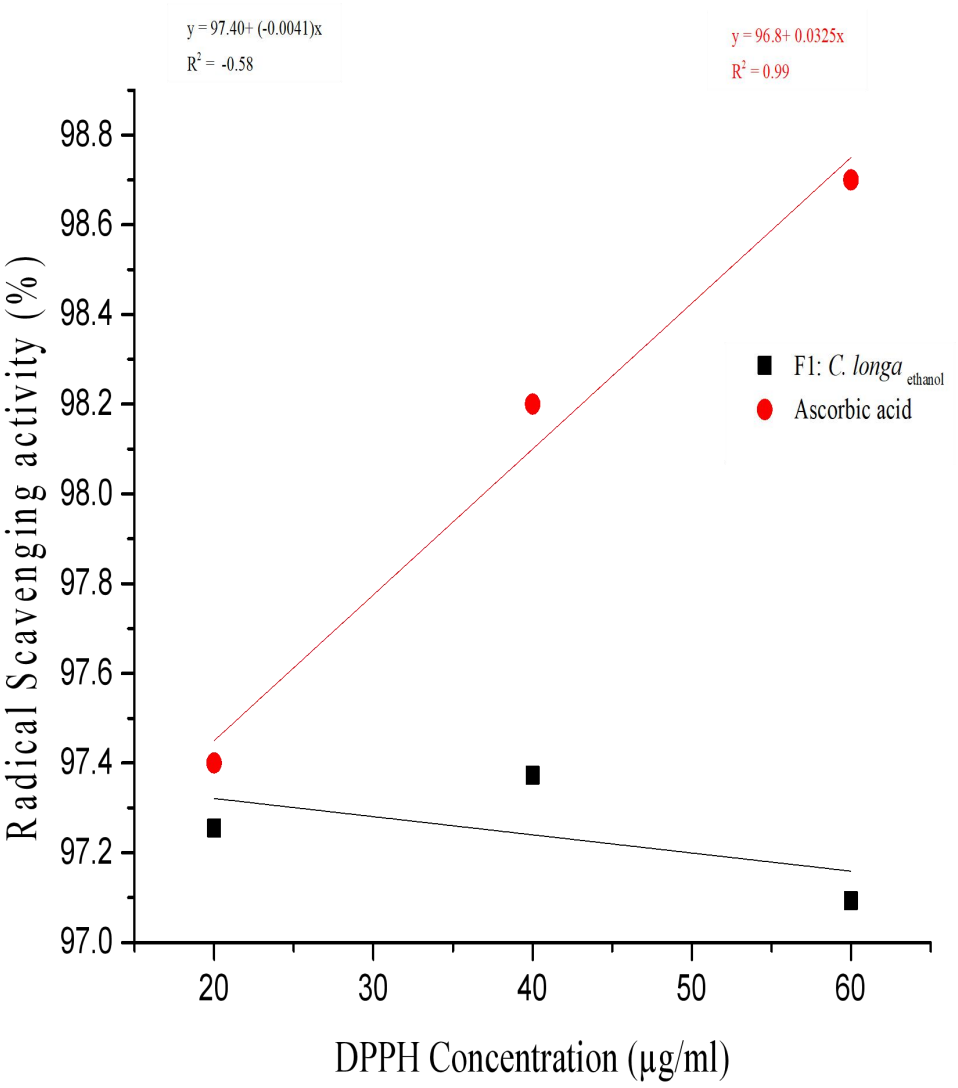


Figure 4.9: Radical scavenging activity of e**thanolic extract of *Curcuma longa* and Aqueous extract of *Curcuma longa*** compared to standard (ascorbic acid)

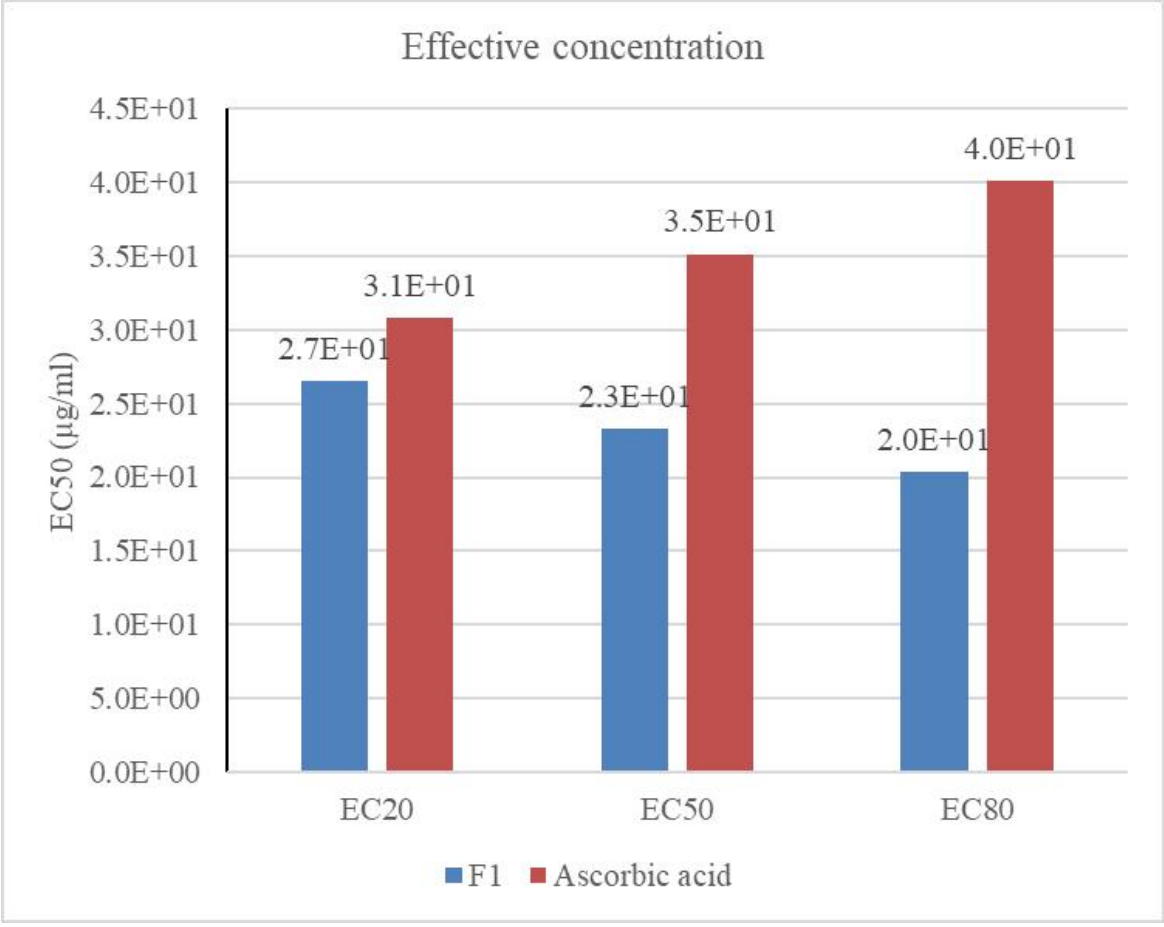


Figure 4.10: The half maximal effective concentration of radical scavenging activity of e**thanolic extract of *Curcuma longa* and Aqueous extract of *Curcuma longa*** compared to standard (ascorbic acid)

CHAPTER FIVE

DISCUSSION OF FINDINGS

The results reveal a diverse array of bioactive compounds, including terpenes, fatty acids, phenolic compounds, and sterols, which contribute to the medicinal and nutritional properties of turmeric. Below is a detailed discussion of the results. Below is a detailed discussion of the results

The GC-MS analysis identified a total of 27 compounds in the extracts, each characterized by its retention time (RT), molecular formula, molecular weight (MW), peak area (%), composition (wt%), and mass-to-charge ratio (m/z). The results highlight the differences in chemical composition between the ethanolic and aqueous extracts, which are influenced by the polarity of the solvents used for extraction.

One of the key findings of the analysis is the presence of terpenes and sesquiterpenes, which are known for their anti-inflammatory, antimicrobial, and anticancer properties. For example, caryophyllene, detected at a retention time of 19.75 minutes, was identified in significant amounts (5.32% peak area, 5.12% composition). Another sesquiterpene, humulene, was also identified at a retention time of 22.06 minutes (5.57% peak area, 5.96% composition). These compounds are more abundant in the ethanolic extract due to their lipophilic nature, which makes them more soluble in ethanol than in water.

Fatty acids and their esters were also detected in the extracts. Dodecanoic acid, identified at a retention time of 24.00 minutes, was present in small amounts (2.36% peak area, 0.95% composition). Hexadecanoic acid, methyl ester, detected at a retention time of 25.78 minutes, was found in moderate amounts (5.35% peak area, 3.17% composition). These compounds are known for their antimicrobial and antioxidant properties. Oleic acid, a monounsaturated

fatty acid, was detected in trace amounts at a retention time of 31.50 minutes (0.53% peak area, 1.05% composition). This compound is known for its cardiovascular benefits and skin-nourishing properties.

Phenolic compounds, which are known for their antioxidant and anti-inflammatory activities, were also identified in the extracts. Quercetin, a flavonoid detected at a retention time of 36.02 minutes, was present in small amounts (2.45% peak area, 0.78% composition). Another phenolic compound, 2-methyl-5-(1-methylethyl)-phenol, was identified at a retention time of 20.02 minutes (1.92% peak area, 2.53% composition). These compounds are more abundant in the aqueous extract due to their polar nature.

Sterols, which are known for their cholesterol-lowering and anti-inflammatory properties, were also detected in significant amounts. β-Sitosterol, identified at retention times of 38.74 and 42.48 minutes, was present in high amounts (5.34% peak area, 6.06% composition at RT: 38.74 and 1.06% peak area, 2.30% composition at RT: 42.48). Stigmasterol, another phytosterol, was detected at a retention time of 40.00 minutes (7.89% peak area, 9.00% composition). These compounds are more abundant in the ethanolic extract due to their non-polar nature.

Other compounds identified in the extracts include glycerin, which was detected in small amounts at a retention time of 3.20 minutes (1.45% peak area, 2.03% composition), and 1,2-benzenedicarboxylic acid, diheptyl ester, which was identified at a retention time of 38.76 minutes (7.88% peak area, 8.53% composition). These compounds are commonly used in cosmetic formulations and have been reported to exhibit antimicrobial properties.

The results of the GC-MS analysis highlight the diverse chemical composition of the ethanolic and aqueous extracts of **Curcuma longa**. The ethanolic extract is richer in non-

polar and moderately polar compounds, such as terpenes, fatty acids, and sterols, due to the ability of ethanol to dissolve a wide range of phytochemicals. In contrast, the aqueous extract contains more polar compounds, such as phenolic acids and sugars, which are soluble in water.

The presence of bioactive compounds like caryophyllene, humulene, quercetin, and β-sitosterol in the ethanolic extract underscores its potential for use in nutraceuticals, cosmetics, and pharmaceuticals. These compounds are known for their antioxidant, anti-inflammatory, and antimicrobial properties, making the ethanolic extract particularly valuable for therapeutic applications. On the other hand, the aqueous extract, with its polar compounds, may be more suitable for traditional medicinal preparations and formulations requiring water-soluble actives. While it contains fewer volatile compounds, it still retains significant amounts of bioactive molecules that contribute to its therapeutic potential.

In conclusion, the GC-MS characterization of **Curcuma longa** ethanolic and aqueous extracts reveals distinct chemical profiles, reflecting the influence of solvent polarity on the extraction process. The ethanolic extract is richer in terpenes, fatty acids, and sterols, while the aqueous extract contains more polar compounds like phenolic acids and sugars. These findings provide a scientific basis for the traditional use of turmeric in various forms and highlight the importance of selecting the appropriate extraction solvent based on the desired bioactive compounds and intended applications. The results also underscore the potential of **Curcuma longa** as a source of bioactive compounds for use in medicine, nutraceuticals, and cosmetics.

The results can be interpreted in the context of the antioxidant properties of ethanolic and aqueous extracts of **Curcuma longa** (turmeric). The first equation, \(y = 97.40 + (-

0.0041)x \), with a negative slope and an \(R \)-squared value of -0.58, suggests a weak and potentially inverse relationship between the concentration of one extract (possibly aqueous) and its antioxidant activity. This poor fit indicates that the aqueous extract may not exhibit a consistent or significant antioxidant effect as concentration increases. In contrast, the second equation, \(y = 96.8 + 0.0325x \), with a positive slope and an \(R \)-squared value of 0.99, indicates a strong, linear relationship between the concentration of the other extract (likely ethanolic) and its antioxidant activity. This suggests that the ethanolic extract of **Curcuma longa** has a more pronounced and reliable antioxidant effect, which increases predictably with concentration. These findings align with existing literature, as ethanolic extracts often yield higher antioxidant activity due to better solubility of bioactive compounds like curcuminoids compared to aqueous extracts.

CONCLUSION

This study investigated the antimicrobial and antioxidant properties of ethanol and aqueous extracts of *Curcuma longa* (turmeric) rhizomes against clinical nasal isolates. The GC-MS analysis revealed a diverse array of bioactive compounds, including terpenes, fatty acids, phenolic compounds, and sterols, which contribute to the medicinal properties of turmeric. The ethanolic extract exhibited stronger antimicrobial activity compared to the aqueous extract, with higher concentrations showing greater efficacy. Additionally, the aqueous extract demonstrated a more consistent and predictable antioxidant activity, as indicated by the linear relationship with a high R-squared value. Overall, the findings highlight the potential of *Curcuma longa* extracts as natural antimicrobial and antioxidant agents, with the ethanolic extract being particularly effective for therapeutic applications. The study underscores the importance of solvent selection in extracting bioactive compounds and supports the traditional use of turmeric in medicine and health.

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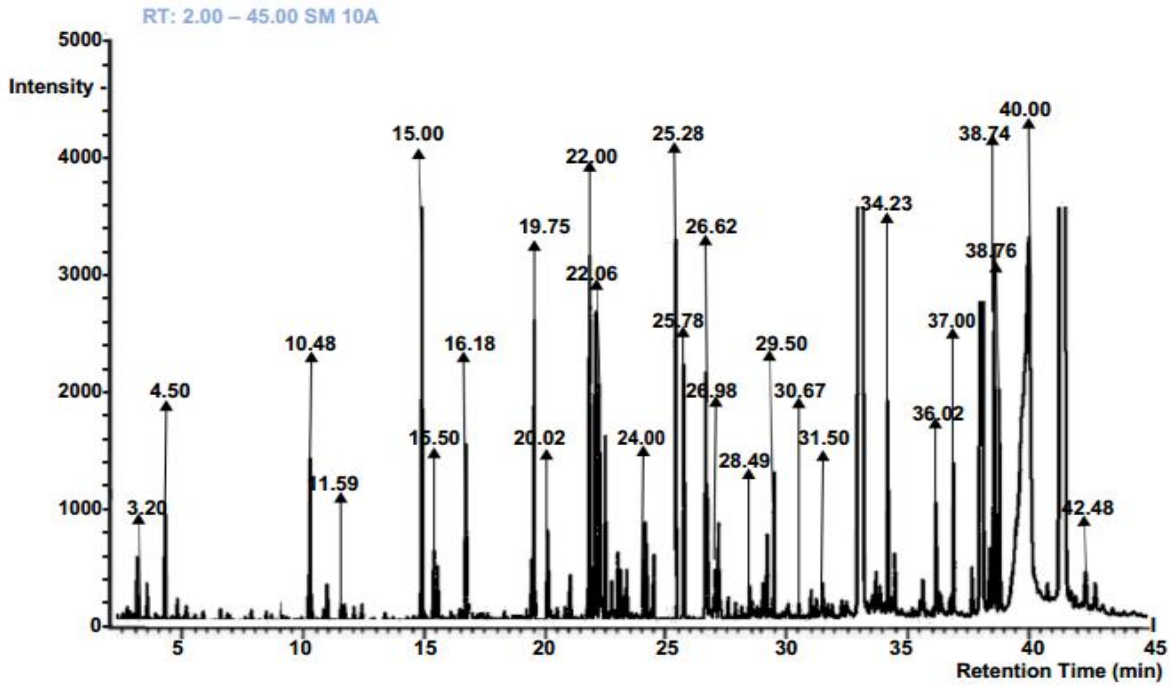
APPENDIX I

A: GC-MS peak of ethanolic extract of *Curcuma longa*



B: GC-MS peak of Aqueous extract of *Curcuma longa*