JOURNAL OF ADVANCED MICROBIOLOGY

DOI: 10.5530/jam.5.1.1

Research Article

Antimicrobial potency of three leaf essential oil of *Curcuma* species with reference to commercial counterpart: A brief comparison

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Received 12 June 2024
Revised 28 July 2024
Accepted 30 July 2024

Abstract
Curcuma species have been utilized in ancient healing practices for many generations and are gaining importance worldwide due to their novel bioactive compounds. *Curcuma caesia*, *Curcuma longa* and *Curcuma amada* are member of the family Zingiberaceae and is used in various regions for its anthelmintic, laxative and vulnerary properties. It is useful in the treatment of asthma, leprosy, leukoderma and anaemia. In this study the essential oil was extracted from the leaf of three different *Curcuma* species by hydro distillation. Extracted essential oils were subjected to antimicrobial activity using disc diffusion method tested against five bacterial strains and four fungal strains. In this study, it was seen that the three essential oil of the *Curcuma* spp. are very potent and rich in antimicrobial efficacy. The antimicrobial assay results showed that the essential oil is very effective against the selected bacterial strains but it is somehow inactive towards some fungal strains. Antibiotic resistance presents a complex issue that necessitates a comprehensive solution, encompassing tactics aimed at enhancing the efficacy of existing antibiotics and minimizing their utilization. In this regard, the present study would shed light on the effective utilization of these underutilized crops for broad spectrum antimicrobial activity.

Keywords
Antimicrobial activity, *Curcuma*, Zingiberaceae, Microbial strain, Essential oil.

Introduction

Curcuma species are gaining importance world widely and for centuries, this species has been utilized in traditional medicine to address various health conditions. The biological potential of *Curcuma* spp. have been boosted by finding new bioactive compounds with various benefits like antioxidant, antiviral, antimicrobial and anti-inflammatory properties. Essential oils have demonstrated a multitude of advantageous effects for the preservation of health and the management of diverse ailments[1]. Moreover, as per previous studies, *Curcuma* species are considered as nutritionally rich food product[1]. The essential oil of *Curcuma* species possesses anti-microbial activity towards various micro-organisms. They can be potentially used against different bacteria and fungus but it is also important to isolate the major component which is responsible for the antimicrobial effect for evaluation of the component[2].

Infections are one of the major causes of morbidity and mortality in the world. As per a report of 2019, globally among the 13.7 million deaths due to infections, 33 bacterial pathogens were found to be responsible for 7.7 million death rates among the study (GBD 2019 Antimicrobial Resistance Collaborators). From the year 1930s to 1960s, Over the past forty years, only three novel classes of antibiotics have been introduced, despite the initial marketing of twenty classes. This trend highlights the challenges in effectively managing bacterial infections[4,5,6]. Various types of bacteria, including vancomycin-resistant enterococci (VRE), methicillin-resistant *Staphylococcus aureus* (MRSA), *Acinetobacter baumannii, Escherichia coli, Klebsiella pneumoniae* and *Pseudomonas aeruginosa*, pose a significant risk to the health of both humans and animals. Additionally, there has been an increase in bacterial pathogens that have natural resistance to antibiotics, rendering current antibiotics ineffective.

Antibiotics are widely acknowledged as crucial medical treatments that significantly contribute to reducing morbidity and mortality rates in humans. However, their extensive use has led to a notable increase in the development of resistance among pathogens, resulting in significant negative impacts on human health. This has led to a reduction in therapeutic options[7,8]. Addressing antibiotic resistance requires a comprehensive approach, including optimizing the use

of existing antibiotics, improving diagnostic techniques for identifying infection causes, developing new antibiotics and vaccines, implementing infection control measures to prevent the spread of resistant strains and conducting educational awareness campaigns for the public and healthcare providers. These efforts are essential in mitigating future challenges related to antibiotic resistance[9].

It is crucial to identify the specific antibiotics that play a significant role in the spread of local pathogen resistance in order to inform the creation of an effective antibiotic policy and subsequently decrease their utilization[10]. In the present study three different *Curcuma* species essential oil efficacy were screened.

Curcuma caesia (Roxb.) belongs to the Zingiberaceae family and is commonly referred to as "Kala haldi" in different parts of India. It can be found in West Bengal, Madhya Pradesh, Orissa, Chhattisgarh, and Uttar Pradesh states. This plant thrives in areas with moist deciduous forests[11]. The effective use of *Curcuma caesia* has been used effectively for a long time. The plant's rhizome is used for sprains and bruises[12]. It has anthelmintic, laxative and vulnerary properties. It is also beneficial for scabies, leukoderma, blood disorders, sprains and small-pox. Additionally, it helps in treating asthma, leprosy and anemia. The inner part of the rhizome is bluish black and has a sweet smell. Turkish people use these roots as a rubefacient after a Turkish bath[13]. The plant is considered highly fortunate and is frequently utilized in India for different remedies. The herb's rhizomes are employed to treat cough, pneumonia and cold in children, as well as fever and asthma in adults. In India *Curcuma caesia* is used to relieve toothaches, heal skin and wound infections, and remedy rheumatism[1]. The plant has become endangered because it is being excessively used without being replenished. Additionally, it contains antifungal protein that can combat drug-resistant *Candida albicans*[14].

Curcuma longa L. is a perennial herb that grows up to 1 m tall with a compact stem belongs to Zingiberaceae family and is found in tropical and subtropical regions worldwide. It is extensively cultivated in countries like India and China. In India, it is commonly known as "Haldi" and has significant economic importance in Malaysia, Indonesia and India. The rhizomes of this herb are pyriform, ovate, oblong and often have short branches. They are commonly used as a household remedy in Nepal[15]. The powdered variant has been consistently utilized for its aromatic qualities, serving as a seasoning and possessing digestive attributes[16]. Traditional Indian medicine asserts that its powder can be utilized to treat a variety of ailments including coryza, manorexia, biliary disorders, hepatic disorder, cough, diabetic wounds, sinusitis, and rheumatism[17]. In the 19th century, researchers discovered the coloring compound in turmeric and named it curcumin. Curcumin is extracted from the rhizomes of *C. longa* L. and gives turmeric its yellow color. It is the main component of the plant and is known for its anti-inflammatory properties. In the ancient period ayurvedic or hindu medicine is extensively used for the treatment of sprains and swellings caused by injuries[18]. Also *C. longa* L. is extensively utilized in Chinese traditional medicine to treat ailments characterized by abdominal discomfort. Turmeric continues to be employed in various forms during religious rituals.

Curcuma amada (Roxb.) is a noticeable spice that looks very similar to ginger (*Zingiber officinale*) but gives off a taste reminiscent of raw mango (*Mangifera indica*). The term *Curcuma* was introduced by Linnaeus in 1753 in his book Species Plantarum. It is believed to have originated from the Arabic word ‘kurkum’, which translates to yellow color[19,20]. *Curcuma amada* (Roxb.), also referred to as mango ginger, is an aromatic herb belongs to family Zingiberaceae. It is a perennial plant with rhizomatous growth. The family Zingiberaceae encompasses a diverse range of 70-80 species, consisting of both annual and perennial herbs with rhizomatous characteristics[21,22]. The genus first appeared in the Indo-Malayan area and can be found across Asia, Africa and Australia in the tropical regions[23]. The plant reaches a height of 1 meter. Each plant has 5-6 pairs of leaves and the rhizomes of mango ginger are fleshy, buff-colored, measuring 5 to 10 cm in length and 2

to 5 cm in diameter. They are divided into nodes and internodes. Scaly leaves are arranged in a circular pattern at the rhizome nodes, creating the appearance of growth rings with scars on the surface. The rhizomes are branched and the branching occurs in a sympodial manner. The rhizomes exhibit a distinct raw mango flavor and possess a strong pungent taste. They find application in various culinary dishes, medicinal remedies and as a source of starch. In the realms of Ayurveda and Unani medicinal traditions, mango ginger serves as a remedy for a wide array of conditions, functioning as an appetizer, diuretic, laxative, aphrodisiac, emollient, antipyretic and expectorant. Furthermore, it aids in the treatment of asthma, bronchitis, itching, inflammation and various skin ailments. Externally, a paste derived from the rhizome is utilized to alleviate sprains, bruises, contusions, and rheumatic pain[1]. The present study is focused on assessing the antibacterial and antifungal properties of essential oils derived from the leaves of three *Curcuma* species (*Curcuma caesia*, *Curcuma longa* and *Curcuma amada*) through the disc diffusion method. It aims to compare the efficacy of these oils with their commercial counterparts, analyzing their potential applications. Furthermore, the research aims to identify the key bioactive compounds responsible for the antimicrobial effects. By investigating the possibility of using these essential oils as an alternative to traditional antibiotics, the article addresses the pressing issue of antibiotic resistance in pathogens. Moreover, it emphasizes the potential of these lesser-known medicinal crops for their broad-spectrum antimicrobial activity, advocating for their cultivation and medicinal use.

Materials and methods

Collection of plant samples and extraction of essential oil

The experimental farm of CSIR North East Institute of Science and Technology (NEIST) in Jorhat, Assam, India, provided the fresh leaves of three distinct species of *Curcuma* (*C. longa*, *C. caesia and C. amada*). The collection site was located at coordinates 26º44'00.0''N and 94º09'50.0''E. Dr. Mohan Lal, a plant breeder at CSIR-NEIST, Jorhat, Assam, India, accurately identified the plant species. The leaf samples of *C. longa, C. caesia* and *C. amada* were freshly collected and 300 g for each sample were shifted to the Clevenger apparatus which is set for three hours at a boiling temperature (100ºC) and the essential oil was collected separately in three different glass bottles. The experiment was conducted three times to minimize errors in the experiment. The trace amount of water present in the essential oils were removed by using anhydrous sodium sulphate (Na_2SO_4) and stored in a sealed tube at 4°C for further analysis.

Antimicrobial activity of leaf essential oil of three different Curcuma species

In this assay standard agar disc-diffusion method was applied to measure the anti-microbial activity of three different *Curcuma* leaf essential oil and a minimum inhibitory concentration (MIC) test was also performed.

Microbial strains used in antimicrobial assay in three different *Curcuma* species leaf essential oil

Bacterial and fungal strains

For the study, a total of five bacterial (**Table 1**) and four fungal ATCC (American Type Culture Collection) strains (Table 2) were used.

The bacteria were cultured freshly in MHB (Mueller and Hinton Broth) and the fungus in PDB (Potato Dextrose Broth) for 24 h at 37ºC and 48 h (hours) at 28ºC, respectively, in order to conduct the antimicrobial screening. Following the incubation period, both the bacterial and fungal cultures were adjusted to have an optical density similar to the McFarland standard in saline water[29]. The measurement of optical density was carried out using the Genesis 10 UV spectrophotometer. To assess bacterial susceptibility, the disk diffusion technique was employed, whereby the inhibition zones for various bacteria and fungus were observed and calculated.

MIC and disc-diffusion value determination of three different Curcuma leaf essential oil

After performing the disk-diffusion assay with

Table 1. Bacterial strains were used to determine the antibacterial activity against *Curcuma* spp. essential oils such as

Bacterial strain	ATCC
Streptococcus mutans	25175
Staphylococcus aureus	11632
Salmonella typhimurium	13311
Bacillus cereus	10876
Bacillus subtilis	11774

Table 2. Fungal strains were used to determine the antifungal activity against *Curcuma* spp. essential oils such as

Fungal strain	ATCC
Aspergillus niger	16886
Aspergillus fumigatus	204305
Saccharomyces cerevisiae	9763
Candida albicans	66027

various concentrations of the three *Curcuma* species leaf essential oil (50, 100, 250 and 500 µg/mL) as listed in Table 3, 4 and 5, the zone of inhibition diameters were measured using a scale after the incubation period (24 h for bacterial strains and 48 h for fungal strains). Using a broth micro dilution method, the MIC assay was also carried out to a certain Minimal inhibitory concentration of the three *Curcuma* species leaf essential oil for bacterial and fungal growth. A 96-well micro titer plates were utilized to conduct this test, and ATCC strains of microorganisms were employed throughout the assay. The ratio (1:1) of the essential oil concentration to the microorganism was poured into the well plates, and the plates are then incubated for 24 h at 37°C. The petriplates were then incubated after 10 µL of 2, 3 and 5 triphenyl tetrazolium chloride (TTC) was applied. Wherever there was bacterial development, a bright red color was visible.

Results and discussion

In our study it was seen that the three essential oil of the *Curcuma* spp. were very potent and rich in antimicrobial efficacy. The results showed that the essential oil is very effective against the bacteria but it is somehow inactive towards some fungal strains. *Curcuma longa* essential oil showed a large inhibition zone towards *S. aureus* (10 mm at 50 µg/mL), *S. mutans* (10 mm at 50 µg/mL) and *A. fumigatus* (15 mm at 50 µg/mL).While the essential oil of *Curcuma caesia* showed a large inhibition zone towards *B. subtilis* (22 mm at 50 µg/mL), *S. mutans* (16 mm at 50 µg/mL) and *S. cereviaceae* (12 mm at 50 µg/mL). The essential oil of *Curcuma amada* showed a potent results against *B. Subtilis* (16 mm at 50 µg/mL), *S. mutans* (17 mm at 50 µg/mL) and *A. fumigatus* (10 mm at 50 µg/mL).

Earlier studies showed that crude extracts of curcuminoids and essential oil from different *Curcuma longa* varieties were tested for antibacterial effects on 4 bacterial strains using the agar well diffusion method[30]. Curcuminoids and essential oil both displayed inhibition zones against every bacterial strain tested. The Kasur turmeric variety proved to be the most potent among the three varieties studied. *B. subtilis* was the most susceptible bacterial strain to the turmeric extracts. The diameter of MIC values varied from 3.0 to 20.6 mm across different strains and varieties. The antimicrobial activity

of ionone and turmerone essential oils from rhizomes was tested against various bacteria and fungi. The oils showed strong to moderate inhibitory action against most species, except for *S. typhi* and *Shigella*, even at a 1:1000 dilution[24].

Previous study revealed that the rhizome of four distinct varieties of *Curcuma*, namely *Curcuma longa* (Turmeric), *Curcuma caesia* (Black turmeric), *Curcuma amada* (Mango ginger) and *Curcuma aromatica* (Van turmeric), were utilized to prepare both ethanol and aqueous extracts. The investigation into the anti-microbial properties of the extracts involved testing their antibacterial and antifungal activities. The agar well diffusion method was used to assess the antibacterial activity against *Bacillus subtilis, Staphylococcus aureus* and *Pseudomonas aeruginosa*. For antifungal activity, *Aspergillus flavus* and *Candida albicans* were utilized. The inhibition zones of the extracts were measured and compared to tetracycline and fluconazole to evaluate efficacy. Both *Curcuma aromatica* and *Curcuma longa* ethanolic extracts displayed antibacterial and antifungal activity. Notably, the ethanol extract of *C. longa* exhibited the most significant activity, with a 13 mm inhibition zone against *B. subtilis* at a concentration of 20 mg/ml. Furthermore, the ethanol extracts of *C. longa* showed inhibition zones of 12.0 mm, 11.0 mm and 10.0 mm against *A. flavus, S. aureus* and *C. albicans*, respectively, at the same concentration. *C. aromatica* ethanol extracts also demonstrated moderate inhibition against *B. subtilis, S. aureus* and *C. albicans*, with 11 mm inhibition zones each at a concentration of 20 mg/ml[25].

Another previous study evaluated the phytochemical and anti bacterial properties *Curcuma aeruginosa* and *Curcuma caesia.* Various dilutions (1.25, 2.5, 5.0 mg/ml) of ethyl acetate, hexane, acetone, chloroform, methanol and water sequential extracts derived from the rhizome of *C. caesia* and *C. aeruginosa* were evaluated for their efficacy against gram-positive *S. aureus* (zone of inhibition 22 mm) and *B. cereus* (zone of inhibition 21 mm) respectively and gram-negative *S. typhi*, *V. cholerae* (zone of inhibition 8-19 mm) *E. aerogens, P. aeruginosa* (zone of inhibition 5 to 22 mm and 6-20 mm) and *S. marcescens* (zone of inhibition 27 mm) bacteria respectively[26]. The study further reported on the anti bacterial disc susceptibility test using disc diffusion method using *C. caesia, C.aeruginosa* extracts. Different degrees of inhibitory action against all the bacteria tested were observed in the anti-bacterial studies. The acetone extract of *C. caesia* displayed the highest activity against *S. aureus* among the gram-positive bacteria, while the hexane extract of *C. aeruginosa* exhibited the highest activity against *B. cereus*. In the case of gram-negative bacteria, the chloroform extract of *C. caesia* demonstrated the highest inhibitory action against *S. marcescens*, whereas the methanol extract of *C. aeruginosa* displayed a greater inhibitory action against *S. typhi*[26].

Previous study reported the antimicrobial activity of *C. longa* aqueous extract. The aqueous solution derived from *C. longa* demonstrated antimicrobial effects on *S. aureus*, *E. coli*, *S. epidermidis* and *K. pneumonia* with minimum inhibitory concentrations (MIC) varying between 4-16 g/L and minimum bactericidal concentrations (MBC) ranging from 16-32 g/L. The *Curcuma amada* rhizome powder underwent sequential extraction and was assessed for antibacterial properties using the agar well diffusion method and broth dilution method. The non-polar extracts of mango ginger exhibited significant antibacterial activity against gram-positive bacteria, displaying a low minimum inhibitory concentration ranging from 60 to 180 ppm. Within the mango ginger extracts, the chloroform extract displayed the most potent antibacterial activity (**Fig. 1**). Through antibacterial activity-guided fractionation of the chloroform extract using repeated silica gel column chromatography, a pure compound was isolated. This purified antibacterial compound was subjected to analysis through IR, UV, 2D-HMQCT NMR spectra and LC-MS leading to its identification as difurocumenonol, a novel compound that has not been previously reported[27]. The investigated *Curcuma* species exhibit powerful broad-spectrum antimicrobial properties that may open up new possibilities for future research.

As per the present findings, in *C. longa*

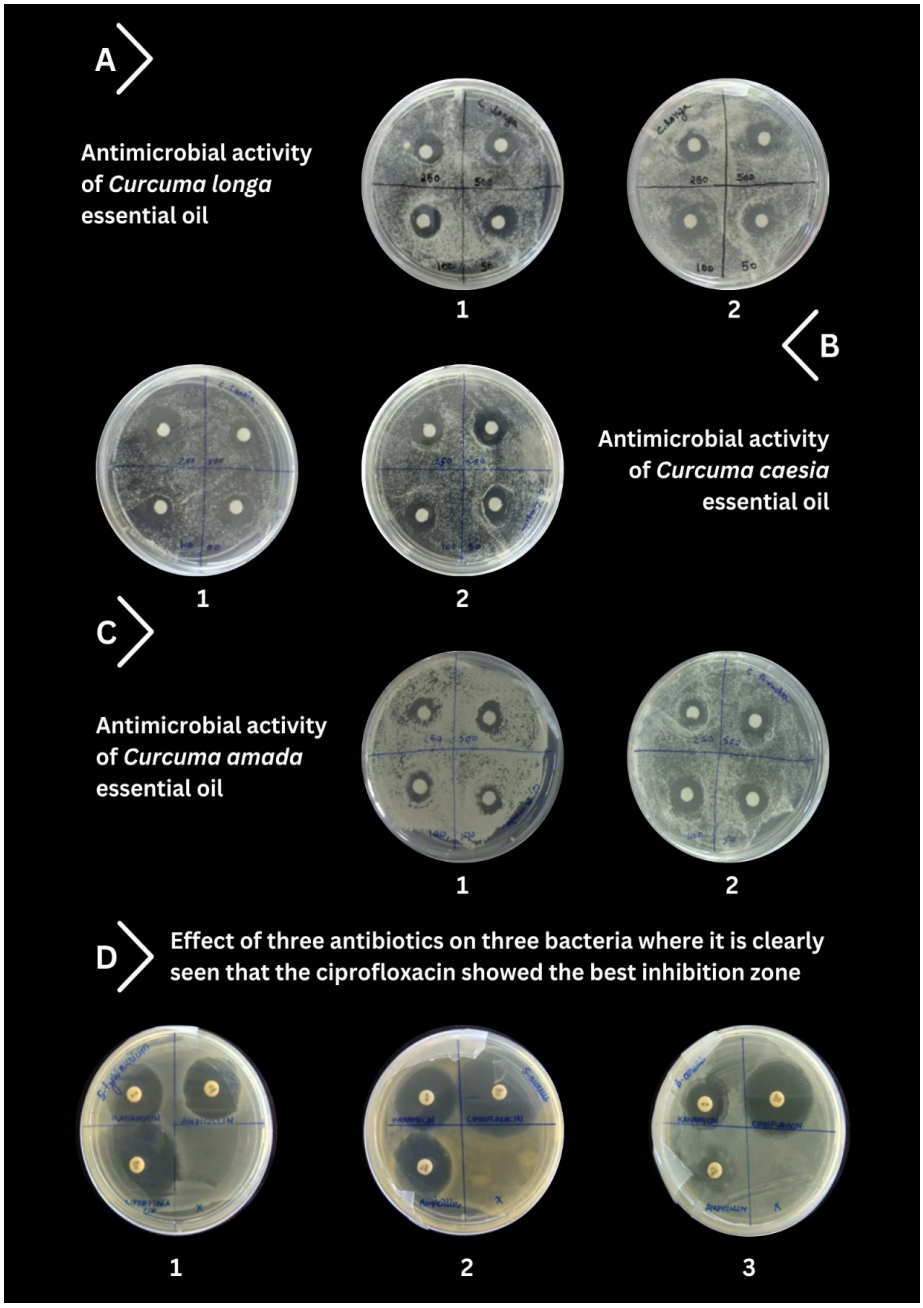

Figure 1. Antimicrobial activities of different *curcuma* species essential oil

essential oil activity against *B. subitilis* (8 mm at 50 µg/mL with MIC 35 µg/mL) is comparable to that of the standard Kanamycin (16 mm at 10 µg/mL); activity against *S. mutans* (10 mm at 50 µg/mL with MIC 35 µg/mL) is comparable to that of the standard Kanamycin (17 mm at 10 µg/mL) (Table 3). While in case of *C. caesia* essential oil activity against *B. subitilis* (22 mm at 50 µg/mL with MIC 45 µg/mL) is comparable to that of the standard Ciprofloxacin (35 mm at 10 µg/mL) and is at far better than Kanamycin (16 mm at 10 µg/mL) and Ampicillin (29 mm at 10 µg/mL); activity against *S. mutans* (16 mm at 50 µg/mL with MIC 40 µg/mL) is comparable to that of the standard Ampicillin (28 mm at 10 µg/mL) and at par ahead of the standard Kanamycin (17 mm at 10 µg/mL) and in case of activity against *B. cereus* (12 mm at 50 µg/mL with MIC 35

µg/mL) is comparable to that of the standard Ciprofloxacin (25 mm at 10 µg/mL), and is at par better than Ampicillin (15 mm at 10 µg/mL) while the standard Kanamycin did not show any activity against *B. cereus* (Table 4). As for the antimicrobial activity of *C. amada* essential oil, the activity against *B. subitilis* (16 mm at 50 µg/mL with MIC 45 µg/mL) is comparable to that of the standard Ampicillin (29 mm at 10 µg/mL) and is at par better than Kanamycin (16 mm at 10 µg/mL); activity against *B. cereus* (12 mm at 500 µg/mL) is comparable to that of the standard Ampicillin (15 mm at 10 µg/mL) and in case of activity against *S. mutans* (17 mm at 50 µg/mL with MIC 45 µg/mL) is comparable to that of the standard Ampicillin (28 mm at 10 µg/mL) and Ciprofloxacin (32 mm at 10 µg/mL) whereas it is at par ahead of the standard Kanamycin (17 mm at 10 µg/mL) (Table 5). Meanwhile as in the case of antifungal activity, the antifungal properties of the three *Curcuma* spp. did not shoe much efficacy. The present finding thus reveals that among the three species *C. caesia* exhibited the most potent antibacterial activity followed by *C. amada* and *C. longa*. The antibacterial property of *C. caesia* was comparable to all the standards signifying its potential as a substitute to the synthetic counterparts. Moreover, the synergistic effects from amalgamation of the three studied *Curcuma* essential oils may provide potent broad spectrum antimicrobial inhibition.

Conclusions

The current research has determined that the essential oil derived from *Curcuma* species exhibited antimicrobial properties against diverse microorganisms. The essential oils extracted from the all three *Curcuma* species exhibited potential activity against different bacteria and fungus but it is also important to isolate the major component which is responsible for the antimicrobial effect also evaluation of the component. As the essential oil is a volatile mixture of the different components and hence the potency of the component responsible for this effect decreases. From the above observations future prospects of these essential oils can be valued and applicable in various herbal drug

Table 3. Antimicrobial activity of *Curcuma longa* essential oil

S. No.	Strain name	50 µg/mL in mm	100 µg/mL in mm	250 µg/mL in mm	500 µg/mL in mm	MIC value (µg/mL)	Control	Kanamycin 10 µg/mL in mm	Ampicillin 10 µg/mL in mm	Ciprofloxacin 10 µg/mL in mm	Fluconazole 10 µg/mL in mm	Blank
1	*S.aureus*	10±0.45	15±0.47	17±0.47	18±0.48	35	+	28±0.57	32±0.97	38±0.97	NA	NA
2	*B.Subtilis*	8±0.45	12±0.47	12±0.47	15±0.47	30	+	16±0.45	29±0.57	35±0.97	NA	NA
3	*B.cereus*	7±0.45	10±0.45	14±0.47	17±0.47	30	+	NA	15±0.47	25±0.57	NA	NA
4	*S.typhimurium*	10±0.45	14±0.45	16±0.47	20±0.57	35	+	25±0.57	27±0.59	30±0.97	NA	NA
5	*A.fumigatus*	15±0.47	18±0.48	18±0.48	25±0.57	40	+	NA	NA	NA	37	NA
6	*A.niger*	NA	NA	NA	NA	NA	+	NA	NA	NA	26	NA
7	*S.cereviaceae*	NA	NA	NA	NA	NA	+	NA	NA	NA	39	NA
8	*S.mutans*	10±0.45	12±0.47	15±0.47	18±0.48	35	+	17±0.47	28±0.57	32±0.97	NA	NA
9	*C.albicans*	NA	NA	NA	10±0.45	NA	+	NA	NA	NA	31±0.97	NA

Table 4. Antimicrobial activity of *Curcuma caesia* essential oil

S. No.	Strain name	50 µg/mL	100 µg/mL	250 µg/mL	500 µg/mL	MIC value (µg/mL)	Control	Kanamycin 10 µg/mL in mm	Ampicillin 10 µg/mL in mm	Ciprofloxacin 10 µg/mL in mm	Fluconazole 10 µg/mL in mm	Blank
1	*S.aureus*	15±0.47	20±0.57	22±0.57	25±0.59	40	+	28±0.57	32±0.97	38±0.97	NA	NA
2	*B.Subtilis*	22±0.57	24±0.57	30±0.97	34±0.97	45	+	16±0.45	29±0.57	35±0.97	NA	NA
3	*B.cereus*	12±0.47	17±0.47	19±0.57	21±0.57	35	+	NA	15±0.47	25±0.57	NA	NA
4	*S.typhimurium*	NA	NA	NA	15±0.47	NA	+	25±0.57	27±0.59	30±0.97	NA	NA
5	*A.fumigatus*	NA	NA	NA	NA	NA	+	NA	NA	NA	37	NA
6	*A.niger*	NA	NA	NA	NA	NA	+	NA	NA	NA	26	NA
7	*S.cereviaceae*	12±0.47	15±0.47	16±0.47	18±0.48	30	+	NA	NA	NA	39	NA
8	*S.mutans*	16±0.47	18±0.48	19±0.57	26±0.59	40	+	17±0.47	28±0.57	32±0.97	NA	NA
9	*C.albicans*	NA	NA	NA	NA	NA	+	NA	NA	NA	31±0.97	NA

Table 5. Antimicrobial activity of *Curcuma amada* essential oil

S. No.	Strain name	50 µg/mL	100 µg/mL	250 µg/mL	500 µg/mL	MIC Value (µg/mL)	Control	Kanamycin 10 µg/mL in mm	Ampicillin 10 µg/mL in mm	Ciprofloxacin 10 µg/mL in mm	Fluconazole 10 µg/mL in mm	Blank
1	*S.aureus*	10±0.45	14±0.47	15±0.47	18±0.48	35	+	28±0.57	32±0.97	38±0.97	NA	NA
2	*B.Subtilis*	16±0.47	21±0.57	24±0.57	26±0.59	45	+	16±0.45	29±0.57	35±0.97	NA	NA
3	*B.cereus*	NA	NA	NA	12±0.47	NA	+	NA	15±0.47	25±0.57	NA	NA
4	*S.typhimurium*	9±0.45	11±0.45	13±0.47	15±0.47	25	+	25±0.57	27±0.59	30±0.97	NA	NA
5	*A.fumigatus*	10±0.45	15±0.47	17±0.47	19±0.57	35	+	NA	NA	NA	37	NA
6	*A.niger*	NA	NA	NA	NA	NA	+	NA	NA	NA	26	NA
7	*S.cereviaceae*	NA	NA	NA	NA	NA	+	NA	NA	NA	39	NA
8	*S.mutans*	17±0.47	19±0.57	25±0.57	29±0.97	45	+	17±0.47	28±0.57	32±0.97	NA	NA
9	*C.albicans*	NA	NA	NA	NA	NA	+	NA	NA	NA	31±0.97	NA

industries. Traditional medicinal plants have the potential to offer a valuable source of reliable, environmentally friendly and renewable drugs. These plants can be directly or indirectly utilized for their antimicrobial properties. Conducting a more comprehensive investigation into the isolation of compounds and the application of essential oils derived from *Curcuma* species could pave the way for exciting new advancements in drug discovery.

Acknowledgement

The authors express their gratitude to the Director of CSIR-North East Institute of Science and Technology, Jorhat (Assam) for granting access to the lab and field facilities.

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